



# **PESTICIDE USE IN AUSTRALIA**

**A review undertaken by the Australian  
Academy of Technological Sciences  
and Engineering**

## **Pesticide use in Australia**

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and Engineering.

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## **FOREWORD**

The Australian Academy of Technological Sciences and Engineering is one of the four national learned academies. Membership is by nomination and its Fellows have achieved distinction in their fields. The Academy provides a forum for study and discussion, to explore policy issues relating to advancing technologies, to formulate comment and advice to government and to the community on technological and engineering matters, and to encourage research, education and the pursuit of excellence.

Australian agriculture and land management has progressively been adapting to the Australian environment as our understanding of it increases. At the same time, it has also been adapting to the increasing pressures of the international marketplace in terms of competition for both price and quality of products and commodities sought by importing nations. Australian agriculture continues to make impressive efficiency gains – the cereal industry, for example, has improved its economic efficiency by over 2 per cent per annum over the past 20 years. A component of continual improvement is the management of unwanted plant and animal pests and diseases. Chemical pesticides have played a vital role in increasing efficiency, and more active and more selective pesticides, together with better application technology are being introduced. Yet the community needs to be assured that these technologies are safe, and that the benefits far outweigh any risks.

The last major review of pesticides in Australia was the July 1990 *Report of the Senate Select Committee on Agricultural and Veterinary Chemicals*, chaired by Senator Mal Colston. The report contained 45 recommendations relating to the then current legislation and regulatory system; the need for a nationally unified approach; the potential place of non-chemical management systems including integrated pest management and biological control; the social, health and environmental impacts of chemicals; and the need for better training in the management of their use. The report recognised that farm chemicals had a significant economic benefit to Australia. It was a time when individual international markets, consumers and producers were responding to chemical and environmental concerns. The report concluded that individual users of farm chemicals must accept the challenge and the responsibility of using agricultural and veterinary chemicals safely and judiciously and in a manner which would safeguard other people and the environment.

Since that time, there have been major changes in chemicals available for pest management, and in the regulatory processes, agency structures, and farming systems surrounding their use. In addition, biotechnology has introduced some alternative genetic options to the traditional use of chemical pesticides, albeit options that raise a new range of concerns among a segment of the community.

There have also been a number of recent Australian and overseas enquiries into aspects of the use of pesticides, including:-

- Monitoring the Environmental Effects of Agricultural and Veterinary Chemicals in Australia – Preliminary Investigations (1997). A Report to the Environment

Protection Group from Aquatech Environment, Economics and Information, Canberra. (Aquatech 1997)

- Management of Agricultural and Veterinary Chemicals – A National Strategy (ARMCANZ 1998).
- Review of Trends in Agricultural Pesticide Use in New Zealand (MAF1999).
- The Future Role of Pesticides in US Agriculture (National Research Council 2000).

Recognising the time which had elapsed since the 1990 Senate Report and the changes that had since taken place, the Australian Academy of Technological Sciences and Engineering sought and received funding from the Australian Research Council to prepare this report, *Pesticide Use in Australia*

The report addresses current trends, particularly since 1994-5, in the use and methods of application of pesticides; the impact of pesticides and their residues on community health and on the environment; current regulatory processes and their accessibility to public scrutiny in Australia; and the impact and potential impact of the introduction of genetically modified material on the use of pesticides. The report has restricted its review to the use of pesticides in the rural environment. It has not considered urban uses of these pesticides, for example in public health, home gardens or for termite control in buildings. The veterinary administration of chemicals internally to livestock has also been excluded from the report's purview.

The purpose of the study is both to generate a succinct update for policy-makers since the Senate Standing Committee Report, and also to make available a detailed account of developments in pesticide regulation, use and monitoring for readers seeking information about current pesticide status issues in Australia.

The study was overseen on behalf of the Academy by a steering committee comprising Prof Roy Jackson (Professor of Chemistry, Monash University), Professor Ian Rae (Technical Director of the Australian Academy of Technological Sciences and Engineering) and Dr John Huppatz (Deputy Chief, CSIRO Plant Industry), supported by Catherine Hollywell (Manager, Chemical Standards Branch, Department of Natural Resources and Environment, Victoria), Tim D'Ombra (environmental consultant, Ballarat), Greg Healy (Global Manager, Regulatory Affairs and Product Development, Nufarm Ltd) and Ron De Groot (Technical and Development Manager, Crop Care Australasia Pty Ltd).

The Academy commissioned a series of papers on aspects of pesticide use from Dr Don McNee assisted by Don Hay; Professor Tony Chisholm; Dr John Chapman; Dr Lyn Fragar AO assisted by Dr Allan Black; and Dr John Stanley assisted by Dr Peter Gregg with Dr Mark Lonsdale. The project was managed and the final report prepared by Dr John Radcliffe AM (formerly South Australian Director-General of Agriculture and subsequently Deputy Chief Executive [Environment and Natural Resources], CSIRO Australia).

Valuable assistance was provided by officers of Commonwealth and State agencies. Particular recognition is given for help by staff of Agriculture Fisheries and Forestry Australia, the National Registration Authority for Agricultural and Veterinary Chemicals and the peak body of the agricultural chemicals industry, Avcare - the National Association for Crop Protection and Animal Health. A detailed list of contributors is included in the Acknowledgements section. The preparation and publication of the study was made possible by a \$220 000 Linkage – Learned Academies Special Projects Grant which is now managed through the Federal Department of Education, Science and Training.

## **EXECUTIVE SUMMARY**

Achieving optimal use of chemical pesticides and other management practices to control pests is a challenging resource management problem, involving informed risk evaluation and management. The use of pesticides has greatly increased world food security and standards of living. Substantial changes have been made in the chemical pesticides used in Australia over the past decade. Pesticides are an integral and important input in Australian agriculture.

Their importance is increasing, and they are becoming a higher proportion of farmers' input costs as primary producers and their industry bodies strive to remain internationally competitive. At the same time, those very same industry bodies and an increasing number of their members, recognise market and community demands for crop production systems which ensure continued safe, wholesome commodities with technologies that are environmentally sustainable.

As the last major review of pesticide use in Australia was the July 1990 *Report of the Senate Select Committee on Agricultural and Veterinary Chemicals*, the Australian Academy of Technological Sciences and Engineering received sponsorship from the Australian Research Council to undertake a study on the issue. There have been major changes in the regulatory processes, agency structures and farming systems surrounding pesticide use since 1990. The report addresses current trends, particularly since 1994-5, in the use and methods of application of pesticides, and the impact of pesticides and their residues on production systems and the environment. The issue of pesticide use and human health is also discussed together with current regulatory processes in Australia and their accessibility to public scrutiny, assuring the safe use of pesticides. The potential impact of genetically engineered material on the use of pesticides has also been examined. The report has restricted its review to the use of pesticides in the rural environment. It has not considered urban uses, including for home garden use and termite control. Veterinary chemicals for internal use were also excluded.

The study recognises but has not sought to review the beneficial health impact of pesticides achieved in disease control (through insect vector control) and through increased and consistent access to cheap, high quality foodstuffs and fibre production, both locally and globally.

The study has been undertaken by a group of authors overseen by a Steering Committee appointed by the Academy of Technological Sciences and Engineering.

### **Pesticide Use**

Determining specific data about recent and current trends in the use of pesticides in Australia has proven difficult. There is a dearth of detailed information about the extent of use of chemicals, expressed either in terms of the active ingredient (that chemical component of the pesticide formulation which is biologically active), or in terms of the formulated products (the form in which the pesticide is prepared for commercial sale to potential users). Formulated products may involve the incorporation of one or more active constituents into an appropriate preparation at a designed concentration within a carrier, sometimes also including an adjuvant. It has been possible to access product sales

data, and from that information, has been possible to draw conclusions regarding aspects of use.

The principal forms of pesticides used in Australia can be categorised into insecticides, herbicides, fungicides and growth promotants.

The Australian crop protection market expanded from just over \$1100 million in 1996 to just under \$1600 million in 1999, a 40% increase or some 10% per year (in nominal \$ terms). Herbicides are the largest group of pesticide products with annual sales in 1998 and 1999 of just over \$800 million. The significant increase in herbicides in recent years, now plateaued, has arisen from continuing adoption of minimum tillage technologies in an expanding cereal area in concert with a reduction in size of the national sheep flock.

The sales of insecticides increased by 40% to some \$500 million between 1998 and 1999. The sales of fungicides increased by around 30% to \$200 million at the same time, while the market for plant growth regulators remained constant over those two years at some \$60 million per annum. Much of the insecticide increase was due to the 70% expansion in the area sown to cotton in this period.

The most extensively used pesticide in Australia today is glyphosate, a broad spectrum, non-selective post emergence herbicide with high activity on virtually all annual and perennial plants. Glyphosate shows no pre-emergence or residual activity because it binds strongly to soil particles and is readily metabolised by soil microorganisms. Use approaches 15 000 tonnes per annum. The next most widely used herbicides are atrazine and simazine. These are selective systemic herbicides which provide knockdown and residual action for control of many broad-leaved weeds and some grasses in forestry and agricultural crops. About 3 000 tonnes of each of these are used annually, much of them in industrial rather than agricultural uses for seasonal weed control. Over 1 000 tonnes of the plant cell growth disrupting group of chemicals including phenoxys, benzoic acids and pyridines are used annually. The herbicides 2,4-D and its derivatives, along with MCPA, are the major chemicals used in this group. A similar level of chemicals in the pyridils group is also in use. Paraquat dichloride and to a lesser degree, diquat, are the primary chemicals contributing to this group.

The most widely used groups of insecticides in recent years have been the organophosphates which include parathion methyl, chlorpyrifos, dimethoate, profenfos and diazinon. Around 5 000 tonnes of active ingredients from this group, which comprises around 30 identifiably distinct chemicals, have been used annually. The next most significant group of insecticides are the acetyl choline esterase inhibitors, comprising various carbamates, of which about 3 000 tonnes have been used each year. Metham sodium is the most highly used carbamate. Over 500 tonnes per annum are used of those insecticides which act as GABA-gated chloride channel antagonists, the most important of these being endosulfan, which is a cyclodiene organochlorine, but which does not build up in the fat of mammals or persist in the environment. Of the remaining insecticides, the twenty chemicals in the pyrethroids and pyrethrins group are the most widely used, totalling up to a couple of hundred tons per annum.

There are about 20 principal fungicides, which together represents over 3 000 tonnes use per annum. The two most significant of these are mancozeb, a dithiocarbamate, and

captan, a cyclic imide which is used to control a wide range of fungal diseases, and also used as a seed treatment on field crops, canola, ornamentals, and vegetables.

The annual use of plant growth regulators exceeds 500 tonnes. The main chemical is ethephon, which is an ethylene generator used to optimise blemish-free and pest-free fruit crops.

At present, there is no detailed and publicly available information in Australia on usage of individual pesticides, either nationally or by regions. The National Pollutant Inventory, set up under a National Environmental Protection Measure, does not include agricultural and veterinary chemicals. The development of a database on agricultural and veterinary chemical use would allow government, industry and the wider community access to use data, giving the ability to recognise changes in use patterns, determine what is causing any observed trends, and relate them to changes in productivity, the environment and any perceived health risks, allowing sound scientific conclusions.

Avcare, the National Association for Crop Protection and Animal Health has announced its intention to establish a crop protection and animal health database, with a dedicated taskforce to oversee the project. The level of segmentation of the database will be further defined by the taskforce and the time frame for its implementation is to be identified.

Meanwhile, there is increasing overseas interest in developing formal and comprehensive pesticide use reporting systems. Within the United States of America, the states of California, New York, New Hampshire, Arizona and New Jersey have pesticide use reporting requirements. Legislation has been considered in Wisconsin and Massachusetts. The Oregon Department of Agriculture is to introduce what is required to be “a comprehensive, reliable and cost effective system for collecting, organising and reporting information on all categories of pesticide used in Oregon” from January 1, 2002. This pesticide use reporting system is to be useful to government, researchers, policy makers and the public, and is to ensure public health and safety and to protect Oregon’s water and environment. This system, involving full electronic reporting, is likely to be one of the most comprehensive thus far generated

**It is recommended that Australia resolve to establish a comprehensive and integrated pesticide use reporting system to assure the integrity of the quality of its agricultural produce. Its design must ensure that benefits of any such system must exceed the costs, be conducive to encouraging compliance, and have the commitment of industry to be successful and valued. The issue should be addressed jointly by Commonwealth and States/Territories pesticide agencies, the chemical industry and peak commodity-based producer organisations, in conjunction with community representatives. It is further recommended that any pesticide-use reporting system should be established with the capability of providing inputs for an economically rigorous cost:benefit analysis of the value of pesticide use in production systems, and the value of regulatory changes which may be proposed from future regulatory policies.**



## **The Economics of Pesticide Use**

Over the four decades 1950-90, the value of Australian farm output increased 250 per cent. Australia recorded the highest rate of growth of land productivity (output per unit of land) of any OECD country over the three decades to 1990. Moreover, the productivity growth rate achieved in Australian agriculture over this period was substantially higher than that achieved in the rest of the Australian economy and in the agricultural sectors of other developed countries taken as a whole. In the period 1989-99, the annual gross value of production at farm gate averaged \$25 billion. Since the late 1940s, chemical pesticides have been a significant input into Australian agriculture and their use in Australia has increased substantially, as it has globally.

The 1990 Senate Select Committee noted that there was no quantitative estimate available of the impact of farm chemicals on Australia. A 1998 benefit-cost analysis of regulatory and other methods of government intervention in Agvet chemical use undertaken in South Australia found very favourable benefit-cost ratios for government intervention in Agvet chemical control over use. However, a complete set of data on the nature, extent and cost of pesticide use would be needed before any balance sheet of costs and benefits – as broadly defined above – could be attempted. Such data are not readily available.

**This review concludes that there is justification on economic policy grounds to have government intervention in a pesticide regulation system, and that the COAG good governance principles be fully integrated into an evaluation of the necessity for and potential means of achieving a comprehensive pesticide-use reporting system, as well as for all future regulatory changes governing pesticide availability and use.**

## **Pesticides in Farming**

Decisions concerning the use of pesticides in Australian agriculture are made by their potential users, the primary producers. The quantities of pesticide active ingredients used in Australian agriculture depend strongly on the prevailing market prices and the anticipated returns by growers from alternative commodity options, each of which may have different pesticide needs. Other factors affecting producer decisions include technological changes in agricultural production systems and practices. These factors need to be seen in the larger context of maintaining the international competitiveness of Australian agriculture, meeting the Quality Assurance (QA) requirements of purchasers and enhancing labour efficiency.

There have been significant advances in pesticide management over the past ten years, accompanied by increases in the quantities of insecticides and plant growth regulators used, and maintenance of the quantities of herbicides used, but accompanied by a reduction in the risks associated with their use.

Australian farmers have made positive changes to pesticide use in their production systems. Farmers have enhanced their understanding of pesticide use and handling, albeit

many are still not meeting the full range of personal protection standards in their own pesticide handling and application. They are now more conscious of the impact of pesticides used in farm production systems on farm product quality, on the on-farm and the off-farm environment and of the attitudes of the community in which they live. That consciousness has resulted in marked changes in farm practices. IPM programs are being adopted across Australian agriculture. As a result, there have been some important recent advances particularly in reduced insecticide use per unit area.

The study examined in detail the use on and impact of pesticides on four indicator crop production systems embracing an intensive broadacre crop (cotton) which is largely exported, an intensively produced vegetable crop largely grown for the domestic market (potatoes), two widely grown and related fruit crops, again largely domestic market oriented (apples and pears), and the dominant broadacre dryland winter cereal crops in Australia, wheat, barley, oats and triticale. These four crop production systems are representative of the whole spectrum of crop production systems in Australian agriculture.

From an examination of pesticide use in these industries, a number of conclusions have been reached. In the second half of the 1990s, there was a noticeable movement away from broad spectrum, generally more toxic or 'hard' pesticides to those which target pests more specifically, are more efficacious and generally less toxic and therefore 'soft'. These 'soft' pesticides are usually still under patent and hence more expensive. This movement from 'hard' to 'soft' pesticides has contributed in part to the annual increase in the expenditure on pesticides by Australian farmers during the study period. However, Australian farmers are increasingly adopting integrated pest management (IPM) strategies and practices, although the extent of adoption varies between industries. In the cotton industry, where 30% of the crop is being grown with genetically modified varieties, there has been an increased use of IPM in consequence of a halving of insecticide applications on these varieties. The movement towards greater use of integrated pest management is also being driven by the increasing proportion of farmers' costs deriving from pesticide use. The change is being underpinned by R & D, funded to a significant extent by industry through the various Research and Development Corporations whose investments in pest management research have shown sound economic returns.

Australian farmers have access to world class pesticide application technologies. There is evidence that it is being adopted, but perhaps not as rapidly as desired in some industries. Significant crop production efficiencies can be achieved through improvement in pesticide application methods. The reality is that a major crisis such as the 1995 cotton pesticide contamination of beef is sometimes necessary to ensure industry-wide adoption of appropriate technologies.

Australian primary producers have strong incentives to meet pesticide residue standards on export markets. Grains, meats and wine grapes are three important groups of primary commodities that now have particularly effective systems, achieved with minimal government intervention in the case of wine. Very low pesticide residue status is also now efficiently achieved in the grain and meat industries, encouraged by a more centralised industry-government approach.

The incentives to control pesticide residues in domestically consumed foods have arguably not been as strong as they have been for export markets. Nevertheless, there is little evidence of significant residues in Australian food. However, the comparatively recent introduction of Quality Assurance (QA) schemes by the large food retailers in Australia provides a further potentially powerful force toward ensuring a low pesticide residue status in domestically consumed foods, particularly horticultural commodities.

When contemplating the future use of pesticides, we must acknowledge that the risk of new pest insect introductions is ever-present, and that weed problems are continuing to grow, with pesticide resistance increasing their complexity

**The trends in pest management of the past decade towards use of “softer” pesticides with specific modes of action, and IPM techniques which can allow reductions in pesticide use, should be further encouraged.**

**Drawing on the experience of the cotton industry, other agricultural and forestry based industries should closely examine the benefits that may accrue to them from the wider development of Best Management Practices for their industries, and the scope for individual growers to secure ISO 14000 accreditation for the production systems which they develop to meet those Best Management Practices standards. This study has noted that an issue within this framework needing particular attention is the re-examination by growers of their pesticide and other chemical stores to ensure they meet current industry standards.**

**The investments made by the rural industries through their R&D Corporations into more effective pest control should be continued and increased.**

### **The Impact of Pesticides on Human Health**

Despite the benefits widely recognised by international agencies arising from the use of pesticides, there has been continuing public concern worldwide about possible impacts on human health resulting from the application of pesticides and the presence of pesticides in the food chain once they have been applied. The study defines and describes

- current practices and underlying principles of toxicological assessment, establishment of maximum residue levels and worker exposure assessment during the registration process,
- processes and procedures for ensuring safe use and minimisation of exposure to health risk during application,
- monitoring procedures in place aimed at identifying possible risks to human health due to pesticide exposure and
- gaps in current knowledge and procedures that could expose populations to risk of exposure to pesticides.

**The legislative requirements to protect manufacturing workers and farm applicators from exposure to pesticides are complex and overlapping and some aspects of practical protective equipment and information required to ensure compliance are lacking. Consideration should be given to developing a system of**

**formal reporting of workers' exposure to pesticides, including the establishment of an Adverse Health Effects Register that records all acute health effects definitively shown to arise from pesticide use.**

**The food safety monitoring programs in place in Australia are impressive by international standards, and compare favourably with similar studies undertaken in the United States of America and the European Union. There has been a consistent demonstration of very low levels of pesticides and contaminants in Australian diets. However, to provide continuing assurance to Australian food consumers and export customers, monitoring must be maintained of chemical residues that can enter the food chain.**

**One key issue that has emerged from this collation of residue information, and is reflected in community concerns, is the difficulty in securing access to timely and accurate information about residue monitoring programs and their outcomes. Awareness should be increased of web-based technology already being introduced, with added appropriate links, to overcome these concerns.**

### **Pesticides in the Environment**

The toxic properties of chemicals vary greatly between species and the effects are influenced by a variety of environmental factors.

This study has encompassed the transport, degradation and environmental impacts of pesticides in Australia. A wide but uncoordinated range of environmental studies involving surface and groundwater, soils, pastures and livestock, natural biota, and air is discussed. The extent of current environmental monitoring has been evaluated, and suggestions made on ways in which pesticide impacts on the environment may be further reduced. It is noted that overseas fate and transport studies are not directly transferable to Australian ecosystems, although most overseas toxicity data can be used for risk estimates.

**Any consideration of the environmental impact of pesticides must differentiate between hazard, which is an inherent property of a chemical that makes it capable of causing adverse effects, and risk, which is the probability that the harm from the chemical is realised under the specific conditions being considered or likely to be encountered within its permitted uses.**

Endosulfan has been perceived as the chemical with greatest potential for risk in catchment and water environments. It has been widely used in the cotton industry. Levels found in surface waters in cotton-growing areas of eastern Australia declined from 89% exceeding 0.01µ/L in 1993-4 to only 29% in 1999-2000. Only 10% exceeded the ANZECC/ARMCANZ standard of 0.03µ/L. The National Registration Authority for Agricultural and Veterinary Chemicals (NRA) has imposed more stringent controls on the use of this chemical. Some rivers which in earlier years showed significant levels, had no detectable levels in 2000.

Residues of organochlorines, withdrawn from agricultural use twenty years ago, are still occasionally found in surface waters. Current pesticides are much less persistent but are still being detected in some surface waters.

Pesticide contamination of groundwaters has been noted world-wide. Where groundwater contamination has been detected in Australia, it has usually involved triazine herbicides. Pesticide residues in Australian groundwaters have generally been lower than those overseas, and a number of recent surveys show reductions in the extent of residues now being detected. However, poor land management practices in a few areas are continuing to create groundwater contamination risks.

The measurement of pesticide residues in sediments or biota may be more useful than testing for residues in water. Residues of endosulfan, organophosphorus and other pesticides have been detected in Australian biota near intensive agricultural areas. The NRA controls on the use of endosulfan are expected to reduce the risk to biota, particularly of any fish kills in cotton-growing areas.

**Relatively speaking, little is known of the effects of pesticides on Australian species in their natural habitats. More information is also required on the effects of newer pesticides on birds and termites in their natural range. Although the risk of off-target herbicide damage to commercial crops, especially vineyards, is well established, off-target damage to native plants and trees needs further attention.**

**More emphasis needs to be given to monitoring the biological effects of pesticides on organisms and ecosystems rather than just testing concentration effects in individual species.**

Monitoring of the impact of pesticide use on the natural environment is not well or consistently structured, being spread between the Commonwealth and states/territories agencies. It has often been carried out in an *ad hoc* manner in response to short term events which are perceived to impact on stakeholder groups. Any longer-term trends have been difficult to detect. A greater breadth of evaluation, encompassing the post registration monitoring of results by the NRA, together with a more integrated approach by the states/territories is desirable.

**A comprehensive integrated national environmental monitoring program should be implemented.**

**The recommended National Adverse Health Effects register should be broadened to become a National Adverse Pesticide Effects Register, recording acute incidents where pesticides have had an adverse impact on the natural environment.**

### **Regulation**

Beginning in the 1950s, individual States and Territories registered pesticides under their own legislation and gradually worked towards harmonisation of registration requirements through a clearance process coordinated by the then Commonwealth Department of Primary Industries. However, significant differences between States remained with only some States having legislation in place to control the use of pesticides at the farm level.

Following the detection of organochlorine residues in Australian beef in 1987 and the Senate Select Committee enquiry in 1990, the then Australian Agricultural Council agreed in August 1991 that a single national Agvet chemicals registration scheme should replace the eight State and Territory registration schemes. The National Registration Scheme, administered by the National Registration Authority for Agricultural and Veterinary Chemicals, a Commonwealth statutory body commonly known as the NRA, commenced in March 1995.

The assessment of pesticides by the National Registration Authority for Agricultural and Veterinary Chemicals appears to be a rigorous process that uses internationally accepted principles of risk assessment, though the Authority's existence and role is little known in the general community. In particular, assessments reported in the full texts of recent reviews of products under the Existing Chemicals Review Program are indicative of a careful scientific approach and use of all available information and literature in the assessment. It is imperative that this leading-edge proficiency in its assessments is maintained. There are still ambiguities in the role of the NRA *vis à vis* other Federal and State agencies.

**While recognising that the NRA has a close relationship with AFFA for the assessment of the potential for a chemical to cause an undue trade hazard through the use of trade advisory notices, international sensitivities are continuing to increase, in some cases to generate trade barriers. The effectiveness and transparency of the process will be improved if AFFA and the NRA finalise an inter-agency protocol and also set in place a process for regularly reassessing the agreed protocol.**

**The NRA should endeavour to have its role better known and more transparent to the general community, to engender a greater awareness of and confidence in the Australian pesticide regulatory system.**

**While its activities have been encompassed within the National Competition Policy Review, and its efficiency has been audited by the Australian National Audit Office, it is ten years since the NRA was established and so it is considered that it would be timely for an independent review of the NRA to be jointly commissioned by the Federal and States/Territories Ministers of Agriculture/Primary Industries. The review should encompass the operations, management, governance, efficiency and effectiveness of the NRA and the level of public awareness and confidence in its operations as well as the legislation under which it operates.**

Primary responsibility for developing policy advice on agricultural and veterinary chemicals issues rests with the Agricultural and Veterinary Chemicals Policy Committee, established in 1993 under the auspices of the then Standing Committee on Agriculture and Resource Management. Originally, it had 17 members and 7 observers drawn from agricultural/primary industries, environment, health, forestry, occupational health and safety and urban planning agencies, the NRA and CSIRO. It was restructured to provide a

more senior level of participation in 2001 with a reduced membership from agricultural/primary industries portfolio agencies and CSIRO. Other portfolio and industry representation is on two advisory committees.

**While this study supports the elevation of AVCPC membership from the technical to the policy level, the effectiveness of the revised arrangements, particularly in the light of the isolation of representatives from other portfolios, and from other organisations into two subordinate bodies, should be reviewed after two years.**

Following earlier residue detections impacting on product markets, the remaining uses of organochlorines were banned in 1992. However, there have since been further residue events with other chemicals, some involving spray drift onto non-target crops, pastures and livestock, and one involving drought feeding of cattle with cotton-trash which had earlier been sprayed with chlorafluazuron, whose residues were subsequently detected in the beef. A national review of pesticide spray drift was commenced in 1993, and final guidelines have recently been prepared for publication.

In 1995, a National Competition Policy (NCP) review of Agricultural and Veterinary Chemical legislation was undertaken. After earlier efforts had not made conspicuous progress, an outcome of the NCP review was the establishment of a Control-of-Use Task Force to develop a nationally consistent approach to pesticide use, particularly with regard to off-label use. However, its accomplishment yet remains elusive.

**As part of completing its tasks, the Control-of-Use Task Force should initiate a comparative analysis between the states and territories of the outcome effectiveness of current control-of-use mechanisms used in the respective states. This could be done by evaluating AQIS data for pesticide residue levels found in export produce, food residue data from the National Residue Survey, and States/Territories data on adverse environmental, health and OH&S incidents or claims.**

Over sixty pieces of legislation remain on the statute books of the Commonwealth, States and Territories, directly or indirectly impacting on the management of agricultural and veterinary chemicals. The continued variation between the states/territories agencies responsible for control of use of pesticides is of concern. To ensure that overseas trade competitors do not identify these mechanisms as inconsistencies in the production of export commodities, these pesticide use policies should aim to achieve harmonised outcomes as a matter of urgency and priority.

**Whilst identical States/Territories legislation which is exactly complementary to that of the Commonwealth is unlikely to be achieved, nor is it necessary, it is recommended that legislation which better achieves harmonised outcomes should be sought as a matter of principle. The legislation should be established to agreed standards using a set of parameters which are capable of consistent adoption and enforcement. These parameters and their descriptions and interpretations should be posted in a common, agreed form on the web-sites of all the Commonwealth and States/Territory agencies responsible for pesticide management.**

As a further example of current anomalies in pesticide management arising from responsibilities shared by different portfolios, a recent study has identified approximately

650 anomalies for Agvet chemicals in food commodities between the NRA MRL Standard and the ANZFA Food Standard A14. This is currently a major problem for growers when their products comply fully with NRA requirements, including its MRL standards, but do not meet the ANZFA Food Standard A14 at the point of attempted sale. A recent NRA proposal to ANZFA suggested that NRA MRLs should be listed as provisional in the ANZFA code until ANZFA administrative processes were complete. This change would make NRA permits immediately useful to producers. Delegation of the task of approving MRLs to the professional officers in ANZFA would serve as a means of improving timeliness.

Communication with growers and provision of consistent technical information in plain English, or in some cases in other more appropriate languages, remains a problem.

**The NRA and/or the AVCPC should review the currently available pesticide information technology services and determine whether or not the current scope of the services provides an adequate, and sufficiently accessible user-friendly information technology service on appropriate pesticide use for a wide array of pests and crops to pesticide users, including those for whom English is not their first language.**

**The AVCPC should address how simple, robust summary versions of Material Safety Data Sheets should be provided, expressed in plain English, and potentially also in other community languages for those for whom English is not their first language.**

### **Pesticide Handling and Management**

A notable finding in some Western European countries, is that food consumers are giving as much weight to being assured that the production of the food they consume has not had adverse environmental/resource impacts, as they are to being assured that the food does not contain residues harmful to human health. Both Quality Assurance (QA) and Environmental Management Systems (EMS) programs represent a form of quasi-regulation which impose hurdles for producers additional to those imposed by the Commonwealth and State pesticide regulations. With respect to pesticide use, the hurdles arise because 'new' production and management systems are being mandated which, if properly implemented and managed, would ensure that acceptable pesticide standards are assured. In consequence, the overall monitoring system for pesticide residues in food, fibre and the environment, whether set by regulation or demanded by purchasers, will become more comprehensive.

For Australian primary producers, meeting EMS codes of practice will become as important as food safety and quality assurance schemes. These are currently reflected in certification for AS/NZ14001. Farmers may find it increasingly difficult to find markets for food produced under management systems that are unable to establish certification for environmental performance standards including providing evidence of freedom from harmful environmental pesticide or other impacts.

**Farmers should ensure they are able to certify that their commodities are produced from management systems that meet both minimum performance standards**



**including freedom from any pesticide residues at levels of unacceptable risk, and contemporary environmental standards.**

The national training and accreditation program for farm chemical users was established in the early 1990s by the NFF and the Rural Training Council of Australia (RTCA) to develop and co-ordinate training so as to raise competency levels of users of agricultural and veterinary chemicals. A range of educational providers have assumed responsibility for this training. The agricultural and veterinary chemical industry also has a national training and accreditation program, known as Agsafe Accreditation. Commercial operator training and accreditation programs are also in place or are being developed for both commercial aerial and ground operators who apply agricultural chemicals. All of the programs regularly enhance standards with higher requirements for training and accreditation of chemical users.

As a result, there have been significant improvements in the levels of educational achievement by producers and contract applicators in pesticide handling and management over the past ten years. These are increasingly required before users can gain access to some pesticides, thereby generating benefits for both pesticide users and agricultural product purchasers.

In recent years there have been significant industry/government-driven changes to the packaging in which pesticides have been supplied, and to the subsequent disposal of chemical containers and surplus chemicals. These programs have significantly reduced the risk of environmental damage from pesticides.

Biotechnology has dramatically increased the range of characteristics we can incorporate into our crops. However, the development of genetically modified organisms has engendered considerable public debate, some of which may impact on market opportunities.

The introduction of genetically modified crop varieties as an alternative to some pesticide use has already been shown to reduce dependence on pesticides and to reduce the levels of application.

The first adoptions of gene transfer technology for commercial crop varieties have been directly aimed at pest control. These form categories of genetically modified crops which are either as “pest-protected” or “herbicide tolerant”. Globally, 90% of the genetically modified crop varieties currently in commercial use either confer insecticidal properties on plants to kill pest insects that feed on them (examples being Bt corn and Bt cotton varieties), or confer herbicide tolerance properties to crop varieties so that a particular broad-spectrum herbicide can be used to control a wide selection of weeds within the crops without damaging the crop itself.

Currently, cotton is the only broad acre crop in a high pesticide-use industry having varieties with a genetically modified pest-protected attribute which enables comparison with non-genetically modified varieties. The reduction in use of insecticides on Bt cotton during the four seasons for which data are available has ranged between 43 and 57% for *Helicoverpa* spp. sprays and between 38 and 52% for all sprays. However, this involves the use of a single resistance gene and a rigorous refugia protocol to minimise the risk of

resistance to the gene being developed in the insect population, with Bt cotton plantings being limited to 30 per cent of the total crop area. Current research suggests a 70-80 per cent reduction in insecticide applications may be applicable and that 70-80 percent of the total crop area is likely to be approved for two-gene varieties currently being developed. The introduction of Bt cotton has also increased the adoption of Integrated Pest Management (IPM) practices.

Herbicide resistance in weeds has become a major crop-growing problem. To this end, new crops (notably canola) have been introduced into rotations, initially using varieties with natural tolerance to those herbicides used to manage weeds during the crop growth phase. Genetically modified crops with tolerance to herbicides are also being developed, and their management will essentially be the same. The use of herbicides such as glyphosate will reduce the use of herbicides having residual effects on subsequent crops. However, herbicide resistance development in the weeds, along with possible weed development of the crop itself, are still management issues

**In the next five years, an increased number of pest protected or herbicide tolerant crops will become available to impact on pesticide use, particularly where genes are pyramided and resistant management strategies can be varied to allow a larger proportion of the total crop to be planted to genetically modified varieties. In view of this, it is recommended that the newly-appointed Gene Technology Regulator and the Chief Executive of the NRA jointly increase awareness of the respective roles and responsibilities of each organisation so that their roles and their methods of risk assessment are transparently evident to plant breeders, industry organisations, pesticide companies and produce users alike.**

### **The National Strategy for Agricultural and Veterinary Chemicals**

ARMCANZ endorsed a National Strategy for Agricultural and Veterinary Chemicals in 1998. The intent of the Strategy is to “maximise the benefits from the use of agvet chemicals while minimising the risks of undesirable side-effects”.

The Strategy outlines a number of objectives which give expression to this intent. These objectives include integrated farm, forest and natural resource management; reduced reliance on chemicals; increased efficiency and effectiveness of chemical assessment and approval processes; reduced risks associated with use of chemicals (including best management practices); better understood potential impacts of chemical use on human health and reduced adverse effects; better understanding of potential impacts of chemical use on the environment and reduced adverse effects; maintenance of acceptable residue levels in food and fibre; enhanced market access for primary produce; and assurance of safe disposal of unwanted chemicals and containers.

Although some progress is taking place, there appears to be little current impetus toward implementing the National Strategy.

**The National Strategy for Agricultural and Veterinary Chemicals is a sound approach to moving forward in Australia’s pesticide management policies and practices, but it is noted that this strategy has now been extant for over three years with only limited achievement towards its implementation. The Strategy should be**

**progressed forthwith to ensure a consistent national approach to the risk management of agricultural and veterinary chemicals.**

There is a small but commercially important market in Australia for products grown without use of synthetic pesticides, and there needs to be continuing effort to advance approaches that reduce risks by using fewer, safer or even no pesticides. Some organic production systems access organic (non synthetic) pest control products that remain unregistered. These require critical examination and if appropriate, registration. The adoption of any new organic systems, as is the case for any technological changes, should be on a basis of overall net benefits including environmental gains.

The current state of agricultural and forestry technology is such that a rapid transition to an economy free of synthetic pesticides could not be accomplished without a dramatic drop in output. This would be because of increased per unit of production input costs, the potential dilution of current niche “organic” market profit premiums and more significantly, a probable marked reduction in the standard of living in Australia and in its position in the world economy.

Despite pressure from some consumer and environment groups, and growth of an organic produce sector, pesticides will continue to play an important role in sustainable agriculture and forestry in Australia and also in a wide variety of other aspects of modern Australian life.

It is a truism of pest management that new threats to production continue to evolve. We know that in some cases farm practice can speed this evolution through unwise use of pesticides, for example in generating pesticide-resistant strains. Similarly, in the broader sphere of management, new standards are continually being set, new health and environment studies are reported, and consumer attitudes change.

**As new threats to production continue to evolve, new and enhanced technologies will need to be developed and adopted in the future if Australia is to retain the markets for its food and fibre products. This management model is known as continuous improvement, and it applies in agribusiness just as much as it does in industrial manufacture or office procedure. It needs to be applied to the entire pesticide pathway.**

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# **1. INTRODUCTION**

Pest management has been an aspect of land management in Australia from earliest times. Many species have been introduced, either deliberately or accidentally and become pests. Pesticide chemicals have been recognised world-wide as tools in the battle against pests to ensure the supply of adequate supplies of competitively priced safe wholesome food for human-kind. Any adoption of chemical pesticides must follow from a consideration of the benefits in relation to the hazards and risks involved

Pests have long been the scourge of farmers. In Australia, the small population of indigenous inhabitants had followed a hunter gatherer lifestyle, having learned the nutritional and medicinal capabilities of the environment within which they lived. Their primary management tool was fire, used for refreshing plant growth and harvesting animals within an ecosystem which had adapted to periodic fire events.

Arable agriculture and animal husbandry was brought to the Australian landscape by the first European settlers in the late eighteenth century. As well as introducing the commercial crops and livestock with which they were experienced, they also brought with them a variety of other species to make themselves “feel at home” in their new land. Some were brought for enriching their gardens, others for the sporting purposes such as coursing and hunting. Still further species arrived by default, as accidental contaminants in imported consignments. Many of these species adapted readily to the environment and irrevocably changed Australia’s original natural ecosystems and later farming and grazing ecosystems.

They became pests.

The classic example is the rabbit. Introduced with the first fleet, they were first thought to be a useful source of food, and then encouraged as a traditional target for game hunting, for which they were released in a variety of locations, the first being thought to be at Barwon Park, near Winchelsea, Victoria in 1859. In South Australia, rabbits were initially protected for spring breeding in the South Australian *Game Act 1866*. In 1870, they had been released near Kapunda for the hunt, but had become a major pest of the agricultural areas by 1880 (Rolls 1969).

Ever since, land managers have been seeking ways to control these pest “escapes” using a variety of methods including the hand removal or the controlled grazing of pest plants and by shooting and trapping of feral animals. Some biological control introductions were tried, classically successfully so between 1925 and 1932 in the case of cactoblastis moth (*Cactoblastis cactorum*) for the control of prickly pear (*Opuntia* spp), and unsuccessfully in the case of cane toads (*Bufo marinus*) for the control of Frenchi and Greyback cane beetles. The most recent success story has been the eradication of Papaya fruit fly (*Bactrocera papayae*) which was detected near

Cairns in October 1995. By quarantining an area of 70 000 sq km, and adoption of an attractant-baiting malldison program extending over four years and costing nearly \$40 million, the pest, which threatened the entire tropical fruit industry and significant native species, was eliminated.

Chemicals have long been recognised as an additional management tool in the battle against pests. However, community concern began to develop about their use, and various regulatory processes were introduced by the states. These concerns were heightened with the recognition that there could be environmental disadvantages in the use of 1,1,1-trichloro-2,2-bis(4-chlorophenyl) ethane (DDT), which had been developed and used in World War II to great advantage in managing the insect populations responsible for transmission of diseases, particularly malaria. The marked benefits of these synthetic pesticides had tended to mask some of the problems that they caused to the environment, but Rachael Carson's book *Silent Spring* (Carson 1962) focussed public concern onto the environmental harm caused by some of these compounds. The features that made some of these chemicals so effective were the same ones that enhanced their potential environmental harm (Metcalf 1980). These included: persistence – which led to development of resistance, secondary pests, widespread environmental contamination, biomagnification and effects on animals higher in the food chain (including humans); and high and non-specific toxicity – which enhanced effects on non-target species (National Research Council 2000). Following *Silent Spring*, pesticide use came under increasing scrutiny.

Nevertheless, these issues are not simple.

Pesticides, by definition, are biologically active substances which are intended to kill or incapacitate pest species. That portion of the pesticide formulation which is biologically active and kills or controls the target organism is known as the “active constituent”. As an unintended result, the active constituents may also affect non-target species (Aquatech 1997). The formulated product, or formulation, is the pesticide prepared for commercial sale to potential users, involving the incorporation of one or more active constituents into an appropriately formulated preparation at a designed concentration within a carrier, sometimes also including an adjuvant. Each product is subject to formal registration as is discussed in further detail in Chapter 7.

A consideration of any harm pesticides may cause must be offset by a consideration of the benefits conferred by their use. Bioaccumulated DDT causes thinning of eggshells and reproductive failure in birds. In humans, it may be a carcinogen and could interfere with lactation, though neither of these harms has been conclusively confirmed. Developed countries have little to gain from its use. However, it is still used by 23 tropical countries. Its use over twenty years in Sri Lanka reduced the annual burden of malaria from 2.8 million cases and 7 300 deaths to 17 cases and no deaths (UNDP 2001). The need to continue the use of DDT for vector control in certain countries has been recognised by means of special provisions incorporated into a recently concluded United Nations sponsored treaty, the Stockholm Convention on Persistent Organic Pollutants (POPs). Since it opened for signing in May 2001, the Convention has been signed by over 90 countries, including Australia, but ratified by only one, Canada. Details may be found at <http://irptc.unep.ch/pops/>. Production and use of DDT is to be eliminated except for those countries seeking and being

granted specific exemption, and then only for disease vector control under defined conditions.

Pesticides are generally perceived as a necessary evil. Necessary, because of high world demand for food and fibre, high cosmetic standards demanded by consumers, strong economic forces on producers to remain competitive, requirements by quarantine for trade, and because pesticides represent the only rapid method of intervention when pests exceed levels causing economic damage. An evil, because pesticides are generally acknowledged to have a potential for negative impact on our health and environment, and because their use may lead to problems of pest resurgence, secondary pests and pesticide resistance, the combination of which is often referred to as a “pesticide syndrome” (Doutt and Smith 1971).

Whether to use a pesticide ultimately requires an evaluation of the benefits in relation to the costs of its introduction, both in terms of its efficacy and the economics of its use, but also in terms of the hazard (the inherent properties of a chemical that may make it capable of causing adverse effects) and the risk (which is the probability that harm is realised under a particular set of conditions where the chemical is to be used). These issues have underpinned the consideration in this study of pesticide use from a perspective of agricultural systems, health, the environment and regulatory systems.

## **2. THE PESTICIDES**

Pesticide use has been changing. The real total investment in pesticides has been progressively increasing over the past twenty years. Farmers have been prepared to incur higher chemical costs in pursuit of more effective pest control. The primary categories of pesticides are insecticides, herbicides, fungicides and growth regulators, whose total market value in 1999 was nearly \$1600 million. Issues affecting pesticide choice include efficacy including the possible development of biological resistance, pesticide and commodity prices, the possibility of residues, toxicity to operators and the community, off-target impacts, market implications, and the impact of their use on other pest strategies such as integrated pest management. There are about 6000 products using 2000 technical grade active constituents currently approved for use in Australia. There are over 250 chemicals for which more than one tonne is imported and/or manufactured in Australia annually. The most widely used pesticide is the herbicide glyphosate. However, there is no detailed and publicly available information on the usage of individual pesticides. Consideration should be given to establishing a pesticide use reporting system in Australia.

### **2.1. THE EXPENDITURE ON AGRICULTURAL PESTICIDES**

Recent changes in land use have resulted in changes in the range of pesticides used in parts of Australia. The use of pesticides varies greatly with different agricultural industries. Some industries such as grapes, citrus and other fruit growing, experience consumer and industry pressure to minimise pesticide use (J. Kassebaum, PIRSA, pers. comm.). There has been a gradual increase in the adoption of improved integrated pest management (IPM) practices that decrease the need for some chemical pesticides (ARMCANZ 1998).

Data on the magnitude of pesticide use are not readily available. Even what is available can be difficult to interpret. The figures are usually presented in one of three ways: weight or volume of active ingredient, value of sales, or number of applications. Although weight of active ingredient is the most accurate measure, it is difficult to use in general comparisons. It is obviously useful when comparing alternative uses of a single type of pesticide, but if a high rate of one pesticide is replaced by a smaller amount of another, questions immediately arise as to the effective equivalence in the comparison. It may be that a much larger amount of one pesticide is more desirable, environmentally, than a small amount of another. More recently developed pesticides are generally applied at far lower rates of active ingredient. Analyses using only weight of ingredients might suggest a dramatic reduction in pesticide being used over years in a particular industry. Depending on the

environmental properties of the pesticides, this may or may not reflect a desirable trend.

### **2.1.1. Expenditure**

Historical data showing the extent of expenditure on all agricultural chemicals over the period 1974-75 to 1997-98 are available. These data (Table 1) show that the total real investment by farmers in agricultural chemicals has steadily increased.

Sales of crop protection pesticides increased by some 836% during this 23 year period (an annual increase of 36%), while the area of farms decreased by 6.6%.

In the 16 years from 1974-75 to 1990-91, sales increased by 294% or 18% per year. In the 7 years from 1990-91, total crop protection pesticide sales increased by 138% or nearly 20% per year.

**Table 1**  
**Pesticide Sales, Total Area of Farms and Prices Paid for Chemicals**

<b>Year</b>	<b>Total Crop Protection Sales+ (in '000 of 1998 \$)</b>	<b>Total Area of Farms# (in million ha)</b>	<b>Index of Total Crop Protection Sales (in 1998 \$ / ha of farms)</b>	<b>Index of Prices Paid for chemicals (97-98=100)</b>
1974-75	138 985	499.6	0.28	34.0
1978-79	240 554	493.2	0.49	50.0
1982-83	350 942	483.8	0.72	66.0
1986-87	463 801	471.0	0.98	89.4
1990-91	547 151	462.8	1.18	96.4
1991-92	688 709	466.0	1.48	97.5
1992-93	744 026	460.1	1.61	98.0
1993-94	650 195	469.0	1.39	97.2
1994-95	796 118	463.3	1.72	97.9
1995-96	971 865	465.2	2.08	98.1
1996-97	1 116 847	466.1	2.39	99.0
1997-98	1 300 827	466.4	2.79	100.0

Source: ABARE Australian Commodity Statistics

+ The term total crop protection sales encompasses the sales of herbicides, insecticides, fungicides and plant growth regulators.

# The term total area of farms is the area of all farms in Australia. It includes pastoral properties as well as agricultural and horticultural farms.

These data are not helpful, however, in showing what comprises use, or whether new products have come out which are more valuable and offer less risk, and nor do they give a measure of effectiveness over the 25 years. We cannot establish a relationship between changes in herbicide use in relation to changes in soil tillage practices, nor can we ascertain what changes have occurred in volume of active constituents used to formulate various chemicals. Nevertheless, it is apparent that farmers have been

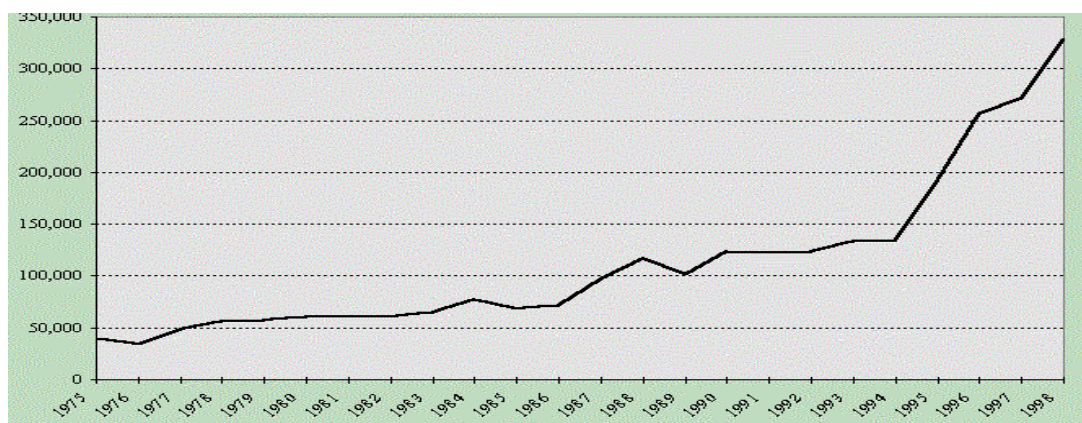
prepared to incur increasing costs in real terms in pursuit of more effective pest control with chemicals.

### **2.1.2. Categories of Pesticides**

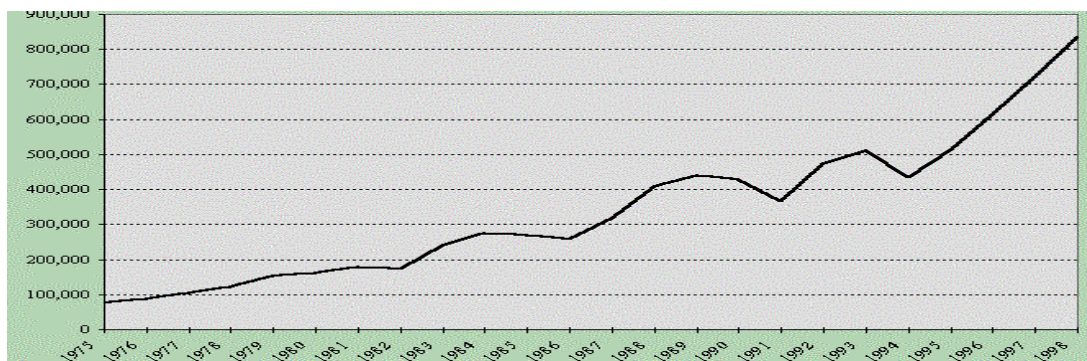
The principal categories of pesticides used in the rural areas of Australia are insecticides, herbicides, fungicides and growth regulators, and they are of major importance in commercial agriculture and horticulture. Further chemical categories are rodenticides, acaricides and molluscicides, but in the overall context of pesticide use in Australia, their use is minor. However, these lesser categories of pesticides can be important in unusual and specific circumstances, for example rodenticides in the control of mouse plagues.

Details of total costs incurred for insecticides; herbicides; and fungicides and growth promotants are given in figures 1-3

**Figure 1:- Total Insecticide Sales, 1975-1998, expressed in thousands of 1998-value dollars**

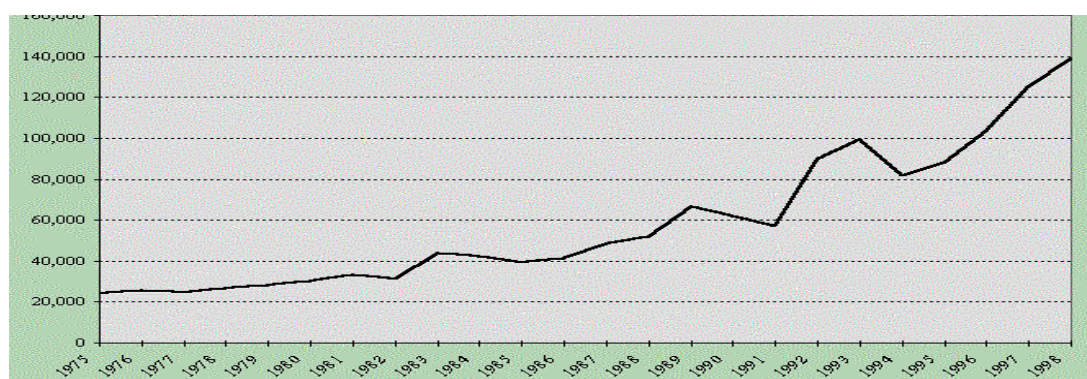


**Figure 2:- Total Herbicides Sales, 1975-1998, expressed in thousands of 1998-value dollars**





**Figure 3:- Total Fungicides and Growth Promotant Sales, 1975-1998, expressed in thousands of 1998-value dollars**



Data from Agriculture, Fisheries and Forestry Australia

### **2.1.3. Chemical costs as a proportion of farm cash costs**

There has been a progressive increase in most agricultural industries in the cost of farm chemicals as a proportion of total cash costs. Data for the ten-year period from 1988-9 to 1998-9 for broad-acre agriculture are given in table 2.

**Table 2**  
**Percentage of total farm cash costs in broad acre agriculture attributable to purchases of chemicals**

Year	Chemicals as % of total farm costs
1988-89	2.6
1989-90	3.4
1990-91	3.1
1992-92	4.2
1992-93	4.3
1993-94	4.3
1994-95	4.3
1995-96	4.9
1996-97	6.3
1997-98	6.2
1998-99	6.7

Source: ASPIRE database (ABARE 2000)

### **2.1.4. Determining Recent Trends and the Current Use of Pesticides**

Obtaining specific data about the recent and current use of pesticides in Australia presents some difficulties.

Two possible sources were identified. The first is the National Registration Authority for Agricultural and Veterinary Chemicals (NRA) which was established and operates under the *Agricultural and Veterinary Chemicals (Administration) Act 1992* and the *Agricultural and Veterinary Chemicals Code Act 1994*, and whose functions are further discussed in Chapter 7. The second source of information is the agricultural chemical companies themselves.

The NRA collects information on the volume of pesticides, expressed in terms of active ingredient and of formulated product manufactured in Australia, imported into Australia and exported from Australia. It provides this information to Agriculture, Fisheries and Forestry, Australia (AFFA). The provisions in the legislation establishing the NRA provide for the detailed information to be collected, information which is confidential. The confidentiality of this information precludes specific data being made publicly available.

Australia is a potential signatory of the Rotterdam Convention on the Prior Informed Consent Procedures for Certain Hazardous Chemicals and Pesticides in International Trade (PIC). The Convention covers chemicals that are banned or severely restricted for health or environmental reasons. The listing of a chemical on PIC confers obligations on participating countries. Under Article 14 of the convention, certain information cannot be considered confidential, including information that gives the properties, identification and uses of the chemical, together with information specific to the regulatory action (to ban or specifically restrict a chemical); information contained in the material safety data sheet; the expiry date of the chemical; information on precautionary measures including hazard classification; the nature of the risk; and the relevant safety advice and summary results of toxicology and ecotoxicology tests. (S. McCutcheon, AFFA, pers. comm.). Negotiations on this treaty were completed relatively recently and it has not formally commenced. It will not do so until 50 countries have ratified the Convention. Australia has signed but not as yet ratified the Convention. In the meantime, an interim procedure is operating (I. Coleman, AFFA, pers. comm.).

Under the treaty, Australia would not need to provide detailed information on imports, manufacture or exports but would use the information it has to provide a description on the nature of the characteristics and use of any chemical proposed for listing.

Agricultural chemical companies collect pesticide use information to develop their market strategies. The information has commercial significance so it is guarded closely. Both dollar value and volume of use information are collected.

The information is collected by an independent market research company from both the participating companies and also from the market place. In the period of this study, 1996 to 1999 inclusive, participating companies provided between 70% and 80% of the chemicals in the market so the information is robust.

While absolute values for the volume of pesticides used in Australia were not provided, information on the dollar value of the Australian pesticide market and on

the trends in the volume of pesticides used in Australia were provided by industry to this study.

Information on the trends in volume of pesticides used was provided for herbicides, insecticides, fungicides and plant growth regulators. These trends were identified by citing the volume of pesticide used in 1996 as the base and that for each subsequent year as a percentage of the base year. This pesticide information refers to the whole Australian market and is gathered and cited for calendar years.

The information on the pesticide market value and that on the trends in volume of technical grade active ingredient pesticide use was provided on behalf of Australian agricultural chemical industry by Crop Care Australasia Pty Ltd, Brisbane, a major agricultural chemical company in Australian agriculture.

### **2.1.5. The Pesticide Market**

The Australian crop protection market expanded from just over \$1100 million in 1996 to just under \$1600 million in 1999, a 40% increase or some 10% per year (in nominal \$ terms). Industry estimated the market in 2000 would reduce by some 5% to around \$1550 million.

The sales of insecticides increased by 40% to some \$500 million between 1998 and 1999. The sales of fungicides increased by around 30% to \$200 million at the same time.

Herbicides are the major pesticide market with annual sales in 1998 and 1999 of just over \$800 million while the market for plant growth regulators also remained the same over those two years at some \$60 million. (P. Chalmers, Crop Care Australasia Pty Ltd, pers. comm.)

The Australian agricultural chemical industry identifies five (5) significant segments of the Australian crop protection market. These are:-

- broadacre cropping – wheat, oats, barley, grain sorghum, canola, peanuts etc
- cotton
- sugar cane
- horticulture – fruit, vegetables etc
- other

The monetary values of these markets in 1998 and 1999 (Table 3) were:-

**Table 3:-  
Australian Crop Protection Market 1998 and 1999**

Segment	1998 Value (\$M)	1999 Value (\$M)	Estimated 2000 Value (\$M)
Broadacre	750	750	750
Cotton	250	400	350
Horticulture	225	250	250
Sugar Cane	50	50	50
Other	150	150	150
Total	1400	1600	1550

Source: Crop Care Australasia Pty Ltd.

These data help to explain the significant increase in the value of cotton insecticides in 1999 when the area planted to cotton increased markedly and the 1998-99 cotton crop was subjected to huge insect pressure and pest control was difficult to achieve. These issues are discussed in more detail in Chapter 4.

A number of other factors contributed to the recent market expansion for pesticides. These include a marked shift from grazing enterprises, particularly sheep, to cropping (Table 4), continued pest pressures on crop production and on-going pressures on the terms of trade for crop products. The enhanced demands of consumers and importing countries on food quality and, in particular, freedom from insect pests, diseases and weed seeds also contributed to the market expansion.

The total area cropped in Australia increased by nearly 20% from just under 18 million ha in 1996 to just over 21 million ha in 1999. At the same time, sheep numbers declined by 5% from some 121 million to 115.5 million. During the same 4 year period, Australian pesticide sales expanded by nearly 30%, a greater rate of expansion than that in the area cropped (Table 4).

**Table 4:-  
Trends in Pesticide Sales, Area Cropped and Sheep Numbers**

Year	Pesticide Sales index	Area cropped index	Sheep numbers index
1996	100	100	100
1997	110	111	99
1998	120	110	97
1999	129	119	95

Source: Crop Care Australasia Pty Ltd and Australian Bureau of Statistics

A factor in this market expansion was the increased use of under-patent more target specific or 'soft' pesticides as opposed to the older, generic broad spectrum or 'hard' pesticides. The new materials are, understandably, more expensive.

An example of the impact on price when a pesticide comes out of patent is the reduction in the price of the insecticide deltamethrin, from around US\$500/kg active

ingredient in 1995 to some US\$220/kg in 2000 when patent protection expired. The price of out-of-patent pesticide active ingredients has also fallen during the review period. For example, the price of glyphosate has fallen from some US\$7.30/kg active ingredient in 1995 to US\$2.70/kg in 2000. The reductions in the price of out-of-patent pesticides is largely driven by China which is now a very significant pesticide producer with an aggressive marketing and pricing policy (S. Ho, Alliance Chemical Pty Ltd, pers. comm.).

Given the significant price reductions in out-of-patent pesticides during the study period, the annual increases in the value of the Australian pesticide market underline the shift to softer, under-patent pesticides.

The annual monetary value of the Australian crop protection market is a legitimate but somewhat blunt indicator of trends in pesticide usage. The volume of pesticide active ingredients used is a sharper indicator of those trends. Other useful indicators include changes in:-

- pesticide formulation
- pesticide packaging
- pesticide application methods
- pesticide regulatory requirements
- operator training and accreditation

### **2.1.6. Trends in the Volume of Pesticide Used, 1996-1999**

Over the 4 years 1996 to 1999, the volume of herbicides applied nationally was some 6 times the volume of fungicides used, while the volume of insecticides applied was about 3 times the volume of fungicides used. The volume of plant growth regulators used was some 20% of the volume of fungicides (P.Chalmers, Crop Care Australasia Pty Ltd, pers. comm.).

The volumes of herbicides, insecticides, fungicides and plant growth regulators used in Australian crop production in the each of the years 1996 to 1999 are shown in Table 5:-

**Table 5**  
**Indices of the Volumes of Crop Protection Pesticides Used in Australia, 1996-1999**

Year	Herbicides	Insecticides	Fungicides	Plant Growth Regulators	Total
1996	100	100	100	100	100
1997	108	115	108	103	110
1998	114	139	123	98	125
1999	98	140	146	107	138

Source: Crop Care Australasia Pty Ltd.

NOTE: all figures are indices for calendar years.

The growth product categories have been insecticides and fungicides over this 4-year period. Most of the 40% increase in volume of insecticides applied was the result of

the extreme insect pressure on the 1998-99 cotton crop and a 70% increase in the area planted to cotton. Some 320 000 ha were planted for cotton in 1995-96. By 1998-99, the area had increased to 550 000 ha (Anon 1999d).

The 46% increase in the volume of fungicide used in the review period also derived from significant changes in farm production systems. These changes included the marked shift from sheep and wool production to the more profitable grain growing particularly in southern and western sheep/grain farming systems.

As stated earlier, sheep numbers declined by 5% from 121 million to 115.5 million between 1996 and 1999. At the same time, the area planted to wheat increased by 25% from 9.2 million ha to 11.5 million ha (Anon 2000b). This land use change not only reduced the area under pasture but it also reduced the length of the pasture phase and increased the length of the crop phase in rotations with the accompanying increase in the incidence of disease.

Another key influence in the increased volumes of fungicides applied is the diversification of grain production, again particularly in the southern and western grain systems. These grain crop production systems have changed from the traditional wheat, barley and oats to encompass canola, lupins, field peas and faba beans. The area planted to canola increased by 230% from 377 000 ha to 1 247 000 ha between 1996 and 1999. The area planted to other oilseed crops increased by nearly 100% from 146 000 ha to 291 000 ha in the same period. The area planted to lupins increased at the same time by just over 5% to 1 406 000 ha (Anon 2000b).

Unlike wheat, barley and oats, these newer crops do not have cultivars with resistances to disease incorporated into their genetic makeup, so fungicides are more widely used. However, increasing volumes of fungicides are also reportedly applied to wheat and barley crops as the suite of diseases attacking those crops expands. The use of fungicidal seed dressings on cereal crops, canola and pulse crops has also reportedly expanded.

The volume of herbicides applied during the study period fluctuated marginally. That there was so little change was unexpected, given the reported increase in the substitution of conventional tillage methods with minimum till and/or no-till practices in Australian broadacre cropping systems. These are discussed more closely in Chapter 4.

## **2.2. THE PESTICIDE CHEMICALS**

The first generation of synthetic pesticides, introduced in the 19<sup>th</sup> Century, comprised chemicals containing heavy metals such as copper, arsenic and lead (Ordish 1976). Synthetic organic chemicals were introduced during and after the Second World War with the widespread use of 1,1,1-trichloro-2,2-bis(4-chlorophenyl) ethane (dichlorodiphenyl trichloroethane, DDT) and 2,4-dichlorophenoxy acetic acid (2,4-D). Many other synthetic pesticides soon followed. By 1999, the NSW Parliamentary Standing Committee on State Development was able to report that in NSW alone, there were approximately 3800 registered pesticide products. The principal groups of chemicals used as insecticides, herbicides, fungicides and growth regulators are set out below.

### **2.2.1. Insecticides**

#### **2.2.1.1. Organochlorine (or chlorinated hydrocarbon) pesticides**

These were the first group of synthetic organic pesticides, introduced in the 1940s. Organochlorine pesticides act by stimulating the nervous system, resulting in disturbance of the transmission of the nerve impulse and continuous and involuntary transmission of signals (Kamrin 1997). In general, organochlorine compounds are hydrophobic, with low water solubilities and high n-octanol-water partition coefficient ( $K_{ow}$ ) which provides a direct estimate of hydrophobicity or of the partitioning tendency from water to organic media such as lipids, waxes and natural organic matter such as humin or humic acid. (Table AF 1 ). If they are transported to aquatic environments, they are most likely to be found in sediment.

Organochlorines are not generally mobile in soil and are resistant to environmental degradation. They persist for long periods in the environment, dissolve in body fat (lipids) and accumulate in terrestrial and aquatic environments. This bioaccumulation is most evident at the top of the food chain in aquatic and terrestrial communities. In the past, some predatory birds and fish have been shown to contain high body levels and hence can exhibit reproductive failure. DDT and the other organochlorines appear to disrupt the ability of birds to mobilise calcium, resulting in thinning of their eggshells. The eggs may be crushed by the parents during incubation or attacked by bacteria (Kamrin 1997). Fish reproduction has been affected when organochlorines, such as DDT, concentrate in the egg sac.

Most uses of organochlorine pesticides have been discontinued in Australia. DDT has been banned from general use in the USA since 1972 and in Australia since 1987 (ANZECC 1991) but its use in parts of Asia has been increasing (Iwata *et al.* 1994). The only remaining use in Australia of a persistent cyclodiene organochlorine pesticide is for mirex to control the termite *Mastotermes darwiniensis* in mango plantations in the Northern Territory (J.Alcock, DPIF, NT, pers. comm.). Mirex is one of 12 persistent organic pollutants (POPs) included in the United Nations Environment Program Stockholm Convention, which was adopted and opened for signature in May 2001. Mirex is used in baits and is thus carried back to the termite nest, or it may be injected into trees. Alternatives are being studied but have not been commercially developed (Konkes 2000). Australia has obtained an exemption for the continued use of mirex for a period of five years which commences from the date of the Stockholm Convention's entry-into-force.(J. Holland, Envir. Aust., pers. comm.). The volume of use is low (5–10 kg per annum) and exposure is minimised by its use as baits or by drilling infested trees.

Endosulfan is one chlorine-containing compound that is still in use for cotton and other crops. It has been extensively studied in Australian situations (Schofield 1998; Chapman 1998). Ghadiri & Rose (2001) showed that endosulfan isomers in

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(Tables giving a wide range of chemical, toxicological and biological properties are given in Appendix F as tables AF 1 to AF 21.)

Australian soil can have half lives about 30 weeks, with half-lives of 34-47 weeks found in submerged soil. It can be toxic to birds and fish. Most organochlorine compounds are only slightly acutely toxic to birds but there are some exceptions, most notably endrin (Table AF 2). Endrin and endosulfan are very toxic to fish.

Organochlorines slowly evaporate and, due to their physical and chemical properties, are translocated throughout the world by wind and rain, resulting in worldwide dispersion in the environment. The continued use of DDT in tropical countries can still lead to low-level contamination in remote areas through long-range transport (Iwata *et al.* 1993).

#### **2.2.1.2. Organophosphorus (OP) pesticides**

Organophosphorus pesticides are now the most commonly used insecticides. This group of pesticides inhibit and inactivate the enzyme acetyl-cholinesterase (AChE). Acetylcholine (ACh) is a substance produced in nerve cells of animals that acts as a chemical switch by transmitting a nerve impulse from a nerve cell to a specific receptor such as another nerve cell or a muscle cell (Kamrin 1997).

Organophosphorus insecticides inhibit the ability of the AChE enzyme to break down the ACh and end the nerve impulse. Without the action of AChE, ACh builds up at the junction of the nerve cell and the receptor site, and the nerve impulse continues, resulting in continued over-stimulation of muscles. The final result can be death by respiratory or heart failure.

Most organophosphorus chemicals do not persist for long in the environment, ranging in soil from a few hours to as long as months after application (Table AF 4) (Kamrin 1997) depending on the chemical and the soil conditions. They are not very mobile in soils that have high organic content, and are more stable under acidic conditions than under alkaline conditions. For instance, profenofos degradation in water varied from 93 days at pH 5 to 14.6 days at pH 7 and only 5.7 hours (0.25 d) at pH 9 (Tomlin 2000). Degradation of organophosphorus pesticides in surface water varies greatly with temperature. For example, parathion methyl has a half-life of 8 days during the summer and 38 days in winter (Kamrin 1997). Diazinon persists in the environmental more than many other organophosphorus insecticides (Nowell *et al.* 1999). Its half - life on sheep fleece in New Zealand was calculated as 32 days in winter and 12 days in summer (Rammel & Bentley 1989). It can be released from the wool grease into water during wool scouring.

#### **2.2.1.3. Carbamates**

Carbamate pesticides also act on both target and non-target species by inhibiting the enzyme acetylcholinesterase (AChE). Unlike most organophosphorus pesticides, the inhibition of AChE by carbamates is reversible and they do not appear to induce a delayed neurotoxic reaction (Kamrin 1997). Carbamates generally do not persist in the environment (Table AF 7). Most are unlikely to contaminate groundwater. They usually remain active for a few hours to a few months in soils and crops. Carbamates are degraded more rapidly in alkaline conditions. For instance, the DT50 of carbaryl in water at pH 7 is 12 days but at pH 9 it is just 3.2 hours (Tomlin 2000). Aldicarb has been found in groundwater in the USA particularly in areas of higher rainfall, shallow water tables and acidic soils (Kamrin 1997). Aldicarb is readily degraded into compounds which are not only equally or more toxic, but are also more persistent and



considerably more mobile (OECD 1986). Carbamates do not appear to cause reproductive toxicity in mammals but can be toxic to many types of birds and mammals (Table AF 8) and small numbers of birds have been killed by aldicarb in the UK and USA. Incorporation of granules beneath the soil surface greatly reduces the risk to birds and small mammals (NRA 2001). Most carbamates are highly toxic to bees (Table AF 8). Bendiocarb has been observed to reduce earthworm populations but most other carbamates have low toxicity to earthworms (Kamrin 1997). Carbamates are often highly toxic to aquatic invertebrates but less so to fish (Table AF 9). They do not generally bioaccumulate in aquatic systems

#### **2.2.1.4. Pyrethroids**

The earliest pyrethroid pesticide is the natural plant extract pyrethrum. The synthetic pyrethroids have been based on the pyrethrum structure with modifications to the active sites, to produce powerful and effective control agents. Pyrethroid pesticides inactivate the nerve junctions of target and non-target organisms by interfering with the balance of sodium ions (Kamrin 1997). These compounds are highly toxic to insects and fish but less toxic to mammals (Table AF 11), because of their ability to metabolise and excrete pyrethroids. In humans, they are rapidly metabolised and renally eliminated. Pyrethroids are commonly combined with other insecticides to enhance their efficacy against pests.

Pyrethroids have high *K<sub>ow</sub>* values (Table AF 10), hence they tend to adsorb strongly to soil and sediment particles and are moderately persistent.

Long-term exposure of mammals to some pyrethroids can result in pathological liver changes and liver damage. Low doses are unlikely to cause reproductive effects (Kamrin 1997). Most pyrethroids have very low toxicity to birds but are highly toxic to bees and other non-target invertebrates (Table AF 11). Pyrethroids have very high toxicity to fish and aquatic invertebrates (Table AF 12), and they can bioaccumulate in fish to some extent.

#### **2.2.1.5. Insect growth regulators**

These are selective insecticides, have been developed in recent years. They impact the growth of target insects at critical stages of their life cycle. Some, such as diflubenzuron and triflumuron, have the specific action of inhibiting the production of chitin, a compound that hardens the developing exoskeleton in insects (Kamrin 1997). Others mimic the action of insect growth and developmental hormones (Dhadialla *et al.* 1998). For instance, fenoxycarb and methoprene mimic juvenile hormones, and tebufenozide mimics steroidal ecdysone moulting hormones (Dhadialla *et al.* 1998). Insect growth regulators such as diflubenzuron are used on forest and field crops to selectively control insects and parasites. Studies on tebufenozide and fenoxycarb in Australian orchards (Valentine *et al.* 1996) indicated that non-target invertebrate predators of pests were largely unaffected by these insect growth regulators. Several of these chemicals have high *K<sub>ow</sub>* values and some, such as chlorfluazuron, tend to persist in the environment (Table AF 13). Most have very low toxicity to mammals, birds (Table AF 14) and fish (Table AF 15), but their toxicity to invertebrates, particularly that of triflumuron, is often higher (Table AF 17) (Tomlin 2000).

#### **2.2.1.6. Miscellaneous Insecticides**

A large number of miscellaneous insecticides commonly in use are from a small number of chemical groups. The agricultural industries have welcomed the introduction of insecticides that belong to novel chemical classes, if they can be fitted into an Integrated Pest Management (IPM) program. Tables AF 13-17 outline some of the physico-chemical and toxicological properties of fipronil, spinosad and chlorfenapyr. Chlorfenapyr and other chemicals are currently being evaluated in the NRA's on-going new pesticides assessments. Fipronil, a phenyl pyrazole insecticide that acts on the central nervous system of insects by blocking the GABA-regulated chloride channel, has veterinary uses and some uses in protecting bananas, brassicas, mushrooms and rice but has more recently been recommended for use on cotton (Environment Australia 1998). It is highly toxic to bees via oral or contact routes and has high toxicity to galliform birds (quail, pheasant and partridge) but not to other species. Environment Australia (1998) assessed that there could be a marginal hazard of fipronil to birds in some crops (see Chapter 5) and recommended that the company supply further data on birds in the higher risk crops. The hazard of fipronil to mammals was considered low, albeit based on limited data (Environment Australia 1998). It had low earthworm toxicity but it is likely to be highly toxic to soil insects. Large-scale locust control spraying with fipronil in Madagascar in 1997 resulted in non-target impacts on termite populations and possibly indirect effects on some lizards and birds (Dinham 2000). This led to the Madagascan government withdrawing authorisation for fipronil in mid-1999. Fipronil has high acute aquatic toxicity.

Spinosad is a new active ingredient to control pests in vegetables and cotton (Environment Australia 1998a). It is derived from a soil bacterium *Saccharopolyspora spinosa*, being first registered in 1997 in the USA (US EPA 1997). It has a complex multiple ring structure made up of two components, spinosyn A and spinosyn D. Spinosad has generally low toxicity to non-target organisms, at a low application rate and was compatible with integrated pest management strategies. Toxicity tests against beneficial terrestrial invertebrates indicate that spinosad gives a significantly improved margin of safety (about 10-fold) compared with the pyrethroid cypermethrin (Environment Australia 1998a).

One pesticide that has made inroads into conventional pesticide usage is the bacterium *Bacillus thuringiensis* (known as "Bt"). There are several varieties of Bt insecticides, which produce endotoxins with insecticidal activity during the sporulation phase. With certain carriers and formulations, the endotoxin can be transferred selectively to the pest species, for example lepidopteran larvae, as they feed on the target crop. Most of the formulations of *Bacillus thuringiensis* exhibit little or no toxicity to beneficial terrestrial invertebrates, birds, mammals or aquatic organisms at the highest concentrations tested. Nowell *et al.* (1999) considered that Bt had significantly reduced the level of conventional pesticide usage in forestry in the USA, and probably in other areas as well.

It should be noted that some metabolites of organophosphorus, carbamate and pyrethroid insecticides may be more toxic than the parent compound to some organisms. DDE, a metabolite of DDT, also shares its toxicity. In contrast, transformation products of many herbicides tend to be less toxic than the parent compound (Kookana *et al.* 1998).

Phosphine, either supplied as a gas mixture or generated *in situ* by reaction of calcium phosphide with ambient moisture, is used to control insects in stored grain. Trials have indicated that carbonyl oxysulfide can be used to similar effect.

Methyl bromide has had specific uses in the protection of strawberry crops but is scheduled for phase-out under the Montreal Protocol (Vienna Convention) for ozone-layer protection.

### **2.2.2. Herbicides**

Herbicides are used in Australia to control weeds in crops, in public and industrial areas to maintain rights of way, and to facilitate the operation of irrigation and drainage channels (Kookana *et al.* 1998a). The use of herbicides has increased in recent years, mainly because of the increased use of minimum-tillage practices in association with glyphosate to reduce soil erosion and to minimise nutrient runoff (Kookana *et al.* 1998). Much of the total cropped area in Australia (66%) is used for growing wheat, barley, oats and sorghum (ABS 1996) and herbicides are extensively used in these crops. Herbicides, including atrazine, simazine, glyphosate, picloram and triclopyr, are also widely used in forestry (Nowell *et al.* 1999).

#### **2.2.2.1. Phenoxy herbicides**

The modes of action, uses, properties and toxicities of herbicides vary between the different classes of herbicides. Phenoxy herbicides (eg. 2,4-D) act like plant hormones, disrupting normal cell growth and the plant's water and nutrient transport system (Kamrin 1997). The phenoxy compounds do not generally persist in soil beyond about 2 weeks, although 2,4,5-T (which is no longer used) had half-lives in soil ranging from 55 days to 5 months (Kamrin 1997).

#### **2.2.2.2. Triazines**

The triazine herbicides act by interfering with plant photosynthesis. Triazines exhibit a wide range of toxicities to aquatic organisms, depending on the compound and the species. Atrazine concentrations as low as 10 µg/L have been reported to inhibit algal growth but some algal species may establish resistant communities. Species richness and total abundance of emerging benthic macroinvertebrates were significantly reduced by atrazine concentrations of 20 µg/L and above (Boey & Cooper 1996; NRA 1997). Some classes of herbicides are poorly bound in soil and tend to leach into surface water or groundwater. The half-life for atrazine in estuarine sediment is 15-20 days, but in soil, 30% of the original atrazine may still exist after 3 years (Boey & Cooper 1996).

Atrazine and simazine are relatively stable in water and have been detected in ground and surface waters in the USA and Australia (Kookana *et al.* 1998b). Widespread contamination has led the United States Environment Protection Agency (US EPA) to restrict most uses of atrazine, simazine and cyanazine to certified applicators, reduce application rates, and for atrazine, apply requirements for buffer zones near surface waters and remove most non-crop uses (Kamrin 1997).

#### **2.2.2.3. Phenylureas**

The phenylurea herbicides also interfere with plant photosynthesis and are broken down slowly in soil by microorganisms to give half lives from a few months up to a year in some cases. Peterson and Batley (1991) used a model to predict diuron persistence in a pond ecosystem, and found that 90% of diuron would be in the sediment after 175 days.

#### **2.2.2.4. Sulphonylureas**

Sulphonylureas are chemicals that act by inhibiting acetohydroxyacid synthetase - AHAS (also known as acetolactate synthetase) – ALS, an enzyme involved in the synthesis of branched chain amino acids, and hence the biosynthesis of cell-building proteins (Kamrin 1997).

#### **2.2.2.5. Bipyridiliums**

The most commonly used bipyridilium herbicides, paraquat and diquat, adsorb strongly to soil clays and organic matter, and they are very persistent in soils. The half-life of these herbicides has been estimated to be 1000 days (Wauchope *et al.* 1992), and they may accumulate in soil with repeated applications (Kookana & Aylmore 1993).

The physico-chemical properties of herbicides are tabulated in abbreviated form in Table AF 16. Most herbicides have low toxicity to mammals and birds (Table AF 17) and variable toxicity to aquatic organisms (Table AF 18).

### **2.2.3. Fungicides**

Fungicides are made up of a variety of chemical classes, some of which also include herbicides. One of the earliest fungicides was Bordeaux mixture, a copper compound that was frequently used on grapes. Elemental sulphur is still commonly used as a fungicide. Mercury was used in a number of important fungicides in earlier years, such as phenyl mercury acetate used on turf. However, since 1996, there have been restrictions on use of many, but not all, pesticides that contain mercury, mainly because of mercury's potential to accumulate in the environment (Commonwealth of Australia 1995).

Common synthetic organic fungicides belong to groups such as carbamates (eg. benomyl), indoliones (captan), benzenoids (metalaxyl), benzimidazole (thiabendazole), organochlorines (chlorothalonil), dithiocarbamates (mancozeb) and triazoles (triadimefon). (Some thio- and dithiocarbamates, such as molinate and thiobencarb, are used as herbicides. Amitrole is the only triazole that is used as a herbicide.)

Many fungicides do not persist in the environment. Most fungicides have low toxicity to mammals and birds (Table AF 20) but their toxicity to aquatic organisms varies with the chemical (Table AF 21). Thio- and dithiocarbamates can affect animals in a similar manner to the carbamates, by inhibiting the AChE enzyme. Most have very low toxicity to mammals and birds, but some have high aquatic toxicity (Table AF 21). Physicochemical properties of selected fungicides are outlined in Table AF 19.

#### **2.2.4. Vertebrate pesticides**

Specific pesticides are used to control mammalian pests throughout Australia. Target species may be rats and mice in house, food storage or farm situations, rabbits, wild dogs and dingoes. In New Zealand, possums and other introduced mammals are pest species that sometimes require chemical control. Early chemicals used for control of mammalian pests included strychnine, thallium, arsenic, cyanide and sodium monofluoroacetate (“1080”). The latter is still used commonly. Specific pesticides such as the plant extract rotenone are used as piscicides for removing nuisance fish from waterways.

Strychnine is a plant alkaloid used as a rodenticide. It acts on the spinal cord as an antagonist to the neurotransmitter glycine (Tomlin 2000). The sulphate salt is soluble in water at 30 g/L. The lethal dose for rats is around 1 – 30 mg/kg but rats often avoid strychnine bait. In 1993, grains laced with strychnine rodenticide were broadcast over some 375,000 ha of agricultural land to control one of the worst incidences of mouse-plague in southern Australia (R Sinclair, Primary Industries SA, cited in Kookana *et al.* 1998).

Sodium monofluoroacetate (“1080”) is commonly applied in Australia for control of vertebrate pests such as rabbits and foxes. It is very soluble in water and is biodegradable but its rate of biodegradation is slower at low temperatures (Eason *et al.* 1994). Although sodium monofluoroacetate is highly toxic to mammals, it does not appear to be mutagenic (Eason *et al.* 1999b). It has low aquatic toxicity; fingerling trout showed no visible effects in 1080 at concentrations up to 1000 mg/L (Rammell & Fleming 1978).

Rotenone is a plant extract used as an insecticide (commonly called “derris”) but it is also sometimes used under permit to control fish populations in fish management (Tomlin 2000). It is readily soluble in water and decomposes rapidly. It has moderate toxicity to most mammals but high toxicity to pigs.

More recent mammalian pesticides act by inhibiting blood coagulation, and are usually used in cereal-based baits to control rodents. The first generation anticoagulants, which include warfarin, pindone, coumatetralyl and chlorophacinone, generally act by blocking prothrombin formation in the liver (Tomlin 2000). They often require multiple feeding on the baits to induce lethal effects. Their toxicity to birds and fish is moderate to high

Second generation anticoagulants are generally more toxic, quicker acting and persistent and they tend to bioaccumulate. These include bromadiolone, brodifacoum, difenacoum and flocoumafen, and frequently act by interfering with the normal synthesis of vitamin K-dependent clotting factors in the liver of vertebrates (Eason & Murphy 2001). Their acute toxicity to rats is high; 0.3 mg/kg for brodifacoum, 1.1 mg/kg for bromadiolone, 1.8 – 2.5 mg/kg for difenacoum and 0.25 mg/kg for flocoumafen (Tomlin 2000). Their potency is so high that a rat may absorb a lethal dose by taking a small amount of a 50 mg/kg bait of bromadiolone on one occasion (Tomlin 2000). Eason and Spurr (1995) report high toxicity to native mammals; acute LD50 for brushtail possum *Trichosurus vulpecula* was 0.17 mg/kg and for Bennett’s wallaby *Macropus rufogriseus*, 1.3 mg/kg. Brodifacoum has very high

toxicity to birds, fish and aquatic invertebrates: Brodifacoum has significant potential to kill non-target species, particularly birds. The risk of death is increased if there are repeated exposures to the toxin. As brodifacoum accumulates and persists in the liver, predatory and scavenging species are most at risk from secondary poisoning (Eason & Spurr 1995).

#### **2.2.5. “Organic Pesticides”**

The growth of the organic farming industry has created increasing interest in the possible use of naturally occurring products such as neem oil, neem extracts (whose active ingredient is azadirachtin) and pyrethrum. These products are being increasingly sought by growers for use in both agriculture and animal husbandry (S. MacDonald, NRA, pers. comm.). Neem-based products are not currently registered as pesticides in the marketplace. Registration requires rigorous scientific assessment in terms of safety. Since such products are not currently registered, they cannot legally be used as pesticides.

### **2.3. THE CHOICE OF PESTICIDES**

There are a number of factors which influence farmer choice of pesticides. Primary considerations are efficacy of pest control and price but likely residues, toxicity to operators and neighbours, environmental and other off-target impacts, trade or market implications and the effect on integrated pest management (IPM) strategies have increasingly been recognised in pesticide choice.

In recent years, there has been a noticeable shift from the more toxic, broad spectrum chemicals, for example organophosphate insecticides, to those which are more target-pest specific, efficacious and less toxic to humans. Examples for specific crops are given in Chapter 4.

The development of pesticide resistance in pest populations has also influenced farmer choice, both in terms of the pesticides available to farmers and in the implementation of IPM and pesticide resistance management programs. Development of pest resistance to certain groups of insecticides has been an on-going issue, particularly in areas of intensive pesticide use, and integrated pest control management (IPM) strategies have been developed to reduce pesticide usage and to slow the development of resistance (Shaw 1995). These strategies frequently rely on rotation of different pesticides during a season. With pest resistance pressures, agricultural industries welcomed the introduction of insecticides that belong to novel chemical classes, where they could be fitted into an IPM program. Insect growth regulators (described above) are one such class that has gained increasing use over the past 10 – 20 years. More recently, chemicals that have been introduced that belong to the “novel chemical” grouping have also been valuable.

The emergence of pesticide resistance has brought a consciousness among most farmers of the need to manage chemical use to avoid the rapid build-up of resistant pest populations.

Some examples of pesticide resistance emerging in Australian agricultural crop production systems include :-

- various insect pests (including heliothis) to organophosphates and synthetic pyrethroids
- fungal diseases to the benzimidazole and triazole fungicides
- weed resistance to oxyphenoxo acid ester herbicides such as diclofop-methyl, fluazifop-butyl and fenoxaprop-ethyl
- weed resistance to sulfonyl urea herbicides such as chlorsulfuron
- weed resistance to glyphosate

Pesticide resistance is an international phenomenon. In a recent international survey of herbicide resistant weeds, some 248 unique herbicide resistant biotypes were identified (Anon 2001).

Within Australia, the resistance issue has been addressed by the agricultural chemical industry through its peak body, Avcare, the National Association for Crop Protection and Animal Health, which represents the interests of about 50 companies that account for more than 90% of national agricultural chemical sales. Members include manufacturers and distributors, biotechnology providers and associated service suppliers in the agricultural chemicals and veterinary health products industry.

Avcare has developed pest resistance management strategies to minimise, inhibit or slow down the development of pest resistance to pesticides in conjunction with growers, researchers and industry funding bodies.

These pest resistance management strategies minimise selection pressure to pesticides or groups of pesticides with similar modes of action. That is achieved through growers alternating the use of pesticides or groups of pesticides. It is strengthened by encouraging growers to use cultural pest control practices wherever possible and to target the pest at the most susceptible stage of its life cycle.

To assist growers implement these strategies, the mode of action of all herbicides, insecticides and fungicides sold in Australia is identified on the container label. For example, herbicides which disrupt plant cell growth, such as 2,4-D and its derivatives, are identified as belonging to Group I. Herbicides which inhibit mitosis are identified as Group E.

Under this system, herbicides in Australia have been classified by Avcare in Groups A to N, insecticides have been classified in Groups 1A to 22A while fungicides have been classified in Groups A to L, and Groups X and Y. It should be noted that the groupings developed for use in Australia differ from those published by the International Herbicide Resistance Action Committee at <http://plantprotection.org/HRAC/moa2001.htm>.

Details of the Insecticide, Herbicide and Fungicide chemicals and their groupings are given in Tables 6-8.

**Table 6: Insecticide Groupings and their modes of Action**

<b>INSECTICIDES</b>		
<b>Group</b>	<b>Primary Target Site/Mode of Action</b>	<b>Chemical Subgroups</b>
1A	Acetyl choline esterase inhibitors * all members of this class may not be cross resistant	carbamates*
1B		organophosphates
2A	GABA-gated chloride channel antagonists	cyclodienes
2B		polychlorocycloalphanes
2C		fiproles
3A	Sodium channel modulators	pyrethroids and pyrethrins
4A	Acetyl choline receptor agonists/antagonists	chloronicotinyls
4B		nicotine
4C		cartap, bensultap
5A	Acetyl choline receptor modulators	spinosyns
6A	Chloride channel activators	avermectin, emamectin benzoate
6B		milbemycin
7A	Juvenile hormone mimics	methoprene, hydroprene
7B		fenoxycarb
7C		pyriproxifen
8A	Compounds of unknown or non specific mode of action (fumigants)	methyl bromide
8B		phosphine generating compounds
9A	Compounds of unknown or non specific mode of action (selective feeding blockers)	pymetrozine cryolite
9B		cryolite
10A	Compounds of unknown or non specific mode of action (mite growth inhibitors)	clofentezine, hexythiazox
11A	Microbial disrupters of insect midgut membranes (includes Transgenic B.t. crops) * all members of this class may not be cross resistant	B.t. tenebrionis
11B		B.t. israelensis
11C		B.t. kurstaki, B.t aizawai*
11D		B.t. sphaericus
11E		B.t. tolworthi
12A	Inhibition of oxidative phosphorylation, disrupters of ATP formation	organotin miticides
12B		diafenthiuron
13A	Uncoupler of oxidative phosphorylation via disruption of H proton gradient	chlorfenapyr
14A	Inhibition of magnesium stimulated ATPase	propargite
15A	Chitin biosynthesis inhibitors	acyl ureas
16A	Ecdysone agonists	tebufenozide and related
17A	Homopteran chitin biosynthesis inhibitors	buprofezin
18A	Unknown dipteran specific mode of action	cyromazine
19A	Octopaminergic agonist	amitraz
20A	Site II electron transport inhibitors	hydramethylnon
21A	Site I electron transport inhibitors	rotenone, METI acaricides
22A	Voltage dependent sodium channel blocker	indoxacarb

Avcare, the National Association for Crop Production and Animal Health



**Table 7: Herbicide Groups, and their modes of action. (This table is illustrative only of resistance risk relationships between groups of herbicides and does not show all products)**

<b>HERBICIDES</b>			
<b>Resistance</b>	<b>Group</b>	<b>Mode of Action</b>	<b>Chemical Groups</b>
High Risk	A	Inhibitors of fat (lipid) synthesis	Aryloxyphenoxypropionates (“Fops”) (diclofop) Cyclohexanedines
	B	Acetolactate synthetase (ALS) inhibitors	Sulphonylureas (metasulfuron, chlorsulfuron) Imidazolinones, Sulphonamides
Medium Risk	C	Photosynthesis inhibitors (photosystem II)	Triazines (atrazine, simazine, terbutryn), Triazinones (metribuzin), Ureas (diuron, linuron) Nitriles (bromoxynil) Benzothiadazoles, Uracils Acetamides, Pyridazinones, Phenyl-pyridazines
	D	Inhibitors of tubulin formation	Dinitroanilines (trifluralin), Benzoic Acids, Pyridines
	E	Mitosis inhibitors	Thiocarbamates (molinate), Carbamates (chlorpropham), Organophosphorus (bensulide)
	F	Carotenoid synthesis inhibitors	Nicotinanilides Triazoles (amitrole) Pyridazinones Isoxazolidinones Pyrazoles
	G	Protophyrinogen oxidase inhibitors	Diphenyl ethers Oxidiazoles
	H	Protein synthesis inhibitors	Thiocarbamates
Low Risk	I	Plant cell growth disrupters	Phenoxys (2,4-D, 2,4-DB, MCPA) Benzoic acids (dicamba) Pyridines (triclopyr)
	J	Fat synthesis inhibitors	Alkanoic acids (propan)
	K	Herbicides with multiple sites of action	Amides (napropamide, metolachlor) Carbamates (asulam) Amine propionates Benzofurans (ethofumesate) Phthalamates Nitriles (dichlobenil)
	L	Photosynthesis inhibitors (photosystem I)	Bipyridils (paraquat, diquat)
	M	EPSP synthase inhibitor	glyphosate
		Glutamine synthetase inhibitors	Glycines
<b>Note: Generic herbicide names given only. There are some products which also appear in secondary positions.</b>			

Derived from Avcare, the National Association for Crop Production and Animal Health

**Table 8: Fungicide mode of action groups with Active Constituents**

<b>FUNGICIDES</b>			
<b>Group</b>	<b>Activity Group</b>	<b>Chemical Group</b>	<b>Active Constituent</b>
A	Benzimidazole	Benzimidazole	benomyl, carbendazim, thiabendazole, thiophanate-methyl
B	Dicarboximide	Dicarboximide	iprodione, procymidone
C	DMI	Imidazole	Imazalil, prochloraz
		Piperazine	triforine
		Pyrimidine	fenarimol
		Triazole	bitertanol, cyproconazole, diclobutrazole, flusilazole, flutriafol, hexaconazole, myclobutanil, paclobutrazole, penconazole, propiconazole, tebuconazole, triadimefon, triadimenol, triticonazole
D	Phenylamide	Acylamine	benalaxyl, furalaxyl, metalaxyl, metalaxyl-m
		Oxazolidinone	oxadixyl
E	Morpholine	Morpholine	tridemorph
F	Phosphoro-thiolate	Organophosphorus	pyrazophos
G	Oxathiin	Anilide	carboxin, oxycarboxin
H	Hydroxy-pyrimidine	pyrimidinol	bupirimate, dimethirimol
I	Anilinopyrimidine	Anilinopyrimidine	cyprodinil, pyrimethanil
J	Hydroxyanilide	Hydroxyanilide	fenhexamid
K	Strobilurin	Strobilurin	azoxystrobin, kresoxim-methyl, trifloxystrobin
L	Phenylpyrroles	Phenylpyrroles	fludioxinil
Y	Multi-site activity	carbamate	iodocarb
			propamocarb
		phosphonate	fosetyl-al
			phosphorus acid
		Inorganic	copper (cuprous oxide)
			copper (hydroxide)
			copper (oxychloride)
			iodine
			mercury
			sodium metabisulphite
			sulphur
		Dithiocarbamate	mancozeb
			metiram
			thiram
			propineb
			zineb
			zineb (+ copper oxychloride)
			ziram
		Phthalimide	chlorothalonil
		Chlorophenyl	quintozene
		Quinone	dithianon
		Hydroxyquinoline	8-hydroxy quinoline sulphate
		Pyradinamine	fluazinam
		Cyclic imide	captan

Group	Activity Group	Chemical Group	Active Constituent
Z	Unspecified	Cinnamic acid derivative	dimethomorph (+ mancozeb)
		Sulfamide	dichlorofluanid
			tolyfluanid
		Dinitrophenyl	dinocap
		Organophosphate	tolclopfos-methyl
		Guanidine	dodine
			guazatine
		Thiadiazole	etridiazole
		Quinoxaline	oxythioquinox
			pencycuron

Avcare, the National Association for Crop Production and Animal Health

## **2.4. INDIVIDUAL PESTICIDE USE**

Details of specific pesticides which have been registered by the National Registration Authority for Agricultural and Veterinary Chemicals for use in Australia and the registrants of those chemicals may be obtained from the Authority's web-site at <http://www.nra.gov.au/nra/tgac.pdf>. As at 25 July 2001, the then currently approved list contained 143 pages of approvals encompassing about 6000 products comprising 2000 technical grade active constituents.

There are over 250 registered agricultural chemicals of which more than one tonne is imported and/or manufactured and used each year in Australia. About seventy of these are insecticides with a total annual total usage approaching 10 000 tons, ninety are herbicides representing nearly 30 000 tons, and fifty are fungicides whose total use approaches 4 000 tons of active ingredient per year. To this can be added about 800 tonnes of plant growth regulators, 100 tons of molluscicides, around five tons of ectoparasiticides and a couple of tonnes of rodenticides (AFFA, unpublished, 2001).

### **2.4.1. Insecticides**

The most widely used groups of insecticides in recent years have been the organophosphates. Around 5 000 tonnes of active ingredients from this group, which comprises around 30 identifiably distinct chemicals, are in use annually. The most used chemical from this group has been parathion methyl, (a non-systematic insecticide and acaricide with contact, stomach and some respiratory action, used to control a range of chewing and sucking insects in fruit, vegetable, pasture seed and cotton crops), with over 1 000 tonnes used per annum. A generally similar amount is used of chlorpyrifos, a non-systemic insecticide affecting the nervous system of insects by inhibiting the action of cholinesterase, being used on soils and foliage of a wide range of fruit, nut, viticultural, grain, cotton and ornamental crops. A further important use following the ban on organochlorines, is for termite control in the building industry. Other major organophosphorus insecticides include dimethoate (used to control thrips, mites and flies, particularly in interstate trade of some fruit and vegetable crops), and forms of profenofos. Although the total use of diazinon is comparatively smaller, it has been important for controlling ectoparasites in sheep by dipping, though its use may be phased out in the foreseeable future.

The next most significant group of insecticides are the acetyl choline esterase inhibitors, comprising various carbamates, of which about 3 000 tonnes are used each year. The most important in this group is metham sodium, which is a dithiocarbamate used against soil insects, but also as a soil fungicide, nematicide and herbicide.

Over 500 tonnes per annum are used of those insecticides which act as GABA-gated chloride channel antagonists. The most important of these has been endosulfan, which is a cyclodiene organochlorine, but which does not build up in the fat of mammals or persist in the environment. It has been widely used for control of *Helicoverpa* spp. in cotton, and is also used on vegetables and a range of vegetable, fruit, pulse, oilseed, cereal and ornamental crops. It should be noted that ultra-low volume formulations of this product have been prohibited from use from 31 March 2001 because of detection of the product in beef cattle from spray drift (NRA 2001b).

Of the remaining insecticides, the most important are the pyrethroids and pyrethrins which act as sodium channel modulators. There are nearly twenty chemicals in this group, totalling up to a couple of hundred tonnes of use each year. The pyrethroid bifenthrin also has become a significant organochlorine substitute for termite control.

Insect growth regulating chemicals fill quite specialised niches, and the use of the individual chemicals is only around 1 tonne per annum, and for some, less than this amount.

The most important insecticides used in Australia, as represented by national use in the period 1997-1999, are shown in table 9. Of those listed, forty-eight are understood to have exceeded 10 tonnes annual usage. Among this group, fourteen had greater than 100 tonnes use annually and three others exceeded 1 000 tonnes annual use.

**Table 9:**  
**The most important insecticides in use, 1997-9**

<b>INSECTICIDES</b>			
Acephate	Cypermethrin alpha	Maldison	Pirimicarb
Allethrin 20:80	Cyromazine	Metham sodium	Pirimiphos methyl
Amitraz	Deltamethrin	Methamidophos	Profenofos
Azinphos ethyl/methyl	Diazinon	Methidathion	Profenofos Q grade
Beta-cyfluthrin	Dichlorvos	Methiocarb	Propoxur
Bifenthrin	Dicofol	Methomyl	Prothiofos
Bioallethrin	Dimethoate	Methoprene	Spinosad
Bioresmethrin	Disulfoton	Methyl bromide	Tau fluvalinate
Bt aizawai	Endosulfan	Monocrotophos	Tebufenozide
Bt israelensis	Esfenvalerate	Omethoate	Temephos
Bt kurstaki	Ethion	Parathion	Terbufos
Cadusafos	Fenamiphos	Parathion methyl	Tetramethrin (various)
Carbaryl	Fenitrothion	Permethrin	Thiodicarb
Chlorfenvinphos	Fenoxycarb	Permethrin 25:75 cis:tr	Trichlorfon
Chlorpyrifos	Fenthion	Permethrin 40:60	Triflumuron
Cypermethrin	Fipronil	Phorate	Vamidothion
Cypermethrin 40:60	Lamda cyhalothrin	Phosmet	
Note: Highlighted chemicals were registered to only one company as at 25 July 2001			

### **2.4.2. Herbicides**

The most widely used pesticide in Australia today is glyphosate, a broad spectrum, non-selective post emergence herbicide with high activity on virtually all annual and perennial plants. When applied post-emergence, it shows no pre-emergence or residual activity. This is because glyphosate binds strongly to soil particles and is readily metabolised by soil microorganisms. It has been widely adopted in recent years as the basis of “minimum tillage” crop-sowing systems. This chemical is unique in its ability to inhibit the enzyme EPSP synthase. Annual average use approaches 15 000 tonnes.

The next most widely used herbicides are atrazine and simazine. These are selective systemic herbicides which provide knockdown and residual action for control of many broad-leafed weeds and some grasses in forestry and agricultural crops. About 3 000 tonnes of each of these are used annually, much of them in industrial rather than agricultural uses for seasonal weed control. These chemicals are among the group of photosynthesis (photosystem II) inhibitors which number nearly twenty technical grade active constituents, include triazines, ureas, nitriles, benzothiadiazoles, uracils acetamides, pyridazinones and phenyl-pyridazines. The most significant of the remainder is diuron. Taken as a whole, about 8 000 tonnes of this group of chemicals are used annually.

Over 1 000 tonnes of the plant cell growth disrupting group of chemicals including phenoxy, benzoic acids and pyridines are used each year. The herbicides 2,4-D and its derivatives, along with MCPA, are the major chemicals used in this group.

A similar level of chemicals in the pyridils group is also in use. Paraquat dichloride and to a lesser degree, Diquat, are the primary chemicals contributing to this group.

Other herbicide groups with usage above 500 tonnes per annum include the lipid synthesis inhibitors of the aryloxyphenoxypropionates and cyclohexanediones of which diclofop-methyl is the most important, and the tubulin inhibitors, comprising a small group of dinitroaniline chemicals.

The most significant individual herbicides in use in 1997-9 are shown in Table 10. Of those listed, it is understood sixty-six had use exceeding 10 tonnes per annum. Among the latter group, nineteen had use exceeding 100 tonnes per annum and an additional four exceeded one thousand tonnes use per annum.

**Table 10: The most significant herbicides used, 1997-9**

<b>HERBICIDES</b>			
2,2-DPA	Diclofop-methyl	Linuron	Propachlor
2,4-D and derivatives	Diflufenican	MCPA	Propaquizafop
Acifluorfen mfr. conc.	Diquat mfr concentrate	MCPA as K salt	Propyzamide
Acrolein	Disod.methyl arsonate	MCPA various esters	Pyridate
Ametryn	Diuron	Mecoprop	Pyrithiobac sodium
Amitrole	EPTC	Metolachlor	Quizalofop-p-ethyl
Asulam	Fenoxaprop-P-ethyl	Metosulam	Sethoxydim
Atrazine	Flamprop-M-methyl	Metribuzin	Siduron
Bensulide	Fluazifop-p-butyl	Metsulfuron methyl	Simazine
Bentazone	Flumetsulam	Molinate	S-metalochlor
Benzofenap	Fluometuron	Monosodium methyl arsenate (MSMA)	Tebuthiuron
Bromoxynil	Flupropanate sodium mfr. Concentrate	MSMA concentrate	Terbutryn
Butoxydim	Fluroxypyr 1 methylheptyl ester	Napropamide	Terbuthylazine
Chlorpropham	Glufosinate ammonium	Norflurazon	Thifensulfuron-methyl
Chlorsulfuron	Glyphosate	Oryzalin	Thiobencarb
Clethodim	Glyphosate isoprop. salt	Oxadiazon	Tralkoxydim
Clodinafop-propargyl	Glyphosate trimesium	Paraquat	Tri-allate
Clopyralid	Haloxypyr-methyl (R isomer)	Paraquat dichloride mfr concentrate	Triasulfuron
Cloquintocet-mexyl	Hexazinone	Pendimethalin	Tribenuron methyl
Cyanazine	Imazapic	Pebulate	Triclopyr (butoxyethylester)
Dazomet	Imazethapyr	Picloram (various forms)	Trifuralin
Dicamba	Ioxynil octanoate	Prometryn	
<b>Note: Highlighted chemicals were registered to only one company as at 25 July 2001</b>			

### **2.4.3. Fungicides**

The principal fungicides are those which are described as having multi-site activity. Approximately 20 chemicals fall in this group, which represents over 3 000 tonnes use per annum. The two most significant of these are captan, a cyclic imide which is used to control a wide range of fungal diseases, and also used as a seed treatment on field crops, canola, ornamentals, and vegetables, and mancozeb, a dithiocarbamate. The dicarboximide and triazole/pyrimidine groups of fungicides each represent about 100 tons of use per year. In addition, about 500 tons of elemental sulphur is used annually as a fungicide.

The most important individual fungicides in use are listed in Table 11. Of those shown, it is understood that twenty-four had use exceeding 10 tonnes per annum. Within that group, eighteen chemicals had use exceeding 100 tonnes per annum and one exceeded 1 000 tonnes per annum.

**Table 11: The most significant fungicides in use, 1997-9**

<b>FUNGICIDES</b>			
Benalaxyl	Dimethirimol	Mancozeb mfr concentrate	Sulphur
Bitertanol	Dimethomorph	Metalaxyl	Tebuconazole
Bupirimate	Dithianon	Metiram	Thiabendazole
Captan	Dodine	Penconazole	Thiram
Carbendazin	Etridiazole	Pencycuron	Tolclofos-methyl
Carboxin	Fenarimol	Prochloraz Mn chloride	Triadimefon
Chlorothalonil	Fluazinam	Procymidone	Triadimenol
Copper hydroxide	Flutriafol 50:50	Propamocarb	Tridemorph
Copper oxychloride	Fosetyl Al	Propiconazole	Triforine
Cuprous oxide	Furalaxyl	Propineb	Triticonazole
Cyproconazole	Guazatine mfr concentrate	Pyrazophos	Zineb
Cyprodinil	Iprodione	Pyrimethanil	Ziram
Dichlofluanid	Mancozeb	Quintozine	
<b>Note: Highlighted chemicals were registered to only one company as at 25 July 2001</b>			

#### **2.4.4. Plant Growth Regulators**

The annual use of plant growth regulators exceeds 500 tonnes. The main chemical is ethephon, which is an ethylene generator.

### **2.5. MONITORING OF CHEMICAL USAGE**

At present, there is no detailed and publicly available information in Australia on usage of individual pesticides, either nationally or by regions (Aquatech 1997). The National Pollutant Inventory, set up under a National Environmental Protection Measure (NEPM; NEPC 2000a), does not include agricultural and veterinary chemicals. The development of a database on agricultural and veterinary chemical use would allow government, industry and the wider community to interpret analytical data, to determine what is causing the observed trends, and to make accurate decisions on chemicals (ARMCANZ 1998). For example, a recorded reduction in pesticide residues may be due to better management, changed usage or just seasonal differences. At present, no member of the public can make a judgement on this. The data on pesticide usage would be important in assessing human and environmental exposure, establishing the effectiveness of management schemes, supporting trade of agricultural products, providing feedback to the NRA process, supporting government policy and management decisions across industry groups and providing meaningful exposure data for research and development. Information on geographical distribution of use of specific pesticides is critical to setting priorities for pesticide monitoring (Aquatech 1997).

Under the aegis of Standing Committee on Agriculture and Resource Management, the Bureau of Rural Sciences initiated the development of methodology that might be used for aggregate data on use and type of chemicals, although it would not have provided data to the level of active ingredient (E. Bleeps, BRS, pers. comm.). The collection of such data is expensive and, to date, there has not been uniform acceptance of any proposals. Ideally, the data should identify the chemical, the

activity, frequency of application (eg. number per year), where the chemical is used and some description of the catchment, the time of year, method of application and the target pest being treated.

Meanwhile, Avcare recently decided to establish a crop protection and animal health database (P. Chalmers, Crop Care Australasia Pty Ltd, pers. comm.). It is intended that this database should provide information on the recent and current trends in product use in both volume and dollar terms. The intended geographic coverage is Australia but the methodology should be applicable to other countries and regions. Avcare expects that information collected in this manner will enable trends to be observed within each of the broad file categories and will allow for the dissection of information to product category and local authority area. It is also envisaged that information will be required on various sub-segments such as post emergent herbicides. A dedicated taskforce has been appointed to oversee the project.. The level of segmentation will be further defined by the taskforce and the time frame for its implementation is being identified..

It is proposed the database will be maintained in three broad files. These and the ensuing categories are shown in Table 12:-

**Table 12 Proposed Crop Protection and Animal Health Database**

File	Description	
	Crop Protection	Animal Health
<b>Product Category</b>	Herbicides, Insecticides Fungicides, Other	Ectoparasiticides, Vaccines Endoparasiticides, Other
<b>Market Segment</b>	Broadacre Cropping, Cotton, Sugar Cane Horticulture, Other	Beef, Dairy, Sheep, Pig, Poultry, Other
<b>Geographical Segment</b>	Statistical Local Area	Statistical Local Area

Source: P.Chalmers, pers. comm.

The agricultural chemical industry merits support for this initiative to develop and maintain the proposed pesticide use database, particularly its intention to provide product use information in both volume and dollar terms.

Overseas, there is increasing interest in developing formal and comprehensive pesticide use reporting systems. Within the United States of America, California, New York, New Hampshire, Arizona and New Jersey have pesticide use reporting requirements. Legislation has been considered in Wisconsin and Massachusetts.

Within California, full reporting use has been in place since 1990 requiring monthly returns to the county agricultural commissioner who reports the data to the California Department of Pesticide Regulation. Data include date, location, kind and amount of pesticide applied and commodity crop involved. Growers have site identification numbers from the county agricultural commissioner, and all operators must have a unique operator identification number before they can purchase and use a pesticide.



In New York state, data collection began in February 1997 and within six months, over 13 000 commercial pesticide applicators had become registered. Data collected include commercial pesticide applications; sales of pesticides to farmers and the location of intended use; sales of restricted use only pesticides to commercial applicators for use; and sales to dealers for resale. Commercial applicators, including lawn and garden applicators, make annual returns. Data are analysed by Cornell University.

In Arizona, both private and commercial applicators fill out forms on a weekly basis to send to the Arizona Department of Agriculture advising on location of use, crop and pesticide applied. Location information is not reported for non-agricultural applications. In New Hampshire, about 700 farms and 1 000 commercial applicators submit about 2 000 annual pesticide use reports. New Jersey collects data from certified pesticide applicators on a triennial cycle.

The 1999 Oregon Legislature passed, and Governor John Kitzhaber signed, legislation known as House Bill 3602 (Chapter 1059, Oregon Laws 1999) - *Pesticide Use Reporting Program*. This legislation assigns to the Oregon Department of Agriculture the development and implementation of a comprehensive, reliable and cost effective system for collecting, organising and reporting information on all categories of pesticide use in Oregon. Reporting under this system was due to begin on January 1 2002. This is to produce a pesticide use reporting system useful to government, researchers, policy makers and the public to ensure public health and safety and to protect Oregon's water and environment. This system, involving full electronic reporting, is likely to be one of the most comprehensive thus far generated (Rothlein and Jenkins 2000).

These authors noted that operating these data collections has not been without difficulty, the realities often leading to backlogs of data entry and processing tasks.

## **2.6. CONCLUSION – PESTICIDE USE**

**It is recommended that Australia resolve to establish a comprehensive and integrated pesticide use reporting system to ensure the integrity of the quality of its agricultural produce. Its design must ensure that the benefits of any such system must exceed the costs, be conducive to encouraging compliance, and have the commitment of industry to be successful and valued. The issue should be addressed jointly by Commonwealth and states/territories pesticide agencies, the chemical industry and peak commodity-based producer organisations, in conjunction with community representatives. Industry has indicated a willingness to contribute to addressing the issue.**

### **3. THE ECONOMICS OF CHOOSING, USING AND REGULATING PESTICIDES**

There have been major efficiency advances in Australian agriculture since 1950 due in part to the use of pesticides. United States estimates suggest that for every dollar spent on agricultural chemicals, there is a return of four dollars in the value of crops saved. Australian data on pesticide use is so incomplete that a quantitative judgement cannot be made on the economic, social and environmental impacts of pesticide use in Australia. A complete set of data on the nature, extent and cost of pesticide use would be needed before any balance sheet of costs and benefits could be attempted. Any pesticide use reporting system established should have the capability of providing the required information. From a perspective of economic theory, there are sound reasons for the intervention by governments in the registration and use of pesticides.

#### **3.1. THE BENEFITS OF PESTICIDE USE**

Over the four decades 1950-90, Australian farm output increased 250 per cent. Knowledge flowing from research and development and improved management were the key resources accounting for this striking increase in output. Australia recorded the highest rate of growth of land productivity (output per unit of land) of any OECD country over the three decades to 1990. Moreover, the productivity growth rate achieved in Australian agriculture over this period was higher than that achieved in the rest of the Australian economy and in the agricultural sectors of other developed countries taken as a whole (Chisholm, 1992; Knopke et al, 1995). Since the late 1940s, chemical pesticides have been a significant input into Australian agriculture. Their use in Australia has increased substantially, as it has globally.

The value of annual sales of agricultural chemicals in Australia is around \$1.6 billion at the factory gate, but the Australian market is small (less than three per cent) compared with the global market. Chemical pesticides have made a valuable contribution to Australia's agricultural productivity growth, by reducing damage from pests and thus reducing the gap between agriculture's realised and potential output. (Dann et al, 1994). Real expenditure on agricultural chemicals rose more rapidly than any other major component of farm costs in Australia, over the two decades to the mid-1990s. In part, this increase was attributable to Australian farmers substituting chemical inputs, in conjunction with minimum tillage techniques, or replacement for mechanical tillage to reduce costs of planting and weed control and to combat soil erosion.

Some indication of the contribution of agricultural chemicals to productivity, is given by an estimate that the average return to a dollar invested in pest control in United States agriculture amounts to about \$4 in the value of crops saved (Pimentel et al, 1993). Of course, this type of benefit assessment does not take account of any indirect environmental and health costs and benefits associated with the use of pesticides.

Pesticide use also significantly enhances the productivity of Australia's forestry sector and pesticides are a significant input in aquaculture. Finally, pesticides are used

selectively as one means of controlling the spread of feral (non-indigenous) weeds and pests in Australia's network of national and state parks and other conservation and natural reserve areas, on both public and private land. Feral weeds and pests arguably pose the biggest threat to the preservation of Australia's indigenous biodiversity, but it is notoriously difficult to put a monetary value on the amenity and future capacity so provided.

It is now recognised that Australia faces some major land degradation problems which will influence future productivity growth (Chisholm, 1994). Pesticides may play a role in helping to overcome some of these degradation risks. However, pesticides themselves if improperly managed, may bring alternative risks. The increasing importance of pesticides in achieving productivity increases in recent decades, together with heightened community perceptions regarding risk in production systems and consumer reactions have resulted in major changes to the regulatory system for agricultural pesticides over the past decade.

A growing awareness of the possible negative spillover effects of agricultural chemicals on the environment and human health has led to a search for, and the development of, safer chemical pesticides and other means of combating pests, such as biological controls, biotechnology, and improved integrated pest management practices. The demand for good human health and environmental amenities (including a 'clean' environment), in terms of the 'willingness-to-pay', is positively correlated with real income. In societies where per capita incomes continue to rise, people will become less and less tolerant of the negative impacts of pesticide use on the environment and human health. The global growth of markets for organically grown food directly reflects the concerns some people have relating to use of synthetic pesticides.

Countries are still able to maintain their own separate environmental protection and health protection regulations even in an era of freer trade and increased globalisation of the world food markets. For example, among the countries Australia trades with, Japan and Canada have had stricter pesticide-residue regulations than the United States (National Research Council, 2000).

### **3.2. PESTICIDE USE, MARKET FAILURE AND THE NEED FOR GOVERNMENT ACTION**

Both agricultural pests and pest management resources have special characteristics that create a distinctive and complex class of resource management problems:

- the mobility of many pest types may cause severe open access or common property problems. Property rights to pests are not usually assigned. Consequently, individual farmers may not consider the effects of the impact of their pest management actions on pest population on neighbouring farms and elsewhere.
- mobility of pesticides via wind currents, water or other media may cause offsite damage to crops, livestock, wildlife flora and fauna and humans.
- there is a risk that farmers acting individually will not take into account the impact of their pesticide use activities on build-up of resistance by pests, just as individual

motorists do not consider their contribution to road congestion. The extent of the externality problem associated with pest resistance is greater for highly mobile insect pests than for weeds. However, resistant weed seed can spread via contaminated crop seed.

- the health of farmers and farm workers may be directly affected by pesticide use.
- consumers of farm products may be adversely affected by pesticide residues.

Most of the external effects of pesticide use on environmental quality are strongly dependent on the location of application. A major exception is application of methyl bromide which is a global “public bad” insofar as it causes ozone depletion. The damage to the ozone layer is independent of the location of its use on the earth.

From the perspective of economic theory, the above pest and pesticide problems stem from essentially three types of market failure:

- *externalities* which occur when an activity undertaken by an individual or firm affects others with spillover effects which have not been taken into account by the individual or firm;
- *incomplete information* which occurs, for instance, when producers are not well informed about appropriate techniques of production and sound management practices, or when consumers do not have accurate information about important characteristics of particular goods;
- and *public good* characteristics which arise when the consumption of a good or service by one person or group does not diminish the supply available to others. The use of a lighthouse is a classic example.

In the absence of government action, independent choices by individual producers, consumers and farm workers are unlikely to provide the level and form of pest control and safety that society desires.

The major impacts and types of market failure causing sub-optimal use of pesticides under a *laissez faire* regime are summarised in Table 13. A common characteristic of the first three impacts shown in the table, relating to spread of pests, is that the acting party generates positive externalities. Thus, under a *laissez faire* regime, too little pest control will be undertaken and the spread of pests will be socially excessive.

**Table 13**  
**Market Failure and Sub-Optimal Pest Control (a)**

<b>Description of Impact</b>		<b>Type of Market Failure</b>
1.	Farm-farm pest spread	External cost to farmers
2.	Farm-environment pest spread	External cost to the public
3.	Environment-farm pest spread (b)	External cost to farmer
4.	Pesticide resistance	External cost to farmers
5.	Destruction of beneficial species	External cost to farmers
6.	Emergence of secondary pests	External cost to farmers
7.	Chemical residue in food	External cost to consumer
8.	Air pollution	External cost to the public
9.	Chemical residue in surface waterways	External cost to the public
10.	Chemical residues in groundwater	External cost to the public
11.	Worker safety	Imperfect information
12.	Research and extension	<u>Public good nature of research and extension</u>

a This is a modified version of a classification of market failures presented by David Pannell (1994).

b Excessive spread of pests from the environment to farms usually stems from publicly-owned land. This is a form of government failure rather than market failure.

The major impacts of market failures may be divided into impacts on environmental quality, human health and the external costs imposed on other farmers. The most common type of market failure is the externalities (spillover effects) associated with the application (or lack of application) of pesticides. Externalities are the dominant type of market failure causing impacts 1-10 in Table 13. Negative externalities may also arise from transport and storage of pesticides and disposal of pesticide containers and unused pesticides.

Under optimal resource allocation, a pesticide should be used at the level at which the social value of its marginal product is equal to the sum of the private marginal costs plus spillover (externality) costs. In principle, the spillover effects that introduce wedges between private and public (social) costs and benefits under a *laissez faire* system, can be corrected by government action. However, such action is justified only when the benefits of a government action seeking to correct a market failure exceed the costs. With respect to control of chemical residues in food, some agricultural industries are responding to powerful market forces by internalising externalities and thus becoming self-regulating. The Australian export wine industry is a notable example. High standards demanded by wine importers are relayed to wine grape growers through a small number of major buyers of Australian wine grapes. These major producers and exporters of Australian wine have developed manuals for safe use of agricultural chemicals for growers. Growers are required to keep diaries detailing their pesticide spraying activities. These diaries, and vineyard samples, are checked randomly. Issues relating to industry self-regulation of pesticides using quality assurance (QA) schemes are discussed later in section 7.5 and environmental management systems (EMS) in section 8.1.

Put simply, the objective of the regulatory process should be to attain an appropriate level of control of pests in Australia at the lowest feasible social cost. Social costs include user expenditure on agvet chemicals, public costs of agvet chemical administration and governance, and social 'spillover' costs of pesticide use on human health, the environment and trade. Clearly, a sound system of agvet chemical

management requires an effective monitoring system for pesticide residues in food (and fibre) and the environment and monitoring of adverse human health impacts, resulting from transport, handling and application.

The 1990 Senate Select Committee was advised by the then Department of Arts, Sport, the Environment, Tourism and Territories that quantitative data on pesticide use was so incomplete that an informed judgement could not be made on the economic, social and environmental impact of agricultural and veterinary chemicals. The then Bureau of Rural Resources advised that it was not possible to estimate returns per dollar for pesticide use in Australia, while the National Farmers Federation commented that the economic importance of agricultural chemicals in aggregate terms is difficult to assess accurately.

The only recent benefit-cost analysis of regulatory and other methods of government intervention in agvet chemical use was undertaken in South Australia (South Australian Government, 1998b). This study found very favourable benefit-cost ratios for government intervention in agvet chemical control over use.

Failure to ensure that any chemical use meets the standards of the marketplace nevertheless can have dire economic consequences. The NSW Parliamentary Standing Committee on State Development (1999) reported the economic costs to cattle producers of the contamination of export beef with the pesticides endosulfan and chlorfluazuron. Many international markets are requiring very low or zero levels of pesticides in produce and exceedence of these residue limits can adversely affect Australia's trade. The market limits are not necessarily related to potential health issues and are often lower than domestic residue limits. The routes of contamination were quite different, but these incidents resulted in regulatory action, such as the early withdrawal of chlorfluazuron from the registration process and tough restrictions on endosulfan usage.

A complete set of data on the nature, extent and cost of pesticide use would be needed before any balance sheet of costs and benefits – as broadly defined above – could be attempted. Such data are not readily available.

A number of features of good government regulations have been identified and endorsed by the Council of Australian Governments (COAG 1997). First, the need for, and objective of government action should be clearly identified and stated. Second, it should be established that the benefits of government action exceed the costs and that a regulatory instrument provides the lowest social cost means of intervention. Third, a regulatory measure should attain a high degree of compliance at low cost. (It is noted that the Government's policy of requiring Regulation Impact Statements requires an assessment of impact costs and benefits, using quantitative measures such as financial and economic costs and benefits where possible.) Measures to encourage compliance include brevity and clarity in stating the purpose and nature of the regulation and adequate consultation and public education. Fourth, regulatory instruments should, as far as possible, be performance (output) orientated, rather than process (input) based. Fifth, if government intervention relates to public health or occupational health and safety, as it often does, risk analysis provides a useful methodological tool. In addition, a regulatory instrument should be designed in the author's view, to provide a strong and continuous incentive for agents (farmers)

to be innovative and search for lower social cost ways of attaining the regulatory objective(s).

### **3.3. CONCLUSIONS – ECONOMIC POLICY**

**There is justification on economic policy grounds to have government intervention in a pesticide regulation system**

**It is recommended that the COAG good governance principles be fully integrated into an evaluation of the necessity for and potential means of achieving a comprehensive pesticide-use reporting system, as well as for all future regulatory changes governing pesticide availability and use.**

**It is recommended that any pesticide-use reporting system be established with the capability of being adopted to provide the inputs for an economically rigorous cost:benefit analysis of the value of pesticide use in production systems, and to enable evaluation of proposed future regulatory changes.**

## **4. - PESTICIDES IN FARMING AND FARMING SYSTEMS**

Pesticide use was examined in four major crops - cotton, potatoes, apples and pears, and winter cereals. These crops were selected as indicative of intensive broadacre crops, intensive vegetable crops, horticultural crops and the principal dryland broadacre crops. Pesticides used in cotton production have increased at a slower rate than the area planted, and the introduction of genetically modified varieties has reduced applications and encouraged greater use of integrated pest management. The cotton industry has been leading Australia in the introduction of grower-managed resistance management technologies and Best Management Practice programs in agriculture. Fungicides are the most significant pesticides used with potatoes. There appear to have been some increases in recent years in insecticide and herbicide use, though it has been difficult to identify the precise circumstances, highlighting the need for having adequate data on pesticides used with individual crops. The apple and pear industries are now using “softer” (more target specific) pesticides and sex pheromone traps to control insect pests. Integrated mite control has greatly reduced aspects of chemical use. Plant growth regulator use is declining, though they are still used for crop-thinning with older varieties. Research has resulted in a move to lower volume application technologies and reduced pesticide applications, and industry-wide residue testing has been established. Again, industry statistics are hard to interpret due to stone fruit crop use being potentially confounded with that for apples and pears. Dryland cereal yields have increased by 2.5% annually over the twenty years to 1999, the introduction of minimum tillage, with herbicides substituting for excessive cultivation, being a significant factor. Weed problems remain a continuing difficulty for growers, with herbicide resistance becoming much more common. The introduction of canola into rotations to break disease cycles and aid weed control has been an important recent change. Primary producers will continue to make significant use of synthetic pesticides, but commodity purchasers are increasingly requiring growers to have quality assurance systems in place.

### **4.1. AGRICULTURAL PRODUCTION SYSTEMS**

The use of pesticides in contemporary agricultural production systems has attracted public scrutiny for decades and that scrutiny, if anything, is intensifying. This public scrutiny derives, in part, from consumer demand for ‘clean and green’ food and fibre products. Under that banner, food and fibre should be produced with minimum or no use of synthetic products, including pesticides. The irony is that many, if not all contemporary food and fibre product quality standards cannot be met without the use of those same synthetic products, particularly agricultural chemicals.

This chapter focuses on pesticide usage in crop production systems. While a pasture phase is often an integral part of crop production systems, no attempt has been made to address pesticide usage, whether of agricultural or veterinary chemicals, in the



nation's animal industries. The focus on pesticide use in crop production systems derived from the knowledge that pesticide use was greater in those systems.

The scope of agricultural and horticultural cropping industries is huge – at least 100 crops valued in all in 1999 at some \$15 billion.

Four crop production systems have been chosen as indicators for intensive study. These are:-

- cotton
- potatoes
- apples and pears
- winter cereals

These indicator crop production systems embrace an intensive broadacre crop (cotton) which is largely exported, an intensively produced vegetable crop largely grown for the domestic market (potatoes), two widely grown and related fruit crops, again largely domestic market oriented (apples and pears), and the dominant broadacre dryland winter cereal crops in Australia, wheat, barley, oats and triticale. These four crop production systems are representative of the whole spectrum of crop production systems in Australian agriculture.

Other Australian crop production systems are also significant users of pesticides, for example, sugar cane, canola, grain sorghum, rice, lupins, faba beans, field peas, citrus, grapes, stone fruit and bananas. Most if not all crops, particularly fruit and vegetable crops, rely to a greater or lesser extent on pesticides to control weeds, insect pests and diseases and to meet the post harvest product quality standards demanded by markets.

Information on pesticide usage was obtained from industry influentials in both the public and private sector. It was also obtained by studying published material and reports. Data on the recent and current trends in the volume of pesticide use and on methods of application are presented both for Australia and for the four indicator crop production systems.

## **4.2. THE INDICATOR CROPS**

### **4.2.1. Cotton crop production systems**

#### ***4.2.1.1. The cotton industry – a brief pen picture***

Australian cotton production now exceeds 3 million bales annually, small by world standards but significant in Australian agriculture. A bale of cotton is 227 kg.

Australian cotton yields average 1400kg/ha or 6 bales/ha, second only to Israel and nearly double the yields of the United States of America. The area planted increased by more than 70% in the four years to 1998-1999 to exceed 550 000ha (Table 14)

This increase resulted from existing growers expanding their enterprises and from traditional grain growers in New South Wales and Queensland diversifying into

cotton. Semi-commercial production also commenced in Western Australia and experimental crops were grown in the Northern Territory during the review period.

**Table 14**  
**Australian Cotton Industry Statistics**

<b>Year</b>	<b>Production (‘000 bales)</b>	<b>Area (‘000ha)</b>	<b>Yield (kg/ha)</b>	<b>Gross Value of Production (\$M)</b>	<b>Value of Exports (\$M)</b>
1995-96	1800	320	1400	1150	800
1996-97	2700	400	1560	1400	1100
1997-98	2900	450	1620	1450	1450
1998-99	3200	550	1380	1500	1700

**Note:-** The gross value of production is the value at the farm gate. The value of exports includes the value of cotton seed exported. Cotton seed derives from the ginning process and is valued post farm gate.

**Source:** Cotton Yearbook 1999.

The area of dryland cotton varies from year to year. It ranges between 10 and 20 % of the total area planted. Major influences include the relative profitability of dryland cotton and grain crops, previous cropping history, the timing of planting rains, the availability of contractors for critical crop management operations and farmer crop preferences.

Australia is now the third largest exporter of cotton after the USA and Uzbekistan. The major customers for Australian cotton are Indonesia, Thailand, Japan and Taiwan. Australia also exports cotton seed as well as raw cotton. The value of cotton seed exports is also increasing (Anon 1999d)

#### **4.2.1.2. Pesticides used in cotton production**

Some 34 insecticides marketed under more than 100 trade names are registered for use in Australia and used on Australian cotton farms. Further, some 23 herbicides and 7 plant growth regulators are registered and used (Shaw 1999).

Fungicides registered for use and used in the cotton industry are almost exclusively used in seed treatment by the seed companies servicing the cotton industry.

The major insecticides used in the cotton industry include:

- dimethoate
- endosulfan EC
- methomyl
- amitraz
- *Bacillus thuringiensis* (Bt)
- pyrethroids
- profenfos
- chlorpyrifos
- spinosad

The major herbicides used in the cotton culture include :-

- glyphosate
- trifluralin
- diuron
- fluometuron and prometryn
- s-metalachlor

The significant plant growth regulators in the industry include:-

- dimethipin
- oleyl alcohol
- thidiazuron + diuron
- endothal
- mepiquat
- thidiazuron
- ethephon
- sodium chlorate

#### **4.2.1.3. Pesticide application in cotton**

In December 1998, Dr C.S. Parkin of Silsoe College at Cranfield University, United Kingdom, reviewed pesticide spray application research, extension and, to a limited extent, farm practice in Australian cotton production systems (Parkin 1999). He made several recommendations on the future direction of R&D but his comments on industry practices included:-

- aircraft now apply only 45% of chemicals applied to cotton. The balance is applied by ground rigs. This is a significant and recent change ensuing largely from an increase in the area of rain-fed cotton and a determination among irrigated cotton growers to reduce the incidence of spray drift. In the early 1990s, ground rig application of pesticides to cotton was extremely rare; aerial application of pesticides was almost universal.
- with a maximum recommended air temperature of 28°C, ground rig applications are almost invariably made at night. This is very sound practice.
- ground rig nozzles and nozzle fittings on Australian cotton farms are appropriate.
- aerial application of pesticides is a vital crop management practice in pest control in cotton; ground rig spraying in irrigated and water logged areas is not feasible.
- aerial application techniques used in the Australian cotton industry are in line with best practice elsewhere.
- some growers treat aerial application as 'fire fighting' and to be used when other methods fail. They put undue pressure on aerial operators to apply pesticides under conditions where, at best application is poor, and at worst, there is a likelihood of serious spray drift incident.
- the majority of on-farm chemical storages are not of an acceptable standard.
- the cotton industry Best Management Practice (BMP) manual provides a good framework for the analysis of pesticide related problems.

Although the cotton industry been historically sensitised and alert to pesticide contamination issues, recent changes in pesticide application in the cotton industry largely but not exclusively derive from the 'pesticide contamination in beef' incidents in 1995. At that time, cotton pesticide residues in Australian beef threatened that multi-million dollar export industry.

Woods and Dorr (1997) reported that about 60% of the contamination incidents reported in New South Wales that year were attributed to spray drift and in 50% of those cases, the MRL for beef was exceeded. Although these incidents represented only 0.025% of aerial spray missions, the consequences of such incidents could

jeopardise Australian exports of beef and cause the imposition of draconian legislation.

A significant change in pesticide application in cotton in 1999-2000 derived from the new label for endosulfan applications (Shaw 1999). Application of that chemical has restrictions and requirements for users. The restrictions include the total quantity of active ingredient which can be applied, the number of sprays, the timing and method of application, the establishment of buffer zones for minimising down-wind impact during application, the specific requirements regarding notification of neighbours, training, the development of a spray and drift management plan and record keeping.

The regulations pertaining to the use of endosulfan on cotton were again modified for the 2000-01 season. The major modification was the suspension of registration of all ULV endosulfan formulations from June 30 2000. Stocks were phased out during the 2000-01 season.

Full details of the current regulations are on the label and in the booklet which accompanies the label on every endosulfan container. Those regulations on the label also require users to apply the product in accordance with the cotton industry's BMP manual (Williams & Williams 2000).

The cotton industry, through the Australian Cotton Industry Council, is now actively promoting pesticide spray application guidelines, not only to reduce spray drift on unintended targets but also to reduce pesticide applications and to improve pesticide efficiency (Anon 1999d). This initiative is now an integral part of the cotton industry's BMP program.

The current BMP program (Williams & Williams 2000) focuses on improving pesticide use on cotton farms through identification of on-farm hazards, assessment of their potential risk, developing plans to reduce those risks and providing evidence through an audit process that the plans have been carried out.

Inglis (2000) reported on a survey of a 16% sample of the Australian cotton growers to assess progress particularly against the target of having 100% of cotton growers trained and auditable by June 30, 2001.

Some outcomes of the survey were:-

- 82% had attended a BMP and a Spray Drift Management Plan (SDMP) workshop.
- 92% had developed a SDMP
- 87% had started to implement the BMP program on their farm
- over 70% had developed action plans and implemented them
- 22% had already been audited
- 16% did not intend to be audited

Just prior to this cotton industry initiative, at least one cotton grower had received ISO 14 001 accreditation to gain market advantage for his cotton. That experience was extremely useful to the industry when the BMP program was being developed. The programs are seen as complementary, BMP being developed as an industry-wide program, and ISO 14 001 as an certification recognising that an individual farmer has

received certification for his environmental management system (B. Pyke, CRDC, pers. comm.).

Recently, a major cotton industry aerial spray business has received ISO 14 000 accreditation for its operations in applying pesticides. This initiative could well encourage other aerial applicators to seek similar accreditation (B. Pyke, CRDC, pers. comm.).

#### **4.2.1.4. Industry commitment to reducing reliance on pesticides**

The cotton industry derives pest management technology from both Cotton Research and Development Corporation (CRDC) projects and those of the Australian Cotton Cooperative Research Centre (Australian Cotton CRC). Both bodies allocate between 30 and 40% of their budget to R&D in pest and pesticide management and in pesticide application.

The Australian Cotton Growers Research Association (ACGRA) is the industry body which participates in research priority setting and assists in assessing R&D projects. It also supports the transfer of relevant technology through active involvement in cotton extension activities including organising the biannual Australian Cotton Conference. The 10<sup>th</sup> such conference in Brisbane in August 2000 was attended by over 2000 delegates.

Pesticides are a major input in Australian cotton production, particularly insecticides and herbicides. In irrigated crops, pesticides account for some 35-40% of total growing costs. In dryland crops, pesticides account for some 45-50% of total growing costs (Anon 1998).

The pesticide strategies for dryland and for irrigated crops do not vary all that much. However, pesticide costs/ha for dryland crops are lower as ground rigs are invariably used to apply insecticides as band sprays. Irrigated crops regularly receive an overall spray from aircraft. Further, dryland crops usually have a shorter growing season requiring 1 to 2 fewer spray applications (J. Marshall, Cotton Seed Distributors, pers. comm.).

The cotton industry is somewhat unique in Australian agriculture in that crop consultants are an integral component of the industry. Frequently known as 'bugcheckers', these largely self-employed consultants provide pest management advice to growers for a fee. Their involvement in the cotton industry reflects both the importance of insect control in crop management and its complexity.

The cotton industry has faced a number of challenges in pest control in recent years. These include:-

- enhanced pesticide resistance of the major insect pest, *Helicoverpa* spp. commonly known as heliothis.
- serious pesticide residue problems in companion farm products, particularly beef
- a scarcity of new pesticides, particularly insecticides
- restrictions on the use of the insecticide, endosulfan

- pesticide contamination of rivers and dams
- community health concerns over pesticide spray drift (Anon 2000g).

The industry has had to deal with pesticide resistance of its major pest, heliothis for many years. It now also has to manage pesticide resistance in mites and aphids. It has done this by developing resistance management strategies which are updated annually in industry forums.

These strategies guide growers in the rotation of groups of pesticides at various crop growth stages and in the number of sprays of each chemical group applied during the growing season. The strategies also stress the insect pest thresholds to be monitored and used in scheduling insecticide sprays, the use of heliothis trap crops and the use of cultivation to reduce over-wintering insect populations.

These strategies are modified for optimum regional impact. For example, in 1999-2000, separate resistance strategies were promulgated for northern New South Wales and southern and central Queensland on one hand and for the Macquarie and Lachlan River Valleys on the other. The length of the growing season is the main reason for these separate strategies.

If during the cotton growing season, a grower, a group of growers or a region believes the current insecticide resistance management strategy is disadvantaging them, the industry has a process for handling or arbitrating within-season requests for changes to the strategy (Shaw 1999).

The success of these insecticide resistance management strategies is measured by its almost complete adoption by growers over many years and by its outcomes. The industry is still using and relying on insecticides such as endosulfan and the synthetic pyrethroids some 20 years after widespread heliothis resistance to those chemicals was identified.

These challenges have resulted in the effective development of R&D programs which seek to reduce reliance on conventional pesticides, to prolong the life of useful pesticides, to develop biological and mechanical control methods and to establish systems to minimise the off-farm impact of pesticides (Franzmann & Lea 2000).

Severe outbreaks of mites, tipworm, aphids, mirids and heliothis in the 1998-99 crop escalated insecticide costs of some growers by up to 25%. In some extreme cases, growers spent up to \$1000/ha on insecticides. These pesticide-driven systems also favoured the development of insect resistance to pesticides and did not achieve satisfactory insect control (Shaw 1999).

As a result of all these influences, the Australian cotton industry has developed a major focus of reducing dependence on synthetic pesticides through an IPM strategy.

The major components of the cotton industry IPM strategy are:-

- the introduction of INGARD single gene Bt cotton, supported by an insect resistance strategy (for further discussion, see chapter 9).
- the development of a resistance management strategy for conventional pesticides based on detailed monitoring and analysis of resistance mechanisms.

- the enhancement of the role of beneficial predators and parasites in cotton pest management with increased emphasis on maintaining and augmenting these beneficial insects.
- the adoption of higher damage thresholds particularly early in the season and the use of decision support systems.
- the adoption of area-wide management strategies of heliothis. These strategies include avoiding successive heliothis susceptible crops and the use of trap crops followed by pupal destruction to reduce insect populations (Anon 2000g).

A more detailed consideration of cotton industry IPM and related pesticide resistance strategies is provided in Chapter 9.

The silverleaf whitefly (*Bemisia tabaci*), a recently introduced pest, is a threat to the cotton industry as it is a major pest of cotton in many overseas countries. It is not, as yet, a pest in commercial cotton crops in Australia but a hybrid as a result of breeding with the common indigenous biotype was found in a crop at Emerald at the end of the 1999-2000 season. The industry is monitoring the situation closely (Franzmann & Lea 2000).

#### **4.2.1.5. Impact of IPM on the Australian cotton industry**

By adopting a range of IPM tactics, especially the preservation of beneficial insects, South Burnett cotton growers reduced insecticide costs from \$700/ha in 1997-98 to \$350/ha in 1998-99. That reduction is significant given that 1998-99 was a season of extreme insect pest pressure and one in which insects were extremely difficult to control. A 50% decrease in pesticide costs in that season is a remarkable achievement (Wilson 2000).

The industry appointed IPM extension officers in each of the major cotton growing districts in 1998 and many growers are conducting their own IPM experiments, almost universally doing so in conjunction with their crop consultants.

At the 10<sup>th</sup> Australian Cotton Conference, cotton growers, consultants and industry leaders all cited examples where adoption of IPM approaches to pest control had reduced reliance on synthetic insecticides (Coulton 2000, MacPherson & Coulton 2000).

Preliminary results from a current economic evaluation of IPM industry initiatives were also presented at that Conference (Hoque *et al.* 2000). The study categorises insecticide strategies into 'soft' or 'hard' options according to their disruptive effects on beneficial predatory insects. The study also examines the impact of INGARD and conventional cotton varieties under both 'soft' and 'hard' insecticide strategies.

In 1998/99, the spray costs of the 'soft' option were lower than those of the 'hard' option. They were lower by 21% for INGARD crops and by 17% for conventional crops. In the following 1999-2000 season, the 'soft' option was less expensive than the 'hard' option by 42% for INGARD crops and by 44% for conventional crops.

Over the two seasons, the average gross margin for the ‘soft’ option was greater than that for the ‘hard’ option by 25% for the INGARD crops and by 5% for conventional crops.

Summarising, insecticide spray costs decreased and gross margins increased under ‘soft’ insecticide strategies. Insect control in the first of the study years was perhaps the most difficult in memory whilst insect control in the second year was relatively easy.

#### **4.2.1.6. Trends in the volume of pesticide use in cotton**

The recent trends in volume of pesticides used in the cotton industry using 1996 as the base year are shown in Table 15:-

**Table 15**  
**Indices of Volumes of Crop Protection Pesticides Used in Cotton**

<b>Year</b>	<b>Herbicides</b>	<b>Insecticides</b>	<b>Fungicides</b>	<b>Plant Growth Regulators</b>	<b>Area Planted</b>
1996	100	100	100	100	100
1997	109	119	81	102	123
1998	122	152	105	97	136
1999	134	138	90	91	172

Source: Crop Care Australasia Pty Ltd. and The Australian Cotton Grower.

NOTE: all figures in the above table are indices. The pesticide indices are for calendar years. The area planted indices are for the cotton season ending that year. That is, the 1999 area index is for the 1998-99 cotton season.

The volume of insecticides used is some 4 to 5 times the volume of herbicides used and 100 to 150 times the volume of fungicides used on the crop during the review period. Of the total volume of pesticides applied to all crop production systems in Australia in the study period, nearly 20% was applied to cotton. The industry is a very significant purchaser and user of pesticides (P.Chalmers, Crop Care Australasia Pty Ltd, pers. comm.).

#### **4.2.1.7. Trend highlights - Cotton**

- The area planted to cotton increased by over 70% during the review period. Over that same four year period, the volume of insecticides applied increased by only 40%, and the volume of herbicides applied increased by 34%. Fungicide usage and that of plant growth regulators declined during that significant industry expansion.
- Despite the poor alignment of the period of area planted statistics and that of the volumes of pesticides used, the increase in pesticides used by the cotton industry is significantly less than the increase in the area planted. There has been a



significant reduction in the volume of all pesticides applied per unit area of cotton planted.

- The volume of insecticide applied to cotton in Australia each year during the review period was higher than that applied in the base year. The volume applied peaked in the 1998-99 cotton season in response to markedly increased insect pressure and difficulty in insect control.
- The volume of insecticide used in the calendar year 1998 was some 50% higher than that used in the base year 1996. At the same time, the area planted increased by 36%. In 1999, the volume of insecticide used was some 40% above that for the base year, but the area planted had increased by 70% over that in the base year.
- Cotton industry IPM strategies appear to be working. If that is the case, there should be a further reduction in the volume of insecticides used in 2000. Insect pressure in the 1999-2000 cotton season was low and the industry reported much lower use of insecticides.
- The volumes of herbicide used during the period increased each year by some 10%, again a much lower increase than the increase in area planted. That increase would be in the broad leaved herbicides as pre- emergent herbicide applications for grass control have declined. Grass weeds are no longer a problem in cotton production systems.
- The volumes of applied fungicides and plant growth regulators remained static or reduced marginally over the review period.
- The use of plant growth regulators has been modified in the review period by a change in the plant structure of the newer cotton varieties and through improved crop husbandry. The newer cotton varieties are shorter with a reduced need for the application of plant growth regulators to facilitate harvesting. Further, the distinctive, deeply lobed, narrow blade okra leaf varieties have a reduced need for defoliation prior to harvest.

#### **4.2.2. Potato crop production systems**

##### ***4.2.2.1. The potato industry – a brief pen picture***

Potatoes, the nation's largest vegetable industry, are grown in every Australian state. Victoria is the main production state. Production in South Australia on irrigated sandy soils has increased significantly in recent years and is approaching that of Victoria. The crop is grown by just under 2000 growers (Anon 2000b).

Potatoes are available in Australia all year round with the heaviest supplies in the January to September period (Anon 2000f).

Potato production for human consumption and the value of that production over the period 1996 to 1999 are shown in Table 16:-

**Table 16**  
**Australian Potato Industry Statistics**

<b>Year</b>	<b>Production (‘000t)</b>	<b>Area (ha)</b>	<b>Yield (kg/ha)</b>	<b>Gross Value of Production (\$M)</b>
1996	1309	41 812	31.3	414.1
1997	1286	41 083	31.3	449.4
1998	1372	42 560	32.2	493.1
1999	1327	41 298	32.1	437.7

Source: Australian Bureau of Statistics

Some 60% of the national production is grown for processing. The remaining 40% are fresh market varieties.

Some 15 000 to 18 000t of potatoes have been exported annually in recent years. Those exports are valued at \$6.5-7.5 million. The major export destinations are the Republic of Korea, Singapore, and Papua New Guinea (Anon 2000f).

Seed potatoes are also grown in Australia mainly in Victoria. In the year to March 31, 1999, some 5 772ha of potatoes were grown for seed on just over 550 properties. The production of potatoes for seed was some 146 000t (Anon 2000b).

In the period of this study, there have been major changes in the market access requirements demanded of growers. The major retail and processing buyers now require direct suppliers of potatoes to have some form of quality assurance (QA) system in place. These systems require activities critical to product quality and food safety, including pest management practices, to be documented and available for audit.

The QA system required by buyers varies. Before a grower plants a crop, the appropriate QA system to supply the intended market has to be in place. This restricts grower market options and industry has had very limited or no success in evolving a uniform QA system. What has been agreed is that the QA demands of buyers will intensify the scrutiny of on-farm practices including those pertaining to pesticide use (Coleman 2000), thereby serving as an added, market driven quasi-regulation system (further discussed in Section 7.5).

In Australia, there is a strong swing in customer purchase of potatoes in supermarkets (Table 17) and this trend is expected to continue.

**Table 17**  
**Where Potatoes are Purchased in Australia**

	<b>1993 study</b>	<b>1999 study</b>
Supermarkets	49%	64%
Greengrocer	48%	30%
Other	3%	6%

Source: Australian Potato Industry Strategic Plan

This change in consumer purchasing habits probably will further reinforce the imposition on growers of differing QA systems as supermarket retailing is extremely competitive

#### **4.2.2.2. Pesticides used in potato production**

Some 200 agricultural chemicals, several of them under different trade names, are registered for use on potatoes in Australia. That includes some 80 herbicides, 60 insecticides and over 50 fungicides (Anon 2000a).

The major insecticides applied include nitofol, thimet, pirimor, chlorpyrifos and dimethoate. The major fungicides used include mancozeb, chlorothalonil and difenoconazole. Among the herbicides used in potato production are metribuzin, diquat/paraquat and diquat as diquat dibromide monohydrate (S. Harper, QDPI & R. DeJong, Elders Ltd, pers. comm.).

Plant diseases are by far the major problem. The major diseases include:-

- target spot (*Alternaria solani*)
- black scurf (*Rhizoctonia solani*)
- powdery scab (*Spongospora subterranea*)
- common scab (*Streptomyces scabies*)
- Verticillium wilt (*Verticillium dahliae*)
- Pink rot (*Phytophthora erythroseptica*)

Most potato diseases are carried over from season to season or from one area to another on infected seed tubers. To reduce the effect of these debilitating diseases, seed certification schemes have been established to service the industry. These schemes have reduced virus problems in the Australian potato crop but have not prevented the introduction of tuber-borne fungal diseases into new production areas.

New standards are being introduced into the tuber seed industry to reduce the high incidence of fungal diseases in certified seed. Recent improvements include the use of tissue cultured plants, micro propagation, mini tubers and reduced generation times but many seed crops still become infected in the final multiplication stage.

The industry expects the demand for increased yields of blemish-free potatoes to continue for all sectors but particularly for washed potatoes. Under current technologies, fungicide use on tuber seed is expected to increase (Wicks & Boer 2000).

Insect pests are of economic significance in the potato areas of northern Australia, the Atherton Tableland, the Lockyer Valley and Darling Downs, and coastal and inland northern New South Wales. In Tasmania, in contrast, the use of insecticides is very limited (P. Hardman, Simplot Ltd, pers. comm.).

The more important insect pests are:-

- potato tuber moth (*Phthorimaea operculella*)
- green peach aphid (*Myzus persicae*)
- loopers (*Chrysodeixis spp*)
- heliothis (*Helicoverpa spp*)
- white fringed weevil (*Graphognathus leucoloma*)
- African black beetle (*Heteronychus arator*)

#### **4.2.2.3. Industry commitment to reducing pesticide use**

The Horticultural Research and Development Corporation (HRDC) manages and oversees potato industry R&D. Some 25% of the annual allocation for potato industry R&D targets priority pest and disease management issues.

Since 1992, the R&D Committee of the Australian Potato Industry Council (APIC) has collaborated with HRDC in setting R&D priorities through industry strategic plans (Anon 1999c). APIC and HRDC developed the current Australian Potato Industry Strategic Plan in May 1999. This 5 year plan is updated annually.

The Plan details the industry goals to 2004 and among them is one to “reduce reliance on agricultural chemicals”. The strategies to implement this plan are twofold. Firstly, the industry will support the development and implementation of integrated insect pest and disease management programs which will reduce its reliance on chemicals. Secondly, the potato industry will support the development of resistance in varieties to major insect pests and diseases particularly those identified as major targets of chemical use.

Australia has a single breeding program at Toolangi in Victoria. This program supplies material for trials in Western Australia, Queensland and Tasmania after two years of field testing at Toolangi and in South Australia, New South Wales and Victoria after three years of field testing. The breeding program is currently screening the germplasm for resistance to potato cyst nematode, powdery scab and target spot (Kirkham *et al.* 2000).

Both HRDC and APIC strongly support the occasional Potato Industry Conferences, the latest of which “Potatoes 2000—Linking Research to Practice” was held in Adelaide in July/August and attended by just under 300 delegates.

#### **4.2.2.4. IPM initiatives in the Australian potato industry**

IPM initiatives have largely targeted insect pest problems. In potato crops, IPM uses biological controls (predators and parasites) and cultural controls (eg. irrigation and weed control) supported by the strategic use of insecticides. These IPM strategies

must deal with all insect pests simultaneously not just the major pests such as potato moth and heliothis (Horne P, 1997, 2000). Strategies have been developed to deal with a number of problems including:-

- insecticide resistance
- operator and farm worker health and safety
- chemicals being withdrawn from use by regulators or by chemical companies
- poor insect control
- unintentional kills of beneficial predators and parasites

The awareness and adoption of IPM by Australian potato growers was studied in a series of surveys between 1992 and 1996 (Horne *et al.* 1999, Horne *et al.* 1998). Of the 2000 questionnaires mailed to growers, just over 600 or 25% of growers responded – a reasonable sample. The response rate varied among the states and ranged from 23% in Western Australia to 36% in Tasmania.

The proportion of potato growers practising IPM varied from 15% in New South Wales to 30% in Queensland. Some 25 % of South Australian growers, 16% of Victorian growers and 18% of Western Australia growers used IPM, all aligning with the state by state significance of insect pest control in potato production.

The crisping sector of the potato industry had the highest level of IPM adoption with some districts having 100% of growers using IPM. The very high levels of adoption of IPM were achieved in potato growing districts where advisers or consultants assisted growers to adopt the strategies. That is an indication of the complexity of IPM practices and strategies (Horne *et al.* 1999).

Some of the economic benefits of adopting IPM have been quantified. A Victorian grower reported to the 2000 Australian Potato Conference that he had saved over \$50 000 in chemical costs in the 5 years he had practised IPM without compromising yield or quality (O’Sullivan & Horne 2000).

A 1996 analysis of IPM strategies (Strange 1996) also highlighted the impact on crop gross margins through reduction in the number of insecticide sprays (Table 18):-

**Table 18**  
**Impact of Reduced Number of Sprays on Potato Gross Margins**

<b>Reduction in no. of Sprays.</b>	<b>Cost savings/ha (\$)</b>	<b>% increase in gross margin</b>
1	60	0.75
2	125	3.25
3	190	4.75
4	275	6.75
5	325	8.25
6	400	10.0
7	475	12.0

Source: Strange (1996)

#### **4.2.2.5. Trends in the volume of pesticide use in potatoes**

The recent trends in the volume of pesticides used in the Australian potato industry using 1996 as a base year are shown in Table 19:-

**Table 19**  
**Indices of Crop Protection Pesticides Used on Potatoes**

Year	Product Category			
	Herbicides	Insecticides	Fungicides	Area Planted
1996	100	100	100	100
1997	103	109	102	98
1998	101	135	105	102
1999	120	116	102	99

Source: Crop Care Australasia Pty Ltd. and Australian Bureau of Statistics

NOTE all figures in the above table are indices. The indices for pesticides are for calendar years. Those for the area planted are for years ending March 31.

Fungicides are the most significant pesticide applied to the potato crop. The volumes of active ingredients applied are 6 to 7 times the volumes of applied insecticides and 3 to 4 times the volume of applied herbicides. No plant growth regulators are applied to potatoes in Australia.

The volume of pesticides applied to potatoes is less than 1% of the total volume of pesticides applied to crop production systems in Australia. This reduces the robustness of the data but it is the most reliable information available (P.Chalmers, Crop Care Australasia Pty Ltd, pers. comm.).

#### **4.2.2.6. Trend highlights - Potatoes**

- The area planted to potatoes fluctuated marginally during the review period.
- The significant changes in pesticide use in potatoes during the period under review were an increase in herbicide use in 1999 and an increase in applied insecticide in 1998 and 1999 but particularly 1998.
- The volume of fungicide, the major pesticide used in potatoes, has remained constant during the review period. Increased volumes are expected to be used in the immediate future as the industry seeks to reduce the incidence of fungal diseases on tuber seed potatoes.
- The increased volume of herbicide used in 1999 could be the result of an increase in plantings in South Australia, with potato growers using herbicides to bring new sources of land under crop including increased use of glyphosate to knock down weeds prior to planting, instead of the conventional cultivation. It could also

derive from quite wet conditions early in the 1999-2000 crop when growers had to use herbicides instead of cultivation to control weeds.

- The increases in the volume of insecticides used in 1998 and to a lesser extent in 1999 are difficult to explain. The 1998-99 and 1999-2000 potato seasons were generally dry in Victoria and Tasmania. Marginally more insecticides are applied in dry years to keep insect pests under control but nowhere near the 20-30% increases recorded.
- Potato industry leaders in southern potato growing districts believed the increase in volumes of insecticide used would ensue from increased applications in northern potato growing districts where insect pressures are higher and the suite of insect pests greater. However, industry leaders in the northern potato growing areas are at a loss to understand the increased volumes of insecticides. Atherton Tableland potato growers have reduced insecticide applications to the extent that re-sellers in the district report a 60% reduction in sales in the last decade. Growers in that district are now applying 3-4 insecticide sprays each season; many apply fewer sprays. Industry leaders in the Lockyer and Fassifern Valleys in SE Queensland are also not aware of increased insecticide applications in 1998 which were partially maintained in 1999. They expected the volumes used to have declined.
- The increases in the volumes of herbicides used and of insecticides in the study period are warning signals to the industry. They may be short term phenomena; they may signal a significant change in farm practice. The increase in herbicide use of some 20% in 1999 and in insecticide use of over 30% in 1998 are quantum changes. They cannot be passed off as aberrations of the method by which the data were collected.
- If these trends continue, the insect and weed control practices of Australian potato growers will need to be studied, and new extension programs developed and implemented if the industry strategic plan goal 'reduce the reliance on agricultural chemicals' is to be achieved.
- The information also illustrates the importance of collecting data on pesticide usage on individual crops.

### **4.2.3. Apple and pear crop production systems**

#### ***4.2.3.1. The apple and pear industry – a brief pen picture***

The Australian apple and pear industry comprises some 2000 growers. About half the national production of apples comes from New South Wales and Victoria. Victoria, particularly the Goulburn Valley, produces more than 80 per cent of the national pear production (Anon 2000b).

Apple and pear production and value of production trends over the period 1996 to 1999 are shown in Tables 20 and 21 respectively:-

**Table 20**  
**Australian Apple Industry Statistics**

<b>Year</b>	<b>Production (kt)</b>	<b>Yield (kg/tree)</b>	<b>Gross Value of Production (\$M)</b>
1996	281	53	305.3
1997	353	62	378.4
1998	309	53	272.7
1999	334	56	321.2

Source: Australian Bureau of Statistics

**Table 21**  
**Australian Pear Industry Statistics**

<b>Year</b>	<b>Production (kt)</b>	<b>Yield (kg/tree)</b>	<b>Gross Value of Production (\$M)</b>
1996	156	113	90.7
1997	168	118	106.2
1998	153	111	107.8
1999	157	112	112.4

Source: Australian Bureau of Statistics

The Australian industry exported some 36 000t of apples and 21 000t of pears in 1997/98 valued at some \$38 million and \$23 million respectively. The major export destinations of Australian apples are Malaysia, Singapore, the United Kingdom and Sri Lanka while the major destinations of Australian pears are Singapore, Malaysia, Hong Kong and Indonesia (Anon 2000c, Anon 2000e).

#### ***4.2.3.2. Pesticides used in apple and pear production***

Some 100 agricultural chemicals are registered for use in apples and pears, several under different trade names. They include more than 30 insecticides and 30 fungicides and a dozen or so herbicides (Anon 2000a).

The significant fungal disease in apples is black spot or scab. Other diseases include powdery mildew, blossom blast, silver leaf and brown rot (Anon 1999e, Anon 1995).

The important insect pests include codling moth, mites, woolly aphids, apple dimpling bug and light brown apple moth. A number of other insect pests need to be controlled at times including heliothis, mealy bug, looper, fruit fly, Harlequin bug, scale insects, and soil borne insects, earwigs and crickets (Anon 1999e).



Plant growth regulators are applied to thin the crop chemically and spread maturity. However, current label registrations apply mostly to older varieties. Plant growth regulators are not applied to many of the newer, premium priced varieties such as Pink Lady (J. Purbrick, Australian Apple and Pear Growers Assoc., pers. comm.)

Significant pesticides used in apple and pear production include (Anon 1999e, Anon 1995) :-

<b>Insecticides</b>	<b>Fungicides</b>	<b>Herbicides</b>	<b>Plant Growth Regulators</b>
azinphos methyl	dithianon	diquat and paraquat	ethephon
fenoxycarb	mancozeb	2,2-DPA	NAA
parathion methyl	dodine	amitrole	carbaryl
pirimicarb	bitertanol and agridex	glyphosate	
chlorpyrifos	bupirimate		
endosulfan	metiram		
codling moth pheromone	thiram		

Widespread adoption of integrated mite control has enabled all growers to reduce the use of chemicals and the significance of the pest. Mites, formerly the most important insect pest problem, are now of little or no significance other than in Western Australia.

Apple and pear growers are now using ‘softer’ more target specific pesticides fenoxycarb, chlorpyrifos, pirimicarb and sex pheromone traps to control insect pests. These have replaced or partially replaced the broad spectrum, generally more toxic insecticides such as azinphos methyl and methidathion. There are also opportunities to reduce fungicide applications to control scab or black spot through achieving a high level of control early in the season.. The newer variety Pink Lady , however, is very susceptible to black spot and requires late season applications in some years. Another newer variety, Gala and its red strains are very susceptible to powdery mildew, the control of which requires fungicide applications in some years (Anon 1999e).

#### **4.2.3.3. Pesticide application in apples and pears**

Until comparatively recently, high volume sprays were used to apply pesticides in apple and pear crops. With the advent of air assisted sprayers, it has become common to achieve more efficient coverage of crops using much lower volumes of water (S. Dullahide, QDPI, pers. comm.).

Estimates vary, but reductions in pesticide usage of between 20% and 40% can be gained by proper calibration and use of concentrate spraying equipment in apple and pear orchards because of the better coverage obtainable. This issue has been the

subject of a joint NRA and chemical industry initiative which has resulted in the NRA publishing guidelines which delineate labelling requirements in relation to product rates when using concentrate and semi-concentrate sprayers in orchards and vineyards. The apple and pear industry has also invested heavily in pesticide application R&D. The industry and HRDC have invested over \$700 000 in those R&D programs in the 6 years to June 2000 (Anon 1999e).

Some of the outcomes claimed for this apple and pear industry research are:-

- modifications to spray rigs reduced on-farm pesticide applications by 25% to 40%.
- pheromone traps have the potential to reduce pesticide applications by 30% (where codling moth is a significant pest).
- some 12 workshops on sprayer calibration were held throughout the apple and pear growing districts and 450 spray calibration manuals were distributed. Some 80% of growers were reported as using lower spray volumes following these workshops.
- providing good (tree canopy) distribution was achieved, concentrate sprays are as effective as conventional high volume sprays. The upper canopies of trees are difficult targets for concentrate sprays.

Some grower resistance to the use of concentrate sprays and lower spray volumes was initially encountered pending resolution of concerns that some growers had about the impact of this technology on their existing Integrated Pest Management programs. A further study has examined the impact of a range of pesticides on beneficial insects when applied as concentrate sprays. The highlights of this study were:-

- some 69% of the apple and pear growers indicated that the spray application research projects improved orchard spray calibration.
- just over 50% agreed the research helped achieve better control of pests and diseases and lowered the number of sprays each season.
- some 36% indicated the spray technology assisted them obtain better fruit yield and quality.
- only 35% of respondents to the survey had reduced production costs.

This indicates that recent changes in the methods of pesticide application in the apple and pear industry have been adopted cautiously despite the significant investment in research to provide the technology to underpin the desired improvement.

#### **4.2.3.4. *Industry commitment to reducing pesticide use***

HRDC and the apple and pear industry have been collaborating in industry research since 1988.

The Australian Apple and Pear Growers Association (AAPGA) appoints an Apple and Pear R&D Committee. This Committee participates in setting R&D priorities through strategic plans. It also assists in the review and assessment of R&D projects from preliminary submissions through to review of final recommendations.

This Committee also recommends to AAPGA, which in turn provides advice to HRDC on the projects to be supported by industry levy funds.

It also actively seeks voluntary contributions to R&D from others than industry levy payers, the growers. These voluntary contributions can come from processors, re-sellers etc who may require some specific apple and pear industry R&D and are willing to fund it (M.Uloth, HRDC, pers. comm.).

HRDC allocated between \$ 600 000 and \$ 1 000 000 to research into apple and pear production in each of the 4 years between 1996-97 and 1999-2000. The proportion of those funds dedicated to R&D on pest control, pest and pesticide management and pesticide application varied from 60% to over 80% during that period (D. Ryan, HRDC, pers. comm.).

The apple and pear growing industry, through AAPGA, has led Australian rural industries in agreeing to reduce pesticide usage. In 1991, it reached agreement with a number of organisations to explore the possibilities for achieving reduced pesticide usage (J. Purbrick, Apple and Pear Growers Assoc., pers. comm.).

The pesticide reduction targets agreed were 25% in 3 years, 50% in 5 years and 75% by the year 2000. A baseline of usage was not established so it is impossible to determine if those targets have been achieved.

What has been achieved and regularly reported to other parties to the agreement includes:-

- the de-registration of pesticides no longer used in the industry
- research into superior pest control practices particularly IPM technology
- the promotion among growers of the use of 'soft' pesticides—those which target specific pests as replacements for the broad spectrum 'hard' pesticides
- the disposal of unwanted pesticides
- cessation of the use of cosmetic products which for example, added colour to apples

This agreement remains in force today.

AAPGA and HRDC have also recently funded an integrated fruit production program (IFP). This is an umbrella program which pulls together on-farm production, post harvest, environment and marketing components through an audit system. This program was initiated in 1999. It is being implemented through regional focus groups.

#### ***4.2.3.5. IPM initiatives, Australian apple and pear industry***

To help underpin this commitment, AAPGA and HRDC have funded nearly 40 R&D projects since 1991, an investment of \$3.55 million. This R & D program derived from a 1991 workshop in which the apple and pear industry set priorities to allocate resources and responsibilities to develop an IPM program for the industry and get it adopted by growers.

This program was evaluated by an independent economic consulting firm, Agtrans Research, in 1999 (Anon 1999e). The key findings of the evaluation were:-

- the investment has accelerated further development of IPM and crop regulation technologies over the nine year period and for IPM at least, has resulted in significant changes in both industry practice and culture.

- the outputs and outcomes of the R&D program have been consistent with the declared objectives and strategies defined in both HRDC and the apple and pear industry plans.
- the investment has had an important strategic positioning role, in particular with respect to future marketing strategies and market access.
- the benefit cost analysis undertaken suggested economic returns have been significant – benefit-cost ratio of 1.5:1 and an internal rate of return of 12% assuming a 7% discount rate .
- the R&D investment has impacted positively on the extent and rate of adoption of IPM practices in the industry.
- the overall R&D investment has been focused and well managed.

The survey data included responses from some 99 of the 240 growers (41%) in the initial sample of the Australian apple and pear industry.

The significant survey outcomes included:-

- some 80% of the respondents were practicing IPM
- the time of first adoption of IPM was:-
 

1996 to date	28%	1993 to 1995	23%
1990 to 1992	17%	Pre-1990	32%
- the average number of sprays per year to control pests and disease has reduced by 28% since the adoption of IPM.
- some 80% of growers are using reduced spray volumes.
- orchard size and layout are important in determining the extent of cash cost savings. Larger growers are more likely to achieve cost savings.
- the benefits of IPM were ranked as follows:-
  1. improved health for those on the farm
  2. lowered impact on the environment
  3. reduced resistance to chemicals
  4. cost savings
  5. improved market prospects
- chemical re-sellers in three major centres, Batlow, Shepparton and Stanthorpe, all reported reduced sales of 'hard' chemicals since 1990. They are selling more higher priced 'soft' chemicals including mating disruptants.
- improved application (improved equipment and attention to calibration) helped reduce applied quantities of pesticides.
- while pesticide residues could be expected to be lower, there was no available time trend information to substantiate a lowered incidence of residue violations since 1990.

A pilot residue testing program was initiated in 1998. In 1999, industry established an on-going residue testing program through the National Residue Survey to detect trends in residues over time. The apple and pear industry meets the cost of this annual survey (J. Purbrick, Apple and Pear Growers Assoc. pers. comm.)

- growers are of the opinion that adoption of IPM will be essential to maintain access to markets in future.
- chemical thinning as opposed to hand thinning was adopted by 80% of the respondents. The principal incentives are more even cropping; larger, evenly sized fruit; and reduced labour costs for pruning and thinning.

- the total cost of pest control, including chemicals and application, was estimated at around \$1000/ha for apples. At an average yield of 40t/ha, pest control costs are around \$25/t. Industry sources estimated that IPM reduced apple and pear pest control costs by some 15% or \$3.75/t.
- in 1999, the area of apples and pears using codling moth pheromones to disrupt insect mating was estimated at 25% of the national planting.
- most survey respondents are now using 'soft' chemicals such as chlorpyrifos, pirimicarb, tebufenozide, lime sulphur and mating disruptants.

The Agtrans Research study indicated that the respondents to their survey who had adopted IPM since 1991 had reduced the number of sprays per year by 23%. However, over 80% of all respondents are now using 'soft' chemicals and reduced spray volumes.

Industry advice (Cole & Riches 1999, Penrose 1997) is that pest management has changed significantly since 1991 when the charter with the Australian Consumers Association and other community organisations was signed. The significant changes include:-

- reduction in the number of sprays to control pests and diseases
- the substitution of 'soft' chemicals for 'hard' chemicals
- improved pesticide application methods and effectiveness
- the use of mating disruptants
- the encouragement of predators and other beneficial insects
- establishment of industry wide residue testing

#### **4.2.3.6 Trends, volume of pesticide use in apples and pears**

The recent trends in volume of use of pesticides in the Australian apple and pear industry using 1996 as the base year are shown in Table 22:-

**Table 22**  
**Indices of Volumes of Crop Protection Pesticides Used on**  
**Apples and Pears**

Year	Product Category				No. of Trees
	Herbicides	Insecticides	Fungicides	PGRs	

**Data for this table was obtained from the usual sources. However, because of doubts about how well they were a true reflection of pesticide use in the industry they are not presented here, having been removed at a late stage during the preparation of this report.**

The study examined data on tree numbers collected by the Australian Bureau of Statistics, but these relate to trees six years old or older and thus do not give a good picture of the industry and are not included here. Previously, it was only after about six years that apple and pear trees began to produce commercial crops. Until a tree was sufficiently mature, the grower derived little or no income from the investment it

represented, and correspondingly did not use much pesticide in its management. During the 1990s, however, tree varieties and management practices changed considerably, so that significant yields could be expected from trees that were 2-4 years old. That being the case, the official statistics which show approximately 10% increase in tree numbers in the study period would not give a true indication of the scale of the industry, since its growth in terms of younger trees would not be revealed. The figures in Table 20 show considerable fluctuations in yield in kg/tree. Seasonal variation would no doubt be the reason for some fluctuation in production, but it is possible that fruit-bearing tree numbers also increased.

The industry has also pointed out that broad categorisation of pesticides tends to conceal significant information such as costs of pesticides that would reflect in the 'volume' figures presented in Table 22. For example, the highly effective but insecticide parathion ethyl was withdrawn from use during the study period. For the industry, this meant its replacement with safer but more expensive substances. Similar changes took place in the fungicide regime, with cheap but more hazardous materials giving way to safer but more expensive alternatives.

Management of apples and pears accounts for just over 1% of the total volume of pesticides used in Australia in the study period. This small size of the market adversely affects the robustness of the information but, as with potatoes, it is the best information available, collected by an independent market research company on behalf of the entire industry (see section 2.1.4) (P. Chalmers, Crop Care Australasia Pty Ltd, pers. comm.). The data collections take account of the fact that some growers would produce stone fruits and possibly even grapes, as well as apples and pears, and so care was taken to disaggregate the sales volumes into these separate streams and thus avoid inflation of the apple and pear figures.

Fungicides are the most significant pesticide applied to apples and pears. The volumes applied nationally are 2.5 times the volume of herbicides applied and 1.5 times the volume of applied insecticide. Only very minor volumes of plant growth regulators are applied.

#### **4.2.3.7 Trend highlights – Apples and pears**

- Of the 80% of apple and pear growers who have adopted IPM, some 70% had done so before 1996. Major reductions in the volume of pesticides used could have occurred before the first year of this study.

**Analysis of trends of pesticide use in the apple and pear industry is not possible in the absence of reliable data.**

Analysis of trends of pesticide use in the apple and pear industry is not possible in the absence of reliable data.

#### **4.2.4. Winter cereal crop production systems**

##### ***4.2.4.1. The winter cereal industry – a brief pen picture***

The four winter cereal crops are wheat, oats, barley and triticale. Of these, wheat is by far the major crop in Australia.

In the review period, there has been a significant expansion of winter cereal plantings in Australia, mainly in response to relatively low returns from wool. Record production over the last four years has been achieved. As well as increased plantings, significant improvements in wheat and barley productivity and yields have driven the record production.

The area yield, production and gross value of production of the winter cereal crops in the period 1996 to 1999 (Anon 2000b) are shown in Tables 23, 24 and 25:-

**Table 23**  
**Australian Wheat Industry Statistics**

<b>Year</b>	<b>Area (‘000 ha)</b>	<b>Production (‘000 t)</b>	<b>Yield (t/ha)</b>	<b>Gross Value of Production (\$M)</b>
1995-96	9 221	16 504	1.8	4 305
1996-97	10 936	22 925	2.1	4 878
1997-98	10 441	19 227	1.8	3 802
1998-99	11 583	21 465	1.9	4 011

Source: Australian Bureau of Statistics

**Table 24**  
**Australian Barley Industry Statistics**

<b>Year</b>	<b>Area (‘000 ha)</b>	<b>Production (‘000 t)</b>	<b>Yield (t/ha)</b>	<b>Gross Value of Production (\$M)</b>
1995-96	3 111	5 823	1.9	1 276
1996-97	3 366	6 696	2.0	1 308
1997-98	3 521	6 482	1.8	1 032
1998-99	3 167	5 987	1.9	836

Source: Australian Bureau of Statistics

**Table 25**  
**Australian Winter Cereal Statistics**

<b>Year</b>	<b>Area (‘000 ha)</b>	<b>Production (‘000 t)</b>	<b>Yield (t/ha)</b>	<b>Gross Value of Production (\$M)</b>
1995-96	13 689	24 671	1.8	5 965
1996-97	15 700	31 948	2.0	6 519
1997-98	15.265	27 976	1.8	5 165
1998-99	16 005	29 957	1.9	5 088

Source: Australian Bureau of Statistics.

Wheat accounted for 55% of the area planted to all grain crops in the four years to 1998-99, and some 70% of the area planted to winter cereals in the 1996 to 1999 study period. (Anon 1999b).

Over the twenty year period 1979-80 to 1998-99, wheat yields rose by around 2.5% annually. The trends vary from state to state, but the greatest increase occurred in



Western Australia, in part driven by the introduction of minimum tillage practices, a system in which herbicides partially substitute for tillage as a means of controlling weeds (Connell & Cooper 2000).

Wheat and barley are major export commodities although domestic markets are significant (Anon 1999b). The supply and disposal of wheat, barley and of all winter cereals, including oats and triticale in the 1996-1999 period are shown in Table 26:-

**Table 26**  
**Recent Supply and Disposal of Wheat, Barley and All Winter Cereals**

Year	Wheat			Barley			All Winter Cereals		
	Domestic use (kt)	Net exports (kt)	% exported	Domestic use (kt)	Net exports (kt)	% exported	Domestic use (kt)	Net exports (kt)	% exported
1995-96	4 127	13 928	84	1 970	4 042	69	8 206	18 225	69
1996-97	3 512	19 189	81	2 191	4 331	65	7 969	23 670	75
1997-98	5 081	15 678	81	2 081	3 377	56	8 999	19 211	68
1998-99	5 048	15 000	72	2 116	3 163	59	8 644	18 286	68

Source: Australian Bureau of Agricultural and Resource Economics.

The value of wheat exports in 1998-99 was in excess of \$3 000 million while barley exports were worth upwards of \$550 million (Anon 1999b).

A feature of the wheat, barley, oats and triticale crop production systems is the ability of farmers to switch production between cropping and livestock activities and among crops in response to relative price changes and enterprise profitability. This flexibility has enhanced farm financial performance.

In these crop production systems, pasture phases are an important part of the system. The pasture phase breaks weed, insect pest and disease cycles; it reduces the need for pesticide application in subsequent crops. While the pasture phase can be subject to pest attack requiring pesticide application, pesticide applications to the pasture phase are significantly lower than that applied to subsequent cereal crops and crop products.

A pasture phase also has positive effects on soil structure, soil fertility, soil erosion control and usually on subsequent crop yields.

In the last decade or so, the suite of crop planting options for grain growers has widened, particularly in the Australian wheat-sheep zone. The emergence of a greater range of profitable cropping alternatives, particularly in higher rainfall areas, has given greater flexibility to crop rotation, pest control and crop nutrition strategies. Some of the newer cropping options include chickpeas, canola, lupins, and faba beans as well as field peas.

Among the technologies contributing to the productivity increases in winter cereals are better strategies for pest and disease control on farm, in grain storage and handling

systems and better weed control. Pesticides and pesticide usage are key inputs into these strategies (Knopke, O'Donnell & Shepherd 2000).

#### 4.2.4.2. Pesticides used in winter cereal production

In excess of 200 agricultural chemicals are registered for use on winter cereal crops in Australia again many of them under different trade names. That includes over 70 herbicides, 45 insecticides, 11 fungicides and over 90 others including surfactants and plant growth regulators (Anon 2000b).

Pesticides, particularly herbicides, are a major farm input in winter cereal crop production. In a survey of winter cereal growers in Australia in 1999 (Alemseged, Jones & Medd, in press), over 90% of farmers ranked weeds as the greatest problem in their farming enterprise. The problem weeds vary across regions. The most difficult weeds to control as ranked by farmers in each region with the percentage of farmers nominating them are detailed in Table 27:-

**Table 27**  
**Most Difficult Weeds to Control (Farmer Ranking) and % of Farmers Nominating**

Northern region		Southern region		Western region	
Weed	%	Weed	%	Weed	%
<i>Avena spp</i>	65	<i>Lolium rigidum</i>	78	<i>Lolium rigidum</i>	92
<i>Brassica tournefortii</i>	46	<i>Avena spp</i>	51	<i>Raphanus raphanistrum</i>	81
<i>Phalaris paradoxa</i>	27	<i>Aretheca calendula</i>	35	<i>Avena spp</i>	56
<i>Sonchus oleraceus</i>	26	<i>Raphanus raphanistrum</i>	33	<i>Aretheca calendula</i>	44
<i>Polygon aviculare</i>	25	<i>Vulpea spp</i>	22	<i>Vulpea spp</i>	34
<i>Lolium rigidum</i>	24			<i>Bromus spp</i>	31

Source: Alemseged, Y., Jones, R.E. and Medd, R.W. (in press)

The control of insect pests after crop harvest in grain storage and handling systems is the main source of insecticide inputs in winter cereal production. Pest management strategies are required on-farm in both storage and handling facilities and post farm gate in the storages and transport systems of grain handling agencies.

A suite of insects attack stored grain and grain in the handling and transport system. The main pest is the lesser grain borer, (*Rhizopertha dominica*) with the rice weevil (*Sitophilus oryzae*) also being a significant pest (G.White, QDPI, pers. comm.).

The wheat, barley, oats and triticale industries have relied on both grain protectants and fumigants for the control of insect pests of stored grain. Grain protectants have been chemicals applied directly to grain usually as the grain is being moved from one storage or transport facility to another. Fumigants may be derived from products which are introduced as a tablet in the stored grain (for example calcium phosphide

which generates phosphine when in contact with ambient moisture in the grain) or as a gas such as phosphine, carbonyl sulphide or carbon dioxide which may be directly injected into the grain in a sealed environment.

Heavy reliance on grain protectants is now incompatible with the requirements of most markets so fumigation is the major control method. Aeration is an expanding control practice which, in conjunction with appropriate grain handling and storage facility hygiene, is gaining acceptance both on farm and off farm (White & Collins 1998).

The suite of diseases and other pathogens attacking winter cereal crops has expanded in recent years. These include nematodes, yellow spot, stripe rust, crown and common root rot in wheat and net blotch in barley.

#### **4.2.4.3. *Industry commitment to reducing pesticide use***

The Grains Research and Development Corporation (GRDC) facilitates research into the winter cereals, wheat, oats, barley and triticale. The GRDC develops its strategic plans on a 5-year basis following consultation with the peak industry body, the Grains Council of Australia.

GRDC, being one of the nation's largest R&D organisations with a budget in excess of \$100 million, has a more formalised structure including regional and national panels to assess priorities and recommend on GRDC R&D investments.

GRDC also has 25 program teams responsible for evaluating, prioritising, monitoring and reviewing R&D components within individual programs (Anon 2000d).

Among the GRDC R&D programs are those targeting insect pest, disease and weed problems. These programs all seek to develop IPM strategies and practices which include resistant cultivars, chemical, cultural and biological control measures.

R&D on control of pests on stored grain is funded under "meeting quality requirements" which is investment objective 1 in the current GRDC Strategic Plan, "Partners for Profit." (Anon 1997). Disease management R&D is funded under "increasing productivity" which is investment objective 2, while weed management R&D is funded under "protecting and enhancing the environment", investment objective 3.

GRDC allocated some \$10 million in 1999-2000 for R&D projects studying weed, insect pest and disease control, pest management, pesticide resistance management and pesticide application in grain crops. This was some 11% of the total GRDC budget for the year. Not all of those funds are directed at winter cereal crop pests, perhaps 50% is directly relevant to winter cereal production (J. Fortune, GRDC, pers. comm.).

The above allocations do not include GRDC investment in crop improvement and breeding programs, which seek to incorporate genetic resistances to crop pests.

#### **4.2.4.4. Pest management initiatives, winter cereal crops**

The widespread adoption of direct drilling, minimum tillage and stubble retention with the associated increase in herbicide use has had a major positive impact on soil erosion control and on grain crop profitability in all grain growing districts.

Direct drilling can be defined as sowing a crop in a single pass in previously uncultivated soil. Minimum tillage is tillage of the soil using only one or two cultivations prior to sowing.

In the northern and western grain industry regions, this technology has had a positive impact on crop yields. In much of the southern grain industry region, yields under minimum till strategies are comparable to those under traditional cultivation methods. The adoption of minimum till and direct drilling practices has also shown to be loosely correlated to Landcare membership. Over 80% of grain farms in the western region, 70% of grain farms in the northern region and over 60% of farms in the southern region were using those technologies in 1998-99 as shown in Table 28 (Knopke, O'Donnell & Shepherd 2000).

**Table 28**  
**Methods of land preparation for all broadacre crops by GRDC regions 1998-99**

<b>Region</b>	<b>Direct drilling (%)</b>	<b>Minimum tillage (%)</b>	<b>Conventional tillage (%)</b>	<b>Landcare membership</b>
Northern	32	37	27	31
Southern	26	38	36	42
Western	58	22	19	66

Source: Knopke, P., O'Donnell, V. and Shepherd, A. (2000)

While these data are for all grain farms, the trends would be the same for winter cereal crops. The area sown using direct drilling increased from 25% of the total area in 1995-96 to 36% in 1998-99 across all grain regions.

The study of weeds in winter crops in Australia (Alemseged, Jones & Medd, in press) reported herbicide application as the main method of weed control. Farmers in the northern region were less dependent on herbicides than their counterparts in the southern and western regions especially in the use of pre-emergent and post-emergent herbicides.

Some 66% of all winter cereal growers surveyed considered weed problems to be worsening. Over 60% of farmers in the western region considered herbicide resistance to be a serious or moderate problem. Some 17% of northern region growers and 35% of southern region growers considered herbicide resistance in the same light. Herbicide resistance is reported to affect up to 10% of the cropping area nationally and that area is expected to increase in the immediate future.

The problem has already resulted in changes to crop rotations in Western Australia grain growing districts with, for example, the introduction of herbicide-tolerant canola and the use of atrazine sprays. It has also resulted in farmers avoiding the prolonged use of any one herbicide or herbicide group to minimise the development of herbicide resistance.

This aligns with a general world-wide trend which finds that some herbicides are having a reduced efficacy in suppressing weed populations. Herbicide resistance is a key factor. A more detailed account of the consequent adoption of herbicide-tolerant canola in Australian winter cereal crop production is provided in Chapter 9.

Non-chemical control methods are regularly used by winter cereal growers. Fallowing is a common practice in the northern and southern regions but it is rarely used in the western region. Crop rotation is common on all farms, a positive outcome of the enhanced cropping options available.

The use of herbicides as a substitute for tillage in wheat, oats, barley and triticale crops has allowed earlier planting and larger areas to be grown particularly in southern and western regions. It has also facilitated the shift into winter crop production in the higher rainfall traditional sheep areas.

The widespread adoption of direct drilling and minimum tillage has been accompanied by an increase in soil borne and crop stubble diseases including yellow spot, crown rot and common root rot. It has also resulted in changes in weed flora (Knopke, O'Donnell & Shepherd 2000).

The two most widely used grain storage fumigants, phosphine and methyl bromide, are under challenge. Grain storage insect pests are developing resistance to phosphine particularly as a consequence of inadequate fumigation practice, for example by inadequate sealing of storages. The use of methyl bromide is to be phased out of use by 2005 under international agreements because of its impact on the ozone layer.

Some 80% of Australian grain is now fumigated and that proportion is expected to increase. The need for replacement fumigants is urgent although aeration and the accompanying strict hygiene practices are increasingly being used by bulk handling agencies and the larger producers (G. White, QDPI, pers. comm.).

Other fumigants are being researched including ethyl formate which is already used in the dried fruit industry and carbonyl sulphide (J. Wright, CSIRO Entomology Stored Grain Research Laboratory, pers. comm.).

#### **4.2.4.5. Trends, volume of pesticide use in winter cereals**

The trends in volume of pesticide use in winter cereals in Australia using 1996 as the base year are shown in Table 29:-

**Table 29**  
**Indices of Volumes of Crop Protection Pesticides Used on Winter Cereals**

Year	Product Category				Area Planted
	Herbicides	Insecticides	Fungicides	Other	
1995-96	100	100	100	100	100
1996-97	104	117	112	86	115
1997-98	104	123	112	108	112
1998-99	108	132	122	73	117

Source: Crop Care Australasia Pty Ltd. and Australian Bureau of Statistics.

NOTE All figures in the above table are indices. The indices for pesticides are for calendar years. Those for the area planted are for years ending March 31.

The volume of herbicides applied to winter cereal crops are 35 to 45 times the volume of applied insecticides and 35 to 40 times the volume of applied fungicides.

The volume of pesticides applied to winter cereal crop production systems during the review period was some 22% of that applied to all crop production systems in Australia. The information for winter cereal production is robust (P. Chalmers, Crop Care Australasia Pty Ltd, pers. comm.).

#### **4.2.4.6. Trend highlights – Winter cereals**

- The increase in the volume of herbicides applied to wheat, oats, barley and triticale crops in the review period is less than the increase in the area planted. This derives from several factors including the recent diversification in broadacre cropping systems and the conversion of pasture lands to cropping, a land use change accompanied by low weed populations. Other influencing factors include farmer concerns over the development of herbicide resistance and the adoption of other weed control strategies and practices to minimise the development of herbicide resistance.
- However, the increase in the volume of herbicides applied is very likely understated as a result of the significant increase in the concentration of herbicide formulations. For example, the formulation of the knockdown herbicide glyphosate, reportedly the biggest single pesticide product in Australia, initially was 360g/l. It then was marketed as a 450g/l product and now is available as a 480g/l formulation. That is a 33% increase in the concentration of the product. Farmers using the 480g/l product would apply 33% less volume of the active ingredient glyphosate than would those using the 360g/l product.
- The 30% increase in the volume of insecticides used during the review period is related to the increase in the quantities of grain in on-farm grain storages and the increased quantities of wheat, barley, oats and triticale grown and marketed during the study period, 1996-1999. Farmers are storing more grain on-farm to widen

their marketing opportunities in the de-regulated grain industry. This requires enhanced insect pest control practices and an increase in insecticide usage.

- The use of insecticides by grain handling agencies would align with increases or decreases in production. Counterbalancing the anticipated increase in insecticide use with increased tonnages of winter cereal grains has been the short time these agencies have stored grain during the study period since they have been moved rapidly to meet market demand. In-crop application of insecticides also reportedly increased during the study period and would have contributed to the increase in insecticide use.
- The increase in volume of use of fungicides also exceeded the increase in area planted. This derives from the emergence of diseases for which genetic resistance is not incorporated in crop cultivars. The change to direct drilling and minimum tillage practices, has been accompanied by an increase in the suite of diseases infecting winter cereals.

#### **4.3. CONCLUSIONS – FARMING SYSTEMS**

**Primary producers will continue to make significant use of synthetic pesticides. However, there has been a progressive move to greater incorporation of Integrated Crop Management techniques into farming systems, some general though not universal reductions in pesticide applications per unit area and a move from broad spectrum “hard” chemicals to those with specific modes of action, the so-called “soft” chemicals. These trends should be further encouraged. The increasing proportion of pesticide costs as a percentage of total production costs will act as a further incentive.**

**Any total increase in pesticide use is expected to be a result of increases in crop areas planted.**

**The risk of new pest insect introductions is ever-present. Weed problems are continuing to grow, with pesticide resistance increasing their complexity**

**Private commodity purchasers are increasingly requiring growers to have quality assurance systems in place.**

**Drawing on the experience of the cotton industry, the other agricultural and forestry based industries should closely examine the benefits that may accrue to them from the wider development of Best Management Practices for their industries, and the scope for individual growers to secure ISO 14000 accreditation for the production systems which they develop in response to those BMP standards.**

**Once established, Best Management Practice programs must be subjected to continual upgrading in the light of emerging new technologies. Growers need to re-examine their pesticide and other chemical stores to ensure they meet current industry standards. All of the industries reviewed make considerable investment through their R&D Corporations into more effective use of pesticides. The R&D**

**investments made by rural industries into more effective pest control programs should be continued and increased.**



## **5. IMPACT OF PESTICIDES ON HUMAN HEALTH**

Despite the world-wide health benefits arising from the use of pesticides, ensuring an improved and relatively stable food supply, there continue to be concerns regarding aspects of their use, including in Australia. Of 587 non-intentional traumatic deaths recorded in Australian agriculture in 1989-1992, two were due to acute pesticide poisoning. Of the approximately 5000 agricultural workers compensation claims made annually in 1994-1999, 0.4% were attributable to pesticides. A downward trend was observed during this period. However, workers compensation claims represent only between 15 and 19% of all on-farm work-related injuries. There is no information on chronic (long term) effects of pesticides in Australia, but a number of studies are in progress. The annual Australian National Residue Survey, which underpins both domestic and export foodstuff marketing, indicates that in the two years 1999-2001, compliance with Maximum Residues Limits for meat, grain, horticultural and fish and aquaculture products fell within the range 99.97% to 100%. The Australian Total Diet Survey, which monitors residues in table-ready food products prepared for domestic consumption, has consistently demonstrated very low levels of pesticides and contaminants in Australian diets. Public water authorities vary in their approach to pesticide residue reporting, but the typical Sydney water quality sample values in 1999-2000 were well under the NHMRC Health Guideline values. Assessment of pesticides for registration includes metabolism, toxicity and toxicokinetic studies. Data are examined in relation to a variety of health hypotheses. There are in place a range of programs to minimise exposure to pesticides. Nevertheless, although most pesticide users have attended a pesticide handling training course, a high proportion of pesticide users do not yet implement all recommended aspects of personal protection programs.

### **5.1. THE BENEFITS OF PESTICIDES TO HEALTH, AND HEALTH CONCERNS**

Pesticides have contributed to increased agricultural production, generation of income for rural communities and alleviation of famine and food shortages on a world-wide basis. Their continued use appears essential in the future to meet the food needs of a world population which may well be 50% larger than today with hopefully a universally higher standard of living. The most consistently reported determinants of population health status have been such socio-economic factors such as levels of skill, employment levels and family income. On this basis, pesticide use has had a very positive effect on the health of rural communities with strong flow-on through food supply and economic impacts to the health of urban communities.

Nevertheless there has been public concern world-wide about the direct impact on human health resulting from the application of pesticides and the presence of pesticides in the food chain once they have been applied. This chapter will:

- report on the Australian evidence that there is little impact on public health
- discuss gaps in current knowledge and procedures that could expose populations to risk of exposure to pesticides
- describe current practices and underlying principles of toxicological assessment, establishment of maximum residue levels and worker exposure assessment during the registration process

- describe processes and procedures for ensuring safe use and minimisation of exposure to health risk during application
- describe monitoring procedures in place aimed at identifying possible risks to human health due to pesticide exposure

The attention paid to these matters in Australia is reflected at Government level in the discussions at national workshops (Rowland and Bradford, 1998), the adoption of a National Strategy for Management of Agricultural and Veterinary Chemicals (ARMCANZ, 1998) (see chapter 10) and specific reviews (Standing Committee on State Development, 1999, Vols 1 and 2).

Concerns relating to health are multifaceted, and government has responded through the establishment of agencies and regulatory authorities such as the NRA and the National and State Occupational Health and Safety Commissions. Non-Government Organisations such as Farmsafe Australia, primary producers, workers and their unions, environmental advocacy organisations such as the Total Environment Centre, public health workers, medical practitioners, and chemical industry representatives have also been involved at various levels. All such individuals and agencies have the shared objective of ensuring that human health is not compromised due to exposure to pesticides.

Responses to concerns regarding human health impact of pesticides have included:

- Regulatory responses,
- Ongoing advancement of health risk assessment processes, often, but not always, in association with international developments
- Review of registration of older chemicals
- Investigation of specific incidents and concerns by public health authorities and state enforcement agencies
- improved monitoring of residues and health outcomes .....
- Training of pesticide applicators and workers
- Development of priorities for additional research investment

Concerns can be broadly grouped thus:

1. Public concern about the human health effects of pesticides, their breakdown products and the solvents and other carriers used with them. This includes both short term and long term effects, and their effects on people with special sensitivity and children.
2. Exposure to pesticides of workers, particularly during application, and of workers and others during re-entry to sprayed crops.
3. Exposure to pesticides of bystanders to work and families of workers engaged in pesticide application.
4. Exposure of people to effects of pesticides due to spray drift, contamination of water and other environmental exposure.
5. Contamination of food destined for domestic consumption and export market by residues from direct pesticide application or from the environment.

## 6. The possible impact of potential chemical contamination on international trade

*Pesticides*, by definition, exert adverse effects on living organisms and therefore have potential to cause toxicity to non-target species including humans. The properties which determine the nature and degree of toxicity include chemical properties, physical properties, interaction with other chemicals, environmental transformation, and the specificity of the pesticide. It should be noted that the chemical structure of pesticides does not necessarily predict risk. Toxicity studies are performed on all agricultural and veterinary chemicals, as part of the process of development for use and registration in most countries.

*Health* is defined according to the World Health Organization definition – “a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity”. Such a definition creates some tension between the scientific approaches used for the assessment and evaluation of the health impacts of pesticides in use, and being considered for registration for use in Australia, and worldwide.

A full review of the health impact of any pesticide should consider the health advantage that may have been achieved through the development and use of pesticides in both disease control (through insect vector control) and through global and local increased food and fibre production and availability. For example the Harvard Center for Risk Analysis has conducted an evaluation of the likely public health effects of a possible ban on organophosphate and carbamate pesticides in US agriculture (Gray and Hammitt, 1999). In their estimation, any benefits to be derived from a complete ban on organophosphates and carbamates would be more than offset by countervailing health risks posed by their withdrawal.

This chapter reviews the current arrangements and status of health issues in Australia in the light of scientific understandings, populations at risk and community expectations.

## **5.2. PESTICIDES IN THE WORKPLACE**

### **5.2.1. Monitoring of effectiveness of risk control measures**

It is accepted that workers involved in the manufacture, handling, transport and use of pesticides will be the most exposed groups in the community. The processes described later in the report are designed to protect workers from adverse health impact of exposure to pesticides used in the workplace. However, initially it is appropriate to consider the evidence of health impact of pesticides in the workplace.

#### ***5.2.1.1. Exposure of workers handling agricultural pesticides***

There are only eight manufacturers of pesticides in Australia and statistics for the transport of locally manufactured and imported pesticides are not available. The available evidence therefore relates largely to workers in Agriculture. Table 30 shows the total numbers of persons employed according to agricultural industry and employment type as at 30 June 1998.

**Table 30**  
**Persons employed in agricultural industries of Estimated Value of Agricultural Output**  
**> \$22500 for the year ended June 30 1998.**

ANZSIC Code	Description	Proprietors and partners	Employees	Total employmen t
0114-0119	Fruit	17 852	15 615	33 467
0113	Vegetables	6 110	16 280	22 390
0121	Graining growing	23 765	10 067	33 832
0122	Grain-sheep/beef	35 300	12 041	47 341
0123	Sheep-beef farming	10 757	4 182	14 939
0124	Sheep farming	20 931	7 518	28 449
0125	Beef cattle farming	23 391	10 929	34 320
0130	Dairy cattle farming	25 276	9 744	35 020
0151	Pig farming	1 901	3 550	5 451
0161	Sugar cane growing	7 057	5 612	12 669
0162	Cotton growing	1 610	4 283	5 893
Other agriculture	Other agriculture	9 463	17 619	27 082
<b>01</b>	<b>All agriculture</b>	<b>183 413</b>	<b>117 440</b>	<b>300 853</b>

Source ABS (1999)

From this table, it can be seen that there are around 300 000 workers in agriculture in Australia. The number of workers at potential risk of exposure to pesticides would be considerably lower.

### **5.2.2. Reports of adverse health effects of workers due to pesticide exposure**

#### **5.2.2.1. Health surveillance**

The Australian Centre for Agricultural Health and Safety has prepared a preliminary report of its pilot health surveillance for the years 1999/2000 and 2000/2001 (Sankaran and Fragar, 2001). There were few cases of exposure of workers identified through this program, where some 170 tests were undertaken. No other reports of health surveillance are available.

#### **5.2.2.2. Deaths due to pesticides poisoning**

The most comprehensive report of traumatic deaths on Australian farms was reported by Franklin *et al* (2000) for the years 1989-1992. Of the 587 non-intentional traumatic fatalities recorded in coronial files for the 4 years, 6 were due to poisoning by hazardous substances, and 2 of these were due to pesticides – a rate of one fatality each 2 years. These deaths were due to acute poisoning, and do not include any deaths that may have been caused by medical conditions associated with long-term effects of pesticide exposure.

A study of health impacts of hazardous substances in Australian workplaces has been initiated on behalf of the National Occupational Health and Safety Commission.

### 5.2.2.3. *Workers compensation reports*

The National Workers Compensation Statistics Database is maintained by the National Occupational Health and Safety Commission, and is accessible on the NOHSC website. During the five years 1994/95 to 1998/99 there were 327 workers compensation injury/illness claims associated with exposure to plant treatment chemicals and 79 associated with animal treatment chemicals. Table 31 indicates the numbers of such claims by state.

**Table 31:**  
**Australian workers compensation claims for injury/illness associated with Agvet Chemicals, all occupations, all industries by state. 1994/95 to 1998/99**

<b>State</b>	<b>Number claims relating to plant treatment chemicals</b>	<b>Number claims relating to animal treatment chemicals</b>
Queensland	79	15
New South Wales	110	38
Victoria	14	0
Tasmania	14	*
South Australia	25	10
Western Australia	69	*
Northern Territory	12	*
Australian Capital Territory	0	0
Commonwealth	*	8
<b>Total</b>	<b>327</b>	<b>79</b>

\* = small number

Source: NOHSC Website. 4 April 2001

The gender distribution of these claims is described in Table 32

**Table 32:**  
**Australian workers compensation claims for injury/illness associated with Agvet Chemicals, all occupations, all industries by gender, 1994/95 to 1998/99**

<b>Gender</b>	<b>Number claims relating to plant treatment chemicals</b>	<b>Number claims relating to animal treatment chemicals</b>
Female	55	38
Male	266	40
<b>Total</b>	<b>321</b>	<b>78</b>

Source: NOHSC Website. 4 April 2001

The nature of the cases according to nature of injury or disease is described in Table 33.

**Table 33:**  
**Australian workers compensation claims for injury/illness associated with Agvet Chemicals, all occupations, all industries by nature of injury or disease, 1994/95 to 1998/99**

<b>Injury or disease</b>	<b>Number claims relating to plant treatment chemicals</b>	<b>Number claims relating to animal treatment chemicals</b>
Injury and poisoning	242	51
Diseases of nervous system; sense organs	6	0
Diseases of musculoskeletal system	*	0
Diseases of skin; subcutaneous tissue	36	15
Diseases of digestive system	21	0
Diseases of respiratory system	8	8
Diseases of circulatory system	*	0
Neoplasms	*	*
Other diseases	*	*
<b>Total</b>	<b>324</b>	<b>77</b>

\* = small number

Source: NOHSC Website. 4 April 2001

Table 34 indicates the number of cases by industry

**Table 34:**  
**Australian workers compensation claims for injury/illness associated with Agvet**  
**Chemicals, all occupations, by industry, 1994/95 to 1998/99**

<b>Industry</b>	<b>Number claims relating to plant treatment chemicals</b>	<b>Number claims relating to animal treatment chemicals</b>
Agriculture, Forestry and Fishing	84	15
Mining	6	0
Manufacturing	33	8
Electricity	*	0
Construction	17	0
Wholesale trade	27	0
Retail trade	42	*
Accommodation, cafes and restaurants	13	*
Transport and storage	8	*
Communication services	0	8
Finance and insurance	*	0
Property and business services	18	8
Government administration and Defence	17	*
Education	9	10
Health and Community Services	*	7
Cultural and Recreational Services	20	*
Personal and other services	11	*
Not Stated	7	0
<b>Total</b>	<b>323</b>	<b>79</b>

\* = small number

Source: NOHSC Website. 4 April 2001

Reported cases are spread through Agriculture/ Forestry and Fishing as demonstrated in Table 35. It should be noted that these claims relating to pesticides represent less than half of claims due to chemicals and chemical products for these industries, and represent approximately 0.4 percent of around 5000 claims made each year in the agricultural and services to agriculture industries.

It should be noted however, that while the number of cases is small in relation to the total number of workers compensation claims in agriculture, the cost of any individual claim may be significant, and thereby reflect the severity of the adverse effect. A case in Wagga Wagga in New South Wales saw three shearers successfully claim a total of more than \$700 000, when they were exposed to organophosphates applied to sheep for blowfly control.

**Table 35:**  
**Australian workers compensation claims for injury/illness associated with Agvet Chemicals, all occupations in the Agriculture/Forestry Fishing by specific industry group, 1994/95 to 1998/99**

<b>Industry</b>	<b>Number claims relating to plant treatment chemicals</b>	<b>Number claims relating to animal treatment chemicals</b>
Horticulture & Fruit Growing	42	*
Grain, Sheep & Beef Cattle Farming	17	7
Dairy Cattle Farming	0	0
Poultry Farming	0	0
Other Livestock Farming	*	*
Other Crop Growing	11	0
Not Stated	0	0
<b>Total</b>	<b>73</b>	<b>13</b>

\* = small number

Source: NOHSC Website, 4 April 2001

Table 36 demonstrates the costs of claims for “poisoning” (that includes pesticides) in agricultural industries in three years in Queensland, and the impact made by one or two cases.

**Table 36:**  
**Workers compensation claims due to “Poisoning” in agricultural industries in Queensland.**

<b>Industry</b>	<b>1990/91</b>		<b>1991/92</b>		<b>1992/93</b>	
	<b>No claims</b>	<b>Cost of claims \$</b>	<b>No claims</b>	<b>Cost of claims \$</b>	<b>No claims</b>	<b>Cost of claims \$</b>
Agricultural farms & harvesting contractors	2	350	2	100 168	0	0
Fruit growers, driers & packers	0	0	1	92	2	927
Peanut threshing & selling	0	0	0	0	1	202
Poultry farms	3	596	1	54	1	273
Pastoralists (cattle & horses)	0	0	0	0	3	570
<b>Total for agricultural industries</b>	<b>5</b>	<b>\$946</b>	<b>4</b>	<b>\$100 314</b>	<b>7</b>	<b>\$1 972</b>

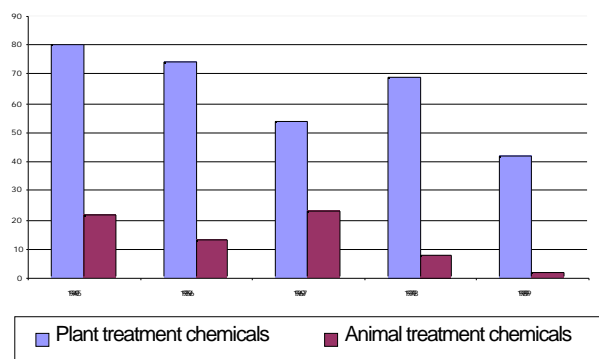
Source: Fragar and Franklin, 2000

Workers compensation claims represent only between 15 and 19 percent of all work-related injuries occurring on farms in Australia (Fragar and Franklin, 1999). This is due to the family business structure of the majority of agricultural enterprises, and the high proportion of work being undertaken by self-employed farmers without workers compensation insurance.



Figure 4 indicates the total number of workers compensation cases by year for the period 1994/95 to 1998/99. Though this is a very limited time period, there is an apparent downward trend in numbers for this period.

**Figure 4:**  
**Australian workers compensation claims for injury/illness associated with Agvet Chemicals, all occupations, all industries by year, 1994/95 to 1998/99**



Source: NOHSC Website. 4 April 2001.

#### **5.2.2.4. Hospital admissions reports**

Numbers of hospital admissions for treatment of on-farm poisoning by agricultural pesticides are available for a range of years for NSW, Victoria and South Australia and have been reported by Fragar and Franklin (1999).

The number of admissions is small. It is estimated that Australia-wide around 30-40 admissions for poisoning by agricultural chemicals may occur each year. Information regarding specific products or product groups is not available. Nor is information regarding the circumstances of these events available, but would include accidental ingestion by children, intentional ingestion by adults, and some worker exposure resulting in toxicity.

#### **5.2.2.5. Other Studies**

Other studies describing farm injury in defined localities in Australia have defined poisoning on farms in a range of different ways. Ferguson (1996), in a survey of 2188 producers in four regions of Queensland for 12 months in 1994/95, found that there were 12 reports of pesticide poisoning. This was 2.7 percent of farm injuries reported for the period. The average cost of each poisoning was estimated to be \$477. In Victoria, 13 adults and 4 children presented to Emergency Departments as a result of poisoning on farms for the year 1996/1997 (Day et al, 1997). This represented 1.1 percent of presentations with farm injury.

A number of General Practice based farm injury surveys have been carried out that indicate cases of pesticide poisoning. There were 4 cases of chemical poisoning on farms reported in the Yorke Peninsula between 1 September 1996 and 30 April 1998 (Franklin *et al*, 1999). This was 6.9 percent of injury cases reported. Chemicals made up 2 percent of farm injuries reported in a 12 month General Practice survey (1997-98) on the Eyre Peninsula (Fanklin *et al*, 1999), and made up 1.7 percent of cases in a

general practice and Emergency Department study in Central Queensland between July 1995 and June 1996 (Franklin *et al*, 1999).

### **5.2.3. Effectiveness of reporting**

#### **5.2.3.1. Reporting of acute health effects**

There is no complete reporting system that provides an indication of the number of cases of pesticide related health effects of workers using pesticides in Australia. The workers compensation systems provide an indication of pesticide related injury claims, but is incomplete because of the structure of agricultural and horticultural industries - primarily farm family enterprises. The workers compensation claims data above indicate 100 claims in agriculture fisheries and forests over a five year period. For the period 1989-1992 there were two non-intentional deaths associated with pesticides poisoning on farms Australia-wide.

The national institution of an Adverse Health Effects Register system for pesticides similar to that which is already in place for veterinary products (see <http://www.nra.gov.au/qa/aer2000.pdf>) would provide a useful contribution to monitoring of acute effects of pesticide exposure for workers.

#### **5.2.3.2. Reporting of long-term effects**

There is currently no information on any chronic or long-term effects of pesticides in Australia. A number of follow-up studies of workers previously exposed to pesticides is currently being undertaken.

An ongoing monitoring program is being carried out by Workcover New South Wales of workers who were authorised to use chlordimeform under special licence in New South Wales during the years 1978 to 1986. Chlordimeform is a formimide insecticide which was then in extensive use in the cotton industry, albeit under stringent controls - use was by permit only to approved operators, and regulations required strict adherence to protective measures. Despite these, surveillance of urinary metabolites indicated that workers may have undergone significant exposure.

About 100 of approximately 500 registered users are being tested for haematuria and urinary cytology, and more recently with BCLA-8 Mab tests (a monoclonal antibody test). Participants have been invited to participate in a more formal study of the BCLA-8 method. Results in 1989 indicated that 14/80 urine samples had microhaematuria, and another study showed 30% to have Red Blood Cells in their urine (Kenyon, pers. comm.). The Australian suppliers of chlordimeform have begun a program of surveillance for long-term bladder changes in their previously exposed workers. The 1996 survey resulted in 1 case of bladder cancer being detected. This example highlights the need for awareness to undertake surveys that may be necessary to determine long-term effects, including for chemicals withdrawn a considerable time ago.

In 1991-92, a study of pesticide exposure of cotton chippers was undertaken by the Australian Agricultural Health Unit and the Epidemiology and Health Services Evaluation Branch of NSW Health. That study found evidence of exposure to

organophosphate pesticides (a lowering of cholinesterase levels throughout the season, and reports of dermal exposure to two tested pesticides - endosulfan and profenofos). This evidence would indicate that workers other than the authorised users of chlordimeform could be at potential risk of bladder pathology. There is a missing link relating exposure to OP's to bladder cancer.

A study has been initiated by the Public Health Unit of the Northern Rivers Health Service, reviewing NSW Department of Agriculture workers who applied insecticides in the course of treatments for cattle tick control in northern New South Wales. This study aims to determine whether exposure to the chemicals used can be related in later life to any increase in illnesses. Data are being accumulated over a considerable number of years, but analysed results are not yet available.

### **5.3. MONITORING OF PESTICIDES FROM A COMMUNITY HEALTH PERSPECTIVE**

Residue monitoring is essentially a matter of risk management in which risks to humans and to trade, confidence in products, the extent of increase in product value and compliance with requirements, must be balanced against costs. (O'Flynn, 1999)

There are several stated purposes for residue monitoring of food and fibre produced in Australia, viz:

- To independently audit the chemical residue status of food commodities
- To provide consumers (both domestic and international) confidence in the quality and safety of these products
- To identify chemical residue problems, their causes and possible solutions:
- To provide scientific advice on the management of chemical residue problems and so contribute to the development of national chemical residues policy
- To monitor and evaluate the risk to public health associated with residues of pesticides and contaminant levels in the Australian diet

(Nicholls, 1997; Marro, 1997)

Quantitative legal limits govern the amount of an agricultural or veterinary chemical that is permissible in a feed or foodstuff. They usually apply to the raw agricultural commodity.

It is normal for **Maximum Residue Limits (MRLs)** to apply to any pesticide used in agriculture. (There is a more detailed discussion of MRLs in section 5.5.4.) MRLs are established following review of the results of supervised trials in which the chemical is used in a manner that reflects **Good Agricultural Practice (GAP)**. Where GAP does not exist (eg when a chemical is no longer available), an **Extraneous (or Environmental) Residue Limit (ERL)** may apply. ERLs are based on the results of appropriate residue monitoring data. In each case, the residue limit is considered to be acceptable from a public health viewpoint, as estimated by comparison of anticipated dietary exposure with the Acceptable Daily Intake (ADI). The residue limit is not a safety limit *per se*. At times, and where appropriate, a withholding period may be necessary to ensure dissipation of the residue to comply with the legal limit. The acceptable daily intake is normally set at one hundredth of the level which shows an effect on the most sensitive animal tested. This means that even in samples

that exceeded the MRL there was a very large in-built safety margin from a human health viewpoint.

There are two key national surveillance systems in place in Australia that monitor pesticides residues in produce.

Trade issues, specifically market access for Australian goods, have been a major driving force for the maintenance of the **National Residue Survey**, conducted by the Department of Agriculture, Fisheries and Forestry – Australia, and funded by agricultural producers (Gebbie, 1997).

The other survey is the so-called “**Total Dietary Survey**”, previously the “Australian Market Basket Survey”. Its aim is to monitor risk to public health and is totally government funded. The ATDS estimates the level of dietary exposure of Australian consumers to a range of pesticide residues and contaminants found in the food supply. Dietary exposure is the intake of pesticide residues and contaminants from food. A 'model' diet has been constructed for each age-gender group based on these foods and food consumption data from the 1995 National Nutrition Survey. The contributions of each pesticide residue and contaminant in every food in a diet were added to give the total dietary exposure.

In addition to monitoring of food produce, public water supplies are monitored to ensure freedom from harmful levels of chemicals including pesticide residues.

There are a number of technical issues associated with residue testing that relate to sampling and laboratory standards. FAO Guidelines (1997) define a pesticide residue as “that combination of the pesticide and/or its metabolites, derivatives and related compounds to which the MRL...applies”.

### **5.3.1. Australian National Residue Survey, and state surveys**

#### **5.3.1.1. Background**

The Australian **National Residue Survey (NRS)** is the major national residues survey. This survey program is ongoing and is extensive by international standards, and is conducted by Agriculture, Fisheries and Forestry – Australia under arrangements established by the *National Residue Survey Administration Act 1992*, (as amended in 1994) and accompanying Acts - the *National Residue Survey (Excise) Levy Act 1998* and the *National Residue Survey (Customs) Levy Act 1998*. A detailed description of the program is found in a publication of the National Office of Food Safety (NOFS 2000). (This office is now Product Integrity – Animal and Plant Health within Agriculture, Fisheries and Forestry - Australia.)

The stated purpose of the National Residue Survey is “To underpin export and domestic marketing initiatives of participating industries and thus to enhance the value of Australian agricultural industries, and to safeguard the health of the general population by:

- providing an independent, authoritative and scientifically rigorous audit of the chemical residue status of the products of participating industries
- providing scientific advice on residues and contributing to the management of residue related issues.” (Australian National Residue Survey website, 27/9/00)

The 1998 Annual Report of the NRS noted that “while trade related limits always meet health requirements with a wide safety margin, they take into account levels that are normally likely to occur (in the case of substances such as metals), and the amount which should not be exceeded if good agricultural practices have been followed (in the case of agricultural and veterinary chemicals). Climate, geography, pests, diseases and products vary from country to country and as a consequence different countries sometimes have different limits for particular residues in particular products.

“The general purpose of residue monitoring is to quantify the occurrence of residues in products (using systems based on sampling and statistical probability), to confirm (or otherwise) that residues in products are within limits, and to alert responsible authorities when limits are exceeded so that corrective action can be taken.”

Some major importing countries of Australian meat products require a Government residue monitoring program, in the country of origin, as a condition of entry for certain products. These include the United States and European Union, both of which audit the operations and results of NRS surveys. Canada, Mexico, Japan and Korea have conditions of entry similar to the United States, and the European Union has specific requirements for fisheries and aquaculture products. Most countries require that imported food commodities are certified as complying with agreed chemical residues limits. The Australian Quarantine Inspection Service (AQIS) certifies meat products on the basis of NRS monitoring surveys.

NRS results are available soon after tests are conducted and are reported regularly to industries and relevant government authorities. State Government authorities are immediately notified when Australian residue standards are contravened, so that they can investigate and take action to prevent recurrence.” (National Office of Food Safety, 1999)

In addition to the NRS, a number of programs are conducted by States – these are generally designed to target suspected problem areas rather than to assess overall contamination by the use of randomized sampling processes (O’Flynn, 1999).

#### **5.3.1.2. Methods**

The commodities and pesticides for testing are selected by a risk assessment process that takes into account:

- international and/or domestic perceptions of public health hazard
- the toxicity of the chemical or its breakdown products
- the likelihood that the chemical or its breakdown products occur in the product
- the extent and results of previous monitoring
- logistic factors such as the availability and cost of suitable analytical methods (O’Flynn, 1999)

Meat, eggs, grains, flour, honey, fruit, vegetables and nuts, fish and aquaculture products are currently included in the survey program. The design specifications of the program are developed in consultation between the NRS and the participating industry to achieve at reasonable cost results with the required statistical validity. Participation by industries is voluntary except where required by government

(e.g. meat, under the Code of Practice for Hygienic Production of Meat), and costs are fully recovered. A summary of methods of sample collection is included in the Report of the 1999 NRS.

### 5.3.1.3. Results

The *National Residue Survey* started monitoring chemical residues in meat in 1961. Since then, the range of commodities tested has expanded – for example, between 1 January and 30 June 1999, there were 31 commodities monitored. In 1998 monitoring surveys were undertaken for 30 commodities; 24 670 samples were collected; 54 000 screen or single chemical analyses were undertaken, and 350 000 tests were reported. The rate of compliance with standards was 99.96% for meat products, 99.99% for grain products and 100.00% for horticultural products (O’Flynn, 1999)

The results of the 289 132 analyses conducted during 1999-2000 (Department of Agriculture, Fisheries and Forestry – Australia, 2000) indicated only 141 analyses detected residues above Australian Standards. These consisted of 56 residues of pesticides and 85 of metals. Table 37 summarises the results of analyses of the major commodities.

During 2000-2001, the National Residue Survey included monitoring surveys for 16 animal commodities, 14 plant commodities, five representative seafood commodities and two representative aquaculture commodities. This involved the collection of over 24 000 samples and subsequent analysis of over 274 000 individual chemical–commodity combinations. For major commodity groups in 1999-2000 and 2000-2001, compliance was as shown in Table 38:

**Table 37**  
**Overview of NRS results 1999 – 2000.**

Commodity	Samples collected	Number of analyses	Over MRL residues	Over MPC metals
Cattle	6 914	57 250	9	11
Sheep	4 949	44 176	0	25
Pig	2 254	35 057	17	10
Horse	442	3 674	1	nt
Poultry	669	8 876	0	0
Other meat species	545	12 244	0	9
Fisheries and aquaculture	717	21 390	0	29
Egg	158	3 242	0	1
Honey	107	5 439	3	0
Cereal grains	4 706	62 302	6 + 6*	0
Flour and bran	242	3 378	0	nt
Pulses	429	6 075	0	0
Canola	388	4 993	1 + 9*	0
Onion	172	4 297	0	0
Nut	132	1 728	1	nt
Apple and pear	317	15 011	3	nt
<b>Total</b>	<b>23 141</b>	<b>289 132</b>	<b>56</b>	<b>85</b>

nt indicates that metals were not analysed.

\* indicates contamination from chemicals used to disinfect grain storage structures and/or sampling equipment.

**Table 38**  
**Percentage compliance, National Residue Survey, 1999-2000 and 2000-2001**

<b>Commodity group</b>	<b>Agvet chemicals 1999- 2000</b>	<b>Agvet chemicals 2000- 2001</b>
Meat products	99.98	98.98
Grain products	99.97	99.97
Horticultural products	99.98	99.97
Fisheries products	100.00	100.00

Although the persistent organochlorines (OCs), such as DDT, dieldrin, heptachlor, BHC and HCB, have not been registered for use in livestock since 1979, they are still present in soil. Endosulfan is a relatively non-persistent OC, still in use on certain horticultural crops as well as cotton. Organochlorine residues can be detected in animal fat and were measured in all meat species. Since none of the persistent organochlorines would have been taken up by plants, any presence in livestock would have been due to soil splash on plants or soil ingestion by animals. In a program targeted at known at-risk properties in 2000-2001, 11 879 samples were examined for organochlorine contamination, with 99.7% compliance. Because of the risk of endosulfan residues from adjacent cotton areas, 1532 samples were taken from 746 properties with a much lower percentage of reportable residues than in previous years. Targeted analytical testing of beef cattle for other cotton industry chemicals is being conducted in 2001-2002.

A special report on residues in grains from 1995-1999 was reported by the NRS as part of the January-June 1999 Report. Results have been summarised in the Report as follows:

- In wheat, the most commonly detected residues were chlorpyrifos-methyl (detected in 22.61% of analyses), fenitrothion (13.20%), methoprene (10.49%) and dichlorvos (4.19%). The only above-MRL results were for dichlorvos (six from 15 759 analyses).
- In barley, the most commonly detected residues were fenitrothion (detected in 23.70% of analyses), piperonyl butoxide (8.72%), bioresmethrin (8.02%) and dichlorvos (5.85%). The only above-MRL results were for fenitrothion (one from 3 472 analyses) and dichlorvos (12 from 3 472 analyses).
- In oats, the most commonly detected residues were dichlorvos (detected in 6.33% of analyses), fenitrothion (6.01%), piperonyl butoxide (5.41%) and chlorpyrifos-methyl (4.11%). No above-MRL results were detected.
- In sorghum the most commonly detected residues were chlorpyrifos-methyl (detected in 18.93% of analyses), dichlorvos (6.33%), fenitrothion (3.89%) and methoprene (3.60%). The only above-MRL results were three chlorpyrifos-methyl and two dichlorvos from 1 516 analyses.
- no organochlorine residues were detected in 7 723 analyses.

Results above MRL were rare events. Between 1995 and 1999 inclusive, above-MRL detections were as follows:

Dichlorvos	6 Wheat
	12 Barley
	2 Sorghum
Chlorpyrifos-methyl	3 Sorghum
Fenitrothion	1 Barley

The horticulture program covered 4 commodities involving 221 samples and 7 267 analyses. Three residues over Australian Standards were detected of diphenylamine, a scald inhibitor on apples.

*States surveys* are targeted programs and in general are reported less routinely.

The **Victorian Produce Monitoring Program** is undertaken annually by the Victorian Department of Natural Resources and Environment, with the aim of confirming that pesticides “are being used according to good agricultural practice and that produce is free from unacceptable levels of agricultural chemicals and heavy metal residues”. The results for 1997/98 have been published, and included 3 376 tests on 174 samples of pulses, fresh fruit and vegetables. Of the 3 215 tests for pesticides residues, the MRLs were exceeded on only six occasions. More than 99.8% of tests for chemical residues and all tests for cadmium met acceptable standards set by ANZFA. Furthermore more than 97% of tests were below the laboratory limits of detection, which are significantly lower than the set MRLs and MPCs.

At the **Sydney Markets Limited (Flemington Markets)**, if any samples are found to contain unacceptable levels, these are traced back to growers, where possible, investigated, and advisory or regulatory action taken to ensure that excessive residues do not recur. Sampling is targeted towards fruit and vegetables that are “likely to have received frequent pesticide applications or crops from production districts where pesticide use was believed to be relatively high” and from “those crops perceived by the public as likely to contain residues”. (Plowman, 1996)

Summary results for the first two cycles – 1989-1992 and 1992-1995 have been published. A total of 53 500 tests were undertaken on 1 026 fruit and 2 049 vegetable samples. Of these, 98.4 percent met the MRL standards, only 50 contained a pesticide residue that exceeded the MRL.

MRLs were exceeded in the NSW survey for three main reasons:

1. **Due to residues of persistent pesticides in the soil.** These were residues of organochlorine pesticides, BHC, dieldrin and heptachlor where soil splash or soil ingestion would be the avenue of contamination.. (18 of the 50 residue violations)
2. **The use of pesticides on crops for which they were not registered, for which an MRL of zero is assumed.** These included one detection each of chlorpyrifos, furalaxyl, methamidophos, permethrin and prothiofos and three detections of fenvalerate. Furalaxyl was not registered for edible crops.



**3. The incorrect use of pesticides on crops for which they were registered.**

These included chlorpyrifos (9), endosulfan (8), fenthion (1), methamidophos (10) and parathion (1).

Trace back and follow up occurred for samples that exceeded the MRL. Traceback was also undertaken where residue levels exceeded more than 50 percent of the MRL, representing a further 1.6 percent of the survey.

**5.3.2. Australian Total Diet Survey**

**5.3.2.1. Background**

The Australian Total Diet Survey (previously the Australian Market Basket Survey) is conducted each 2 years. It is implemented as a cooperative effort of Federal, states and territory departments of Health and is coordinated by the Australia New Zealand Food Authority (ANZFA). The stated purpose of the surveys is to estimate the level of pesticides residues and other contaminants present in food and to estimate the level of dietary exposure in Australia. The Survey monitors residues in table-ready food products prepared for domestic consumption

The latest published report is the 19<sup>th</sup> Australian Total Diet Survey (Australia New Zealand Food Authority, 2001). This survey was conducted during the calendar year 1998 and provided comparison with the previous survey – the Australian Market Basket Survey for 1996 (Hardy, 1998).

**5.3.2.2. Methods**

Total diets are developed using food consumption data from national dietary surveys. The 1995 National Nutrition Survey was used for the 19<sup>th</sup> Study. Six age-sex diets were constructed for the 1996 and 1998 studies – men aged 25-34 years; women aged 25-34 years; boys aged 12 years; girls aged 12 years; toddlers aged 2 years; and infants aged 9 months. Each food was chemically analysed to measure the level of pesticides and contaminants and the sum of contributions for each food gave the total dietary intake.

About 70 foods and beverages were tested for pesticide and contaminant content throughout the calendar year. The 1996 survey included human milk, the 1998 survey did not. All foods were screened for organochlorines; organophosphorus pesticides; carbamate pesticides; synthetic pyrethroids; and fungicides. All food examined was prepared to table-ready state. Hence the food is tested in the cooked or prepared state as though ready for consumption.

The estimated dietary exposure for each age-sex category was compared with Australian acceptable daily intakes (ADIs) and provisional tolerable weekly intakes (PTWIs) for substances such as heavy metals that are unintentional environmental contaminants.

These methods provide a sound basis nationwide for evaluating any possible chronic pesticide intake problems, though there could be scope for additional effort in the field of acute intake problems (D. Hamilton, QDPI, pers. comm.).

### **5.3.2.3. Results**

There has been a consistent demonstration of very low levels of pesticides and contaminants in Australian diets.

***Chlorinated organic pesticides*** - The estimated dietary exposure to these pesticides was within acceptable safety standards in 1994, 1996 and 1998.

***Organophosphorus pesticides*** - The widely used organophosphorus pesticides are mostly biodegradable and do not accumulate in the food chain. The estimated dietary exposures were well within the ADIs during 1996. In 1996, fenitrothion was estimated as the highest organophosphorus pesticide, expressed as a percentage of the ADI in toddlers (approximately 19% of ADI), but was not as high as during the 1992 survey. Azinphos-methyl was the second highest (approximately 16% of ADI) and had decreased since the 1994 survey. In 1998, dietary exposures to organophosphorus pesticides were mostly in the range of 0-5 percent of the ADI.

Fenitrothion is an organophosphate insecticide used to protect stored cereal grains and to disinfect grain storage equipment and facilities. These uses are the likely source of residue levels in foods. The chemical is under review by the NRA under its Existing Chemical Review Program, and while restrictions have been placed on the use of the chemical based on risk to workers and the environment, residue levels have not been considered likely to pose risk to health or trade.

Levels of ***synthetic pyrethroids*** detected in both the 1996 and 1998 surveys were extremely low.

***Fungicides*** - Estimated daily dietary exposure to fungicides for all age-sex categories were well below the ADIs in 1996. The 2 highest levels as a percentage of ADI were diphenylamine (~2.1% of ADI) and vinclozolin (~ 0.7% of ADI).

***Anti-sprouting agents*** - In 1996 only one sample of potatoes had a chlorpropham level of 0.2 mg/kg. All dietary exposures were below the ADI.

The 1998 survey has, however, indicated a need to develop more refined dietary exposure models for dimethiocarbamate fungicides.

### **5.3.3. Other dietary surveys**

#### **5.3.3.1. Backyard egg surveys**

High levels of organochlorines have been detected in backyard eggs, most likely due to exposure to contaminated soils.

The South Australian Backyard Egg Survey was reported as part of the 1996 Australian Market Basket Survey. In South Australia around 24% of the population consumed eggs produced in backyards during 1996. A total of 108 residents contributed 12-20 eggs for the 1996 Backyard Egg Survey. Organochlorine pesticides were detected in samples as follows:

- DDT and/or metabolites was detected in 68% of samples; 4.7% of all samples had levels of DDT above the MRL and Dieldrin was detected in 38% of samples, all at levels less than the MRL.
- Chlordane, and Aldrin were detected in a small number of samples, at levels less than the MRL.
- Heptachlor epoxide was detected in 9% of samples: one was above the MRL.

No organophosphorus or synthetic pyrethroid pesticides or fungicides were detected in the 1996 survey.

#### **5.3.3.2. Organochlorine residues in human milk**

Aldrin, dieldrin, chlordane and heptachlor, used in termite control, were all phased out by the mid 1990's.

It has been known since the 1950s that human milk may contain persistent environmental chemicals. Since then there have been numerous reports of residues in human milk world-wide. As breast milk often constitutes the entire diet of the newborn, concern has been expressed over the possible impact of these contaminants on child development and possible later impact.

The chemicals most frequently reported have been the organochlorine pesticides, specifically dichloro-diphenyl-trichloroethane (DDT) and its main metabolite DDE, hexachlorobenzene (HCB), hexachloro-cyclohexane (BHC), dieldrin and heptachlor epoxide.

Stevens *et al.* (1993) measured organochlorine pesticides levels in milk, adipose tissue, maternal blood and cord blood in two cohorts of nursing mothers in Western Australia. DDT, hexachlorobenzene and dieldrin were found in all samples of milk and adipose tissue, with significant falls in levels since a 1974 survey. The ADI for dieldrin was exceeded in 90 percent of infants and for heptachlor in 2 percent of infants.

A study of human milk concentrations of dieldrin, heptachlor epoxide and oxychlordane of 797 Victorian women following the birth of their first child, was reported by Sim *et al.* in 1998. Termite control of the residence of participants was associated with being in the "high-body-burden" group for all three chemicals, with the highest association being for heptachlor. In 1984-86 the Department of Health Division of Analytical Laboratories conducted a NSW study of pesticides in human milk from 253 lactating women in Sydney and the North Coast areas. (Wallace 1987). All of the samples analysed contained DDT at low levels. Dieldrin was found in 65% of the Sydney samples and 97% of the North Coast samples.

### **5.3.4. Water monitoring programs**

#### **5.3.4.1. Public water supplies**

The **Australian Drinking Water Guidelines** (1996), jointly published by the National Health and Medical Research Council (NHMRC) and the Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ), define quality criteria for water primarily intended for human consumption – including water

used for drinking, bathing and showering. **Health Values** have been established and represent 10% of ADI, as well as **Action Guideline Values** above which it is recommended that authorities should investigate the source and take measures to reduce contamination.

Public water supply authorities vary in their public reporting of pesticide residue testing. Sydney Water Corporation reports compliance with Health Guideline Values in their Annual Reports. The Annual Report on Drinking Water Quality 1999/2000 (Sydney Water, 2000) reported 40 that samples were tested during the year and all pesticides were detected at levels well under the guideline NHMRC Health Value.

In 2001, the **NHMRC Drinking Water Review Coordinating Group** released for public comment a document – *Framework for Management of Drinking Water Quality* (NHMRC/ ARMCANZ, 2001). This document proposes a quality management approach designed for the water industry that incorporates a preventive risk management approach from catchment to consumer. The proposed system places less emphasis on compliance monitoring and more on maintaining the integrity of water supply systems and barriers to ensure protection of public health.

#### **5.3.4.2. Rainwater tank surveys**

A program of water sampling of rain water tanks was undertaken by officers of the NSW Health Department – Orana and Far West Region during the 1991/92 cotton growing season with small levels of residues of endosulfan and dieldrin being found most frequently.

A rain water tank sampling survey in the Namoi Valley of New South Wales during April-May 1996. A follow up study was undertaken during the 1996/97 season (NSW EPA, NSW Health, 1998). Levels of pesticide detected were below the MRLs, except in one case due to the domestic use of chlorpyrifos.

#### **5.3.4.3. Pesticide residues in surface and ground water**

A water quality program is being undertaken by the NSW Department of Land and Water Conservation that includes monitoring the rivers and streams of northwest NSW. No sample even approached the drinking water health values, but endosulfan, atrazine and chlorpyrifos in some samples exceeded the Action Guideline Value established by the NHMRC / ARMCANZ Guideline – “intended for use by regulatory authorities for surveillance and enforcement purposes, and provide a mechanism to measure compliance with approved label directions.” (NHMRC/ARMCANZ, 1996). The report for the 1999/2000 (Muschal, 2001) similarly found that no samples exceeded the drinking water health values for pesticides.

### **5.3.5. Other residues of human health importance**

Studies have been undertaken that monitor pesticides residues in wool associated with ectoparasite control. These have been reviewed in an NRA report commissioned by the Woolmark Company (Savage, 1998).

Health concerns relate to the possible occupational exposure of sheep handlers and shearers, and those associated with first stage processing of wool, as well as the

potential for residues in products that use lanolin – pharmaceuticals and cosmetic products. The review report found that the average concentration of organophosphates in raw wool in the 1997/98 season was 5.8 mg/kg wool wax. While this level would probably allow lanolin manufacturers to meet the current standard, substantial refining would be required to meet new standards being proposed by the Advisory Committee on Pesticides and Health of the Department of Health.

The issue is still under consideration by the relevant stakeholders.

#### **5.4. REGULATION OF CHEMICAL TOXICITY – INTERNATIONAL ASSESSMENT**

**The Australian regulatory process is comparable to those of most advanced Western Countries. Differences are due to different patterns of use of pesticides, product availability, agricultural needs, and assessments of risk and benefit, and it is suggested that this will always be the case.** For example, Australia has a greater need for insecticides than Northern Hemisphere countries which, in turn, are more reliant on fungicides than Australia. Agricultural and public health practices will always vary between countries as long as their topography, agricultural practices, pest pressures and public health needs differ.

In recent years, there has been significant progress made in the exchange and utilisation of regulatory assessments of chemicals, including pesticides and veterinary drugs.

The World Trade Organisation has afforded recognition to the recommendations of the Codex Alimentarius Commission (Codex). Australia has longstanding participation in, and support for, the objectives of Codex through participation in its Committees such as the **Codex Committee on Pesticide Residues (CCPR)** and the **Codex Committee of Residues of Veterinary Drugs in Food (CCRVDF)**. Australia has actively contributed to their relevant expert advisory committees, the **Joint FAO/WHO Meeting on Pesticide Residues (JMPR)** and the Joint FAO/WHO Expert Committee on Food Additives (**JECFA**). These advisory bodies are comprised of a mixture of appropriately independent academic experts as well as key professionals who have been drawn from leading regulatory agencies, such as the US Environmental Protection Agency, the UK Ministries of Health and Agriculture, Fisheries & Food, and the Japanese Ministry of Health.

The work of the JMPR and the JECFA is supported by the **Intergovernmental Forum on Chemical Safety (IFCS)**, a collaborative program of the **International Labour Organisation, United Nations Environment Programme** and the **World Health Organisation**. Australian experts have contributed to IFCS activities that include production of comprehensive Environmental Health Criteria monographs, Concise International Assessment Documents, Health and Safety Guides and Data Sheets on pesticides as well as other chemicals.

Previously, the **OECD Chemicals Programme** contributed significantly to the co-ordination of regulatory protocols and requirements for the testing of chemicals in general. Whilst this provided an international framework for the testing of unspecified chemicals, the programme did not specifically address the requirements for testing

and assessment of agricultural and veterinary chemicals, such as the assessment of the potential hazard of pesticide residues in food. In recent years, the OECD has developed its Pesticide Programme so that seeks to harmonise the regulatory approaches and practices within its members. This has led to increasing exchange of regulatory evaluations and hazard appraisals for pesticides, thus leading to sharing of the national burden and, hopefully, increased consistency and efficiency. Australia has played an active role in the OECD Pesticides Programme since its inception.

## **5.5. ASSESSMENTS OF PESTICIDES FOR REGISTRATION FOR USE IN AUSTRALIA**

The legislative and regulatory frameworks governing the registration and clearance of pesticides in Australia are discussed in chapter 7. The requirements include a number of specific aspects relating to human health.

The health assessment requirements are laid down in a series of manuals produced by the National Registration Authority for Agricultural and Veterinary Chemicals (NRA, 1996 and 1997). Assessment of the toxicology, animal metabolism, toxicokinetics and public health impact is carried out for the NRA by the Commonwealth Department of Health and Ageing (Therapeutic Goods Administration), residues data are assessed by the Residue Evaluation section of the NRA, and occupational health and safety assessment is generally carried out for the NRA by the National Occupational Health and Safety Commission (Pesticides Unit)

### **5.5.1. Public Health Assessment**

The following data are required for the public assessment of pesticides for use in Australia:-

#### ***5.5.1.1. General information***

General information required includes:

- the proposed use and justification for the proposed end-use pattern and the claims for use of the product.
- complete information on the chemistry and manufacture of the product..

#### ***5.5.1.2. Metabolism and toxicokinetics***

Information that describes the metabolism and toxicokinetics of the product is required. Specific data requirements include:

1. Metabolism and toxicokinetic studies in laboratory animals
  - Absorption after oral administration, and desirably after dermal application
  - Distribution and storage in tissue of animals, bioaccumulation
  - Biotransformation in animals
  - Excretion or elimination of parent compound and/or its degradation products
2. Metabolism database

#### ***5.5.1.3. Toxicological studies***

Toxicity testing is a dynamic field, and new developments may require companies to use new or modified tests “to detect potential activity in a new area of concern”

The data package submitted by chemical companies includes complete reports of all animal and *in vitro* studies that have used material containing an impurity level comparable to that in the commercial product.

Studies must be conducted in accordance with “good laboratory practice” with animal numbers necessary to allow valid conclusions to be drawn. Studies to be submitted are:

- **Acute toxicity studies** (including studies on the active constituent and studies on the product to be marketed in Australia). These studies examine the adverse effects arising from a single dose of a substance or multiple doses given within 24 hours
- **Short-term toxicity studies.** These are repeat-dose studies up to 90 days, to test possible health hazards from repeated exposure over a limited time. Rats are usually used for these studies, using the most relevant route of likely human exposure.
- **Sub-chronic toxicity studies.** assessment of possible effects of short-term repeated exposure and preliminary dose range-finding studies prior to chronic studies being undertaken. These studies should demonstrate a range of activity from the no-observable-effect level (NOEL) to a clear effect level.
- **Long-term toxicity studies** which are required to assess long-term effects that may not be demonstrated in the sub-chronic toxicity studies, e.g. from cumulative toxicity, and carcinogenic, or cancer forming potential of the product. These studies include chronic toxicity studies, involving long-term continuous daily oral administration of the chemical to two species – preferably rat and dog, to provide an assessment of inter species variation, and carcinogenicity studies, carried out whenever “biologically significant residues of the compound or its metabolites occur or human exposure results from the normal use pattern”. The compound is fed to the animals throughout most of its lifespan, at the highest dose that does not cause toxicity. Rodent species are recommended, and cancer rates are compared to the normal rate in that species and strain of animal. A carefully designed combined study of chronic toxicity and carcinogenicity, may provide adequate data for each of the assessments.
- **Reproduction studies,** involves feeding of the compound to one or more generations and provides information about reproductive performance.
- **Developmental toxicity studies.** These studies involve feeding of the compound to at least two mammalian species (preferably rats and rabbits) of pregnant females over a specified period of gestation. They provide information on toxicity to the embryo and foetus, and potential for developmental abnormalities and altered growth
- **Genotoxicity (mutagenicity) studies** to determine the potential of the chemical to cause genetic damage in humans. by measuring for potential mutagenic and chromosomal damage effects.

- **Other studies** which may be required include:
  - Toxicity studies of metabolites and impurities where these may contribute significantly to the toxicity of the chemical
  - Further investigation where individual chemicals show specific toxicological effects
  - Toxicity of mixtures - where two or more active constituents are formulated together, toxicity studies are undertaken with the formulated product
- **Human toxicological data**, including all available information relating to human experience with exposure to the compound, must be provided.
- **Toxicological database** information on all studies that have been undertaken on the chemical, identifying those that have been submitted as part of the current application is required.

#### **5.5.1.4. Indices of public health significance**

From the data and studies submitted the following public health indices are defined for active ingredient.

- **No-observable-effect level (NOEL).** The definition of the NOEL is “the highest concentration or amount of a substance, found by study or observation, to cause no detectable (usually adverse) alteration of morphology, functional capacity, growth, development or life span of the most sensitive test organism (animal)”. The NOEL is expressed as mg/kg body weight/day.
- **Acceptable daily intake (ADI).** The ADI is defined as “the daily intake of a chemical which, during an entire lifetime, appears to be without appreciable risk on the basis of available information at the time.” The figure is based on the NOEL determined in toxicity studies, with the application of a “safety factor” or “uncertainty factor”. The most commonly selected safety factor is 100. The hundred-fold margin is arbitrary. It provides for humans being up to 10 times more sensitive to the toxicity of a pesticide than the most sensitive animal studied and some individuals being up to 10 times more sensitive than the general population..
- **Acute Reference Dose (ArfD),** which is the dose in food or drinking water that can be ingested over a short time – one meal or less than 24 hours without risk of adverse health effect.

#### **5.5.2. Poisons scheduling**

Poisons scheduling classifies substances on the basis of their toxicities and hazards. Substances, including drugs, veterinary drugs, pesticides, household and industrial chemicals solvents, adjuvants and additives, are assessed. The assessment of toxicological hazard, along with the planned pattern of use, is utilized to determine the hazard potential. The resultant classification, undertaken by the National Drugs and Poisons Schedule Committee, imposes restrictions upon the availability, supply and use of a chemical or product. The classifications are adopted into States/Territories legislation.



### **5.5.3. First aid and safety directions**

Following review of the toxicological data, identification of the relevant toxicological end-points and the pattern of use, and a hazard appraisal, directions for safe use and first-aid in the case of acute poisoning are designated and required to be applied to the label of the registered product. If followed they should minimize the risk to those directly exposed to that product.

### **5.5.4. Residue assessments**

The **maximum residue limit (MRL)** is defined by the NRA as “the maximum concentration of a residue, resulting from the officially authorized safe use of an agricultural or veterinary chemical, that is recommended to be legally permitted or recognized as acceptable in or on a food, agricultural commodity or animal feed. The concentration is expressed in milligrams of the residue per kilogram of the food (mg/kg)” (NRA, Maximum Residues, 1996).

It should be noted that MRLs are not health or safety limits. As a matter of principle they are set as low as possible in accordance with Good Agricultural Practice. As advised earlier, in each case, the residue limit is considered to be acceptable from a public health viewpoint as estimated by comparison of the anticipated dietary exposure with the Acceptable Daily Intake.

During evaluation and prior to registration of a product, the NRA establishes MRLs for pesticide products in all types of raw food and some processed food where chemical residues may be anticipated. Foods may be of either plant or animal origin and may be consumed by either people or animals.

Applications for registration of chemical products must include data showing the nature, level and safety of residues and metabolites resulting from the end use pattern. The MRL is determined following rigorous consideration of available data, particularly data generated from supervised agricultural trials at specified application rate.

Good Agricultural Practice (GAP) in the use of agricultural and veterinary chemical products is defined by the NRA as “the nationally recommended, authorised or registered use-pattern of chemicals that is necessary for effective and reliable pest control under actual conditions at any stage of production, storage, transport, distribution and processing of food commodities and animal feed”.

Evaluators consider the most extensive permitted use of the product – i.e. the maximum label use pattern, that defines the Good Agricultural Practice needed to control diseases or pests. Safety is determined in relation to either the acceptable daily intake or the acute reference dose or both as appropriate.

The following are taken into account in the assessment process:

- how accurately the chemical and/or toxicologically significant metabolites can be measured in animal tissues and/or plant material;
- how rapidly the chemical may be degraded by soil and other environmental processes;

- how rapidly the chemical may be processed by either plant and/or animal tissues;
- how frequently and at what interval the chemical is used, taking account of the potential for bio-accumulation;
- how close to harvesting of plants and/or slaughtering of livestock the chemical is used (including withholding periods);
- the acceptable dietary exposure to low levels of chemicals in food;
- the effects of processing (e.g. flour from wheat, wine and dried fruit from grapes, sugar from sugar cane); and
- any differences in MRLs and residue definitions between Australia and its major trading partners and those of the Codex Alimentarius Commission of the United Nations.

The data requirements to establish MRLs are detailed in Part 5A of the Agricultural Requirements Manual of the NRA, and are briefly described as follows.

#### **5.5.4.1. Trials data**

Trials data are used to show whether and to what level, residues occur in edible crops, fodder, animal tissues, milk and eggs. Studies show the rate of disappearance of residues and/or the interval that elapses before the residues substantially disappear

Trials are to address the maximum use rate, and proponents are encouraged to submit trials at a rate of one-and-a-half to two times the maximum use rate at one of the trial sites. Specific guidelines for conduct of the studies are available from the NRA.

**Crop residues trials data** include crops for human consumption and crops used as livestock feed.

**Livestock residue trials data** are required for relevant livestock, poultry, egg and milk residues from direct application (including residues in wool), from feeding of treated crops (animal transfer data), and from treatment of livestock premises.

**Analytical methods** details required from the applicant include complete details of the analytical methods used for determining residues in the trials, and a suitable method for routine monitoring and for regulatory control. Criteria to be met by the method submitted are laid down in the NRA Guidelines.

#### **5.5.4.2. Fate of residues in storage, processing and cooking**

Information is required in some cases regarding the subsequent effect of processing and cooking on the level of residues originally recorded at harvest or slaughter so that the likely pesticide residue intake in the diet can be estimated. Processing includes peeling, washing, cooking and food processing. Situations in which processing studies may be required include:

- when the theoretical maximum daily intake exceeds the acceptable daily intake (ADI)
- where there is a possibility that processing may convert residues into metabolites that have toxicological significance
- when it is evident that residue levels in the processed food/feed will be greater than in the raw commodity

- when the commodity contains residues above the limit of quantitation and processing studies are mandatory, for example, wheat.

#### **5.5.4.3. Maximum Residue Limits**

The applicant is required to nominate MRLs for the active constituents contained in the product. These must be consistent with the proposed use-patterns of the end-use product. While the applicant proposes MRLs, the NRA independently evaluates the data and establishes the MRLs. The value nominated for Australian end-use will be determined after consideration of MRLs in other countries, including those published within **Codex Alimentarius**, under the aegis of the **Codex Alimentarius Commission**, a joint FAO/WHO body responsible for the World Food Programme.

#### **5.5.4.4. Applicant's proposed withholding periods**

The applicant will also propose the withholding period, and this will be established by the NRA after evaluation using available data. Withholding periods may be applied so that any subsequent residue will comply with the MRL.

If the MRL is shown not to give rise to detectable residues in food, or is avoidable, the MRL will normally be set “at or about the limit of **analytical quantitation**”.

### **5.6. CURRENT ISSUES**

#### **5.6.1. Developing an Acute Reference Dose**

The Australia New Zealand Food Authority (ANZFA) has requested the Therapeutic Goods Administration (TGA) to establish an Acute Reference Dose (ARfD) for pesticides. The ANZFA plans to undertake acute dietary exposure assessments for pesticides on a routine basis. High pesticide residue variability has been noted for individual fruits and vegetables and this is the basis for requiring a reference dose to be set to ensure consumption does not result in acute toxicological effects.

Internationally, the Joint FAO/WHO Meeting on Pesticide Residues (JMPR) has been considering the most appropriate animal study and design protocols to be used where an Acute Reference Dose is to be established.

The ARfD has been established for few pesticides to date in Australia, primarily those that have been included in the Existing Chemical Review Program of the NRA. The TGA is continuing to establish its policy for establishment of Acute Reference Dose figures in relation to:

- study type that provides the most relevant data
- study duration
- toxicological endpoint
- the need for an Acute Reference Dose figure for individual pesticides

#### **5.6.2. Long term health effects of pesticides**

Some of the basic principles and constraints involved in considering *chronic toxicity* include:

- acute effects of a particular pesticide are of little, if any, help in anticipating its possible chronic effects
- a number of chronic effects are only likely to be expressed after very prolonged exposure to a pesticide - several decades for some cancers. The slower the onset, the more difficult to prove a particular cause for three reasons:
  1. The wide range of other possible causative factors,
  2. The lack of accurate exposure information likely to be available, and
  3. Any effect has to show up against a background incidence of “natural” disease which is part of the process of ageing.

Hence, pesticides which produce a “unique” disease are most likely to be identified, particularly if they produce a similar effect in animals. However, if a pesticide increased the incidence of a very common human disease, it may be impossible to identify by direct means (House of Commons 1987).

In 1993, Maroni and Fait published a comprehensive review of the 1975-1991 literature describing the long-term health effects of prolonged exposure to pesticides. The authors noted that despite the increasing use of agricultural pesticides, the adverse effects on human health have not been exhaustively evaluated and that the role of pesticides in disease development remains controversial. “Of particular concern in the eyes of the public are allergic diseases and long-term health effects. Further, while animal studies provide valuable information on absorption, bio-transformation and elimination of chemicals, on mechanisms of toxicity, epidemiological studies on humans exposed to pesticides provide more direct information, and cannot be replaced by other methods of investigation to confirm the existence of adverse health effects”. The authors noted that while there have been population studies based on geographic area, any association remains “vague and difficult to prove”. Hence the increasing attention being focused on humans with occupational exposure, who experience higher doses than the general population. “Therefore studies on occupationally exposed subjects are likely to contribute the most valuable information to investigate associations between pesticide exposure and long-term health effects.”

#### **5.6.2.1. Pesticides and cancer**

Moroni and Fait noted that, when compared with the general population, total mortality, and non-cancer causes of deaths (with the exception of deaths by accidental causes) were found to be consistently lower among pesticide manufacturers or users. This finding was mostly been attributed to the “healthy worker” effect. There was also a very consistent reporting of low overall cancer incidence among agricultural workers.

However, an increased risk of myelolymphoproliferative disorders (especially multiple myeloma) had been reported in farmers, although further studies were noted to be required to control for confounding variables to make the evidence for association with pesticides (mainly phenoxyacid type compounds) more compelling.

Several studies have pointed to a possible association between brain cancer and pesticide exposure, although no firm conclusions could be drawn and further studies were recommended. One association between arsenicals and lung cancer had been reported, but the possible influence of smoking as a confounder gave rise to difficulties in other studies examining links between lung cancer and pesticides use.

However, an association between prostate cancer and pesticide related occupations had been consistently reported, especially among farmers

In 1996, the National Cancer Institute of Canada convened an Ad Hoc Panel on Pesticides and Cancer to examine the possible contribution of pesticide exposure to the development of human cancer (Ritter, 1997). The Panel focussed primarily on exposure in the general population and examined the literature as well as the regulatory framework for pesticides use in Canada. The Panel concluded that “it was not aware of any definitive evidence to suggest that synthetic pesticides contribute significantly to overall cancer mortality”.

However, the Panel found that phenoxy herbicides have been implicated with causing an excess of some cancers in farming and pesticide applicator populations, and that evidence for association with non-Hodgkins lymphoma was “*suggestive for high occupational exposure*”.

There is a considerable literature relating to a hypothesis that breast cancer may be related to exposure to certain persistent pesticides such as the organochlorines, most of which are now banned in Australia. While a number of studies demonstrate higher concentrations of PCB and DDE, a study reported by Kreiger et al (1994) was considered by the Panel to be the most comprehensive study to date was. That study found that no association could be found between DDT and/or PCB levels and breast cancer.

The Canadian Ad Hoc Panel noted that DDT and its metabolite DDE have been implicated in the aetiology of human breast cancer, and is the topic of “*intense research interest*”.

#### **5.6.2.2. Pesticides and neurological disease**

Association between pesticides exposure and neurological disease has been the subject of recent research interest in a number of areas.

A number of conditions affecting peripheral nerves have been described following exposure to anticholinergic pesticides. In the rare occurrences of acute poisoning, organophosphate-induced delayed polyneuropathy (OPIDP) is a rare but well described condition occurring several weeks after acute poisoning by certain organophosphate pesticides. It affects both sensory and motor peripheral nerves, and has been reported in patients who have displayed typical symptoms and signs of cholinergic toxicity (Moretto and Lotti, 1998; Jamal, 1997). “Intermediate syndrome” is another rare condition that has been described as occurring 24 to 96 hours following acute organophosphorus pesticide poisoning (de Bleeker et al, 1993). It is characterized by proximal muscle weakness and may affect muscles involved in respiration.

In the case of chronic pesticides exposure, in the absence of acute poisoning, a number of studies have reported peripheral nerve impairment, including nerve conduction delays, (Steenland et al, 1994; Stokes et al, 1995). However, other studies have failed to demonstrate this association (Engel et al, 1998).

There are a number of studies describing neuropsychological deficits in workers exposed to organophosphate pesticides. Deficits have been measured using standardised neuropsychological tests and include cognitive symptoms – impaired memory and psycho-motor speed, and affective symptoms including irritability, anxiety and depression (Keifer and Mahurin, 1997; Stephens et al, 1995).

A study reported by the Institute of Occupational Medicine, Edinburgh (1999) found an association between neuropsychological deficits and chronic peripheral neuropathy with organophosphates use in sheep dips. This report has been considered by an expert panel convened by the National Registration Authority to determine its relevance to Australia (NRA 2000). The panel found that the Institute's study could not establish a definitive link between organophosphorus pesticide exposure and chronic health effects, although such a link could not be eliminated, and that the main source of exposure to organophosphate sheep dip chemicals is associated with handling the concentrate, and therefore that all practical measures should be undertaken to ensure safe use of such chemicals in Australia..

#### **5.6.2.3. Pesticides and endocrine disorders**

In 1997 the US EPA issued a special report to review the key scientific findings relating to environmental endocrine disruption (US EPA 1997). In light of the review report, the US EPA position was that the endocrine disruption was not considered “to be an adverse endpoint *per se*, but a step that could lead to toxic outcomes such as cancer or adverse reproductive effects”. Existing toxicological test requirements should detect these outcomes. The EPAs and other regulatory agencies, including Australia, are continuing to review developments in this area.

A watching brief is also being kept on the issue of the potential for pesticides to cause endocrine disrupting effects in Australian natural ecosystems, as the risk from such effects is unclear. The susceptibility of Australian marsupials to endocrine-disrupting effects is one area that may require research, if a risk is established.

### **5.6.3. Mixed exposures**

A well recognised issue for the evaluation and registration process for pesticides is the limited capacity for assessment of health risk associated with exposure to mixtures of pesticides and/or their adjuvants. This is discussed later in relation to worker exposure where the risks are perhaps greatest .

The question of synergism related to oestrogenic activity of mixtures of chemicals that may individually be only weakly oestrogenic is being examined (US EPA, 1997).

### **5.6.4. Susceptible populations**

#### **5.6.4.1. Children**

An issue being considered in recent years is that of whether current assessment procedures and establishment of ADIs adequately addresses the needs of children. A number of workshops and agencies have considered this issue. Two major arguments have been used to suggest special ADIs should be established for children – that

infants and children are more susceptible to the effects of chemicals and, on a per kg body weight basis, food intake is higher in children than adults.

The JMPR in 1999 concluded that the routine use of an additional safety factor is not scientifically justified on current information, and that toxicants should be assessed on an individual basis where data indicates that it is necessary.

The Advisory Committee on Pesticides and Health of the Therapeutic Goods Administration at its meeting in April 2000, agreed that development of the core toxicological data packages required in the pesticide registration process include animal reproductive and development studies that should allow potential differences between adults and young animals to be considered.

In 1997 a study – the Minnesota Children’s Pesticide Exposure Study (MCPES) was conducted by the US EPA and researchers to evaluate children’s exposure to environmental contaminants both individually and in combinations, to evaluate exposure pathways and to compare health risks of the chemicals studied (Minnesota Department of Health, 2000). Researchers gathered personal and pesticides use data, and collected environmental samples from 102 homes with children in Minneapolis, St Paul, and Goodhue and Rice Counties. The study reported that “generally children’s exposures to carcinogens did not approach harmful levels, whether considered separately or combined in a variety of ways.”

“Children’s total cancer risk from all exposures to carcinogens ranged from two to seventy per one hundred thousand. Benzene was the single chemical that contributed a large share of each child’s overall risk.”

#### **5.6.4.2. Hypersensitivity and Multiple Chemical Sensitivity**

The condition previously referred to as multiple chemical sensitivity (MCS), more recently called idiopathic environmental intolerances (IEI), is a highly complex problem that has been debated in professional circles and at international workshops for many years without consensus. Exposure to pesticides is a commonly reported trigger of symptoms in persons with the multiple chemical sensitivity (MCS) condition, and numerous advocacy groups and coalitions in Australia and world-wide have advocated reduced environmental exposures to pesticides along with other chemicals.

A Position Statement was produced by the American Academy of Allergy, Asthma and Immunology in 1986 and updated and published in 1999 following review of the more recent literature (1999). The condition refers to “a subjective illness in certain persons who typically describe multiple symptoms which they attribute to numerous and varied environmental chemical exposures in the absence of objective diagnostic physical findings or laboratory test abnormalities that define an illness”.

Because of the subjective nature of the condition, an objective case definition has not been established, making scientific study of the condition difficult. The Academy found there was a lack of scientific evidence for any of the allergic, immunotoxic, neurotoxic, cytotoxic, psychologic, sociologic and iatrogenic theories which have been postulated as causal mechanisms,

A Position Statement published by the American College of Occupational and Environmental Medicine (ACOEM) (1999) notes the limitations of the published research, but “recognises that data have accumulated that support some tentative conclusions about MCS”. The ACOEM recognises that available evidence:

- points strongly against an immunological basis for MCS;
- has noted overlap between MCS, chronic fatigue syndrome, fibromyalgia, and other historic non-specific conditions;
- demonstrates that odour related symptoms are common in the general population; and
- suggests an excess of symptoms of psychological distress consistent with anxiety and depression in many, but not all, patients.

Though not directly related to agricultural pesticide use, it may be noted that the ACOEM endorsed moves by regulatory authorities to improve indoor air quality to reduce human illness and discomfort.

#### **5.6.5. Impact of odours associated with pesticide products**

Following a submission from the NSW Environment Protection Authority, the National Registration Authority and the TGA are currently considering the potential health impact of odours associated with certain pesticides. A number of pesticides are associated with release of mercaptans which can have a strong, offensive and nauseating odour. In January 2001 the NSW Environmental Protection Authority released a draft policy relating to both point and diffuse stationary sources of odours – *Assessment and management of odour from stationary sources in NSW*. (NSW EPA, 2001). A Working Group assembled by Australia’s NRA is considering how health effects of odours associated with certain pesticides e.g. profenofos, should be assessed and regulated.

### **5.7. PATHWAYS OF EXPOSURE TO PESTICIDES**

Pesticides enter the human body by inhalation, by ingestion and by absorption through the skin.

Persons could be at risk of exposure to pesticides at any point through the chain of production and use of pesticides and consumption or contact with residues, viz:

- Workers in manufacturing plants – handling technical grade, concentrated material
- Workers in formulating plants - handling technical grade material
- Workers handling pesticides during transportation and storage
- Emergency personnel attending fires and spills
- Workers mixing, loading and applying pesticides
- Bystanders to pesticides applications
- Workers and others who may enter sprayed crops
- Gardeners using garden products
- People in treated buildings
- Consumers using household products
- Exposure to residues in food and water
- Accidental ingestion, including child poisoning



- Intentional poisoning – suicide and homicide

The chain of production and use is further outlined in Appendix A

Occupational exposure to pesticides used in the primary industries, including agriculture, forestry, fisheries and the associated food and fibre industries occurs most frequently by inhalation and dermal routes. There is a potential exposure to spray draft in rural localities which has been of concern to some communities. Accidental and intentional poisoning generally is by ingestion.

### **5.7.1. Exposure during manufacture and packaging**

Most pesticides used in Australia are imported. However, there were eight Australian pesticide manufacturing sites listed among pesticides registered by the NRA in 2001. In addition, there is considerable formulation and repackaging undertaken locally. The health and safety of workers in these plants is protected under occupational health and safety (OHS) laws in each state, and hazardous substances regulations where relevant.

As reported above, Moroni and Fait noted that, when compared with the general population, total mortality, and non-cancer causes of deaths (with the exception of deaths by accidental causes) were found to be consistently lower among pesticide manufacturers or users.

Internationally the best-known reports of exposure and adverse health effects occurring during manufacture were associated with the manufacture of now-withdrawn 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) and the generation of the by-product 2,3,7,8-tetrachlorodibenzo-p-dioxin which were reviewed by the Committee on the Future Role of Pesticides in US Agriculture (2000). However by the time it was withdrawn, 2,4,5-T only had minute traces of dioxin in it. Note that dioxins are permanent and pervasive contaminants in our environment resulting from natural events (eg, bushfires, lightning strikes, volcanos) and as unintentional by-products of industrial processes usually involving combustion.

Chlordimeform, discussed earlier in section 5.2.3.2, is the formimide insecticide which was in extensive use in the cotton industry in NSW between 1978 and 1986. It could be rapidly absorbed through the skin, and also through inhalation or ingestion. The major metabolite - 4-chloro-o-toluidine was implicated in the development of haemorrhagic cystitis and bladder cancer in workers exposed to the pesticide during its production in Britain, Germany and the USA. Both products have been withdrawn.

A cluster of cases of glomerular haematuria in a pesticide manufacturing and formulating factory in South Australia was reported by Gun *et al* (1998).

### **5.7.2. Exposure during transportation and storage**

Spillages of pesticides from their containers occur from time to time during transport accidents on public roads in Australia. While there have been media reports of short-term effects for bystanders and emergency personnel there have been no collated reports of such events or their health outcomes

### **5.7.3. Exposure during application**

Workers are exposed to higher levels of pesticide than the general public during the course of mixing and loading chemicals, when they are handling the concentrated form, and during application. The impact that such exposures may have on the health of pesticides handlers is not well documented internationally (Committee on the Future Role of Pesticides in US Agriculture, 2000). A report prepared by Faulkner (1993) noted that workers in the following industries are at potentially high risk of exposure to pesticides in New South Wales:

- Vegetable production
- Orchardring
- Cotton production
- Rice production
- Mushroom and greenhouse production
- Banana production
- Sheep and wool production.

However, as outlined in section 5.2.2.3, the number of workers compensation cases reported is a very small proportion of the total number of claims made in the “agricultural” and services to agriculture” industries.

### **5.7.4. Exposure of bystanders to pesticides application**

Bystanders to pesticides application include people in the vicinity of aerial or ground rig spray applications where spray drifts. These may be workers in adjacent fields or paddocks, passers-by on roads and lanes and people living in the vicinity or spraying operations. Many of the complaints to Australian state regulatory authorities involve complaints of exposure to pesticides and/or their odour in such circumstances. Rarely is the level of such exposure found to be of other than short term health significance, although individuals with special sensitivity find such exposures an ongoing problem (Standing Committee on State Development, 1999). Another group at risk of exposure are the families of workers engaged in pesticides handling. Exposure may be to pesticides residues on workers clothes being laundered (Grieshop *et al*, 1994) and on other contaminated household items.

### **5.7.5. Exposure to residues in food and water**

The levels shown in surveys of food eaten are well below the statutory limits and are of no health risk. The population is exposed to pesticides residues from infancy (from milk, including breast milk) through childhood and adulthood, but at very safe levels. In principle special attention to safe and acceptable levels of residues for children is required in light of their smaller body size and their differing dietary patterns to adults. In practice the low levels in food protect them from any adverse effects.

### **5.7.6. Accidental and intentional poisoning by pesticides**

Accidental ingestion is rare, although it is the primary cause of childhood poisoning by pesticides. In the early 1950's, pesticides represented a high proportion of

childhood poisonings admitted to the Camperdown Children's Hospital in Sydney. Between 1983 and 1988 the overwhelming cause of poisoning was for pharmaceuticals (Campbell and Oates, 1992). However, cases of accidental poisoning by pesticides are still being recorded.

Intentional use of pesticides for self-harm is a major public health issue in several South East Asian countries (WHO 1999, Division of Medical Toxicology and Risk Assessment 2001), notably Sri Lanka (Premaratna *et al.* 2001). This is not the pattern in Australia.

## **5.8. MINIMISING HEALTH IMPACTS ON WORKERS**

Workers handling pesticides in Australian agriculture include farmers, farm managers, employees and contractors. The total number of persons working on farm businesses with an estimated value of agricultural operations (EVAO) of more than \$22 500 was earlier shown to be 301 000 in 1998. (ABS, 1999). This provides a very crude estimate of the order of the number of workers exposed to pesticides in the course of end-use of products and in the course of re-entry to treated crops or re-handling treated products.

Assurance of protection of workers from adverse health effect of exposure to pesticides in Australia is achieved in the following ways:

- **Safe product** - assessment of occupational health and safety (OHS) risk of the product during production, formulation, packaging, and adequate safety guidance on e.g. labels and material safety data sheets (MSDS)
- **Safe operations** – by workers engaged in transport, storage, mixing/loading, application, clean up and first aid and emergency care.
- **Monitoring** of effectiveness of risk control measures

The following examines each of these factors.

### **5.8.1. Safe product - occupational health and safety assessment of pesticides**

#### ***5.8.1.1. OHS risk assessment in the registration process***

The registration process for pesticides in Australia includes assessment of occupational health and safety (OHS) risk to workers involved at all stages in the production and use of each pesticide, including risks associated with re-entry and/or re-handling (see chapter 7). The OHS data package is generally assessed by the National Occupational Health and Safety Commission (NOHSC) for the NRA.

Part 6 of the NRA Guidelines Manual (1997) outlines the data requirements and indicates that assessment of the impact on the health and safety of workers handling or using the product, or exposed to product residues in the course of their work under Australian conditions uses a risk assessment methodology. This methodology includes evaluation of the hazard – the toxicology, and physicochemical properties of the product; and assessment of exposure to the product – based on measured and/or

extrapolated data. Agricultural data requirements are noted to be consistent with the state and territory OHS hazardous substances requirements under OHS legislation.

The following sections list the studies required for the occupational health assessment of products prior to their registration and is derived from the NRA Guidelines Manual (1997).

Definitional information includes:-

- **Active constituent** - information required includes physical and chemical properties, including volatility and vapour pressure, corrosive hazard.
- **Product**, including the identity of product and its ingredients - information requirements include the physical and chemical properties and additionally descriptions of packaging and formulation types.

Information regarding the toxicology of the product and its metabolites that are relevant to occupational health provides information regarding the characteristics of the hazard potential. These include:

- **Human health effects and biological indices** – all information relevant to occupational use, including information on poisonings (in particular information on human toxic and lethal doses), epidemiological studies relevant to workplace exposure.
- **Animal testing information for risk assessment** – to define relevant end-points for assessing occupational risk, in the absence of human data.
- **Selection of toxicological endpoints** (See section 5.3) for risk assessment – factors to be considered when identifying relevant end-points include its relevance to the use pattern of the product, likely routes of worker exposure, the severity and significance of the toxicological end-points and the quality of the study.
- **Dermal absorption** – a summary of available dermal absorption studies is provided. An absorption rate of 100% is assumed for OHS risk assessment, unless well designed studies demonstrate a lower rate.

These data then allow the OHS assessors to classify the product according to hazardous substances classification criteria (NOHSC, 1996), and to tailor risk assessment according to the level of concern. Hazards are broadly grouped as follows: acute lethal toxicity, irritation, sensitisation, non-lethal toxicity from a single dose, and repeat dose toxicity (Vickers, 1997).

Two sets of information on likely occupational exposure are required to estimate exposure reaching the skin (penetrating through clothing) and the absorbed dose, as follows:

- General information on points of potential worker exposure is required. This includes descriptions of handling systems during manufacture, formulation and packaging if these are undertaken in Australia, and descriptions of application systems during end use and re-entry or re-handling or other potential exposure after use.

- Measured or extrapolated exposure information. Exposure data may be derived from measured worker exposure studies conducted under actual conditions of use, however, calculations based on surrogate data or modeling may indicate that such studies are not needed.
  - Measured worker exposure studies should cover manufacturing, formulation and packaging, end use and re-entry, re-handling and other situations of potential worker exposure. Detailed test guidelines for worker exposure studies have been developed by the OECD and the US EPA, and both are acceptable for Australian assessments.
  - Extrapolated worker exposure calculations may be submitted using Predictive Operator Exposure Models (POEMs). There are both the EUROPOEM and the United Kingdom Predictive Operator Exposure Model available. Other models such as the North American Pesticide Handlers Exposure Database also may be used. These models are based on pooled data from worker exposure studies.

A product risk assessment is then made using the information provided. Vickers (1997) indicates that “a common scenario might be:

- Dermal LD50 – Likelihood of contamination with the equivalent human dose in volume of product and prepared spray.
- Assessment of the likelihood of irritation or sensitization.
- One-off exposures of concern - Estimates of the equivalent human dose of product and prepared spray (for example, the dose equivalent to the no-observable effect level (NOEL) for teratogenicity). The likelihood of achieving this dose in each routine use (e.g. from worker exposure studies) and on occasion (from an isolated event) is considered.
- Repeat exposures - Predicted exposures from worker exposure studies or exposure models, where relevant, are compared to the NOEL selected for routine exposures.”

An acceptable margin between the relevant toxicological end-points and predicted exposure is required for OHS assessment to support registration of a product – called the Margin of Safety (MOS), or Margin of Exposure (MOE). As a general rule a Margin of Safety greater than 100 is required when using animal toxicological studies, and a Margin of Exposure greater than 10 is required when using human toxicological data, although a range of other factors will be considered, e.g. the quality of the data, the nature and severity of the toxic effects and the nature of the dose-response relationship.

The NRA Guidelines Manual (1997) notes that NOHSC seeks to adopt the widely accepted tiered approach to risk assessment.

**Tier 1** considers generic surrogate or extrapolated exposure data, and default dermal absorption values. If unacceptable risk is demonstrated, as indicated by unacceptable margins of exposure, then assessment requires a higher tier data assessment:

**Tier 2** uses generic exposure data, specific dermal absorption data and validated protective measures; and

**Tier 3** uses both measured exposure data and specific dermal absorption data or biological monitoring studies where relevant.

The assessment process determines whether any proposed measures are required to control occupational exposure, and assesses exposure reduction measures. NOHSC recommends that companies consider various measures to minimize exposure using the hierarchy of control. Examples of control measures before and during use include closed mixing and transfer systems, dedicated or specific application equipment and personal protective equipment. User comfort is to be considered for personal protective equipment requirements.

Re-entry and re-handling restrictions may be required, depending on the use pattern and potential for exposure.

Information specifying the risk assessment and risk control measures needed to control occupational exposure before, during and after end use is specified on the product label, and a Material Safety Data Sheet (MSDS) is required if the active constituent and the product is classified as 'hazardous' according to the NOHSC criteria (1996)

Specific products may require further information, depending on the product characteristics and planned usage patterns. These may include:

- Special training requirements to maintain OHS.
- Occupational exposure monitoring to confirm that exposure is controlled:
  - atmospheric monitoring
  - health surveillance
- Advice on tank mixes where potentially synergistic effects or chemical changes from certain pesticide combinations may have increased risks.
- Contra-indications suggesting when the use of a pesticide should be discontinued.

### **5.8.2. On-going issues**

Occupational health and safety risk assessment requirements and processes for registration of new pesticide, or from the review of existing pesticides under the Existing Chemicals Review program of the National Registration Authority for Agricultural and Veterinary Chemicals, have become more rigorous over time. Conservative safety factors and precautionary principles are significant components of processes to ensure the health and safety of workers using products that undergo such assessment.

A number of "current issues" associated with the risk assessment process were identified highlighted by Vickers (1997) at a Workshop – Health and Safety Assessment of agrochemicals held in Brisbane in 1997. These included

- limited risk assessment of solvents and other formulation constituents,
- low-volume application and off-label uses may not be encompassed by the risk assessment processes and labels, and
- limitations of the available assessment methods.

These and a number of other issues have been identified in the course of developing guidelines for farmers and end-users in on-farm OHS risk assessment and risk management (L. Fragar, Moree, pers. comm.).

There is a concern over a lack of assessment processes to adequately assess the health effects of worker exposure to a number of different, but perhaps toxicologically related, pesticides. This situation may occur where commercial operators (often contract operators) are engaged in multiple pesticides applications using a range of differing chemicals. Furthermore, tank-mixes of differing chemicals may increase risk of toxicity due to additive, or synergistic effects or potentiation (considerably increased activity). While applicants for registration of products are currently required to “comment on any tank-mixes that may impact on risk assessment, for example tank-mixing of pesticides which are cholinesterase inhibitors or known synergists” (NRA Guidelines Manual, 1997), the OHS hazard and risk assessment process does not include routine assessment of multiple exposures or all possible or likely tank-mix workplace exposure situations, and indeed to do so would present some considerable difficulties.

The rate-determining barrier in the dermal absorption of chemicals is the uppermost layer of the epidermis – the outer horny layer of keratinised cells that are biologically inactive. The passage of chemicals through the inner layers of cells is much more rapid (Rozman and Klaassen, 1996). Absorption will vary depending on the condition of the skin. Removal of the outer layer skin, for example by burns or other skin conditions, greatly increases permeability. Certain working conditions in Australia may result in sunburn and skin damage. For example, cotton chippers, who are people employed to hand-hoe weeds missed in cotton fields by pesticide spraying technology, reported sunburn as a common risk (NAIHO, 1984). The recently published review report for endosulfan (NRA, 1998) did address the re-entry to treated areas by workers engaged in irrigation or hand-weeding activities in the cotton or other broadacre industries in the OHS risk assessment, setting a two-day minimum period before re-entry, while further data on the standard are being generated.

Personal protective clothing and equipment requirements for safe product use – mixing/ loading/ application/ clean down etc, are often impractical and do not appear to take into account the practicalities of current practice. Although most farmers have attended a spraying safety course, the high risk of discomfort increases the probability that operatives will not comply with OHS recommendations. Preliminary examination of data held by the Australian Centre for Agricultural Health and Safety relating to provision of health surveillance services for agriculture in north-west NSW shows that workers such as ground rig operators rarely use the personal protective equipment recommended on the product labels (L. Fragar, Moree, pers. comm.). This was confirmed by the Kondinin Group whose spraying survey in 2000 showed more than 85% of farmers did

not follow standard procedures when mixing, loading and applying chemical in crop and pasture spraying programs (quoted in *Stock Journal* 19 December 2001). Whilst greater compliance could be required, additional research into developing more comfortable protective equipment could well assist better observation of safety requirements.

### **5.8.3. Safe operations – transport, storage, mixing/loading, application re-entry**

Safe pesticides operations that protect the health and safety of workers require the following:

- Safe systems of work
- Ongoing OHS risk assessment and control processes
- Operators with the relevant knowledge and skills– training
- Access to adequate information regarding hazard and risk
- Ongoing compliance with safety requirements

#### **5.8.3.1. Safe systems of work**

The requirement of employers to provide safe systems of work is laid down in all states' occupational health and safety legislation (see also chapter 8). While there is not necessarily a commonly accepted definition of what constitutes 'safe systems', key elements of safe systems of work (SA WorkCover Corporation, 2000) include:

- the organization of work processes
- the methods of using machinery, plant and equipment
- the methods of hiring labour
- job training, instruction and supervision about associated hazards and their management
- what to do when things go wrong.

Employers are expected to make reference to current standards for OHS risk management. These may be found in state regulations and industry codes of practice, for example regulations pertaining to hazardous substances. Other may be found in relevant Australian standards published by Standards Australia, for example standards for guarding of agricultural machinery, relevant for spray equipment etc.

#### **5.8.3.2. Workplace risk assessment and control**

In order to ensure that systems of work are safe, a key requirement in OHS legislation and associated regulations is that hazards in the workplace are to be identified, risks to workers and visitors to the workplace are assessed and risks controlled. Such requirements for hazardous substances are made more specifically in Hazardous Substances regulations (Chapter 8) .

**Hazard identification** - Criteria for designating substances in the workplace as 'hazardous' are laid down in a NOHSC publication (NOHSC, 1994) and many pesticides are included in the List of Designated Hazardous Substances (NOHSC, 1994). Many pesticides currently registered for use in Australia are designated hazardous substances. However, information as to whether a pesticide is a 'hazardous substance' is not included on the pesticide label. Handlers of pesticides must either have access to the List of Designated Hazardous Substances, or assume the hazardous status from the Toxicity Schedule that is included in the Material Safety Data Sheet (MSDS) for the product.

**Risk assessment** - Assessment of occupational health and safety risk in the workplace involves assessment of both the severity of the potential adverse outcome, and the



likelihood that workers and/or others in the workplace will be exposed to the hazard. The key sources of information for OHS risk assessment of use of a pesticide are the pesticide label, and the MSDS.

**Risk control** - Control of risks assessed to be medium to high involves implementation of the most effective control measures that are practicable in the situation of the enterprise. Criteria for “practicability” will include technical, human and economic factors, however, there is a well-established “hierarchy” effectiveness of control measures that employers and managers of workplaces are to follow. (See, for example, Industry Commission, 1995). These include elimination of the hazard; substitution by a hazard of lesser risk (such as a pesticide of lower toxicity); using an engineered control mechanism such as physical separation of the operator from the risk with closed transfer mechanisms during pesticide mixing and loading, and use of enclosed tractor cabins; administrative controls such as adequate required training; and the use of personal protective equipment

#### **5.8.3.3. Worker knowledge and skills training**

An underpinning requirement for safe application of pesticides in Australian agriculture is that all those who are engaged in application of pesticides have the necessary knowledge and skills to ensure that human exposure is limited to safe levels. Managers and employers need the knowledge and skills to manage risk, and operators need the knowledge and skills to operate safely and identify and communicate hazards. As an example, the short ChemCert® course in safe pesticides application (further described in Chapter 8), has been well accepted by farmers and farm workers as providing basic skills for pesticides applicators.

More recently, Farmsafe Australia has produced commodity-specific on-farm management tools and training for the major agricultural product enterprises. These aim to provide the necessary guidance for the implementation of safe systems of work, including pesticides application, for farmers and employers. Delivery of training is administered through a network of State Farm Safety Training Centres and licensed instructors.

#### **5.8.3.4. Access to product information**

A further underpinning requirement for effective risk control is access to relevant product information. This is required by employers and managers of workplaces including farms and other enterprises undertaking pesticide applications, by workers, and by farm advisers including agronomists who work closely with plant production systems. The information required to achieve greatest safety for workers and others in the workplace includes:

- Toxicological information – nature and severity of health effects of exposure
- Effectiveness of control options
- Alternative products/ methods to achieve similar pest control and their relative costs

There is a well-established contract industry for certain sheep husbandry tasks that include dipping and jetting, mulesing and lamb marking – all of which use pesticides designed to control ectoparasites, and thus place such contract workers at risk of exposure on a daily basis. Recently released summary documents relating to use of

diazinon (NRA, 2000) and of chlorfenvinfos (NRA, 2000) do not include such contractors' use patterns in descriptions of use patterns considered in the assessment process. Such a situation poses the question for contractors as to whether the safety directions on the labels are adequate for this category of workers to be confident of protection. (It may be noted that the US EPA announced in December 2000 a ban on indoor use of diazinon from March 2001, with a phase-out by 2004 of outdoor applications.)

Toxicological information is included in product Material Safety Data Sheets, although the standard of information provided is variable in both content, format and language.

#### **5.8.3.5. Health surveillance**

Health surveillance is the monitoring of workers in order to identify changes in health status due to exposure to hazardous substances in the course of their work. OHS legislation require that employers arrange health surveillance of workers where "there is significant risk of health effects" from exposure to hazardous substances, and where there is a valid technology to detect these effects.

Health surveillance requires consultation with a medical practitioner who authorizes the collection of relevant pathology testing, interprets results and recommends to employers and workers action to be taken in relation to results obtained.

Organophosphate pesticides are included in the Schedule of Hazardous Substances for which health surveillance through monitoring of blood and serum cholinesterase levels is required. The following practical difficulties in implementation of this provision of OHS law as it relates to organophosphate use in agriculture and horticulture (Smith, undated) can include

- absence of a clear guideline to provide guidance as to what is "significant risk to health".
- Access to rural medical practitioners who have the required competency to undertake OHS health surveillance, is difficult
- Difficulty for workers to present for blood testing at a time that is optimal for finding lowered plasma levels because both blood sampling and laboratory facilities can be limiting.

A joint NOHSC/ NRA project "Simplifying the safe use of farm chemicals", has been undertaken by Worksafe Australia to address the complexities of safe use of pesticides and to provide practical advice to farmers and farm workers.

#### **5.8.3.6. Compliance**

The OHS Acts in all states and 'control of use' legislation include provisions for prosecution and penalty for failure to comply with requirements that protect the safety of workers and others in the workplace.

Incentives for the institution of "best practice" in safe use of pesticides in agricultural and horticultural enterprises are emerging through a number of quality assurance programs for food commodities. Farmsafe Australia is moving to develop an

accreditation scheme and to identify opportunities for financial incentives for institution of safe systems of work.

“Control of use” legislation administered by different agencies in different states through departments of health, agriculture, and environment is discussed in more detail in Chapter 7. Safe application within this framework requires adherence to label directions, including safety directions.

#### **5.8.3.7. Access to information**

Access to practical information regarding products and their safe use can be difficult given the wide number of agencies responsible for regulation of pesticides – NRA, work health authorities, Federal and state departments of Health, Agriculture, Land and Water Resources, environment authorities, and water authorities.

#### **5.8.3.8. Reports of exposure**

There is no formal system in Australia to monitor and report exposure of workers to pesticides. A small number of worker exposure studies have been undertaken in specific agricultural industry settings - cotton chippers (Clarke and Churches, 1992), horticultural industries (McMullen et al, 1993; Yeung *et al.* 1996), vineyard workers (Galvin et al, 1995), market gardeners (Thomas, 1988; McMullen, 1992; Parker and Bandara, 1995) and sheep handlers (NOHSC, 1997). Fragar and Franklin noted that while studies have revealed either evidence of exposure or breakdown of appropriate preventive strategies – use of personal protective equipment, or safe practice - most of these studies have faced extreme difficulty in achieving a representative sample of subjects, and each therefore must be considered to have in-built bias. They considered that that bias is likely to be towards the most informed and concerned section of each industry where exposure may be anticipated to be the least.

### **5.9. CONCLUSIONS - HEALTH**

**The Australian regulatory processes that assess pesticides for registration to ensure that the risks of potential to harm human health are minimised, are comparable to those of most advanced Western Countries.**

**NOHSC statistics show a declining trend in the frequency of workers compensation claims for injury and illness associated with agricultural chemicals. Industry pesticide management programs must aim to ensure the frequency of on-farm pesticide incidents and compensation claims continues to decline.**

**The food safety monitoring programs in place in Australia are impressive by international standards, and compare favourably with similar studies undertaken in the United States of America and the European Union. There has been a consistent demonstration of very low levels of pesticides and contaminants in Australian diets. Results from Australia’s monitoring programs provide assurance that levels of pesticide residues in Australia’s food chain do not raise human health concerns.**

**However, to provide continuing assurance to Australian food consumers and export customers, the need to continue to monitor residue levels of chemicals that can enter the food chain is supported.**

**One key issue that has emerged from the collation of residue information and reflected in community concerns, has been the difficulty in securing access to timely and accurate information about residue monitoring programs and their outcomes. Awareness should be increased of the web-based technology already being introduced to provide this information, with added appropriate links to overcome these concerns.**

**The legislative requirements to protect manufacturing workers and farm applicators from exposure to pesticides are complex and overlapping and some aspects of practical information required to ensure compliance are lacking. Consideration should be given to developing a system of formal reporting of workers' exposure to pesticides.**

**There should be continued investment in studies on occupationally-exposed subjects to identify any developing associations between pesticide exposure, including mixtures and/or their adjuvants, and long-term health effects.**

**Improved, more comfortable personal protective equipment that recognises the characteristics of the Australian environment and climate would facilitate greater acceptance by users of the need to ensure this equipment is used when handling pesticides.**

**There is no adequate system for reporting acute health effects of pesticides. It is recommended that an Adverse Health Effects Register be established**

## **6. PESTICIDES IN THE AUSTRALIAN ENVIRONMENT**

A range of toxicity standards have been defined for mammals, birds and aquatic organisms. Assessment of hazard and risk is important with respect to possible environmental impacts of pesticides. There have been few ecological risk assessments in Australia. Endosulfan, perceived to present the greatest risk to catchments, has been progressively declining in surface waters. Organochlorines, withdrawn 20 years ago, can still occasionally be detected. Any groundwater pesticide contamination has been generally of triazines but found less frequently than overseas. Pesticide residues have been recorded in Australian biota near some areas of intensive agriculture. There have been examples of off-target damage to other native flora and fauna species and other crops recorded from use of some pesticides. Monitoring the impact of pesticide use on the environment, including on organisms and ecosystems rather than just measuring concentrations, could be better structured between the Commonwealth and the States.

### **6.1. THE CHARACTERISTICS AND IMPACTS OF PESTICIDES**

This chapter focusses on the environmental effects of pesticides. Despite the widespread application of pesticides, there is limited understanding of their transport, degradation and environmental impacts in Australia (Schofield & Simpson 1996). Standard tests are used to evaluate the impact of pesticides on organisms in the environment. Overseas fate and transport studies are not directly transferable to Australian ecosystems, although most overseas toxicity data can be used for risk estimates (Johnston *et al.* 1990; Holland 1999).

#### **6.1.1. Pesticide toxicity in the environment**

The toxicity of chemicals varies greatly with their intrinsic properties, the species being studied and factors in the environment. Important factors that influence the impact of a pesticide on the aquatic environment are: (a) its persistence; (b) the partitioning of the pesticide between the particulate and aqueous phases; (c) its toxicity to aquatic organisms; and (d) its tendency to bioaccumulate. By definition, all pesticides are toxic to some forms of life. Many modern pesticides are developed to be as selective to target organisms as possible, but it is rarely possible to achieve perfect control of one organism without the wider environment being exposed and susceptible non-target species being affected. Different classes of pesticides often show general patterns for toxicities. For instance organophosphorus (OP) and carbamate pesticides are usually more toxic to invertebrates than to fish, but their toxicities to fish can vary from one species to another (WHO 1986). Synthetic pyrethroids generally have low toxicity to mammals and birds but are highly toxic to fish and invertebrates. Modern insect growth regulators target moulting sites in both target and non-target invertebrates. Most rodenticides have high mammalian toxicity, by design. Many (but not all) herbicides have low toxicity to fish and invertebrates.

### **6.1.2. Toxicity classification**

Toxicity classification schemes can assist users in making sense of the many and varied toxicity figures and to provide some overall indication of the broad toxicity class of groups of chemicals. Kamrin (1997) describes the US Environmental Protection Agency toxicity classification schemes for rating the relative toxicity of pesticides to different groups of organisms. These classifications will assist in interpreting toxicity data, and have generally been adopted for screening of new chemicals in Australia (Worksafe Australia & NICNAS 1991).

Acute lethal toxicity is usually measured as the median lethal dose (LD50) or median lethal concentration (LC50), which is the dose or concentration of the test substance that kills 50% of test organisms within a given time period. Chronic toxicity is usually measured as the EC50, the concentration that causes a nominated effect to 50% of the organisms exposed within a given period of time, usually due to multiple or continuous exposures over several weeks, months, or years. There is a wide variety of chronic effect endpoints, of which mortality can be one. Both acute and chronic effects have the potential to affect populations and communities of organisms. Effects may be both direct (for example, death, impairment of growth or reproduction, loss of vigour, genetic impairment) and indirect (for example, depletion of food or oxygen supplies).

Laboratory toxicity tests are usually undertaken under controlled and reproducible conditions (Chapman 1995). However, LC50 or LD50 figures are not fixed immutable numbers but give a general indication of the toxicity under the specific tests conditions. Hence there can be wide variations in some test results from different laboratories, even on the same species (White & Champ 1983). There are similar variations in many tests for physico-chemical properties of pesticides. The most appropriate indication of the toxicities of individual chemicals is obtained by examining species distribution curves, as reported in ANZECC and ARMCANZ (2001).

#### **6.1.2.1. Mammals**

For mammals, acute toxicity is measured as oral (acute ingestion LD50) and dermal (skin LD50) toxicities over (usually) 14 days of exposure to the test substance (Kamrin 1997). The LD50 figures are expressed as the amount of the pesticide (usually in milligrams of active ingredient) applied per kilogram of test animal body weight. The inhalation LC50 is expressed as milligrams of pesticide or formulation in a given volume of air. The classifications of the toxicities of each test substance to mammals are as follows:

- **High toxicity** – Oral LD50: 0-50 mg/kg; Dermal LD50: 0-200 mg/kg; Inhalation LC50: 0-0.2 mg/L; Skin/eye irritation: “severe”.
- **Moderate toxicity** – Oral LD50: >50-500 mg/kg; Dermal LD50: >200-2000 mg/kg; inhalation LC50: >0.2-2.0 mg/L Skin/ eye irritation: “moderate”
- **Slight toxicity** - Oral LD50: >500-5000 mg/kg; Dermal LD50: >2000-20,000 mg/kg; Inhalation LC50: >2.0-20 mg/L Skin/ eye irritation: “slight”

Pesticides exceeding the upper limit of the range for slight toxicity are classified “*Practically non-toxic*” (Kamrin 1997).

### 6.1.2.2. **Birds**

Acute toxicity to **birds** is measured as either the oral LD50, (the amount of pesticide or formulation per kilogram of the test bird's body weight) or dietary LC50 (the concentration of the pesticide in the food eaten by the test bird (Kamrin 1997). To avoid confusion, the oral LD50 is expressed in units of milligrams per kilogram of body weight (mg/kg), and the dietary LC50 is expressed as parts per million (ppm) of feed. A similar classification of toxicity is given below for **birds** (from Kamrin 1997):

- **Very high toxicity** – Oral LD50: <10 mg/kg; Dietary LC50: <50 ppm.
- **High toxicity** – Oral LD50: 10 – 50 mg/kg; Dietary LC50: 50 – 500 ppm
- **Moderate toxicity** – Oral LD50: >50 - 500 mg/kg; Dietary LC50: >500-1000 ppm
- **Slight toxicity** - Oral LD50: >500 - 5000 mg/kg; Dietary LC50: >1000-5000 ppm

### 6.1.2.3. **Aquatic organisms**

Acute toxicity to **fish** and other aquatic organisms is expressed as LC50, the concentration that kills 50% of test organisms within a given period of time, usually 48 – 96 hours. Again, a similar classification of toxicity is given for **fish** (from Kamrin 1997):

- **Very high toxicity** – Acute LC50: <0.1 mg/L; chronic LC50: <0.01 mg/L (<10 µg/L).
- **High toxicity** – Acute LC50: 0.1 – 1 mg/L; chronic LC50: 0.01 – 0.1 mg/L.
- **Moderate toxicity** – Acute LC50: > 1 – 10 mg/L; chronic LC50: >0.1 – 1 mg/L.
- **Slight toxicity** – Acute LC50: >10 – 100 mg/L; chronic LC50: >1 – 10 mg/L.

The toxicity of chemicals to aquatic organisms may be influenced by water quality factors such as pH, temperature, total dissolved oxygen, dissolved or suspended organic matter and water hardness (ANZECC & ARMCANZ 2001).

Most pesticides are applied as proprietary formulations, which generally contain surfactant-like materials that act as wetting agents, solubilisers, droplet stabilisers and suspension aids, and which facilitate efficient and effective transfer to the target site or pest organism. The toxicity of the formulations may differ from that of the parent technical grade chemical. For instance, for the herbicide glyphosate, the commonly used Roundup® formulation was found to be between 3 and 42 times more toxic than the technical grade (Folmar *et al.* 1979). A low toxicity surfactant formulation (Roundup Biactive®) has been introduced to replace the common formulation for use near waterways (ANZECC & ARMCANZ 2001).

A number of factors common in the environment can modify the toxic response of organisms to pesticides by altering the bioavailability of the chemical, and hence altering the exposure of target tissues to the chemical. These factors include pH, temperature, water hardness, salinity, suspended particulate matter, dissolved organic matter and dissolved oxygen. The effects of these factors on aquatic toxicity of pesticides are generally not well understood.

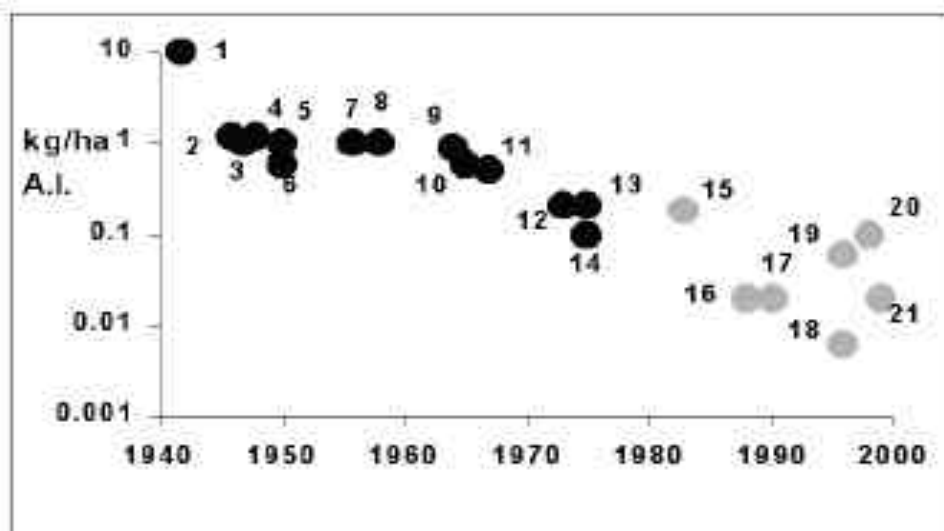
The more recently developed pesticides are generally applied at far lower rates of active ingredient. Analyses for data from the United States using only weight of

ingredients might suggest a dramatic reduction in pesticide being used over years in a particular industry (Figure 5, - note that the y axis has a log scale). Depending on the environmental properties of the pesticides, this may or may not reflect a desirable trend.

Figure 6 illustrates a comparison of the acute mammalian toxicity (oral LD50 for rats) with application volumes for the same insecticides illustrated in Figure 5. It shows that as insecticide application rates have fallen with the introduction of newer insecticides, there has also been a general trend towards lower mammalian toxicity. Mammalian toxicity is, of course, only one aspect of the environmental profile of a pesticide, but in this respect at least, it would appear that there are both qualitative and quantitative factors driving a trend towards more environmentally benign pesticide use.

**Figure 5**  
**Application rates for insecticides used in cotton in the USA, 1940-2000.**

Key to the insecticides in the graph: 1=calcium arsenate, 2=DDT, 3=parathion, 4=toxaphene, 5=diazinon, 6=endrin, 7=endosulfan, 8=carbaryl, 9=chlorpyrifos, 10=monocrotophos, 11=methomyl, 12=permethrin, 13=fenvalerate, 14=deltamethrin, 15=thiodicarb, 16=esfenvalerate, 17=beta-cyfluthrin, 18=abamectin, 19=bifenthrin, 20=spinosad, 21=fipronil.

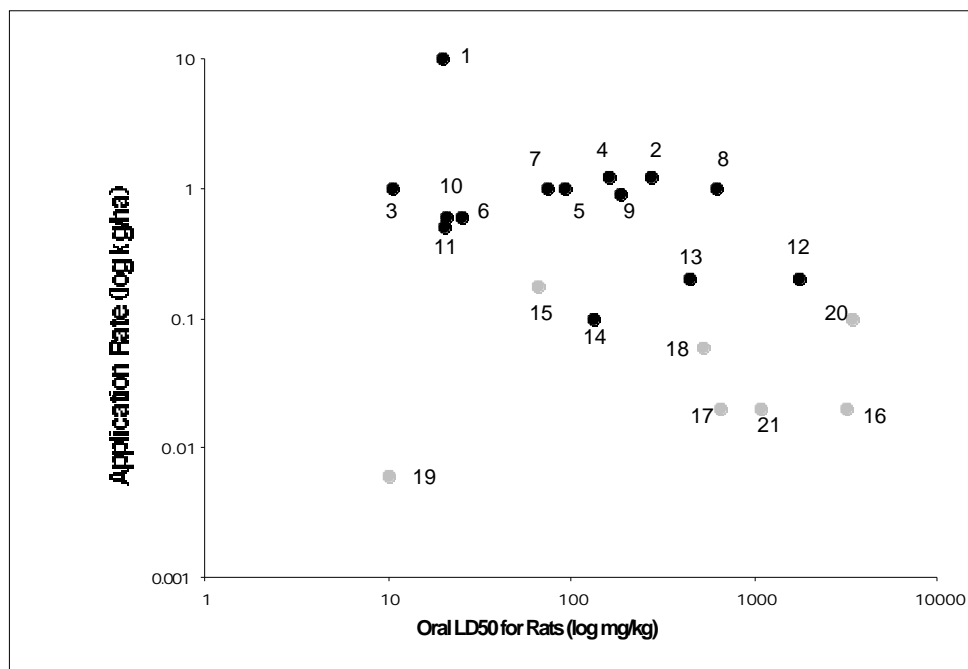


Source:- Metcalf (1986; dark points) and Shaw (2000 and previous editions; light points).



**Figure 6**  
**Mammalian toxicity of insecticides plotted against application volume on USA cotton**

(The dark and light points are early to recent insecticides as in Figure 5. Key to numbers is also the same as for Figure 5.)



Source:- (Metcalf 1986, Metcalf and Luckmann 1994, Shaw 2000).

### **6.1.3. Physico-chemical aspects of pesticides**

Physico-chemical information can be determined for pesticides, and is subject to the various test conditions.

**Degradation rates** in water or soil, particularly, should only be used for general comparisons between pesticides and should not be interpreted in an absolute fashion.

**Persistence** of a pesticide is measured as the *half-life* ( $t_{1/2}$ ), which is the time it takes for half of the initial amount of a pesticide to break down. Thus, if a pesticide's half-life is 30 days, half will be left after 30 days, one quarter after 60 days, one eighth after 90 days, and so on. Often a laboratory half-life test will focus on a particular chemical or biological loss process, such as volatilisation, hydrolysis, aerobic/anaerobic degradation or microbial degradation, whereas field dissipation studies integrate these factors as appropriate to the study site. If the half-life is less than 30 days, the pesticide is considered to be of *low persistence*; if 30 - 100 days it is *moderately persistent*; if greater than 100 days, it is *highly persistent* (Nowell *et al.* 1999).

The propensity of a pesticide to adsorb to soil is indicated by the **soil adsorption coefficient** (SAC). This coefficient varies with the chemical types but also depends on soil properties, such as pH, organic matter content and type, particle size

distribution and clay mineral composition (Kamrin 1997). The soil adsorption coefficients reported in the tables are usually the organic carbon partition coefficient ( $K_{oc}$ ), which takes into account the content of the organic matter in the soil. Where this is not available, the unadjusted observed soil adsorption coefficient,  $K_d$ , is reported in the tables.

A direct estimate of the **hydrophobicity** of a pesticide, or its partitioning tendency from water to organic media such as fats or organic matter in soils is measured by its n-octanol-water partition coefficient ( $K_{ow}$ ). This can be used, for example, as a measure of the likelihood of a pesticide becoming strongly associated with dissolved organic matter in the soil

#### **6.1.4. Hazard and risk assessment of pesticides**

Suter (1995) defines **ecological risk assessment** as “*the process of estimating and characterising the likelihood that adverse effects of human actions on the non-human environment will occur, are occurring, or have occurred*”. Ecological risk assessment can be more complex than human health risk assessment because of the greater number of species, levels of biological organisation, pathways of exposure, toxicological modes of action and indirect effects (Suter 1995). There is a distinction between hazard and risk. **Hazard** is the *inherent properties of a substance ... that make it capable of causing adverse effects*, whereas **risk** is the *likelihood (or probability) that the harm from a particular hazard is realised .... under specific conditions* (UNEP 1999). Two major components in evaluating the risk of chemicals to the environment are “**exposure assessment**” and “**effects assessment**” (Suter 1995; Bradbury 1995).

##### **6.1.4.1. Exposure Assessment**

The exposure part of the assessment can often be difficult because the chemicals can be used in a wide variety of environments and in different ways. For existing chemicals, the evaluations can use a combination of methods and information on usage patterns, data from programs that monitor the levels in air, water or soil, data on residues in organisms and exposure modelling techniques (Holland 1991; Raupach & Briggs 1998). For new chemicals, it is usually necessary to rely on chemical properties, projected use patterns and worst-case estimates of concentrations in air, water or soil.

##### **6.1.4.2. Effects Assessment**

The effects of pesticides on the environment are, in the first instance, evaluated using data from dose-response tests using laboratory animals. Animals are chosen to represent different environmental compartments (ie. air, water, soil etc) and groups of organisms. For instance, in the aquatic environment, the minimum data set for assessment of new chemicals includes toxicity data for a fish, a crustacean (eg. *Daphnia* spp), and an alga (OECD 1981). If more information is required on potential environmental effects, other species, additional endpoints (eg chronic data) or even mesocosm or model ecosystem data may be requested to enable better evaluation of the effects on ecosystems. The test organisms are just surrogates for the wide range of organisms in the environment. For aquatic organisms, the route of exposure is usually

by uptake from water through gills, although for a small range of chemicals, uptake from food can be significant. Terrestrial animals can be exposed by a number of routes, including food, air or skin contact. Hence, tests with mammals, birds and insects are generally designed to reflect each of these exposure pathways.

#### **6.1.4.3. Hazard assessment of new chemicals**

Various forms of predictive hazard or risk assessment are conducted on new pesticides to estimate the potential risks to different environmental components of the proposed uses of the pesticide (ECETOC 1992). The preliminary screening of new chemicals for environmental hazard undertaken by Environment Australia uses a quotient calculation to assess hazard to the environment (Curnow *et al.* 1993; Carruthers 1994), more recently updated in <[www.nra.gov.au/guidelines/nra 93193 pt7 ag.pdf](http://www.nra.gov.au/guidelines/nra%2093193pt7%20ag.pdf)> based on international guidance (Urban & Cook 1986; ECETOC 1992; Rodier & Mauriello 1993). This derives a *quotient (Q)* by dividing the *estimated environmental concentration (EEC)* by the most sensitive *toxicity figure* (eg. *LC50*) for the representative organism of concern (Carruthers 1994). If *Q* is greater than 0.1, further information and assessment is required.

For aquatic environments, the worst case scenario for calculation of the *EEC* is taken to be a pond of 1 ha in area and 15 cm in depth (ie. 1500 m<sup>3</sup> volume) with direct overspray at the highest proposed application rate (Curnow *et al.* 1993).

For soil environments, the *EEC* would be estimated after assuming an even mix of the chemical through the top layers of soil (Carruthers 1994). The depth of mixing would be estimated from the chemical mobility and the type of soil.

#### **6.1.4.4. Assessment of risk**

In some cases, and particularly for existing chemicals that may have a high hazard, there may be sufficient data to allow a full quantitative probabilistic risk assessment to be undertaken. There have been few instances reported in the literature of such risk assessments for pesticides.

It would be generally expected that modern pesticides that have first been assessed by the NRA process and are used appropriately and according to label directions should have little adverse impact on the environment. However, appropriate use will require the user to assess the risks of use at the specific site to manage any specific circumstances that may increase the risk of harm to the environment.

#### **6.1.4.5. Pesticide hazard assessments in catchments**

Batley and Peterson (1992) undertook a screening level risk assessment of pesticides in the cotton growing areas of north-west NSW, based on the mass applied per season over the region, half-life, acute toxicity and the octanol-water partition coefficient (*K<sub>ow</sub>*; Section 3.3). They identified endosulfan as the chemical of greatest potential risk, due to its widespread use, moderate partitioning into water and its very high acute toxicity to fish. Other high-risk pesticides were chlorpyrifos, cypermethrin, lambda-cyhalothrin, fenvalerate, methomyl, profenofos and parathion. These rankings are based on assumptions that environmental risk is highest in compounds that have a low *K<sub>ow</sub>*, ie. where the proportion in the water phase is high. For example, methomyl had relatively high risk ranking because 99.9% is distributed into the water phase, it

has high toxicity and relatively long half-life. The methodology might not sufficiently account for toxicity of pesticides attached to particles (Bowmer 1993).

Under the *Water Board (Corporation) Act 1994*, Sydney Water was required to undertake preliminary ecological risk assessments, covering almost 120 individual chemicals, of their sewage effluents that discharge to ocean and to the Hawkesbury-Nepean and Georges River systems (Sydney Water 1995). The initial assessment is a screening level risk assessment using a quotient method, followed by more detailed assessments for higher-risk chemicals. This was followed by confirmatory toxicity tests on pre-chlorinated effluent using a suite of appropriate test organisms (Sydney Water 1996a, b). A significant number of effluents were toxic and toxicity characterisation tests confirmed that OP pesticides were the main contributors to effluent toxicity (Bailey *et al.* 2000a,b).

Kookana *et al.* (1998a) developed a “**Pesticide Impact Ranking Index**” (PIRI) to rank pesticides in terms of their relative potential to contaminate groundwater and surface waters, and also to compare different land uses in a catchment or region in terms of their relative impact on water quality. The index is based on a risk assessment approach developed by Correll and Dillon (1993) and estimates the “detriment” of a pesticide, as follows:

$$\text{Detriment} = \text{Value} \times \text{Pesticide load} \times \text{Transport function}$$

Each water body is given a *value* score of 1 to 100, based on its size, uses, human health considerations, ecological importance and alternative sources. The *pesticide load* is based on the total amount used, estimated from area of crop (*Area*), proportion using pesticides (*p*), frequency of application (*f*) and dosage of active ingredient (*d*). A toxicity component (eg. LC50 or “Health effect level”) and a persistence component ( $t_{1/2}$ ) is also included. For surface waters the *pesticide load* is calculated as follows (Kookana *et al.* 1998a):

$$\text{Load} = \text{Area} \times \frac{t_{1/2} \times f \times d \times p}{\text{Pesticides LC50}}$$

The *Transport function* uses equations for transport to groundwater (which includes  $t_{1/2}$ ), to surface water *via* runoff, soil erosion and drift, and to air. The PIRI program uses limited toxicity data on rainbow trout but it can conceivably use much larger databases such as in ANZECC and ARMCANZ (2001). There are further details of PIRI at [www.cmis.csiro.au/Envir/Research](http://www.cmis.csiro.au/Envir/Research).

The index was applied to the cotton-growing areas of eastern Australia resulting in ranking of endosulfan, phorate and profenofos as high risk to surface water, and aldicarb, chlorpyrifos and dimethoate as medium risk. PIRI was also used to estimate the risk to groundwater of vegetable production. Fenamiphos had the highest risk, due to its high toxicity, long  $t_{1/2}$ , high application rate and low *Koc* (100). Metham was ranked second, because of low *Koc* and high application rate, but it degrades rapidly (Kookana *et al.* 1998a). The authors stressed the importance of the relative ranking score for a particular area, rather than any absolute figure.

Some recent trends in risk assessment are cause for some concern. Power and McCarty (1998) compared risk assessment guidelines from a range of countries and noted a "trend towards greater stakeholder involvement [and] decreased emphasis on quantitative characterisation of risk and uncertainty". Burgman (1999) expressed concern at this trend, as reflected in the qualitative risk assessment procedure recommended as an Australian Standard (AS/NZS 4360 1999). Qualitative analyses are flawed in that they depend on subjective estimates of risk that fly in the face of research on cognitive psychology (Burgman 1999), ie. subjective estimates are notoriously inaccurate, even when undertaken by experts in the field. Quantitative risk analysis uses formal mathematical tools to estimate risk and uncertainty and is subject to "rigorous, repeatable analytical protocols" (Burgman 1999). Pre-registration assessments for pesticides are undertaken in a formal and quantitative manner but, in contrast, some of the pesticide alternatives, such as genetically manipulated organisms (GMOs), may be assessed by qualitative and subjective self-assessment (Burgman 1999).

#### **6.1.4.6. Towards probabilistic risk assessment in catchments**

There have been few ecological risk assessments carried out at the regional scale and methods are still being developed and tested (Graham *et al.* 1991; Landis & Wieggers 1997; Parkhurst *et al.* 1997; Travis & Hendley 2001). The CRC for Freshwater Ecology is currently developing a catchment-based risk assessment for part of the Murray Darling Basin of eastern Australia (M.Grace; CRC Freshwater Ecology, pers. comm.).

### **6.1.5. Factors affecting the fate of pesticides in the environment**

#### **6.1.5.1. Physical, chemical and biological properties**

Environmental processes that affect the fate of pesticides in the environment waterways may be categorised as *phase-transfer* (ie. between environmental compartments), *transport* or *transformation* processes (Nowell *et al.* 1999).

The behaviour and fate of a pesticide within any environmental compartment (ie. air, water, soil, sediment, biological tissue) is controlled by the physical, chemical and biological properties of the pesticide and by the environmental conditions of the compartment, including biological activity.

The type of data required to evaluate a new pesticide in Australia for its potential hazard (OECD 1981) reflect those factors that directly affect the exposure of organisms to pesticides and their susceptibility to toxic effects. These data include: the amount of chemical used; formulation (eg. liquid, emulsifiable concentrate, ultra-low volume, powder, granules etc); mode of use (eg. ground spray, aerial spray, baits, injection etc); hydrolysis; photodegradation; biodegradation in water and soil; mobility in soil (eg leaching); volatility; adsorption/desorption and field data on dissipation in soil, water and plants (Carruthers 1994). The physical and chemical properties of a pesticide indicate how it will move in the environment and in which environmental compartment it will end up. For instance, pesticides with low water solubility, high octanol-water partition coefficient ( $K_{ow}$ ) and high persistence will be more strongly associated with dissolved organic matter, particulate matter, sediments

or biota (Nowell *et al.* 1999). Soluble pesticides are more easily transported with rainwater as runoff or leach into groundwater.

Properties of surface waters, such as chemistry, acidity, depth, temperature, suspended matter, biological activity and flow rate affect pesticide behaviour and fate (Kamrin 1997). Suspended matter is particularly significant in the turbid rivers and billabongs in the cotton growing areas of eastern Australia but the interactions with suspended material and effects on aquatic toxicity are not well understood. Any amelioration of toxicity due to high suspended material is most likely due to binding of the chemical to the particles. For example, most pyrethroids adsorb strongly to suspended matter and biological surfaces within a few hours and settle in bottom sediments, leaving only very low concentrations dissolved in the water column (Hill *et al.* 1994). Adsorption to plants and loss from surface films by evaporation can also increase the rate of loss of pyrethroids. Surface films may increase exposure for some surface-feeding species, such as some water fleas. Temperature is an important environmental factor that can modify the toxicity of chemicals to aquatic life (Cairns *et al.* 1975). LC50 values for many chemicals change by a factor of between 2 and 4 for each 10°C change in temperature (Mayer & Ellersieck 1988). Patra (1999) has determined temperature-toxicity relationships for some chemicals with Australian species. Sediment characteristics, such as grain size, organic matter, metal content, acidity, influence how a pesticide behaves in sediment.

The fate and behaviour of a pesticide in soil is governed by a variety of complex and dynamic physical, chemical, and biological processes. Those affecting transfer between phases include volatilisation, uptake by plants, surface runoff, leaching and the nature and properties of both the chemical and the soil. The content and type of organic matter and clay minerals are the principal soil constituents governing adsorption of pesticides in soils, and the partition coefficient (*K<sub>ow</sub>*) of the pesticide is the main chemical factor (Kookana *et al.* 1998b).

Depending on the chemical properties, a pesticide that is adsorbed to soil or suspended or bottom sediment may desorb to become mobile in the water and available to aquatic organisms, or be bioavailable directly from the suspended particles. Strong winds and increased stream discharge can resuspend and transport sediment and remobilise pesticides. Sorption of ionic pesticides, such as simazine, chlorsulfuron, triasulfuron and strychnine, in Australian soils decreases with increasing pH (Kookana *et al.* 1998b). Agronomic management practices such as liming and fertilisation can result in relatively abrupt changes in soil pH and consequently affect the behaviour of some pesticides adsorbed to soils (Kookana *et al.* 1998b).

#### **6.1.5.2. Pesticide movement**

Pesticides move into the atmosphere by spray drift, volatilisation or wind erosion. The persistence of a pesticide in the atmosphere depends on how efficiently it is removed by either deposition or chemical transformation. Once pesticides move into the upper atmosphere, they may be transported regionally or possibly globally by the global wind circulation patterns and can be deposited in remote locations (Nowell *et al.* 1999). Pesticides may eventually be deposited in higher latitudes, particularly polar regions. It is of some concern that persistent organochlorines are still being used in developing tropical countries (Iwata *et al.* 1994), resulting in translocation to Polar

regions and contamination of Antarctic mammals. This issue is beyond the scope of this report.

Pesticides may contaminate surface-water bodies directly through overspray or volatilisation from pesticide applications, through careless use or disposal of pesticides, or from urban waste disposal. Indirect contamination can occur through runoff or groundwater flows from contaminated agricultural and urban lands (Hunter 1992).

Irrigation is one of the most important agricultural management practices affecting pesticide transport into water and subsequent accumulation in sediment and aquatic organisms (Nowell *et al.* 1999). Pesticides are usually transported in runoff dissolved in the water, as small undissolved particles, dissolved in humic material, or adsorbed onto eroded soil particles and organic matter (Willis & McDowell 1982). Pesticides adsorbed to very fine particles may be transported in almost the same manner as soluble pesticides and may in fact be as bioavailable (Peterson & Batley 1993). Sorption of pesticides such as endosulfan onto particulate matter is an important mechanism in their transport, cycling and bioavailability in aquatic ecosystems (Hart 1983; Connell & Miller 1984; Nowell *et al.* 1999).

Pesticides applied directly to the soil or injected into the soil may be transported into nearby bodies of surface water, may volatilise, be carried on dust particles by wind, or may percolate through the soil to lower soil layers and groundwater (Kookana *et al.* 1998b).

A number of processes assist the leaching of pesticides into groundwater (R. Kookana, CSIRO, pers. comm.). For instance, with increasing depth through the soil profile, organic matter and biological activity may decrease. Pesticides may be carried by preferential flow through macro-pores, fissures, cracks, root and worm channels. Colloid matter, such as clays or dissolved organic matter can sometimes assist transport to groundwaters (Kookana *et al.* 1998b). Tillage practices in which the mechanical manipulation of the soil is either reduced or eliminated completely reduce inputs of pesticides to surface waters by reducing soil erosion, but may increase the infiltration of some pesticides into groundwater (Nowell *et al.* 1999). This is because such practices often depend on increased herbicide applications and may facilitate development of cracks and pore networks (R. Kookana, CSIRO, pers. comm.).

#### **6.1.5.3. Transformation processes**

Pesticides released into the environment may be broken down or degraded by the action of sunlight, water, chemicals or microorganisms such as bacteria. The properties of the environment affect how fast a pesticide degrades, as does the pesticide concentration and physico-chemical properties. Hydrophobic pesticides are transformed very slowly in soil but the rate of degradation may increase once the pesticide enters the aquatic system (Nowell *et al.* 1999).

The older organochlorine pesticides are very persistent and are still detected in soil, sediment or biota many years after their use was withdrawn. (Nowell *et al.* 1999). Kamrin (1997) listed pesticides with **high persistence in soil** ( $t_{1/2} > 100$  days), including bromacil, chlordane, DDT and residues, lindane, paraquat, picloram and

trifluralin. Those with **low persistence** ( $t_{1/2} < 30$  days) included aldicarb, captan, malathion and methyl-parathion. Pesticides with **intermediate persistence** included atrazine, carbaryl, carbofuran, diazinon, glyphosate, heptachlor, parathion and simazine. Changes in pH can alter the rate of degradation of some pesticides. For instance, the breakdown rate of endosulfan increases in acidic waters, whereas for OP pesticides and the pyrethroid deltamethrin, degradation is faster in alkaline waters (Tomlin 2000). Soil properties that affect microbial activity, such as type and content of organic matter and clays present, and soil temperature and moisture, also affect the rate of pesticide degradation. Frequent use of some pesticides may result in a build-up of micro-organisms in soil, which can enhance degradation of these pesticides (Kookana *et al.* 1998b).

The uptake of pesticides by plants is not well understood but it is recognised that the plant rhizosphere can degrade and transform some pesticides, and **phytoremediation** may be a useful technology to detoxify diffuse, low levels of pesticide contamination (Cunningham & Ow 1996).

The chemical properties of **metabolites of pesticides** may be sufficiently different from the parent compound to affect their fate and transport. Pesticides usually degrade to less harmful breakdown products, but in some cases more toxic products can be produced (Kamrin 1997), which may maintain or even exacerbate the potential hazard to environment. Some organophosphorus and carbamate pesticides may degrade into more toxic compounds. The more persistent identified metabolites require evaluation in the registration process for new chemicals and review of existing chemicals.

#### **6.1.6. Pesticide contaminants in organisms**

Aquatic organisms may take up pesticides by diffusion through surface membranes (eg. gills), from water, by ingestion of contaminated food or particles, or by direct contact with sediment. Once the pesticide is taken up by living organisms, it can be stored in tissues, metabolised or excreted (Nowell *et al.* 1999). Contaminated fish may be consumed by both wildlife and humans, thus moving the contaminant up the food chain, and with possible reintroduction into the terrestrial environment.

**Bioaccumulation** in an organism occurs when uptake of a chemical exceeds its elimination, and results from a dynamic equilibrium between exposure from the outside environment and uptake, excretion, storage, and degradation within an organism (Kamrin 1997). In aquatic organisms, bioaccumulation is affected by properties of the chemical, biological factors and environmental conditions. Important chemical properties include its concentration, solubility in fat (lipid) and water, resistance to degradation and molecular size and weight. It appears that large molecules with high molecular weight are not efficiently transferred across gill membranes, although fish can assimilate them from food (Nowell *et al.* 1999). Biological factors include fat content, species, body size, age, sex, reproductive state, metabolic capability, growth rate and gill ventilation rate (Nowell *et al.* 1999; Jarvinen & Ankley 1999). Environmental conditions include temperature, pH, salinity, concentrations of dissolved organic matter and particulates and degree of water oxygenation. Oxygen concentration may affect uptake rates by influencing the ventilation volume of water passing over the gills. For air-breathing vertebrates such as sea birds, seals and whales, contaminants tend to increase in concentration by



**biomagnification** up the food chain. Biomagnification usually occurs for compounds of high tendency to dissolve in fat, high persistence, and low water solubility. In contrast, autotrophic organisms that draw their food from dissolved components in water take chemicals up by **bioconcentration**. For intermediate organisms, both mechanisms probably occur, with their relative importance depending on the organism, the chemical and other factors (Nowell *et al.* 1999).

Contaminant content changes during growth and development and tends to vary with age, body size and seasonal factors. Interspecies differences among contaminant residues are attributed to differences in feeding habitat, lipid content, metabolic capability, habitat and trophic level (Nowell *et al.* 1999). The ratio of gill area to body weight of fish changes with size, suggesting that small fish may accumulate hydrophobic chemicals more rapidly. Seasonal temperature changes can affect bioaccumulation by altering biological factors such as lipid content and chemistry, the reproductive cycle, food supply or feeding activity, growth rates, filtration rates, oxygen uptake, metabolic rates, enzyme activity, migration and population changes (Nowell *et al.* 1999). Seasonal variations in residues also depend on the species of organism, including its body size, habitat and trophic level, reproductive cycle, and life span. Other seasonal changes influence the accumulation of pesticide residues in sediment and aquatic organisms, such as agricultural management or water-management practices, weather-driven events and environmental conditions.

The rate of elimination is a critical factor in determining whether or not a chemical will accumulate in an organism. When exposure ceases, the body gradually metabolises and excretes the chemical. Contaminant elimination from an aquatic organism occurs by biotransformation (metabolism); by excretion via the gills, skin, urine or faeces; or by growth dilution (Nowell *et al.* 1999). Organism growth, although not strictly an elimination process, causes the contaminant concentration in an organism to decrease as the body mass of the organism increases. Prior exposure to chemical contaminants can induce enzymes that result in increased metabolism and elimination and hence reduced bioaccumulation. When fish are exposed to multiple chemicals, uptake of one chemical may be influenced by another (Nowell *et al.* 1999).

## **6.2. PESTICIDES IN THE AUSTRALIAN ENVIRONMENT**

### **6.2.1. Pesticides in Australian surface waters**

#### **6.2.1.1. Cotton growing areas in eastern Australia**

Raupach and Briggs (1998), as part of a study of pesticides in the cotton growing areas of eastern Australia, used modelling to identify the relative roles of airborne pathways (spray, vapour and dust) and waterborne pathways (runoff) in transporting endosulfan from cotton farms to the riverine environment. They concluded that:

- Runoff-pathway events are large and infrequent;
- Airborne-pathway events are smaller in magnitude, than runoff events but act almost continuously, resembling a 'steady drizzle';
- Of the airborne pathways, spray drift and vapour transport are of similar magnitude, but dust transport is negligible; and

- Most of the observed riverine endosulfan is transported by airborne routes, as the large but infrequent runoff-pathway events are flushed away rapidly. However, endosulfan attached to suspended particles during storm runoff appears to be having a significant biological effect (Leonard *et al.* (1999, 2000).

Irrigation runoff waters in the north-west cotton growing areas of NSW are retained within the farming boundaries in normal operations. Any direct escape of farm runoff water to the river or wetlands within months after spraying will lead to significant environmental contamination (Kennedy 1999). Muschal and Warne (2001) determined the hazard and risk posed to riverine organisms from pesticides. They used monitoring data from the *Central and North Western Regional Water Quality Program*, which is run by Department of Land and Water Conservation, NSW, in collaboration with water users of the Basin. These data are considered the most comprehensive data set on pesticides in a riverine environment in Australia (Kookana *et al.* 1998a; Schofield 1998). Data from the Macintyre, Gwydir and Namoi rivers were compared against ecotoxicology data from ANZECC and ARMCANZ (2001). The preliminary screening indicated that eight of 30 chemicals monitored at 31 sites were likely to pose potential problems. Further analysis indicated that four out of 30 chemicals, endosulfan, chlorpyrifos, profenofos and diuron, could pose an unacceptable hazard to the environment. Interpretation of the total risk was limited by the lack of environmental data available for the less common chemicals. The study focussed on the period when the most agricultural pesticides were used on cotton. Sites at the bottom end of each catchment had the greatest agrochemical contamination with high levels of endosulfan, atrazine and other pesticides.

Since 1993-94, levels of endosulfan in surface waters in these rivers have generally declined; 89% of samples exceeded 0.01 µg/L in 1993-94, 63% in 1996-97, 65% in 1997-98 and 53% in 1998-99. During the summer of 1999-2000, 29% of samples for endosulfan exceeded 0.01 µg/L (Muschal 2001). Only 10% of samples exceeded the revised ANZECC & ARMCANZ 2001; 99% protection standard figure of 0.03 µg/L. Results from a QDPI testing program on the Condamine-Balonne river system showed no endosulfan at any weir along the 1300 kilometres of river to the New South Wales border. While it was generally a dry season, the chemical was not detected even after storm run-off events (AFFA 2001).

In 1999-2000 atrazine exceeded the guideline level for 99% ecosystem protection (0.07 µg/L) in 8% of samples (Muschal 2001). Overall, concentrations of atrazine in north-western NSW surface waters ranged from below the analytical detection limit to 10 µg/L, with some isolated peaks up to 20 µg/L during storm events. These were low compared to overseas results (Boey & Cooper 1996).

The herbicide diuron exceeded the irrigation water guidelines (2 µg/L: ANZECC 1992) for 15% of samples in 1997-98 (Muschal 1998). Diuron has been detected frequently in surface waters of the Murray-Darling Basin, usually at concentrations between 0.2 and 3 µg/L (Boey & Cooper 1996).

In total, six insecticides and nine herbicides (including breakdown products of atrazine) have been detected in surface water samples since 1991. The insecticides are amitraz, chlorpyrifos, parathion methyl, dimethoate, profenofos and propargite; the herbicides are desethyl atrazine, diuron, fluometuron, hydroxy atrazine, metolachlor,

pendimethalin, prometryn, simazine and trifluralin. Trends in pesticides detection over the years 1991-2000 indicated that amitraz, parathion-methyl, dimethoate and trifluralin were not detected in 1999-2000, while being detected in previous years. Profenofos appeared to have peaked in 1998-99. The herbicides desethyl atrazine, diuron, fluometuron and metolachlor appear to be on a continuing upward trend.

A Best Management Practices (BMPs) Manual, which includes issues such as farm design, pesticide application, management of tail-water, pesticide storage and handling, hazard assessment and integrated pest management, has been developed by the cotton industry (CRDC 1997; Anthony 1998). It is possible that reduced endosulfan levels in 1998-99 were due in part to the hot dry summer, which would have limited the transport of chemicals by storm or tailwater runoff, and would also have increased degradation of endosulfan (Muschal 2000). The detection of endosulfan residues in cattle in early 1999 indicated that the level of spray drift occurring during that time of exceptionally high pest pressure was unacceptable. It is likely that the BMP and the restrictions placed on endosulfan applications during the 1999-2000 season (NRA 1999a) have further reduced the endosulfan levels (Muschal 2001).

Storm events can substantially increase both the concentration and load of pesticides in storm surface waters. Significant loads of atrazine were transported off dryland cotton farms in the Namoi catchment during a 24-hour storm event in July 1993 (Preece *et al.* 1993). Cooper and Riley (1996) measured the storm transport of pesticides from dryland cotton production into Cox's Creek in the Liverpool Plains of NSW in January 1995. The high stream flow lasted for over three days and was associated with high turbidity. The loads of atrazine and endosulfan exported in the storm were relatively low, reflecting the lower usage due to drought, but peak concentrations were 2.25 µg/L of atrazine and 0.045 µg/L of endosulfan. It is significant that atrazine had not been used for around 12 months. In another storm monitored in January 1997 on the Gwydir River, Muschal (1997) detected alpha- and beta-endosulfan, endosulfan sulfate, atrazine, diuron, fluometuron and prometryn. The levels of diuron (24 µg/L) and fluometuron (9 µg/L) were particularly elevated, and total endosulfan reached 1.75 µg/L.

#### **6.2.1.2. Irrigation areas in south-western NSW**

Large quantities of herbicides are applied to the irrigation areas of south-western NSW for the growing of rice. The total quantities of molinate applied each season (>100,000 kg in Murrumbidgee Irrigation Area alone) far exceed any other herbicide mostly in spring and early summer. Bensulfuron-methyl is also commonly used on most rice crops, while other herbicides used for general weed control and seedbed preparation include glyphosate, diquat, paraquat, atrazine and diuron (Bowmer *et al.* 1995).

Bowmer *et al.* (1995) reviewed and reported on the pesticide monitoring that has been carried out in these irrigation areas. Supply water from the rivers was of high quality and generally few pesticides were detected. Just a few channels contained low levels of atrazine (0.08 µg/L & 0.2 µg/L); endosulfan sulfate (0.02 µg/L); molinate (7.2 µg/L & 0.5 µg/L); and 2,4-D (0.5 µg/L). Water supplying farms in the Willbriggie district, which had been mixed with MIA drainage water, contained higher

concentrations of some pesticides and more frequent detections. Molinate was detected in 90% of samples over 55-days in spring and early summer, up to a maximum concentration of 3.6 µg/L and atrazine in 20% of samples, up to 0.35 µg/L. The only insecticides detected were malathion (0.06 µg/L) and chlorpyrifos (0.05 µg/L).

Pesticide residues were detected in water from the large drainage channels that received runoff from a variety of crops, particularly in spring and summer (Bowmer *et al.* 1995; Korth *et al.* 1995). Molinate was detected in most drains during its application season, and levels often exceeded guidelines both for drinking water and protection of the aquatic environment. Other pesticides commonly found to exceed guidelines current at the time included diuron, atrazine, endosulfan, chlorpyrifos and malathion. Thiobencarb, metolachlor, bensulfuron methyl, diazinon and MCPA were found less frequently, although sometimes at excessive levels. Water samples collected from surface drainage in Coomealla Irrigation Area in 1993-94 and nearby lakes did not contain detectable herbicides or insecticides.

Sub-surface water from tile drains was monitored for bromacil and diuron at 49 horticultural farms in the MIA in January, May and August in 1992. Drains in around 28% of the farms contained detectable levels of both bromacil and diuron and an additional 10% of the farms showed detectable levels of either compound. Investigation of on-farm management practices indicated that any farms using these herbicides to control weeds were likely to have detectable levels of these compounds in their sub-surface drainage water.

#### **6.2.1.3. Victorian waterways**

Chapman and Stranger (1995) found that water quality was generally good in horticultural areas in the Gippsland area of Victoria in 1994. Where pesticides were detected (in 4 of 5 growing areas), levels were generally below current guidelines. Concentrations in surface water of pesticides currently used in vegetable production exceeded the guidelines available at the time (usually ANZECC 1992) at only two of 21 sites. Triazine and urea herbicides were common in drains: atrazine was found up to 4.9 µg/L (Orbost), simazine up to 1.4 µg/L and diuron up to 4.8 µg/L (both at Koo-wee-rup). However some herbicides were found in a few stream samples: atrazine was found at Rosebud and Bairnsdale (0.14 – 3.2 µg/L); metribuzin (0.15 – 0.28 µg/L) at two locations; simazine at Bairnsdale (0.61 µg/L). Endosulfan (up to 0.04 µg/L) and chlorpyrifos (0.002 µg/L) were also detected in streams at Bairnsdale. Some detections of DDT (up to 0.017 µg/L) and dieldrin (up to 0.02 µg/L) reflected historical use.

#### **6.2.1.4. Tasmanian waterways**

In Tasmania, Davies *et al.* (1994) detected residues of triazine herbicides, atrazine and simazine, in 20 out of 29 streams sampled that drained forestry and agricultural catchments in Tasmania between 1989 and 1992. The forestry spraying was carried out by helicopter with relatively high application rates. Concentrations of herbicides ranged over several orders of magnitude; the highest concentration of atrazine was 53 mg/L (53 000 µg/L) and of simazine, 478 µg/L. Atrazine residues decreased with time after spraying; from a median of 8.1 µg/L on the day of spraying to a median of 0.3 µg/L around 13-15 months later. However, rainfall runoff caused significant but

transient atrazine concentrations in streams, even after 13-15 months, with median values up to 2.0 µg/L. The lower water solubilities of atrazine and simazine, compared to the other triazine herbicides, contribute to their greater persistence in water. The typical half-life of atrazine in these Tasmanian streams was around 3 months. Streams draining forestry land generally contained more pesticides than agricultural streams due to differences in methods of pesticide application, time of application and the nature of the chemicals. However, some agricultural streams contained relatively low levels of cyanazine, propazine and metribuzin.

Walker *et al.* (2001) monitored downstream pulses of chlorpyrifos after spraying in an adjacent orchard in southern Tasmania. Chlorpyrifos concentrations peaked adjacent to the orchard around 10 minutes after spraying, with an average of 0.15 µg/L, but the peak 200 m downstream averaged 0.03 µg/L. Concentrations above 0.01 µg/L persisted for less than 40 minutes after spraying. Three hours after spraying, the chlorpyrifos concentration at the most exposed site was at the limit of detection of 0.002 µg/L. Low levels of chlorpyrifos were intermittently detected during seasonal monitoring in the river.

#### **6.2.1.5. South Australian waterways**

Thoma (1988) reported that almost 84% of water and 100% of sediment samples from streams draining a horticultural catchment (Onkaparinga) in South Australia contained pesticide residues. The order of decreasing occurrence was dacthal > propyzamide > DDT > endosulfan > chlorpyrifos > lindane > chlorothalonil. The authors claimed that downstream effects on water quality were limited (Kookana *et al.* 1998b).

#### **6.2.1.6. Queensland waterways**

Turner (1996) reported that atrazine has been frequently detected in the Condamine-Balonne River system in Queensland, from trace levels up to 2.4 mg/L. Rayment and Simpson (1993) reported the presence of organochlorines, OP insecticides and some herbicides in the surface waters of the Condamine-Balonne catchment. In north Queensland, Russell *et al.* (1996) reported that dieldrin, DDE, 2,4-D and atrazine were detected in between 9 and 27% of samples from the Johnstone and Daintree Rivers. Atrazine, between 0.4 and 14.4 µg/L was found in farm dams on the Darling Downs in Queensland, probably associated with suspended soil particles (BW Simpson; cited in Hunter 1992).

Muller *et al.* (2000) analysed 103 sediment samples collected from irrigation channels and drains in 11 agricultural areas of Queensland for a range of past and presently used pesticides including organochlorines, pyrethroids, ureas, triazines and organophosphorus pesticides. The most commonly detected residues were of endosulfan, which were detected in 78 of the 103 samples at levels up to 840 µg/kg dry weight (dw), and DDT residues (in 74 samples at up to 240 µg/kg dw), mostly from the irrigated cotton areas. In contrast, the herbicides diuron, atrazine and ametryn were most commonly detected in sediments from drains in sugarcane areas, with maximum concentrations of 120, 70 and 130 µg/kg dw, respectively.

#### **6.2.1.7. Western Australian waterways**

Helicopter applications of granulated formulations of atrazine in forestry operations in Western Australia resulted in concentrations in streams between 0.8 and 38 µg/L (McAlpine & Van der Weile 1990).

Despite restrictions on the use of dieldrin in agricultural areas from 1974, dieldrin residues continued to be detected in the 1980s. The highest levels and most frequent detections of organochlorine pesticides in Western Australia were found in the Blackwood, Denmark and Hay Rivers, but no herbicides or organophosphorus pesticides were detected (EPA WA 1989). The highest concentrations were 0.026 µg/L of DDT, mostly from its historical use in cereal in rural areas, and 0.021 µg/L of chlordane (Rutherford 1989). Organochlorines were also reported in the Preston River and the Swan-Canning estuarine systems (Kookana *et al.* 1998b). Dieldrin levels in the Preston River had not declined significantly by 1981 (Atkins 1982), but levels had decreased by 1986 (Klemm 1989). Pesticide application around the bases of power poles may have contributed to pesticide levels in rural waterways (Rutherford 1989).

Some recent monitoring of endosulfan in the Ord River district in northern WA between January 1998 and June 2000 has revealed that most levels of total endosulfan in the rivers were < 0.05 µg/L (A. Maus, WA Water Corporation, pers. comm.). Five samples out of around 100 in the Ord River were between 0.3 and 1.2 µg/L. Concentrations in drains were generally higher in the spraying season, with peaks up to 1.7 µg/L. The peaks were in the dry season (July – August).

#### **6.2.1.8. Marine and estuarine waters**

Low pesticide levels have been found in water samples in Port Phillip Bay, Victoria. . DDT has been recorded at up to 18 ng/L (Black *et al.* 1993). Traces of dieldrin ( $\leq 0.0002$  µg/L, ie. 0.2 ng/L) have been noted by Good and Gibbs (1995a) at many sites, and also DDT residues ( $\leq 0.14$  ng/L). Diazinon was detected in 4 of the 18 sites at between 1 and 2 ng/L. Pesticide levels were found to rise in the Yarra River when between 10 and 60 mm of rain occurred in 5 hours in March 1995; dieldrin ranged between 5 - 8 ng/L; DDE from 0.3 – 0.7 ng/L; DDT 0.8 - 6 ng/L; heptachlor 0.15 - 0.7 ng/L and lindane 1.5 - 2.3 ng/L. The total load of organochlorine pesticides to Port Phillip Bay over 58 hours from the storm was calculated to be 120 g.

Mean organochlorine levels in the Swan-Canning Estuary, WA, from 1974-1985 were low, but they peaked in winter at up to 0.06 µg/L for heptachlor, 0.035 µg/L for dieldrin and between 0.006 and 0.03 µg/L for four other organochlorines (Rutherford 1989). Nevertheless, organochlorine pesticides did not seem to be accumulating in fish or sediments.

#### **6.2.1.9. Sheep dip chemicals reaching waterways**

Organophosphorus (OP) pesticides are commonly used to control ectoparasites of sheep and other livestock. Approximately 3-5 grams of insecticide is deposited on the fleece of each sheep to provide protection against parasite reinfestation (Henderson 1999). OP insecticides from sheep dipping can enter surface freshwaters, by several means including release during scouring. Label rules for all sheep dip chemicals recommend minimum intervals between the external treatment of sheep and shearing. These allow insecticide in the fleece to naturally degrade between treatment and

shearing and hence assist in minimising pollution from wool scouring. Effluent from Australian wool scouring operations would normally be regulated by state agencies but licensing conditions may not always specify monitoring for pesticides. Increasingly, wool scourers are treating their effluents on site, for example by separating their waste streams and composting the solids to which pesticides are likely to be adsorbed.

Badly sited dipping facilities can directly impact surface waters (Henderson 1999). Of 795 sheep dip baths inspected in the UK in 1989-91 (Currie 1992), around 5% were categorised as a high risk to waterways from dip solution leaking, splashing or being directly discharged into a watercourse. Around 15% were classed medium risk, where the bath was within 10 metres of a watercourse or drain. There has been no similar evaluation of Australian sheep dip sites.

In summary, the current pesticides are less persistent than most organochlorines, but such pesticides are still being detected in some surface waters. However, residues of pesticides in waterways have not often been monitored from agricultural operations after changes in land-use or changes in the spectrum of pesticide usage. Measurement of pesticides in spot water samples may not always be the best method of detecting some pesticides and may not give a clear indication of biological effects.

### **6.2.2. Pesticides in Australian groundwater**

Pesticide contamination of groundwaters has been noted worldwide. Vighi and Funari (1995) reported that some 32 herbicides, 19 insecticides, and 2 fungicides had to that time been detected in groundwaters from various parts of world

The Council of Australian Government's water reforms, changes in and tradeability of water rights and the development of high value horticultural industries, have resulted in an increased use of groundwater in Australia (Chartres *et al.* 2001). Groundwater surveys conducted across 15 major agricultural regions in Australia indicate that groundwater contaminants are usually below established Australian health and environmental guideline levels (Chartres *et al.* 2001). Levels of pesticides in most Australian groundwaters are low compared to many overseas results (Boey & Cooper 1996; Watkins & Bauld 1999). There are, however, temporal and spatial variations of contaminants in aquifers, and in some cases, poor agricultural land management practices are creating groundwater contamination risks (Chartres *et al.* 2001).

Triazine herbicides have a low ability to bind to soils and are therefore relatively mobile. Hence they have often been found in groundwater in rural regions of Australia (Bauld 1994). The National Registration Authority (NRA 1997) described atrazine as one of the most widely used herbicides in Australian agriculture, with high potential to contaminate ground and surface water, and narrow safety margins for aquatic organisms. The NRA (1997) proposed measures to monitor and reduce atrazine contamination of aquatic systems, particularly to eliminate poor agricultural practices. Simazine may also occur in groundwater but is not as mobile as atrazine.

The then Land and Water Sciences Division of the Australian Geological Survey Organisation (now in the Bureau of Resource Sciences) has conducted most of the groundwater surveys throughout Australia. Bauld (1994) analysed groundwaters from

four irrigation areas in South Australia, Victoria, NSW and Queensland. Triazine herbicides, most commonly atrazine, were most often detected. In some areas as many as 50 - 80% of bores contained detectable residues of atrazine and/or simazine and their degradation products but drinking water guidelines were exceeded in only 7 - 15% of samples. Atrazine levels were low compared to a median of 0.05 µg/L and maximum of 40 µg/L in the USA (Simpson *et al.* 1992).

#### **6.2.2.1. New South Wales**

Groundwater surveys of irrigation areas in the Wakool-Cadell (sampled in 1995) and Denimein-Berriquin (sampled in 1996) districts of NSW detected atrazine, desethylatrazine (DEA; a metabolite of atrazine), terbutryn and 2,4,5-T, at concentrations up to 0.3 µg/L, although most concentrations were much lower (Watkins *et al.* 1998). Other pesticides detected in some bores included diuron (<2 µg/L), which is used on crops such as lucerne or around irrigation channels, and terbutryn (up to 0.17 µg/L), a triazine herbicide often used on cereal (Watkins *et al.* 1998). Earlier surveys in 1991 also found low concentrations (<0.07 µg/L) of the herbicides simetryn and trifluralin (Bauld 1996). Watkins and Bauld (1999) later reported a general improvement in groundwater quality of Berriquin area with pesticides (usually herbicides) detected in 10% of the twenty groundwaters sampled, compared to 22% in the previous sampling of thirty-seven bores.

Ang *et al.* (1989) found that 14 of 110 groundwater samples collected in the coastal plain of northern New South Wales contained trace levels of pesticides; organochlorines were around 0.05 µg/L and organophosphorus pesticides were around 0.5 µg/L. Only one bore from the Alstonville Plateau in northern NSW, sampled in 1999, contained simazine (0.01 µg/L) (Budd *et al.* 2000). Jiwan and Riley (1993) detected atrazine in around 6% of groundwater samples at five sites in alluvial aquifers under the Liverpool Plains in the north-west of NSW. In the lower Namoi Valley, atrazine concentrations from less than 0.1 to 5.8 µg/L were found in groundwater (Boey & Cooper 1996). The most vulnerable sites for ground water contamination by atrazine are often in floodplain areas where shallow perched water tables exist (Boey & Cooper 1996).

#### **6.2.2.2. Victoria**

Pesticides, terbutryn and a breakdown product of diuron, were detected at low concentrations (0.12 - 1.2 µg/L) in 7% of groundwater samples in shallow aquifers of the Murray Region (Watkins & Bauld 1999). Bauld (1996) reported that almost half of the 51 groundwater samples (49%) from the Shepparton East area of Victoria contained detectable pesticide residues and 43% contained triazines (atrazine and simazine). In contrast, there were very few pesticides found in groundwater in 1994 from a predominantly dryland agriculture region, the Goulburn River Catchment in the Nagambie-Mangalore area of Victoria (Watkins *et al.* 1999a). They detected simazine and atrazine in only one ground (5%) and one surface water at concentrations between 0.06-0.95 µg/L, and only in waters less than 25 years old. Pesticides have been detected more frequently in other areas of the Goulburn Catchment (references in Watkins *et al.* 1999b). This contrast may be due to the less intensive pesticide use on non-irrigated land in Nagambie-Mangalore, as well as other factors, such as deeper water tables and different sub-surface conditions. Ivkovic *et*



*al.* (2001) found atrazine (0.02 & 0.04 µg/L), simazine (up to 0.45 µg/L in 10 bores) and bromacil (2.5 µg/L, 1 bore) in the Cobram area of northern Victoria in 1993.

Traces of herbicides were found in groundwater in horticultural areas of the Gippsland district of Victoria in 1994 (Chapman & Stranger 1995). Linuron (0.41 µg/L) and metribuzin (0.13 µg/L) were found at Rosebud, and atrazine (0.06 µg/L) at Orbost. Metribuzin has also been reported in groundwater in Tasmania (K. Budd, BRS, pers. comm.).

#### **6.2.2.3. Queensland**

Atrazine was not detected in any of 28 groundwater samples taken in 1987 from bores on the Atherton Tableland, Lockyer Valley and Darling Downs in Queensland (Hunter 1992). Keating *et al.* (1996) reported traces of atrazine and hexazinone in the Callide Valley, and chlorfenvinphos and 2,4-D in 3 of 52 samples from the Bundaberg region. Brodie *et al.* (1984) reported that residues of heptachlor and lindane were detected in about 60% of bore water samples in the Burdekin River delta, a major sugarcane producing area. In a survey of the Lower Burdekin basin in Queensland in 1992 and 1993, atrazine was detected frequently, mostly less than 0.1 µg/L but one site had between 1.3 and 1.4 µg/L (Keating *et al.* 1996). No pesticides were detected in the Logan-Albert catchment and several other catchments in 1994 (Please *et al.* 1996). Pesticide levels in groundwaters of the Border Rivers catchment of southern Queensland and northern NSW sampled in 1994 and 1995 were all ≤0.1 µg/L (Please *et al.* 2000). Only atrazine, DEA and fluometuron were found in 5 groundwater samples, and atrazine, DEA and metolachlor in four surface water samples. Overall, pesticide contamination was considered rare in most Queensland groundwaters (Keating *et al.* 1996).

#### **6.2.2.4. South Australia**

Stadter *et al.* (1992) reported atrazine and simazine in groundwaters of the Padthaway area, Schmidt *et al.* (1996) tested 129 bores in south-eastern South Australia and found that 15% of samples contained measurable levels of pesticides. The pesticides detected included dieldrin, lindane, chlorpyrifos and alachlor. In a survey of the southern Mount Lofty Ranges in 1994 and 1995, only two bores contained pesticides (atrazine, DEA, simazine and vinclozolin) between 0.06 and 0.65 µg/L (Radke *et al.* 2000). The pesticides detected in surface water samples (0.04 – 0.6 µg/L) from that area included atrazine, DEA, simazine, metolachlor, chlorthal dimethyl, dicamba, 2,4-D and MCPA (Radke *et al.* 2000). Aldicarb was commonly detected in USA groundwaters, but it has not been detected significantly in Australian groundwater, possibly due to its lower frequency of usage (100 tonnes p.a. compared with 1900 in the USA and 239 in California in 1998; NRA 2001). However, some aldicarb residues were found in shallow tile drains at 10 – 50 µg/L when it was applied to citrus in sandy soils in South Australia (NRA 2001). Aldicarb appeared to persist in these situations.

#### **6.2.2.5. Western Australia**

Groundwaters in the coastal plain near Perth WA are particularly susceptible to contamination because they are shallow (generally <3 m) and the soils are sandy hence highly transmissive. Larsen *et al.* (1998) assessed the groundwater quality of the Jandakot Mound near Perth in May 1995 by analysing samples from 43 bores.

Metribuzin and metoxuron were detected in two bores at  $\leq 0.5 \mu\text{g/L}$  but glyphosate was found at one site at  $380 \mu\text{g/L}$  (still below drinking water guidelines). The herbicides may have originated from nearby spraying in horticultural areas and at public utilities and some were carried directly into deep groundwaters.

The Water Authority of Western Australia (WAWA) has monitored pesticides at various sites over the past 25 years. Sheridan (1991) reported that atrazine was detected in 14 out of 44 unconfined groundwater samples. Groundwater sites in the Perth metropolitan showed increasing frequency of pesticides residues exceeding the current environmental criteria (Rutherford 1989; EPA WA 1989). For instance in 1977, none of the 31 samples exceeded the criteria whereas in 1987, 28 out of 47 samples exceeded criteria for at least one pesticide and criteria were exceeded for 42 individual pesticides. Most of the organochlorine and organophosphorus pesticide residues found in Perth groundwater originated from pest control activities in the Perth area rather than agricultural uses (Davis & Garland 1986; cited in Rutherford 1989). Other areas where pesticides were detected included the Ord River Irrigation area and three sites along the south-west coast (Myalup, Pinajarra, and Busselton).

In summary, pesticide residues in groundwater are generally lower than those overseas. There are, however, temporal and spatial variations of contaminants in aquifers, and in some cases, poor agricultural land management practices are continuing to create groundwater contamination risks. It is important to continue monitoring of Australian groundwaters.

### **6.2.3. Pesticides contamination in Australian soils, pastures and livestock**

Although there have been a number of Australian studies on pesticides there is relatively little understanding of the behaviour of pesticides in soil under Australian soil conditions (see Kookana *et al.* 1998b). Contamination of off-farm soil ecosystems with pesticides in Australia mostly results from early pesticide applications when there were fewer regulatory controls (Kookana *et al.* 1998b).

#### **6.2.3.1. Persistent organochlorines in soils, pastures and livestock**

Although the agricultural use of most organochlorine (OC) pesticides was prohibited by 1987, their residues are still detected in soils. Earlier work had shown that DDT residues persisted in soil for more than one year after spraying of cereals in Western Australia (Rutherford 1989). An extensive targeted survey of organochlorine pesticides in soil was undertaken in 1987, following positive detection of DDT in beef exported from Western Australia (EPAWA 1989). DDT and dieldrin were found in around 40% of over 11 000 samples analysed, and chlordane and heptachlor in 18 - 19%. Around 9% of the samples contained more than 1 mg/kg of DDT and around 4% contained more than 1 mg/kg of dieldrin. However, this cannot be assumed to be typical of soil contamination at that time as the sampling was oriented to areas where possible contamination was anticipated.

Gilbert *et al.* (1992) found that 67% of non-target soils (63 samples) in the Gwydir cotton growing area in New South Wales in 1981 were contaminated with DDT

between 0.03 and 0.39 mg/kg (dry soil; mean = 0.08 mg/kg). The most contaminated soils were nearest to cotton areas and the highest residue on-farms was 1.2 mg/kg. DDT residues in roadside soils in the Namoi district seemed to be declining between 1977 and 1983; DDT was detected in 34% of samples in 1983, compared to 49% in 1977 (Gilbert *et al.* 1992). Contamination was found up to 20 km from cotton areas and some grazing properties still had excessive DDT levels in 1983, rendering them unsuitable for grazing.

In the North Coast of NSW, residues of BHC, dieldrin, and heptachlor in cattle may have originated from grazing on land previously under horticulture and sugarcane (Wilson 1987). The authors considered that soil ingestion was an important route of uptake of pesticides by grazing animals. Harris (1987) analysed soils from 69 sugarcane farms in northern NSW and reported an average dieldrin concentration of 0.12 mg/kg. In soils from banana plantations the dieldrin concentration ranged from 0.06 to 32 mg/kg, depending on location (Harris 1987).

Trace organochlorine compounds were found (concentrations <15 µg/kg) in soils from the Coomealla Irrigation Area and nearby lakes. Soils from a citrus farm also contained DDE (20 µg/kg), simazine (30 µg/kg), bromacil (62 µg/kg) and diuron (1400 µg/kg) (Bowmer *et al.* 1995).

#### **6.2.3.2. Endosulfan and other chemicals used on cotton**

More recently, the detection of endosulfan in export beef, with a potential to damage Australia's export markets, resulted in restrictions in its use (NRA 1999a). The endosulfan residues mainly arose from spray drift onto pasture from adjacent cotton farms in 1999. Previously, residues of the insect growth regulator chlorfluazuron (Helix®) had been found in beef. These residues were found to have resulted from high levels accumulated in cotton trash that was fed to cattle in drought-affected areas (NSW Parliamentary Standing Committee on State Development 1999).

Endosulfan residues in soil of Queensland cotton farms were highest in the top 5 cm but did not appear to concentrate further following repeated applications or from season to season (Simpson *et al.* 1996). The baseline residues of endosulfan (as the sulfate) in soils on cotton farms in NSW were generally less than 0.08 mg/kg (Kennedy 1999). The more water-soluble herbicides, such as prometryn, fluometuron and diuron, were removed within one to two months (Simpson *et al.* 1996). DDE residues were unchanged. Simpson *et al.* (1996) also found a close relationship between soil residues and residues in runoff.

#### **6.2.3.3. Cattle and sheep tick-dip sites**

Soil contamination with organochlorines and other pesticides has been reported at former cattle dip sites in north-eastern NSW and along the Queensland border where animals were drenched in pesticide solutions to control ticks (Barzi *et al.* 1996). There were over 1600 contaminated dip sites in the area (Beard 1993). The average levels at these locations were around 470 - 720 mg/kg of arsenic and 4700 - 5500 mg/kg for DDT. DDT concentrations as high as 10% (100 000 mg/kg soil) have been reported (Barzi *et al.* 1996). Levels of ethion were also very high (up to 45,000 mg/kg, averages up to 6150 mg/kg). The sites also contain residues of up to 15 different pesticides including organophosphorus, carbamate, organochlorine and pyrethroid

pesticides. A small number of these sites were considered to pose issues to human health and the environment (Beard *et al.* 1992) and were identified by NSW Agriculture as priority sites in need of appropriate management to reduce the risks to the environment and human health and are now all undergoing phased remediation (Pearmain *et al.* 1999). It is likely that the detection of DDT and ethion in north coast wildlife is a result of this contamination (Beard *et al.* 1992).

Sheep dip sites are more widely dispersed than cattle tick dip sites. In NSW it is estimated that there are between 25,000 and 40,000 such sites scattered through the state (E. Wong, NSW EPA, pers. comm.). A wide range of chemicals has been used for treatment of sheep against lice, fly and other pests. In earlier years, arsenic and organochlorine pesticides would have been most common. These have now been replaced by less persistent pyrethroid, organophosphorus, carbamate, and triazine pesticides. As for cattle tick sites, the more persistent older chemicals would have the potential for longer-term contamination of soil. No analysis or prioritisation has been undertaken to date on sheep dip sites.

Pre-registration assessments of pesticides for toxicity in the soil frequently rely on data from composting worms, such as *Eisenia fetida*, which are usually very insensitive (J. Holland, EA, pers. comm.; Martin 1986). Booth *et al.* (2001) considered that use of *Aporrectodea* spp. would be more ecological and agriculturally relevant to local terrestrial ecosystems than using composting worms. They also noted that inhibition of AChE activity in worms appeared to be a useful bioindicator for organophosphorus pesticides, though there is other evidence that earthworms in general are not sensitive to chemicals (J. Holland, EA, pers. comm.).

If herbicide residues accumulate in soil, they may injure crops and non-target plants, enhance development of weed resistance, affect soil biota and associated processes such as nitrogen fixation, increase incidence and severity of root diseases and interfere with uptake and utilisation of nutrients by plants (McLaughlin *et al.* 1998). Chlorsulfuron (a sulfonylurea herbicide) can persist long enough in soils to injure sensitive leguminous crops up to 3 years after the initial application (Ferris 1993). However, in general, fungicides, fumigants, and insecticides have greater influence on soil organisms than herbicides because of their higher rates of application and toxicity (Fraser 1994; Kookana *et al.* 1998b).

#### **6.2.3.4. Pesticide waste disposal**

Historical disposal of pesticide containers and wastes throughout rural Australia has also left a legacy of sites contaminated with a wide variety of pesticides. In the past, pesticide clearance and registration assessments in Australia focussed only on the impact of the intended use for the product. In more recent years up until 1995, although taking a life cycle approach covering all aspects of managing the entire pesticide pathway from importation/manufacture to disposal (see Appendix 1), the focus of environmental assessments was on new active ingredients. Consequently, issues relating to disposal of problematic pesticide wastes, for example used baits, wash down waters and used dip solutions, were not considered in any detail in earlier assessments. This approach left the pesticide user without any information on the possible impact from their actions. Once the Chemical Review program started,

disposal issues relating to cattle and sheep dips or past harvest fruit dips came under scrutiny.

The volume of wastes can be quite high, eg. wastes from dipping activities undertaken on a property can produce thousands of litres of waste water with low levels of pesticide residues. Often, these contaminated liquid wastes have been disposed directly to land, a practice that is no longer permitted in a number of states.

The Australian Apple and Pear Growers Association has prepared draft guidance on dip waste disposal for use by its members and Avcare has prepared broader draft guidelines on behalf of all dipping industries. These draft guidelines documents have served as a useful starting point in developing a useful and workable document. Industry, the National Registration Authority and state and territory jurisdictions have commenced discussions with the aim of fully considering the waste disposal consequences as an aspect of registering the use of products and providing appropriate guidance to users on how to dispose of dipping waste without causing harm to the environment, health or trade (M. Gorta, NSW EPA, pers. comm.). Contamination of soil from sheep dipping activities has not been assessed.

There has been limited assessment of pesticide residues in Australian soils. Some instances of livestock contamination have impacted Australia's trade, at least temporarily. Continued progress is needed on addressing pesticide waste disposal issues.

#### **6.2.4. Pesticide residues in and effects on Australian biota**

##### ***6.2.4.1. Persistent organochlorines in Australian freshwater and terrestrial biota***

One of the highest uses of DDT in Australia was in the cotton growing areas of the Namoi Valley, NSW. It was gradually phased out from 1972 and replaced in the early 1980s. In 1975, the cotton growers agreed to close all tailwater drains to the Namoi River, except during extreme storms, to minimise the high levels of contamination from this source. The decline in DDT levels in water and sediments after each spraying season was attributed more to reduction in inputs and dilution, rather than to pesticide degradation (Gilbert *et al.* 1990a). Numerous studies in that period established continuing levels of DDT in fish, birds and other wildlife including frogs, fruit bats and reptiles (Gilbert *et al.* 1992). DDT levels in kookaburras *Dacelo gigas* from the Namoi district in 1975 were up to 1826 mg/kg fat (mean of 798 mg/kg), in contrast to a maximum of 12.6 mg/kg (mean of 4.1 mg/kg) in those from the Central Coast (Gilbert *et al.* 1990b). The results of all of these studies may have contributed in part to the decision to withdraw DDT and other persistent organochlorines from use in cotton by 1981, even though they were not published externally until well after the event.

In a wide-ranging Tasmanian survey from 1975-1977, Bloom *et al.* (1979) analysed organochlorine pesticide residues in native and introduced birds (7 spp), fish (5 spp) and mammals (2 spp) from throughout Tasmania. They found that contamination from DDT, and to a lesser extent dieldrin, was widespread and levels were similar to those in other parts of the world where strict controls were applied.

#### **6.2.4.2. Other pesticides in Australian freshwater and terrestrial ecosystems**

Residues of endosulfan were measured in three species of fish caught from rivers and a dam in the cotton area (Nowak & Julli 1991) over three summers (1987 – 89), as well as in winter 1988, when endosulfan is not used. Endosulfan residue levels were similar in the livers of each of the species, despite their different habits, but no residues were found in fish collected from a reference area, remote from pesticide exposure. Residues did not appear to accumulate from season-to-season. It is unlikely that the fish were taking up the pesticide through the food chain, the more likely route being direct uptake from water (Nowak & Julli 1991). Changes in endosulfan residue patterns in aquatic biota of four similar lagoons in the Wee Waa area were recorded between September 1988 and January 1989, generally corresponding to the intensity and location of nearby spraying (Napier 1992). It was, however, surprising to find some residues in October, well before any spraying had commenced and it is probable that endosulfan was available from the sediments. In January 1989, Napier (1992) found high concentrations (0.27 µg/L) of endosulfan in Jabiru Lagoon near Wee Waa when sampled four days after a fish kill. Concentrations were declining, probably due to degradation or sorption to sediments (Chapman *et al.* 1993). Napier *et al.* (1998) analysed small carp and mosquitofish (< 70 mm) that had survived the kill of larger fish, probably by sheltering amongst dense vegetation. Endosulfan levels in whole fish were between 0.3 and 11.5 mg/kg, and were similar to levels in fish collected from the same location when water concentrations were around 0.1 µg/L. *Gambusia* appeared to accumulate more endosulfan than other species (Napier 1992). High exposure to endosulfan was confirmed by elevated residues in the tissues of fish and invertebrates collected in the lagoons; up to 0.58 mg/kg was found in the yabby *Cherax destructor* and up to 14.6 mg/kg in the mosquitofish in Jabiru Lagoon (Napier 1992; Chapman *et al.* 1993). The residues in the mosquitofish were up to 45 times higher than those found in liver of catfish (0.3 mg/kg) caught from the Gwydir River (Nowak & Julli 1991). The high proportion of beta-endosulfan in the fish indicates recent exposure (Nowak & Julli 1991). The study was not able to assess the ecological significance of residues.

Leonard *et al.* (1999, 2000) found that populations of five common benthic macroinvertebrate taxa (mayflies and caddisflies) in the Namoi River were reduced in 1995-96 downstream of irrigated areas. This seasonal reduction was related to endosulfan concentrations both in the solvent and in sediment. The macroinvertebrate populations in the exposed sites did not recover after drought, in contrast to those at the reference sites. They indicated that endosulfan was entering the river through surface runoff during storm events. The  $\alpha$ -endosulfan isomer remained strongly adsorbed to the larger (>63 µm) particles but the  $\beta$ -isomer readily desorbed and decomposed in the water column to form endosulfan sulfate. Toxicity tests with mayfly *Jappa kutera* confirmed that the sulfate would have been the most likely cause of the decrease in population densities in macroinvertebrate taxa observed (Leonard *et al.* 2001).

Kumar and Chapman (2001) detected residues of profenofos in tissues of three wild-caught fish species in the cotton growing areas of the Namoi Valley, NSW. Levels of profenofos in fish tissue reflected the general levels of profenofos use in the area and

concentrations had decreased six weeks after cessation of spraying. During the spraying period of March 1994, profenofos residues in water in five lagoons and creeks in the cotton growing areas ranged from 1.4 to 3.7 µg/L. However, by May, six weeks after spraying, profenofos was only detected in three of these sites at between 0.4 and 1.2 µg/L. The concentrations in sediments showed a similar trend. The residue levels in fish decreased more slowly after spraying ceased; from 0.28 – 1.1 mg/kg in March to 0.21 – 0.8 mg/kg in May. Acetylcholinesterase (AChE) inhibition in fish was a useful biomarker of organophosphorus exposure and AChE levels recovered even more slowly after spraying had ceased than residues in fish. This was particularly noticeable for gravid mosquitofish *Gambusia*, which still showed <50% reduction in May, and accorded with Australian laboratory investigations (Kumar & Chapman 1998, 2001).

Thomas *et al.* (1998) tested the acute toxicity of ten pesticides used in the Murrumbidgee Irrigation Area (MIA), NSW to the Australian cladoceran *Ceriodaphnia dubia*. The pesticides atrazine, bensulfuron-methyl, bromacil, chlorpyrifos, diuron, malathion, metolachlor, molinate, simazine and thiobencarb had been detected at elevated levels in drainage channels in previous irrigation seasons (Korth *et al.* 1995). With the exceptions of molinate and diuron, the acute toxicity decreased when tests were performed in irrigation supply water, in comparison to laboratory water. The insecticides chlorpyrifos (EC<sub>50</sub> of 0.08 µg/L) and malathion (0.5 µg/L) were the most toxic pesticides investigated and the herbicides bensulfuron (>300 000 µg/L) and simazine (72 000 µg/L) were the least.

Rutherford (1989) described a 1982-1985 Western Australian study on persistence and subsequent crop or pasture effects of nine herbicides, simazine, diuron, trifluralin, dicamba, 2,4-D, diclofop-methyl, chlorsulfuron, picloram and propyzamide. Herbicides generally decayed rapidly, but some effects on plant growth were observed in the following year in periods of very low rainfall (Rutherford 1989).

Crisp (1992) monitored the environment in three areas of WA after dense infestations of early instar locusts were sprayed with fenitrothion (384 g/ha) in 1990-91 over a total area of 250 000 ha. Fenitrothion residues in soil were very low for all sites. Residues in pasture herbage reached a maximum of 37 mg/kg but reduced steadily over time, with an estimated half-life of 3.1 days. The pasture appeared to give the clearest indication of fenitrothion exposure as it seemed to intercept most of the chemical at the time of application. Fenitrothion residues in native vegetation and water varied greatly between sites, possibly due to different application methods or the rugged topography, resulting in differences in terrain, slope, vegetative cover or microclimate (Crisp 1992). The highest residues of fenitrothion in locusts (100 mg/kg) were found at one site three days after spraying but much lower levels were found at other sites.

Pesticide contamination has often been associated with fish kills and fish diseases (Nowell *et al.* 1999). Connell (1993) reported a number of early fish kills in Australia from organochlorines such as in the Tweed River in 1970, where dieldrin and lindane were implicated. However, it should be noted that not all fish kills can be attributed to pesticides, as other factors such as low dissolved oxygen levels can cause many fish kills (Nowell *et al.* 1999).

Napier *et al.* (1998) examined records of fish kills in northern NSW and southern Queensland from the 1970s to 1995, and found that fish kills were reported more often from cotton growing areas and during the growing season. There was an increase in reported kills during the late 1980s and early 1990s. Of the 98 total kills, 54% were from pesticides, 8% from low DO, 10% from other defined causes and 32% from unknown causes. Endosulfan was considered to be the cause in almost 80% of the cases where pesticides were implicated. It is notable that in other inland rivers of NSW where cotton is not grown, only 18% of 50 kills recorded were associated with pesticides.

There have been few reports of fish kills from endosulfan in estuarine systems in Australia. Mortimer and Cox (1999a) reported two fish kills attributed to endosulfan in the Maroochy River, Queensland, but later residue surveys using sediments and crabs did not detect any endosulfan. The toxicity of endosulfan to marine organisms could be increased under conditions of low salinity, such as in estuaries (Scott *et al.* 1987; Forbes 1996). [Urban use of chlorpyrifos has resulted in fish kills in urban creeks in Sydney and Brisbane (NRA 2000a; M. Julli, NSW EPA & M. Mortimer, Qld EPA, pers. comm.). The origins of the pesticide were not clear but possible sources include run-off and sub-surface drainage from areas treated with high concentrations for sub-floor termites, poor disposal practices of household chemicals, and poor disposal of pet wash water (M. Gorta, NSW EPA, pers. comm.).

Fish kills are very visible and dramatic events but kills of invertebrates will usually go unnoticed, unless large animals are involved. Napier *et al.* (1998) made one reference to an invertebrate kill in the cotton districts and some estuarine invertebrate kills were associated with temephos (CEPA 1994). Many insecticides have high toxicity to invertebrates (eg. organophosphorus and carbamate pesticides) and the environmental effects of these chemicals may go unnoticed without careful observation. Small invertebrates can have critical niches in stream functioning and loss of invertebrate populations can also affect organisms at higher trophic levels.

The effect on streams of aerial spraying of the pyrethroid cypermethrin (at 1.26 mg/m<sup>2</sup>) on a *Eucalyptus nitens* plantation in northern Tasmania was monitored by Davies and Cook (1993). Some smaller streams received spray drift at around 0.05 mg/m<sup>2</sup>, resulting in 200-fold increases in macroinvertebrate drift (large-scale movement of aquatic invertebrates, either dead or alive, downstream with the current, caused by the pyrethroids in the water). The drift remained elevated over background levels for 8 days and populations only recovered after winter floods. Stoneflies and mayflies were the most sensitive taxa. Barton and Davies (1993) recommended buffer strips of at least 50 m to protect stream invertebrates. These have also been adopted but are not externally audited (P. Davies, pers. comm.). Forestry spraying operations with atrazine significantly increased the daytime in-stream invertebrate drift (Davies *et al.* 1994). The initial spraying disturbed trout but this disturbance did not seem to affect their growth rate. The long-term effect on stream plant functioning was not studied. The authors suggested that atrazine concentrations between 1 and 20 µg/L for several weeks were unlikely to cause major changes in the aquatic fauna, although sublethal effects may occur above 10-20 µg/L. Concentrations above 100 µg/L, which occurred in about 8% of cases, may have short-term lethal effects on organisms. This resulted in Forestry Tasmania suspending the use of atrazine. Other



forestry operators adopted buffer zones, use modern application technology, and avoided using triazines in sensitive areas (P Davies, pers. comm.).

Most pesticide research in Australia has studied the effects of single chemicals, and guideline figures (eg. ANZECC & ARMICANZ 2001) are generally chemical-specific. Pesticides are often applied as mixtures or, in intensive agricultural areas, occur in the environment as mixtures. Hence, aquatic organisms may be exposed to mixtures of pesticides, resulting in additive, synergistic (more than additive) or antagonistic (less than additive) effects (Day 1991). Korth *et al.* (1995) noted that the toxicity observed in some drainage waters from the irrigation areas of NSW was greater than that predicted from laboratory toxicity tests on known contaminants. This may have been due to toxicity from unmeasured toxicants but could also be a result of the mixtures of chemicals present in the environment. The slow recovery of AChE following profenofos exposure (Kumar and Chapman 1998, 2001), and the cumulative effects of short-term (pulse) doses around 7 days apart (Abdullah *et al.* 1994) highlights the potential for cumulative sublethal effects from various AChE inhibitors. Australian studies by Woods and Kumar (2001) demonstrated that interactions between three different common pesticides could not be predicted from the response to individual pesticides. Direct toxicity assessment using a range of appropriate Australian species and local water conditions can assist in assessing the integrated biological effects of mixtures (Van Dam & Chapman 2001). This approach helped to identify the contribution of OPs to the toxicity of sewage treatment effluents in the Hawkesbury-Nepean catchment (Bailey *et al.* 2000a,b).

#### **6.2.4.3. Persistent organochlorines in Australian marine biota**

Kannan *et al.* (1994) sampled foodstuffs in Australia and found that PCBs, chlordane and DDT were among the more common contaminants in fish whereas DDT was more common in most agricultural products, except fruit. The highest contamination in fish was associated with urban rather than agricultural areas. DDT concentrations in fish samples ranged from 0.14 to 230 µg/kg w/w. The maximum dieldrin concentration was 47 µg/kg in sea mullet from Brisbane (Kannan *et al.* 1994). Concentrations of chlordane and chlordane-isomers in fish ranged from 0.06 to 920 µg/kg wet weight, with higher levels in fish off the coast of Sydney. Chlordane and DDT are thought to originate from run-off from urban catchments and possibly sewer overflows rather than past agricultural uses. Urban data resulted in the government, in 1989, prohibiting fishing within 500 m of the main sewer outfalls, introducing tighter trade waste limits and increased penalties for illegal dumping (Thompson *et al.* 1992) and constructing the deep ocean outfalls off Sydney. There has been considerable reduction in nearshore organochlorine residues since opening of the deep ocean outfalls in 1990-91 (Krogh & Scanes 1996). Similarly, the NSW EPA (1997; Roach & Runcie 1998; Scanes *et al.* 1999) reported on organochlorine concentrations in sediments and fish of Sydney estuaries and in oysters from a range of NSW estuaries. Concentrations of chlordane, dieldrin, DDT and PCB in wild oysters were elevated in many areas of the Georges River, Botany Bay, Middle Harbour and the Lane Cove River (NSW EPA 1997, Scanes *et al.* 1999). Some levels of organochlorines in fish from more contaminated bays and tributaries of Parramatta River and Georges River exceeded Maximum Residue Levels (MRLs; ANZFA 1999) (Roach & Runcie 1998). Hence, the Georges River, Iron Cove and Salt Pan Creek have been closed to commercial net and trap fishing (to be reviewed in 2002) and NSW Fisheries issued a warning to recreational fishers not to eat fish caught in those areas (NSW EPA 1997).

The presence of these organochlorines indicates residues from past practices (NSW EPA 1997). These compounds can remain in sediments for long periods and potentially continue to contaminate marine life. Birch and Taylor (2000) reported that concentrations of organochlorines in sediments of Sydney Harbour were substantially higher than in other harbours and estuaries in SE Australia, and were among the highest reported for any estuary worldwide. The mean levels of dieldrin, chlordane and total DDT in harbour sediments were 12, 60 and 77 µg/kg respectively, while maximum values were 192, 451 and 4875 µg/kg respectively.

By contrast, Kinhill Pty Ltd (1998) surveyed pesticides in Perth's three treated ocean outfalls, including sediment levels. No pesticides could be detected in the effluent (detection limit of 2 µg/L) or associated biota, and levels in sediments were all below criteria recommended by DEP (1996). Chegidden (1979) found that total organochlorine pesticide levels in sediment and mussels in Cockburn Sound, WA, were mostly < 0.001 µg/kg. Sediments from one sampling station had up to 4 µg/kg of dieldrin another up to 4.8 µg/kg of DDT.

The aquatic toxicity of the new insecticide fipronil is high especially to the marine mysid shrimp, but risk for cotton usage was assessed using the freshwater data (Environment Australia 1998). If this chemical is sought to be used on sugarcane, which is traditionally close to marine environments, further marine or estuarine toxicity data may be needed (Environment Australia 1998).

Hutchings and Haynes (2000) suggested that the hot spots of pollution around the Great Barrier Reef, exacerbated by high erosion rates from high tropical rainfall, might impact flora and fauna of the Reef. Some chemicals that have been withdrawn from use in Queensland are still detectable in sediments and biota of the region. Around 25 river catchments discharge directly into the Great Barrier Reef World Heritage Area, Queensland, and 80% of the land area adjacent to the Reef supports agriculture. The concentrations of organochlorine compounds are generally low within the Reef Marine Park, indicative of a relatively unpolluted environment (Haynes & Johnson 2000), except for sites adjacent to human activity, including urban centres and intensive agriculture. Haynes *et al.* (2000a) analysed sediment and seagrass samples from 16 intertidal and 25 sub-tidal sites sampled along the Queensland coast and in the Barrier Reef Area in 1997 and 1998. They found low levels of organochlorines: lindane 0.08 - 0.19 µg/kg; dieldrin 0.05 - 0.37 µg/kg; DDT 0.05 - 0.26 µg/kg; and DDE 0.05 - 0.26 µg/kg.

Dieldrin and DDE were found in aquatic fauna in around 25% of samples of oysters, crabs, mussels and fish from the Johnstone River in Northern Queensland, between 1990 and 1993 (Hunter *et al.* 1996). Even lower frequencies of detection were reported in the Daintree River (Russell *et al.* 1996). Concentrations were well below food limits and no other insecticides were detected. This showed a significant decline, from around 70% detection in the Johnstone River in the 1970s (Russell *et al.* 1996). Mortimer (2000a) measured pesticide content in intertidal burrowing crabs *Australoplax tridentata* and a portunid *Scylla serrata* sampled from estuaries on the Queensland coast between Cairns and Brisbane. Dieldrin was found at all locations, and heptachlor epoxide and DDT residues at most sites, reflecting historical use. Chlordane was only found in crabs in the urban Brisbane area. Mortimer (2000a) estimated the ambient water concentration that crabs were exposed to by back

calculating using the tissue residue data (on a lipid content basis) and the equilibrium between lipid and water ( $K_{ow}$ ). These calculations indicated that dieldrin exceeded the ANZECC (1992) water quality guidelines for protection of aquatic ecosystems (2 ng/L) at all sampling locations, however DDT and its metabolites did not. Similar exceedences were calculated for Moreton Bay (Abal *et al.* 1998) and in estuaries of some northern NSW rivers (Cullen & Connell 1992). The highest level found in sediments, 49 µg/kg of DDT, was not considered likely to have an adverse toxicological effect on sediment-dwelling organisms, as determined by such equilibrium calculations (Mortimer 1998).

Mortimer and Cox (1999b) measured the levels of pesticides in a canal system adjacent to a former landfill site on the Gold Coast, Qld. Only traces of pesticides were found in tissues of oysters *Saccostrea commercialis* and burrowing crab *A. tridentata* in the canal systems, and these levels were similar to those at reference sites near Brisbane. Highest levels were found in crabs, based on lipid weight; for dieldrin (to 0.9 mg/kg), heptachlor epoxide (to 0.8 mg/kg) and total DDTs (to 1.9 mg/kg). However, the degree of contamination was considered minor and all samples of edible portions, when considered on a wet weight basis, were 1-2 orders of magnitude below National Food Standards (ANZFA 1999).

#### **6.2.4.4. Other pesticides in Australian marine biota**

Mortimer (2000a), in the Queensland survey described above, found residues of chlorpyrifos and endosulfan in crabs in the urban Brisbane area, and only at minor concentrations. In the Gold Coast canal system, Mortimer and Cox (1999b) found chlorpyrifos at up to 0.55 mg/kg in oysters *S. commercialis*. However, again the degree of contamination was considered minor and all samples of edible portions were well below National Food Standards (ANZFA 1999). However, in another survey of oysters from canal estates in SE Queensland, Mortimer (2000b) found chlorpyrifos and the pyrethroid bifenthrin (both used for urban pest control) at levels that may be sufficient to harm sensitive organisms. Chlorpyrifos was detected at 3 out of 5 sites at between 0.18 and 0.62 mg/kg lipid weight (lw) basis and 0.0055 and 0.023 mg/kg wet weight (ww) basis. Bifenthrin was detected at 2 out of 5 sites at 0.16-1.9 mg/kg lw and 0.0067-0.033 mg/kg ww. The wet weight figures for both of these chemicals exceeded current food standards (ANZFA 1999).

With increasing land area being converted to agricultural production, particularly sugarcane, inputs of pesticides into the Great Barrier Reef area have increased with time, although the use of organochlorines such as HCH and DDT has ceased. The quantities of the insecticide chlorpyrifos, and herbicides, atrazine, diuron and 2,4-D applied in the Herbert catchment have increased in the last 15 years. Large quantities of methoxymethylmercury chloride (MEMC) have been applied to control fungal disease in sugarcane. The fate of these pesticides in river and Reef ecosystems is largely unknown (Johnson & Ebert 2000). In the analyses of sediment and intertidal seagrass samples from along the Queensland coast in 1997 and 1998, Haynes *et al.* (2000a) found atrazine between 0.1 and 0.3 µg/kg, and diuron from 0.2 to 10.1 µg/kg (up to 1.7 µg/kg in seagrass). The highest levels were mainly in samples collected along the high rainfall, tropical coast between Townsville and Port Douglas and in Moreton Bay. Some herbicide residues were found in only 13% of aquatic fauna samples from Northern Queensland rivers (survey described in the above sub-section) between 1990 and 1993 (Hunter *et al.* 1996); atrazine and low levels of 2,4,5-T were

found in a few samples from the Johnstone River, and 2,4-D was found in both Johnstone and Daintree Rivers (Hunter *et al.* 1996).

Muller *et al.* (2000) suggested that photosynthesis-inhibiting herbicides such as diuron and atrazine transported to the Reef environment by flood events might cause additional stress to marine plants. Haynes *et al.* (2000b) assessed the impact of the herbicide diuron on three tropical seagrasses in outdoor aquaria. All diuron concentrations between 0.1 and 100 µg/L significantly depressed photosynthetic activity in *Halophila ovalis* and *Zostera capricorni* after 5 days exposure, and such depression in *Cymodocea serrulata* occurred at diuron 10 µg/L. This depression remained at least 5 days after plants exposed to 10 µg/L diuron were returned to fresh seawater. Hence, exposure to herbicide concentrations present in nearshore Queensland sediments presents a potential risk to seagrass functioning.

Rutherford (1989) reported Fisheries Department results from 24 fish samples from Wilson's Inlet, near Denmark WA, in which 11 had chlorpyrifos residues between 0.01 and 0.18 mg/kg. Detection of organophosphorus or carbamate insecticides is likely to indicate recent application, as many of these compounds have short half-lives.

In summary, measurement of pesticide residues in sediments or biota can sometimes be more useful than residues in spot samples of water, but it can be still difficult to interpret the ecological significance of residues in organisms. Residues of endosulfan, organophosphorus and other pesticides have been detected in Australian biota near intensive agricultural areas. Very high levels of organochlorines have been detected in sediments of some parts of Sydney Harbour (Birch & Taylor 2000) but their significance to aquatic fauna is not yet known. Controls on endosulfan use (NRA 1999a) may reduce the frequency of fish kills in cotton-growing areas but occasional fish kills from organophosphorus pesticides in urban areas remain an on-going issue. Kills of invertebrates and more subtle ecological effects of pesticides can be equally significant but are more difficult to determine. The correlation of seasonal macroinvertebrate effects with endosulfan levels (Leonard *et al.* 1999, 2000), aided by the use of passive samplers, is the first clear correlation of more subtle pesticide effects. Little attention has been given to the biological effects of pesticide mixtures.

### **6.2.5. Pesticides in air in Australia**

There have been relatively few studies on pesticides in air. Rutherford (1989) reported on monitoring of the herbicide 2,4-D in air near Geraldton, WA, in 1979-1982. This was in response to claims of tomato crop damage. The monitoring was not able to distinguish sources or separate "pulse" and "press" events but did establish that damage may have occurred from short-distance drift of droplets of 2,4-D amine.

In 1993, the Land and Water Resources Research and Development Corporation, the Cotton Research and Development Corporation and the Murray-Darling Basin Commission commenced a research program entitled Minimising the Impact of Pesticides on the Riverine Environment (Schofield 1998). This program, finalised in 1998, provided valuable information on pesticide application, transport, degradation, fate and impact on the aquatic environment. Much of the work focussed on endosulfan on cotton but also provided general principles applicable to other

pesticides, including aerial transport and off-target movement by spray drift and volatilisation. Woods *et al.* (1998) established that spray drift is a complex process that is dependent on such factors as wind speed, temperature, humidity, atmospheric stability and crop structure. The Ultra Low Volume (ULV) formulation of endosulfan had a greater propensity to drift than Large Droplet Placement (LDP) applications. Around 2% of the mean ULV deposited within 500 m downwind of the placement. Woods *et al.* (1998) developed models and a database that are valuable for understanding buffer distances and effectiveness of application technology to reduce spray drift. Droplets from spray drift can cause high levels of contamination within 400m of sprayed crops (Edge *et al.* 1998). Dust is an order of magnitude less significant than vapour (Edge *et al.* 1998; Leys *et al.* 1998)

Edge *et al.* (1998) demonstrated that transport of vapour re-volatilised off sprayed areas could maintain a low background level of endosulfan up to 1 km from the sprayed crop. Volatilisation plays a major role in reducing the levels of endosulfan that remain on-farm (Kennedy *et al.* 1998) but contributes to an irreducible minimum of endosulfan in nearby waterways (Raupach & Briggs 1998). Avoiding the use of endosulfan during very hot weather could assist in controlling some of the volatilisation. This would similarly apply to other relatively volatile chemicals.

The Northern Rivers Public Health Unit has undertaken two monitoring programs for pesticides in ambient air in a rural area of NSW. The studies were undertaken during the period of aerial spraying with the fungicide propiconazole in and around the city of Coffs Harbour, which is bounded on three sides by banana plantations (Beard *et al.* 1995, 1996). The most commonly detected pesticide was chlorpyrifos, which was found in 14% of samples, and was significantly associated with its recorded use by domestic pest control operators in the town. Other pesticides detected included heptachlor (17%), chlordane (1.5%) and ethoprophos (1.3%). Estimated 24 hour exposure to peak heptachlor levels exceeded the WHO Acceptable Daily Intake (ADI) for a 5 kg child. No other peak or mean pesticide exposures exceeded ADIs (Beard *et al.* 1995, 1996). There was no evidence of propiconazole, the only pesticide to be applied by air to the banana plantations, even after a smaller-scale resampling during a month of known aerial application using an alternative sampling technology to better detect propiconazole aerosols.

A number of authors have reported on the contamination of Arctic and Antarctic wildlife, remote from pesticide use, and Iwata *et al.* (1994) attributed this to long-range global transport of pesticides by atmospheric deposition. In respect of persistent substances such as DDT, this view is now widely accepted.

The issue of **odours** from pesticides is essentially a human health issue (Chapter 4). Nevertheless, the reporting of odours many kilometres from the site of pesticide application suggests that there is considerable off-target movement of pesticides or their breakdown products, such as mercaptans, by drift or volatilisation. Odour incidents have comprised a large proportion of the pesticide use complaints reported to the NSW EPA over the last few years, particularly in cotton growing areas (M. Gorta, NSW EPA, pers. comm.). For instance, the NSW EPA received 152 reports of odour incidents between October 1998 and March 1999 inclusive. Many lasted more than 2 hours and most lasted more than 30 minutes. Odour incidents are commonly related to profenofos, chlorpyrifos and to cresol compounds used for disinfecting

chicken sheds (M. Gorta, pers. comm.). Similarly, the detection of pesticides in rain tank water collected from houses several kilometres from spraying operations also underlines the extent of aerial movement of pesticides (NSW EPA & New England Health 2000). Small amounts of spray can drift for longer distances in an unpredictable manner, and volatilisation can contribute to movement of some pesticides off-farm (Edge *et al.* 1998; Raupach & Briggs 1998).

**Fumigants**, by their nature, rapidly disperse into air. Carbon disulfide has a strong, unpleasant odour, while halogenated hydrocarbons such as methyl bromide or ethylene dichloride have the potential to deplete the ozone layer.

There has been very limited assessment of pesticides in air in Australia. Vapour transport can contribute to background levels of pesticides in the environment surrounding intensive agriculture. The number of odour complaints suggests that pesticides move in air over considerable distances.

### **6.2.6. Pesticide effects on the Australian terrestrial environment**

#### ***6.2.6.1. Terrestrial effects of organophosphorus and carbamate pesticides***

Reece *et al.* (1985) documented reports of bird kills from pesticides in Victoria, including birds dying after feeding on wheat grain contaminated with monocrotophos, fenitrothion and trichlorfon. Other reported bird kills involved dieldrin, chlordane and endrin as well as other vertebrate pesticides such as bromadiolone and zinc phosphide (Reece *et al.* 1985). McKenzie *et al.* (1996) reported the deaths of 350 Australian native birds in southern Queensland from fenthion between 1993 and 1994.

Chlorpyrifos has been implicated in a number of incidents involving birds in Australia (NRA 2000a). There have been occasional kills of mainly scavenging species (eg. butcherbirds and crows) after chlorpyrifos baits were used to control surface feeding insects in crops. Magpies died after eating contaminated worms after power poles were treated with chlorpyrifos. The deaths of a large number of ibis nestlings in the Macquarie Marshes in early 1995 may have been due to parent birds bringing invertebrates contaminated with chlorpyrifos back to the nests (NRA 2000a).

Temephos is an organophosphorus pesticide which, as well as having very high toxicity to crustaceans, non-target insects and some oysters, has high toxicity to birds, particularly those with high metabolic rates (eg. some wading birds). It was originally used for control of biting insects in inland and estuarine environments, and has been implicated in some incidents involving wildlife in Australia. In February 1984 a bird kill around Lake Jandakot (Forrestdale Lake) in WA, resulted from birds consuming dead or dying contaminated larvae after temephos granules were applied at 1 kg/ha to shallow water (possibly less than 5 cm depth) to control nuisance midges and mosquitoes. The population of around 4000 wading birds fell by around 50% in one day and 240 dead waders, mostly red-necked stints *Calidra ruficollis*, were collected within 4 days. Temephos concentrations in the gizzards and guts of these birds were between 12 and 18 mg/kg. A minimum depth requirement of 30 cm was then introduced (CEPA 1994) for application of temephos granules.

In the rice-growing areas of south-western NSW, bird fatalities were reported following scattering of seed treated with temephos to control rice bloodworms. The affected species included magpies, grey teals, crested pigeons, galahs and wood ducks, most of which would have collected seed that had fallen on land (CEPA 1994). No fatalities were reported when the emulsifiable concentrate of temephos was used. Use of temephos under strict conditions to control biting midges or mosquitos in estuaries in NSW and Queensland has caused large kills of crustaceans. In NSW temephos use was restricted to prevent aerial application, limit its use to below high tide level and to areas where birds are not actively foraging, prevent use on land and require monitoring of non-target organisms (CEPA 1994). These restrictions saw a reduction in temephos use from around 1000 kg/year to 150 kg/year but have not automatically translated to other states where bird incidents have not been reported. CEPA (1994) recommended the use of temephos only under strict permit conditions and encouraged the exploration of alternatives wherever possible.

Monocrotophos is one of the most toxic pesticides to birds. Following incidents with migratory hawks in Argentina, the distributor of monocrotophos, Novartis, responded to these incidents globally by announcing a phased withdrawal of their monocrotophos products from all world agricultural markets (Hooper *et al.* 1999). This raised issues of effective protection of migratory wildlife and international regulation of pesticides. An International Pesticide Incident Reporting System, is being set up to create a common format for reporting mortality incidents and to harmonise the methods used to assess pesticide impacts on wildlife (Hooper *et al.* 1999). Australia hosts a number of migrant species protected by international treaties but there are no identified pesticide threats at this stage. The NRA (2000b) recently cancelled the registration of the insecticide monocrotophos in Australia.

Fenitrothion, an organophosphorus pesticide, is the most common chemical used by the Australian Plague Locust Commission (APLC) to control the Australian Plague locust *Chortoicetes terminifera* (APLC 2000) in almost two million square kilometres of inland eastern Australia. APLC apply it as ULV formulation at 267 g a.i./ha (Hooper & Wright 1996), although higher rates may be used by other operators. Locust spraying can lead to exposure of non-target organisms to fenitrothion through direct contact with spray or spray drift or through ingestion of residues on vegetation, soil or insects. Preliminary research in the Longreach area of Queensland during the 1988-89 summer indicated that invertebrate fauna was reduced by 50% following spraying but recovery was complete in about 4 weeks (Crisp 1992). Carruthers *et al.* (1993) monitored the effects of fenitrothion in sprayed areas on non-target invertebrates using pit traps. Arthropod populations were immediately reduced at some sites but recovered within 1-4 months. The initial reductions and longer-term effects were not as great as those reported elsewhere (eg. van der Valk 1990). Carruthers *et al.* (1993) suggested the need for more work to fully understand the effects of fenitrothion on non-target arthropods.

The APLC has also been monitoring effects of fenitrothion spraying on small native mammals (APLC 2000) and birds (P. Story, APLC, pers. comm.). Story and Cox (2001) have reviewed the literature on the effects of OP and carbamate pesticides on vertebrates, with particular reference to locust spraying operations, and highlighted the need for continued research into the effects of these chemicals on Australian

species under local conditions. There are very few data on effects of OP pesticides on birds, mammals and reptiles in Australia and it is often necessary to rely on overseas data. One particular challenge is interpreting toxic responses in terms of effects on populations and communities in the natural environment. In general, little is known about the ecotoxicological significance of exposure of wild populations of vertebrates to OP and carbamate insecticides.

Locust population increases provide a significant food source for species able to prey on invertebrates, particularly those that have the ability to gorge feed. Birds can also incidentally ingest pesticides when they feed on sprayed seed and vegetation or by preening contaminated feathers. Geering (1996) considered straw-necked ibis (*Threskiornis spinicollis*) to be the major species at risk in the Gwydir wetlands system, due to their preference for eating locust nymphs over a wide foraging range. Although secondary poisoning from organophosphorus pesticides is not generally considered likely due to their relatively rapid degradation in the field and the diversity of prey consumed (Buerger *et al.* 1995), it may be more significant for birds of the semi-arid and arid regions of Australia because of their large foraging ranges. Locusts can provide the main source of food for up to 25 days (Story & Cox in press). The plains-wanderer (*Pedionomus torquatus*) is of particular concern to the APLC because it is listed as 'in imminent danger of extinction' by the New South Wales National Parks and Wildlife Service (Story & Cox 2001).

Granular formulations of pesticides can reduce off-target spray drift and volatilisation but they can sometimes increase the hazard to certain birds. Caged studies with aldicarb indicate that birds can consume lethal quantities of aldicarb, although some birds appear to reject the granules (NRA 2001).

The small mammals in Australia, particularly the Dasyuridae, are most likely to be affected by pesticide spraying. Some weigh as little as seven grams, they have high metabolic requirements, they are mostly insectivorous and can gorge feed on contaminated insects (Story & Cox 2001). Evans & Batty (1986) found that native dunnarts survived dietary doses of monocrotophos (2 mg/kg over 18 days), despite AChE inhibition of up to 92%. However, they died when given a much higher single oral dose of 8 mg/kg ingested in just four minutes, resulting in brain AChE inhibitions of 66-69%. Monocrotophos in food fed to the Australian native hopping mice *Notomys alexis* and *N. mitchelli* decreased food consumption and body weight (Evans & Batty 1986).

There is a very little scientific material anywhere in the world describing the effects of organophosphorus or carbamate pesticides on reptiles (Sparling *et al.* 2000).

#### **6.2.6.2. Other pesticides in the terrestrial environment**

Fipronil is being trialed for locust control (APLC 2000). It has high toxicity to some species of birds but field observations indicate that seed treated with fipronil may be unpalatable to some species of birds. No bird deaths were reported in trial sprayings by the APLC at between 1.25 and 5 g/ha of active ingredient (Environment Australia 1998). However, given the nocturnal and cryptic nature of many small animals in the semi-arid regions of Australia, and the large ranges of many predatory birds, post-spray surveys may not be completely effective at determining impacts at the low dosages applied by the APLC (P. Story, APLC, pers. comm.). Environment Australia



(1998) assessed that fipronil might be a potential hazard to birds when used on bananas, turf and sugarcane but a low hazard in locust spraying of pasture (A 70g plains wanderer would need to eat about 750 locusts to ingest a lethal dose.) Given the widespread effects of fipronil on non-target termites after locust control spraying in Madagascar in 1997-99 (Dinham 2000), albeit under very different conditions, it may be prudent to also evaluate the effect of this chemical on Australian invertebrates in target areas.

Brodifacoum is a potent second-generation anticoagulant rodenticide used in cereal-based baits in domestic and agricultural situations. Target rats and mice may accumulate very high levels before they die, increasing the risk of secondary poisoning. Brodifacoum is only slowly eliminated from the liver, and therefore accumulates in vertebrates if there are repeated exposures (Eason *et al.* 1999a). This increases the risk of death of non-target species from secondary poisoning, particularly for predatory and scavenging birds. Eason and Spurr (1995) reported that examples of fourteen indigenous and eight introduced bird species have been killed by field use of brodifacoum in New Zealand. Populations of three species have been severely reduced in poisoned areas. The extent of bird deaths seems to depend on the way brodifacoum baits are used and the behaviour of non-target species (Eason & Spurr 1995). It is probable that insectivorous birds, bats, lizards, and frogs are at lower risk but there are few data on these species. Godfrey (1985) reported that several insectivorous bird-species died after eating ants and cockroaches that had eaten brodifacoum baits. A related second-generation rodenticide, bromadiolone, killed wild birds that had scavenged the treated bait in a Victorian garden (Reece *et al.* 1985).

The wide-scale field use of brodifacoum for rodent and possum control in mainland New Zealand is under review (Eason & Murphy 2001) due to concerns about primary and secondary poisoning and contamination of wildlife. Brodifacoum has been detected in significant numbers of pigs, deer, cats, stoats and birds from these areas. However, the benefits of brodifacoum can be substantial where introduced mammals threaten native species with extinction, eg. on offshore islands where non-target effects can be minimised.

Young and De Lai (1997) reported a major decline in predatory birds in North Queensland since 1992, coincident with the introduction of brodifacoum to control rodents. They attributed this decline to secondary poisoning and/or a decrease in prey availability, although habitat loss may also be “an important contributing factor”. Six resident breeding species declined from the Herbert River district (spotted harrier *Circus assimilis*, and five owls). All of these include rodents in their diet. The declines were in the order of 75-85% for harrier and the barn owl *T.alba* and grass owl *T. capensis*. Some owls were found dead or dying with symptoms consistent with anticoagulant poisoning. The authors suggested that other species may also be declining. Although collection of rodent carcasses may seem a useful control mechanism, it is unlikely to be practical in broadscale agriculture. Environment Australia recommended that brodifacoum use in sugar cane be discontinued until sufficient evidence is obtained to support this use (J Holland, pers. comm.). The company withdrew it from registration in the light of the costs of additional studies recommended by Environment Australia to more clearly define the problem.

An alternative rodenticide, coumatetralyl, has limited risk of secondary poisoning (Hone & Mulligan 1982). It was only implicated in one of 56 cases reported by Stone *et al.* (1999) from New York (and that was in conjunction with brodifacoum), whereas brodifacoum was implicated in 42 cases.

Sodium monofluoroacetate (1080) is commonly used in baits to control rabbits, foxes and dingoes in Australia. From New Zealand data involving monitoring water for up to six months after large-scale operations using aerially sown 1080 bait to control possums and rabbits, Eason *et al.* (1999a) concluded that significant contamination of waterways with 1080 or fluoride after possum or rabbit control is unlikely. However, sodium monofluoroacetate is highly toxic to mammals (Section 2.10). Eason *et al.* (1999b) considered that careful use to minimise non-target uptake of the chemical should not cause adverse environmental effects. Native mammals in Western Australia have some in-built resistance to 1080 (Rutherford 1989), due to co-evolution with poisonous native plants. King (1988) determined in a field study that aerial 1080 baiting for dingo control did not kill any of 10 northern quoll *Dasyurus hallucatus* that were released in the baiting area in WA with radio collars. It may be noted that the University of New England genetically modified the rumen bacterium *Butyrivibrio fibrisolvens* so that it could detoxify 1080, but the then Genetic Manipulation Advisory Committee did not approve its release as it had not been established that it would not transfer to pest animals (feral pigs and goats) for which 1080 had use as a control agent.

A number of pesticides have been adapted or specifically developed for treatment of grazing livestock for internal and external parasites. Veterinary chemicals applied to stock orally or as pour-on solutions are generally considered to be of low environmental risk. However, concerns have been raised about the transmission of some of these chemicals to the environment through faeces and the subsequent effect on populations of dung insects and degradation of dung. Macrocyclic lactones are used for parasite treatment of livestock and include such chemicals as abamectin, ivermectin, moxidectin, doramectin and milbemycin (NRA 1998a). Subcutaneous injection of ivermectin (300 µg/kg) in cattle resulted in a peak level in faeces at day 2 of over 800 mg/kg, dropping to 273 mg/kg by day 7 by which time 62% of the expected dose had been excreted. Moxidectin did not accumulate to the same extent but it took 28 days to reach 58% excretion. Residues in sheep dung after oral treatment with moxidectin (200 µg/kg) peaked at day 1 at 3390 mg/kg. Most of these chemicals are non-toxic to mature egg-laying adult dung beetles but residues of some (eg. abamectin and ivermectin) in cattle dung appeared to increase mortality and impair development in larvae and newly emerged adults. NRA (1998a) considered that there was no evidence for long-term damage to dung beetle populations and considered that adequate protection would be provided by label directions specific to each product and the data available.

Wardhaugh *et al.* (1998) identified synthetic pyrethroid effects on two species of dung beetle following the use of deltamethrin as a pour-on treatment for cattle, persisting for up to three weeks after treatment. The authors concluded that use of deltamethrin in this way would measurably affect their populations in the week after treatment. Modelling suggested that repeated use of deltamethrin at 10-21 day intervals, as occurs with pyrethroids in eastern Australia, could result in localised extinctions after 2-3 applications.

There have been few published reports of unintended off-target plant injury due to herbicides. Cases recorded have usually involved non-agricultural uses. In the early 1980s, many kilometres of mature roadside trees were killed by apparently inappropriate use of hexazinone to control roadside weeds in roads radiating from Hay. In another incident about the same time, hexazinone leaked out of a railway spray tanker at a Narrandera siding. Many large old London plane trees along the drainage line were killed or damaged (H. Fisher, NSW EPA, pers. comm.).

In summary, little is known on the effects of pesticides on Australian species in their natural habitat, and almost nothing is known on effects on reptiles. Continued studies are required on the effects of spraying operations in the potentially sensitive semi-arid zone. Some organophosphorus pesticides, such as fenthion and monocrotophos are very toxic to birds and more information is required on the effects of newer pesticides, such as fipronil, on birds and termites. Current restrictions on second-generation anticoagulants appear to be warranted. Off-target crop or tree damage from herbicides is commonly reported but has yet to receive concerted attention (J. Agius, NSW EPA, pers. comm.).

### **6.2.7. Environmental effects of pesticides – Outstanding issues**

#### **6.2.7.1. Older persistent chemicals**

Most agricultural uses of persistent organochlorines (OCs) in Australia were discontinued by 1987 and other uses by 1995 (ANZEC 1991; NSW Agriculture 1996). Environmental contamination by persistent OCs does not appear to have been as widespread as in the USA, but Nowell *et al.* (1999) stressed the importance of continued monitoring of these compounds where they still persist, as the biological significance of very low OC residues to fish, wildlife, and humans is not known.

#### **6.2.7.2. Water quality reference streams**

Poor water quality is only one of many factors that contribute to degradation of a waterway, and pesticide contamination may be just one of a number of contributors to poor water quality. For example, many of the rivers of the Murray-Darling Basin are subject to multiple stresses, of which pesticides are just one (Thoms 1999). The long-term and extensive agricultural and pastoral development of the Basin means that it is often difficult to locate reference streams or billabongs to enable impacts of pesticides to be evaluated separately from the many other impacts.

#### **6.2.7.3. Potential water quality guidelines expansion**

The Australian water quality guidelines (ANZECC & ARMCANZ 2001) provide “trigger values” for 55 pesticides from a range of classes. These are designed to protect freshwater ecosystems from adverse affects from chronic exposure, but half of these are “*low reliability*” figures, due to the limited amount of available data. There are only five reliable pesticide trigger values available for marine waters. These are for DDT, endosulfan, endrin, and temephos with medium reliability and chlorpyrifos which has a high reliability. Hence, there is still a large number of pesticides for which water quality guidelines are unavailable, mostly due to the lack of comprehensive ecotoxicity data. This may indicate that pesticides are being used

when an understanding of the potential risks is limited, at least for the general public, who rely on readily available information.

#### **6.2.7.4. Diffuse pollution by endosulfan**

Diffuse sources of pollution from agricultural areas can be difficult to control. The DLWC's *Central and North-West Regions Water Quality Program* has shown some improvement in levels of a number of pesticides in major rivers in the north west of NSW since the first survey in 1991-92. However, high endosulfan levels are still found in a substantial number of samples collected during the growing season (Muschal 2001). The DLWC data are significant in monitoring the effectiveness of cotton Best Management Practices (BMPs) and the National Registration Authority regulatory restrictions on endosulfan (NRA 1998b, 1999a). These restrictions were aimed at reducing spray drift and include limiting the number of applications to two per season, except three where tailwater is retained (eg. cotton growing in northern NSW and southern Queensland), application of buffer strips, and increased record keeping and training.

#### **6.2.7.5. Irrigation practices from a pesticide viewpoint**

The extent of contamination or environmental effects from pesticides has been investigated less well in other irrigation areas around Australia than in the cotton growing areas of eastern Australia. Normal operations in the irrigation areas in north-west NSW and southern Queensland require storage and re-use of tailwater from flood irrigation, in part because of issues relating to environmental contamination, but most other flood irrigation areas currently have once-through flow. The extent and nature of pesticide usage, coupled with poor or absent tailwater management practices, are factors that contribute to the degree of contamination of waters in intensive agricultural areas. There may be a case for extending such practices to other flood-irrigated areas, where environmental contamination is likely. However, more efficient water use methods will provide alternative options. These include the adoption of improved irrigation practices such as drip irrigation and sub-surface irrigation, microsprinklers, partial root zone drying in the viticulture industries, better design of flood irrigated laser-levelled irrigation bays in relation to soil infiltration characteristics and application flow rates together with the encouragement of water being charged at its true value.

#### **6.2.7.6. Controlling riparian weeds**

Contamination of streams and waterways with herbicides is likely from treatment of riparian weeds. Many herbicides are transient in water (eg. glyphosate, picloram and triclopyr), but care is required with more persistent herbicides such as atrazine or diuron, and with the more toxic ones, such as older formulations of glyphosate. There are very few data on the effect of herbicides on aquatic plants and primary productivity (Rutherford 1989; Forbes 1996).

#### **6.2.7.7. Understanding flood impacts on the Great Barrier Reef**

The concentrations of pesticides are generally low within the Great Barrier Reef Area and are indicative of a relatively unpolluted environment, but there are contaminated sites adjacent to expanding areas of intensive agricultural activity, mainly sugarcane.

There were few studies linking exposure and effects on flora and fauna of the Reef but seagrass functioning could be affected by herbicides that inhibit photosynthesis, such as diuron, when they are transported by flood events (Haynes *et al.* 2000b). More data are required on the combined effects of increased turbidity, temperature and herbicide residues on seagrasses and coral zooxanthellae in the Reef area (Hutchings & Haynes 2000).

#### **6.2.7.8. Estuarine contamination**

There have been fewer studies on contamination of estuaries and few data on effects of pesticides on estuarine organisms, but it can be argued that estuaries may be more sensitive to some pesticides due to their fluctuating conditions, the interaction of toxicity with other components in the water and the high population densities surrounding them (Forbes 1996). Some estuarine invertebrate kills were associated with temephos (CEPA 1994). The occurrence of organophosphorus pesticides in urban streams may impact upon estuaries. A greater awareness of the potential impact of pesticide mismanagement on estuaries is desirable.

#### **6.2.7.9. Subtle effects of pesticides on the environment**

Understanding the cumulative and interactive effects of pesticides on ecosystems and the effects of appropriate pesticide mixtures on Australian aquatic species and ecosystems, particularly in many irrigation areas is still developing. The effects of short-term pulses of many pesticides are not well understood (Abdullah *et al.* 1994; Holdway *et al.* 1994; Naddy *et al.* 2000). This is relevant to application of water quality guidelines. More data are required on the effects of pesticides on birds and reptiles under Australian conditions, particularly on their behavioural responses in the wild. The risk from low levels of pesticides in the environment potentially disrupting endocrine functioning of wildlife (Colborn *et al.* 1996; USEPA 1997; OECD 1997) is currently unclear (Nowell *et al.* 1999) and little is known about causes and effects. A watching brief is being kept on the issue (Manning *in press*).

### **6.2.8. Environmental Monitoring of pesticides in Australia**

#### **6.2.8.1. Why monitor?**

The national evaluation of pesticide risk in the NRA process is based on sound international principles, but there is no post-registration monitoring system to confirm whether the predictions made in the assessments are accurate. Further, there can be large variations in use from site-to-site affecting the risk at the site and outcomes for the environment at that location. Monitoring of residues and/or environmental effects of pesticides in the environment is necessary to evaluate pesticide risk at specific sites and confirm the initial assessment, evaluate the effectiveness of regulatory controls and the effectiveness of changes in practices, to detect potentially-damaging releases (ARMCANZ 1998). It also shows whether the models used to estimate likely environmental concentrations in the assessment process were close to reality. It also establishes background levels and clarifies the long-term impacts on the environment of some pesticides that occur frequently (Kookana *et al.* 1998b).

#### 6.2.8.2. What do we monitor?

The standard form of monitoring for pesticides is to **monitor for chemical residues** in water, air, soil, sediment and biota. These are not mutually exclusive and data from different compartments may in fact complement each other to give a clearer picture of the fate and transport of pesticides. As many pesticides are transient in water, monitoring of sediment and biological tissues can give a more reliable indication of the degree of contamination. Interpretation of data from sampling in water or sediment is complicated by difficulties in obtaining representative samples because of small-scale spatial changes, rapidly varying concentrations by pulse events, movement of water and transport of pesticides.

The *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC & ARMCANZ 2001) promote assessments that integrate biological and chemical monitoring of surface waters and sediments to assess progress towards the goals of ecosystem protection. Biological assessment is seen as a vital part of assessing changes in aquatic ecosystems and achievement of management goals. The Guidelines provide assistance and protocols for selecting suitable biological indicators for specific aquatic ecosystems. The indicators selected will depend on the objectives of the study, ie. broad-scale rapid assessment, early detection, or biodiversity and ecosystem-level response. Further guidance on sampling and monitoring is provided in the Australian Guidelines for Water Quality Monitoring and Reporting (ANZECC & ARMCANZ 2001b). Water quality guidelines usually provide “no-effect” levels or, in the case of ANZECC and ARMCANZ (2001), trigger values that protect at least 95% of species. Even these trigger values are derived from chronic “no-observable-effect-concentrations”. It is often more difficult to settle on figures that indicate that some observable effect may be occurring. The Australian and New Zealand guidelines (ANZECC & ARMCANZ 2001) go some way towards estimating the percentage of a population that may be affected by a given chemical concentration.

Monitoring of **residue levels in biological tissues** can be useful in determining if the animals were exposed to sub-lethal background levels or to a recent lethal exposure (Nowak *et al.* 1995), if supported by well-designed laboratory exposures (Nowak *et al.* 1995; Jarvinen & Ankley 1999). Monitoring of residues in organisms, sediments or soil may be of greater value for determining persistence, trends or potential effects, than monitoring residues in spot samples of water, particularly if results are based on lipid content (Mortimer 2000a). It is often difficult to determine the relationship between residues in tissues and effects on populations and communities in the environment. In addition, chemical residue data in water, sediment or organisms will not always be useful for providing early warning detection of pesticide impact (Trim & Marcus 1990), due to the wide spread of sites, pulsed exposures that may not be detected, and lack of measurement of some pesticides. Some chemicals can have significant effects below detection limits (ANZECC & ARMCANZ 2001). Passive samplers, in the form of solvent-containing polyethylene bags, have been used to integrate varying exposures of pesticides in water and correlate these with biological effects (Leonard *et al.* 1999, 2000) and to detect pesticides in river water that were not detected by manual sampling routines (Muschal 1997, 1999). More work is required on the kinetics of uptake of different pesticides into the samplers placed in the environment, their loss from the samplers, appropriate solvents for some pesticides, and relating concentrations in the solvent to those in the water (R. Hyne, NSW EPA, pers. comm.).

**Sublethal effects** of pesticides on organisms can be used for monitoring of exposure and, sometimes, effects. The standards most often applied to residues of pesticides in fish and other organisms are usually based on human health for consumers (eg. ANZFA 1999), but there is scope to account for wildlife consumers (eg. CCME 1997). The latter procedures are almost exclusively based on North American data and food webs. Acetylcholinesterase (AChE) inhibition in fish brain or heads was found to be a useful within-season biological indicator of organophosphorus exposure in fish (Kumar and Chapman 1998, 2001) and terrestrial vertebrates (Mineau 1991).

**Fish kills** demonstrate an extreme form of environmental degradation, albeit sudden and temporary. As previously noted, natural environmental changes as well as introduced toxicants can cause fish kills. Adoption of more formal protocols for assessing and monitoring fish kills will ensure that the data are useable at a later date.

#### **6.2.8.3. Adequacy of environmental monitoring in Australia**

The level of monitoring of pesticide residues in the Australian environment varies greatly, depending on the state or region, the industry and the environmental medium. The limited amount of monitoring for pesticide residues and its variability from one region to another precludes a clear understanding of pesticide exposure in the Australian environment. There can be a tendency for monitoring programs to be determined by the cost of monitoring rather than on the basis of a risk appraisal and a consequent cost : benefit analysis of undertaking the program. Aquatech (1997) identified that almost two-thirds of chemicals that were on the NRA's Existing Chemical Review Program list were not regularly monitored in the environment, and monitoring of the remainder is restricted to high-use areas, such as the cotton growing regions. The NSW Parliamentary Standing Committee on State Development (1999) also noted that there was a lack of information on many chemicals found in waterways, particularly on what levels are ecologically sustainable for various organisms. The Committee noted that, with the large number of pesticides, "the task of determining the ecological sustainable levels of pesticide exposure for biota is not realistically achievable. ... Better management of pesticides to mitigate or avoid adverse impacts on biota may be the most cost effective avenue for government and the community." The collection of monitoring data by which the effectiveness of pesticide controls can be assessed tends to be rather ad hoc and are not generally designed, collated or used to enable a statistically valid analysis of any chemicals management practices (ARMCANZ 1998). ARMCANZ (1998) recognised that "monitoring is a crucial step in understanding the environmental impact of chemicals and for taking subsequent action to reduce the impacts". Furthermore, as control of use is a state responsibility, it is inevitable that there will be variations in how this topic is approached across the nation.

The most consistent and comprehensive data set for pesticides anywhere in Australia is the *Central and North-West Regions Water Quality Program*, which has been monitoring five catchments in the cotton growing areas of the north west of NSW since 1991 (Muschal 2001). This data set is assisting in monitoring the effectiveness of cotton industry BMPs and controls on endosulfan usage and is proving a valuable resource for pesticide risk assessments in the NSW cotton industry (Muschal & Warne 2001). Even this program is limited by its weekly (at best) sampling of water

column concentrations, and limited sediment monitoring. The program is under threat of being scaled down.

Rutherford (1989) assessed the adequacy of monitoring programs for Western Australia in different environmental compartments. Substantial monitoring of pesticides in air was not considered justified, although there was very little basic data and little understanding of off-site movement of pesticides in air. Monitoring of sediments and indicator organisms in estuaries was recommended. Rutherford (1989) acknowledged that Western Australia's rivers carry significant pesticide loads, but that many are not extensively monitored. Wetlands in WA can receive pesticides and it was suggested that they require monitoring for effects on wetland ecology. The sandy soils in WA allow ready transport of pesticides to groundwater, and continued monitoring of groundwater is essential.

Haynes and Johnson (2000) noted that most of the pesticide monitoring data in the Great Barrier Reef area are now old, and recommended that more contemporary information should be collected on the distribution and impact of contaminants in the Reef environment. They also suggested that the utility of specialised monitoring tools such as **biomarkers** should be examined for tropical marine environments. Forbes (1996) noted that there was little monitoring in estuaries and little information on effects on estuarine organisms.

Aquatech (1997) reported that, in the mid-1990s, only four national bodies were involved in any sort of pesticide monitoring (including event monitoring and research) but no groups were involved in ongoing environmental monitoring at the national level. Most state governments were undertaking some form of pesticide monitoring with the most programs in Victoria (21) and NSW (9). Few of these studies were ongoing programs. Aquatech (1997) established that a total of only \$1,100,000 was spent on monitoring environmental effects in 1994-95 in Australia. The authors recommended that a monitoring strategy should be integrated with the process of registration of agricultural and veterinary chemicals, to complement to the current NRA risk assessment process. ARMCANZ (1998) supported the development of systematic approaches to post registration monitoring

#### **6.2.8.4. Requirements for an effective monitoring program**

Prerequisites for a successful monitoring program are (Aquatech 1997):

- The program must have clearly stated goals and objectives.
- All relevant parties must agree to the strategy, including agreements on funding mechanisms and the provision and sharing of information.
- The monitoring activity must be appropriately targeted to provide the most useful information for the effort expended (ie. it must be cost-effective).
- The potential environmental effects of residues of the chemicals must be known (if not, further information is needed to help set monitoring priorities).
- Results of the monitoring must be seen to have an outcome; for example by being taken into account by NRA in reviewing the conditions of registration for chemicals and by appropriate modification to the monitoring strategy itself.
- The strategy must take into account and collaborate with existing related activity such as the National Competition Policy.



#### **6.2.8.5. Future options for monitoring in Australia**

Eight options have been suggested (Aquatech 1997) for future monitoring of pesticides (environmental effects or contamination) in Australia, noting that the first seven below would require additional resources:

- A comprehensive national environmental monitoring program and database, with a wildlife incident reporting scheme;
- A national database of wildlife and pesticide incidents;
- A 'risk assessment' approach to setting monitoring priorities;
- Industry-based monitoring;
- Monitoring by state and territory agencies (eg. environmental and/or agriculture departments);
- A National Residue Survey (and/or Australian Market Basket Survey, now called "The Australian Total Diet Survey" (see Chapter 5) with appropriate modifications to also cater for environmental concerns;
- Use of ecosystem health indicators as a guide to setting monitoring priorities; or
- Continue with present situation.

It is important that strategies to reduce pesticide exposure do not increase the risk of harm to the environment in other ways. One such strategy, ie. genetically modified organisms (GMOs), is controversial in some sections of the community.

Monitoring of pesticides in Australia is limited and is carried out in an *ad hoc* manner. Some major areas of pesticide use receive little or no monitoring. Much of the pesticide monitoring in Australia has been short-term event monitoring and it is difficult to ascertain clear trends in pesticide contamination since these studies were completed. The situation has not substantially improved since the Aquatech (1997) evaluation, and their recommendations are still current. More emphasis needs to be placed on biological monitoring of organisms and ecosystems for **effects** of pesticides, not just concentrations.

It is a fact of political life that expensive programs like environmental monitoring for pesticide pollution are only undertaken when the perception of risks to human health, trade in primary produce or (less often) environmental damage breaks through the complacency barrier and impact widely on the respective stakeholder groups and the community at large.

#### **6.2.9. Minimising pesticide impacts on the environment**

There are a range of possibilities for further reducing pesticide exposure and impacts on the environment. Some are based on reductions in pesticide usage and others are based on control technologies.

##### **6.2.9.1. Regulatory Controls**

Impacts of many pesticides are minimised by NRA processes which withdraw registration (eg. monocrotophos), impose tough restrictions (eg. those on endosulfan), or change conditions of usage (eg. atrazine). The National Registration Authority currently requires notification of neighbours for some pesticides, notably endosulfan

and 1080, and further notification requirements are being considered in the NRA's ECRP process.

Estuarine species and benthic species are often not well represented in pre-marketing data, and Forbes (1996) recommend that they should be included in pre-market testing where significant pesticide application is likely to occur adjacent to estuarine environments.

Controls of pesticide use are the responsibility of the states. The Agricultural and Resource Ministers Council of Australia and New Zealand (ARMCANZ) has established a Control of Use Taskforce to make recommendations for pesticide control within the various jurisdictions. This will also identify opportunities to improve national consistency of such operational matters as off-label use, more definitive labelling, performance monitoring, etc (Mallen-Cooper, NSW EPA, pers. comm.).

The NSW Government, in its response to the recommendations of the report on pesticide management in NSW of the NSW Parliamentary Standing Committee on State Development (1999) considered that there is merit in developing a strategic planning approach for sustainable agriculture. Options for the development of such an approach in the planning process are being considered.

#### **6.2.9.2. Use of alternative pesticides**

The increased use of biological control agents such as *Bacillus thuringiensis* (*Bt*) has helped to contain the expansion of conventional pesticides in the USA, particularly in forestry (Nowell *et al.* 1999). *Bt* has also been used widely in Australia against lepidopteran pests (eg. Caterpillars), particularly in the context of integrated pest management. The Australian Plague Locust Commission (APLC 2000) has been experimenting with a fungal biopesticide *Metarrhizium* for control of locust outbreaks, as an alternative to the fenitrothion. These can still cause off-target effects and are also subject to development of pest resistance.

The *National Strategy for Agricultural and Veterinary Chemicals* (ARMCANZ 1998) which is summarised in Appendix 2, supports the search for alternative pesticides. The NSW Parliamentary Standing Committee on State Development (1999) recommended that NSW Agriculture support research with increased funding into alternative methods to control and eradicate pests, plant disease and weeds other than by pesticide application. NSW Agriculture has extensive involvement with the organic produce industry and conducts research to reduce or remove reliance on chemical treatments. Other organisations are also involved in such research: these include activities through the Cooperative Research Centre for Weed Management Systems and the Cooperative Research Centre for Biological Control of Vertebrate Pests.

#### **6.2.9.3. Integrated pest management**

The amount of pesticide used as well as the risk associated with their use can be reduced a number of actions. Probably the most common means of pesticide risk reduction is through integrated pest management (IPM) initiatives for various crops, based on a combination of methods (ARMCANZ 1998; Kookana *et al.* 1998a).

Pesticide resistance is another strong reason for introducing IPM (ARMCANZ 1998). Integrated pest management was introduced in the cotton areas of eastern Australia mainly to control resistance to pyrethroids (Shaw 1999) but it also has the potential to reduce exposure to specific pesticides. IPM relies mainly on modifying the pesticides used across an industry sector, usually by rotation of the type of pesticide through a growing season. IPM strategies are mostly aimed at reducing the use of insecticides. There is little scope for reducing fungicide usage and pressures on increasing herbicide usage, mainly from trends to reduced tillage and rising labour costs (Schofield & Simpson 1996).

#### **6.2.9.4. Transgenic crops**

Expansion of industries that require repeated application of pesticides, eg. cotton and horticultural crops, has resulted in increased use of pesticides. Reductions in pesticide usage may be possible using new technology such as genetically modified cotton and other crop plants, which have the capability to deal with key pests. It is, however, likely that there will still be a major reliance on pesticides for some time in the future (O'Connell 1998).

Recent advances in genetic engineering and biotechnology provide an opportunity to replace the broad-spectrum synthetic organic pesticides with biological control methods (Hogan 1990). Use of the *Bacillus thuringiensis* (*Bt*) cotton may reduce the use of conventional pesticides where lepidopteran pests are a problem. It will also reduce worker exposure to the conventional chemicals. *Bt* Cotton use in Australia has the potential to reduce pesticide use by two-thirds (Cameron 1996). However, the long-term effectiveness of transgenic crops in reducing pesticide remains to be seen (Kookana *et al.* 1998b) and pest resistance can still occur (Renner 1999). CSIRO is commencing research on environmental assessments of GMOs using larger scale, longer-term studies of potential effects on biodiversity such as genetically modified cotton, clover, canola and other newer GMOs (M. Lonsdale, CSIRO, pers. comm.). Improved GMO assessments resulting from this continuing research will assist a risk assessment process. Overall environmental gains need to be considered when substituting chemicals with transgenic crops. For instance, use of "Roundup-ready" crops may result in substitution of low volumes of sulphonyl urea and other herbicides with high volumes of glyphosate (G. Stephenson, Uni. Guelph, pers. comm.). These issues are further discussed in Chapter 9.

#### **6.2.9.5. Modifying application techniques**

Spray drift from aerial applications can be modelled using predictive models that consider the effects of application, meteorology, tank mix and environmental variables on off-target spray movements and deposition (Woods 2001; [www.agdrift.com](http://www.agdrift.com)). These models assist in maximising efficacy and minimising off-target drift, and assist regulatory needs. The US EPA exposure assessments currently assume fixed drift levels for specific application methods but is currently evaluating the AgDRIFT® model and proposes to use it for aquatic and terrestrial exposure assessments where actual data are not available (Birchfield *et al.* 2001). Walker *et al.* (2001) found that the spray drift model AgDRIFT® was a useful predictor for drift from orchard mist blowing in Tasmanian apple orchards. Simulations using AgDRIFT® were comparable with field results using pulse monitoring. Large droplet placement (LDP) application technology, in conjunction with down wind buffer

distances was recently used to manage pesticide spray drift in cotton in eastern Australia (Woods 2001), and the current endosulfan label directions reflect these latest findings with specific equipment recommendations. Modern technology, such as Global Positioning Satellite marking systems can facilitate accurate aerial pesticide application (NSW Parliamentary Standing Committee on State Development 1999).

#### **6.2.9.6. Formulations**

Different formulations of pesticides can present different hazards to the environment. Pesticides sprayed onto foliage are more likely to evaporate than those applied to soil, while incorporation of pesticides into soil can further reduce evaporation (Kookana *et al.* 1998b). Granular formulations can also reduce evaporation and runoff but the hazard to birds may be increased. For instance, birds can consume lethal quantities of aldicarb granules, particularly when food is scarce and small numbers of individual birds have been killed by aldicarb in the UK and USA. Incorporation of granules beneath the soil surface greatly reduces the risk to birds and small mammals (NRA 2001).

#### **6.2.9.7. Run-off reduction and use of wetlands remediation**

Containment of contaminated water in dams or wetlands may provide time for pesticides to be removed by sediments or through degradation. On-farm concentrations are sufficiently high that any direct escape of runoff water to the river or wetlands for several months after spraying will lead to significant environmental contamination (Kennedy 1999). Farming practices that reduce runoff such as the provision of vegetation cover can significantly reduce the probability of environmental impacts (Kennedy 1999). Leonard *et al.* (1999, 2001) demonstrated the significance of storm runoff of endosulfan on seasonal macroinvertebrate populations.

Finlayson and Silburn (1996) suggested a number of measures to reduce pesticide movement in runoff from Australian farm fields. These include: using less pesticide; using pesticides with more rapid dissipation rates; reducing the amount of runoff; reducing the amount of sediment loss by silt traps; and decontaminating runoff between field and stream by using other means such as filter strips and dams. The *Filtration and Irrigated cropping for Land Treatment and Effluent Reuse* (FILTER) system has been shown with spiking trials to reduce pesticide loads by more than 98% with chlorpyrifos, molinate, malathion, bensulfuron, diuron, bromacil, atrazine, metalochlor and endosulfan (Biswas *et al.* 2000a,b).

Retaining surface cover can assist in reducing runoff for many pesticides (Connolly *et al.* 1998; Finlayson & Silburn 1996) but for some herbicides, residue cover can provide a source during rain (Baker & Johnson 1983), resulting in a secondary release to the environment.

#### **6.2.9.8. Riparian vegetation and buffer strips**

Buffer strips are used under forestry and some agricultural systems, to filter the sediments and associated nutrients and pesticides. However, so far there is relatively little experience with buffer strips in Australia (Barling & Moore 1993). Vegetated buffer strips have been effective in reducing the off-farm movement of several pesticides into streams (USDA 2000). Walker *et al.* (2001) found that a vegetative

buffer halved the amount of drift moving off a Tasmanian apple orchard treated with a mist blower.

Barton and Davies (1993) evaluated the effectiveness of buffer strips in preventing pesticide contamination of streams draining from *Eucalyptus* plantations in Tasmania. They found that wider riparian buffer strips, but not necessarily the quality of the strips, seemed to be reducing atrazine concentrations on the day of spraying. They estimated that buffer strips of 30 m width for atrazine and 50 m for pyrethroids would be required to minimise the short-term impact of these pesticides on stream ecology. The long-term effectiveness of buffer strips in trapping pesticide contamination is still unclear (Kookana *et al.* 1998b).

#### **6.2.9.9. Control of wastes**

Historical disposal of pesticide containers, surplus chemicals and wastes throughout rural Australia has also left a legacy of sites contaminated with a wide variety of pesticides. Efforts to address this issue, such as through industry waste reduction schemes, surplus chemical collection campaigns (“ChemCollect” and “ChemClear”) and container management programs (“drumMUSTER”) are discussed in the Chapter 8.

Land disposal of waste dip wash from sheep dip facilities in the UK has been regulated more effectively in recent years. In Australia, it is largely unknown what practices are actually used, although label directions give broad guidelines with regulatory power. Both contaminated land and contaminated water may be issues for both cattle and sheep dip sites in Australia.

#### **6.2.9.10. Best management practices**

Best management practices (BMPs) have been developed in several countries including Australia to minimise the impact of pesticides on the environment (ARMCANZ 1998). BMPs extend the concept of IPM and use a variety of the methods described above with the aim of reducing environmental and human exposure. A draft manual of BMPs for the cotton industry has been produced, with a view to minimising the use, the off-farm transport, and the impact of pesticides on the target area (CRDC 1997; Anthony 1998). This largely resulted from the research program, '*Minimising the Impact of Pesticides on the Riverine Environment using the Cotton Industry as a Model*' initiated by the Land & Water Resources Research & Development Corporation, the Cotton Research and Development Corporation (CRDC), and the Murray Darling Basin Commission (MDBC) in 1991 (Schofield 1998). The feasibility and practicality of the proposed BMPs are now being evaluated in the field. The cotton BMPs Manual includes issues such as, farm design, pesticide application, management of tail-water, pesticide storage and handling, hazard assessment and integrated pest management. The cotton BMPs manual may be a model for development of BMPs in other sectors of the agricultural industry.

It is important that BMPs are not seen by industry as a completion of their environmental obligations, as BMPs are an evolving tool (one of many) and are intended to provide a common basis for achieving an outcome that is sustainable for the environment. Adherence to BMPs does not automatically eliminate off-target

exposure or impacts. Continued impetus will be needed to ensure that the participants maintain the BMP requirements and continue to strive for environmental gains.

In summary, uptake of industry BMPs is progressing, albeit slowly, into other agricultural areas and sectors. Some agricultural sectors would benefit from an influential coordinating industry body to drive such reforms. Wider adoption of many of these options has the potential to further reduce the risk of pesticides on the environment. These measures by themselves will not solve all pesticide problems, and it is essential that industry and regulatory bodies maintain the momentum after their introduction. Reliance on transgenic crops and biopesticides may provide only short-term gains, as they too are subject to pests developing resistance (Renner 1999). As further discussed in Chapter 9, overall environmental gains need to be considered when substituting pesticides with transgenic crops.

#### **6.2.10. Successful pesticide reduction in Australia**

Efforts to reduce pesticide usage in the sugarcane and horticultural areas around Bundaberg in Queensland (Stirling *et al.* 1996) have included combinations of IPM strategies such as pest monitoring, use of predators, farm hygiene, buffer plantings and specific chemical and biological control agents (eg. *Bacillus thuringiensis*). The authors suggested that there was some way to go in carrying IPM forward and that short-term cost pressures and changing skill structures in government organisations are working against the knowledge and skills base required to support any effective IPM program.

Although the Northern Territory was allowed to continue with the use of chlordane until 1997 because of the difficulty in controlling the termites *Mastotermes darwiniensis* and *Coptotermes acinaciformis*, persistent organochlorines for termite treatment were prohibited in the remainder of Australia from July 1 1995 (NSW Agriculture 1996). This has resulted in a general reduction in organochlorine levels in Sydney's sewage outfalls (Sydney Water 2000). The construction of Sydney's deep ocean sewage outfalls 3 kilometres out to sea in 1990-91 has also assisted in reducing high residues of organochlorines in nearshore marine organisms, without increasing contamination of offshore species (Krogh & Scanes 1996).

There are indications of decreasing levels of endosulfan in the five river valleys tested by DLWC since 1991. Still, almost 30% of samples in the cotton growing areas exceeded 0.01 µg/L (Muschal 2001) and 10% exceed the current water quality guidelines. This is a marked improvement on almost 90% in 1991-92 and 65% in 1997-98. The recent improvements have followed the full implementation of Best Management Practices and the NRA's tougher restrictions on endosulfan.

Most programs to minimise pesticide effects will incorporate a number of approaches. Moss *et al.* (1996) identified the land use factors that affect the condition of rivers and estuaries in southern Queensland and suggested that priority effort should be given to: control of sediment loss; revegetation of riparian zones; and acquisition of information on the biological status of waters. Some of these factors should assist in the control of pesticide contamination of waterways.

These examples show that there is still considerable scope for reducing and more effectively managing pesticides in Australia, while ensuring adequate control of pests.

### **6.3. CONCLUSIONS - ENVIRONMENTAL EFFECTS**

It must be recognised that the toxicity of chemicals varies greatly with their properties, the species being considered and a variety of environmental factors.

Any consideration of the environmental impact of pesticides must differentiate between *hazard*, which is an inherent property of a chemical that makes it capable of causing adverse effects, and *risk*, which is the probability that the harm from the chemical is realised under the specific conditions being considered or likely to be encountered within its permitted uses.

Endosulfan has been perceived as the chemical with greatest potential for risk in catchment and water environments, and has been primarily used in cotton-growing areas. Levels found in surface waters in cotton-growing areas of eastern Australia declined from 89% exceeding 0.01µ/L in 1993-4 to only 29% in 1999-2000. Only 10% exceeded the ANZECC/ARMCANZ standard of 0.03µ/L. Some rivers which in earlier years showed significant levels, had no detectable levels in 2000.

Residues of organochlorines, withdrawn from agricultural use twenty years ago, are still occasionally found in surface waters. Current pesticides are much less persistent but are still detected in some surface waters.

Pesticide contamination of groundwaters has been noted world-wide. Where groundwater contamination has been detected in Australia, it has usually involved triazine herbicides. Pesticide residues in Australian groundwaters have generally been lower than those overseas, and a number of recent surveys show reductions in the extent of detections now being found. However, poor land management practices in a few areas are continuing to create groundwater contamination risks.

The measurement of pesticide residues in sediments or biota may be more useful than testing for residues in water. Residues of endosulfan, organophosphorus and other pesticides have been detected in Australian biota near intensive agricultural areas. Recent controls by the NRA on the use of endosulfan are expected to reduce the risk, particularly of any fish kills in cotton-growing areas.

Fenitrothion, which has been widely used for locust control, has been shown to reduce non-target invertebrate fauna, with full recovery after four weeks. An alternative, fipronil, is now being trialed, and the effect of this pesticide on invertebrates should be examined.

Relatively speaking, little is known of the effects of pesticides on Australian species in their natural habitats. Some organophosphorus pesticides such as fenthion, can be toxic to birds. More information is required on the effects of newer pesticides such as fipronil on birds and termites in their natural range. The risk of off-target herbicide damage to commercial crops, especially vineyards, is well established, but off-target damage to native plants and trees needs further attention.

**Monitoring of pesticides in Australia has often been carried out in an *ad hoc* manner in response to short term events which are perceived to impact on stakeholder groups. Any longer-term trends have been difficult to detect. A comprehensive integrated national environmental monitoring program should be implemented, based on an appraisal of the risks and a consideration of a cost:benefit analysis for undertaking the program.**

**More emphasis needs to be given to monitoring the biological effects of pesticides on organisms and ecosystems rather than just testing concentration effects in individual species.**

**Any National Adverse Health Effects Register set up should also be broadened to become a National Adverse Pesticides Effects Register to record adverse environmental effects.**

**Monitoring of the impact of pesticide use on the natural environment is not well or consistently structured, being spread between the Commonwealth and states/territories agencies. A greater breadth of evaluation, encompassing post registration monitoring of results by the NRA, together with a more integrated approach by the states/territories is desirable. Primary emphasis should be placed on determining any toxicological impact of pesticides on human health and environmental biology rather than only measuring residual pesticide concentrations. Consideration should be given to providing additional resources to develop a comprehensive national environmental monitoring program and database, including a scheme providing for specific reporting of incidents involving the impact of pesticide incidents on the natural environment,**



## **7. CLEARANCE, REGISTRATION AND CONTROL OF USE OF PESTICIDES**

A national pesticide registration scheme, operated through the National Registration Authority for Agricultural and Veterinary Chemicals, has been in place since 1995. A rigorous process ensures chemicals do not represent an undue hazard with respect to public health, occupational health and safety, the environment or trade and commerce, and have appropriate efficacy. A Chemical Review Program for previously registered chemicals is in place. The NRA can issue permits for off-label minor uses where that use is an offence against state control-of-use laws. The states are responsible for control of use of pesticides beyond the point of retail sale, and there is a wide range of legislation and policy interpretation in place. Improved harmonisation in the states' approach to these issues is desirable. There would be benefits from improved information technology services for pesticide users. There are increasing numbers of quasi-regulations developing in the form of food safety and quality assurance schemes, many driven by multinational food companies and large retailers. Some shortcomings and anomalies are evident. Legislation is in place to establish Food Standards Australia and New Zealand to deliver a more streamlined, efficient and nationally focussed food regulatory system for Australia.

### **7.1. THE DEVELOPMENT OF PESTICIDE REGULATION**

#### **7.1.1. The Origins in the States**

Beginning in the 1950s, individual states and territories registered pesticides under their own legislation and gradually worked towards harmonisation of registration requirements through a clearance process coordinated by the then Commonwealth Department of Primary Industries. However, significant differences between states remained with only some states having legislation in place to control the use of pesticides at the farm level. Nationally, chemical issues including the above mentioned clearance process, representation in international forums (especially the Codex Alimentarius Committee on Pesticide Residues) and sharing of Commonwealth and state residue survey data were overseen by the Coordinating Committee on Agricultural Chemicals (CCAC) under the Standing Committee on Agriculture.

#### **7.1.2. Developing a national approach**

In 1987, Australian agriculture faced a major trade crisis when organochlorine residues (DDT, dieldrin etc.) were detected in beef to be exported to the United States. Markets for Australian meat, valued (then) at \$2 billion were placed in jeopardy.

This residue incident sparked a national debate on the regulation of agricultural and veterinary (agvet) chemicals resulting in a progressive change process with respect to

the management of agvet chemicals in Australia. The voluntary coordinating process of clearance of agvet chemicals prior to registration was replaced in 1989 with a legislative process under the auspices of the newly-created Australian Agricultural and Veterinary Chemicals Council (AAVCC). Concurrent with the formation of the AAVCC, CCAC continued to operate until 1993. A Commonwealth Senate Select Committee on Agricultural and Veterinary Chemicals was also established. In July 1990, the Committee reported that the legislative basis for the chemical regulatory system was overly complex and required significant rationalisation. Its key conclusions were that the then system of AAVCC clearance and individual state registration of agvet chemicals was inefficient and inconsistent and it recommended that it be replaced by a national registration scheme.

The then Australian Agricultural Council agreed in August 1991 that a single national agvet chemicals registration scheme should replace the eight state and territory registration schemes. The scope of such a national scheme was considered in detail by the AAVCC and it was decided that the focus should be on the registration process only (see chemical pathway concept, Appendix A). State registration powers were to be transferred, but each individual state would retain the power to control use of agvet chemicals in accordance with its own policy objectives. The national registration scheme was therefore designed only to cover the steps involved in the assessment and approval processes for chemical products up to the point of retail sale.

In March 1995, the National Registration Scheme (NRS), under which agricultural and veterinary chemicals are assessed, commenced under Commonwealth legislation. A 100 percent cost recovery policy for the registration process was gradually implemented with the states continuing to fund their own control of use functions.. The National Registration Scheme is administered by the National Registration Authority for Agricultural and Veterinary Chemicals, a Commonwealth statutory body commonly known as the NRA. Under the Scheme, the states and Northern Territory adopted a model which transfers registration powers to the NRA. The scheme is not a “natural scheme” under Commonwealth law (except for the ACT) but is rather a cooperative scheme.

The nature of the Australian constitutional division of powers between the Commonwealth and the states and territories poses some difficulties for setting up schemes like the National Registration Scheme. Indeed, a recent High Court decision (Hughes, 2001) raised questions about the capacity of Commonwealth officers and authorities to perform functions under state laws as part of cooperative arrangements with the states. The High Court decision had potential implications for the agvet chemical National Registration Scheme insofar as then current regulatory arrangements to assess, register and control use of agvet chemicals appeared vulnerable to possible legal challenge. In consequence, the Standing Committee on Attorneys-General initiated a generic validation exercise which captures some necessary amendments, the Commonwealth has passed the *Agricultural and Veterinary Chemicals Amendment Act 2001* and complementary legislation is being passed by state and territory parliaments.

Other recommendations made in the Senate Select Committee Report (1990) included a proviso that the regulatory approach with respect to off-label use and ways of funding regular, nationally co-ordinated surveys to monitor the environmental impact

of agvet chemicals, should be examined. In addition, the Committee recommended the phasing out of remaining uses of organochlorine termiticides, a national approach to control of aerial spraying, safe disposal procedures for unwanted chemicals and chemical containers, and improved public information transfer and training of pesticide users.

Since the 1987 organochlorine residues event, more recent pesticide residue incidents have occurred. In the 1990s, residues of chloflazuron (Helix) were detected in beef (1995) after cattle were fed cotton trash as a feed supplement during a period of drought; exports of some horticultural commodities have been rejected due to the detection of residues of pesticides for which no standard has been set by the importing country, therefore meaning zero tolerance; fish kills in some of Australia's inland waterways, attributable to pesticide residue run-off, have been observed and a number of incidents of pesticide spray drift having adverse impacts on human health and other non-target species, have been recorded.

Between 1987 and 1998, a number of further significant changes were made to the national management of pesticides. The Agricultural and Veterinary Chemicals Policy Committee (AVCPC) was established under the Standing Committee of Agriculture and Resource Management (SCARM) in 1993 to replace both CCAC and AAVCC; the remaining uses of organochlorines were banned in 1992; a national review of pesticide spray drift was commenced in 1993; in the early 1990s, Avcare obtained approval under the Trade Practices Act for their Agsafe accreditation program and a national training and accreditation program for farm chemical users was established under the auspices of the NFF and the Rural Training Council of Australia; the AVCPC established a control of pesticide use working party in 1996 which made little progress, but which is currently being considered by a high level control of use task force in the context of the National Competition Policy reform (see next section). Another noteworthy development in the 1990s which serves to illustrate the breakdown of the strong linkage between registration and residues, that existed in the earlier days of the CCAC, was the introduction of legislation for the National Residue Survey and the establishment of the SCARM Residue Management Group.

The above initiatives indicate that a gradual transition took place up to the mid-1990s from a rather uncoordinated system of controls through a tightening of the agvet chemicals registration process with the formation of the NRA. However, whilst the NRA has consolidated its registration role over the last five years, the appropriate controls and incentive structures for downstream pesticide use continue to challenge policy makers.

In 1998, the Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) published a report, "Management of Agricultural and Veterinary Chemicals: A National Strategy" (ARMCANZ 1998).

The strategy for the use of agvet chemicals enunciated in this report was to:

- minimise risks to health, the environment and trade;
- ensure long term sustainability of agricultural productivity;

- best contribute to national prosperity.

The strategy covers a broad range of agvet chemical issues (see Appendix B).

ARMCANZ was a council composed of the Ministers responsible for primary industries/natural resources or the equivalent areas from the Commonwealth, states, territories, and New Zealand governments. ARMCANZ was the main vehicle for Commonwealth/state governments policy coordination in agriculture and natural resource management. The National Strategy thus had the endorsement of all Governments. There was a subsidiary committee structure based on the Standing Committee of Agriculture and Resource Management (SCARM), which was made up of the corresponding portfolio government departments together with representatives from CSIRO and the Bureau of Meteorology. Under SCARM there were a number of committees charged with the responsibility for developing policy advice of concern to both Commonwealth and state governments. (From August 2001, a new Ministerial Council structure was set in place, with agricultural and veterinary chemicals issues falling primarily within the purview of the Primary Industries Ministerial Council [PIMC] and its Primary Industries Standing Committee [PISC].)

For agvet chemical product issues, primary carriage rests with the Agricultural and Veterinary Chemicals Policy Committee (AVCPC). This was restructured in early 2001 with the objective of becoming a high level committee aimed at providing strategic advice. The AVCPC includes representation from Commonwealth, state and territory primary industries agencies as well as CSIRO. The National Registration Authority provides technical advice. In order to ensure the involvement in policy development of Ministerial Councils with responsibility for environment and public health and safety, representatives from relevant portfolios are included on the Ministerial Council Liaison Committee. A similar Liaison Committee has been set up for non-government organisations. Whilst recognising that the previous AVCPC structure was very unwieldy with 23 members, and the raising of the status of the current membership to a more clearly defined policy level is sound, some concern may well be expressed regarding the other portfolios' representatives and other organisations being isolated into two subordinate advisory bodies.

The most notable document recently produced through the AVCPC system addresses the important issue of pesticide spray drift, "Spray Drift Management: Principles, Strategies and Supporting Information" to be published in early 2002. The fact that it took eight years to produce these national management principles reflects limitations in the responsiveness of the then policy-generating framework.

### **7.1.3. National Competition Policy**

In April 1995, all Australian governments endorsed the National Competition Policy reform agenda which included among other matters, the review of all government legislation/regulations restricting competition. The guiding principle is that legislation should not restrict competition unless it can be demonstrated that:

- the benefits of the regulation to the community outweigh the costs;
- the objectives of the regulation can only be achieved by restricting competition.

The National Competition Policy impacts on pesticide use legislation and regulations insofar as all states were required to review all state legislation (including pesticide control of use regulations) before the year 2000, with a view to identifying and removing unnecessary barriers to competition.

In 1998, an independent National Competition Policy (NCP) review of agvet chemical legislation was commissioned by the Victorian Department of Natural Resources and the Environment on behalf of all state and territory governments. The “National Legislation Review: Agricultural and Veterinary Chemicals (Final Report, Jan. 1999)” (Pricewaterhouse Coopers 1999) provides a good analysis of legislation governing the National Registration Authority and the National Registration Scheme for agvet chemicals and control of use arrangements in Victoria, Queensland, Western Australian and Tasmania. The review does not cover control of use legislation in New South Wales, South Australia and the Northern Territory. These legislations are currently the subject of separate NCP reviews by the respective jurisdictions. Moreover, for the states reviewed, the review is restricted to Commonwealth and state/territory legislation which deals exclusively with pesticide use and which potentially restricts competition. An array of legislation that applies jointly to pesticides and other materials was outside the ambit of the review, but within the scope of the present report. This includes Acts and Regulations covering occupational safety and health, environmental protection, and storage and transport of hazardous substances. The review also did not cover programs relating to the safe disposal of pesticide containers and unused pesticides. The National Legislation Review Team made a number of recommendations, including that ARMCANZ establish a control of use task force to develop a nationally consistent approach to off-label use and to consider a number of other control of use matters. In February 1999, ARMCANZ agreed to the establishment of a Signatories Working Group (SWG) with responsibility for drafting a response to the NCP review.

A draft inter-government response to the NCP review was completed in January 2000. This response was broadly supportive of most of the recommendations contained in the NCP review, and was endorsed by ARMCANZ in August 2000. In particular, a control of use task force has been appointed to develop a nationally consistent approach to the important problem of off-label use, responding to a range of issues raised in the National Competition Policy Review. A decade after this was first proposed by the Commonwealth Senate Select Committee on Agricultural and Veterinary Chemicals, the accomplishment of a nationally consistent approach to control of use continues to be an elusive goal, primarily because the states have different and strongly held views on the appropriate forms of government intervention and regulation to control agricultural and veterinary chemical use.

## **7.2. THE NATIONAL REGISTRATION SCHEME**

The starting point for considering the regulatory and management arrangements of agricultural pesticides in Australia is the National Registration Scheme. The scheme is underpinned by a suite of legislation that establishes the Agricultural and Veterinary Chemicals Code (the Agvet Code) under both Commonwealth and state law and the National Registration Authority for Agricultural and Veterinary

Chemicals (NRA) as the agency responsible for administering the Agvet code. The NRA is responsible for the assessment and registration of agricultural and veterinary chemical products prior to sale and their regulation up to and including the point of retail sale. Beyond this point, each state and territory controls the use of agvet chemicals through its own legislation. The focus of this study is on agricultural pesticides. Legislation applying exclusively to veterinary chemicals is not considered.

### **7.2.1. Initiating a National Registration Scheme**

The scheme became fully operational on 15 March 1995. Prior to the scheme, agvet chemical registration was a separate responsibility of each state and territory although an interim legislative clearance process had operated since 1990. Agvet chemical manufacturers and distributors were required to negotiate multiple registration processes with sometimes inconsistent registration requirements. The Senate Select Committee on Agricultural and Veterinary Chemicals in Australia noted that the individual state and territory legislation imposed unduly high administrative and compliance costs and lengthy time delays. In 1991, the Commonwealth, states and territories agreed that the existing system was no longer appropriate and decided to implement an overarching national scheme for the registration of agvet chemicals. The NRA was established in 1992 under transitional arrangements and the new scheme came into full effect in March 1995. The move to a single national registration scheme also incorporated a shift from around 50 percent cost recovery to full cost recovery.

The main components of the current National Registration Scheme are:

- the assessment and registration of agvet chemicals for sale in Australia;
- the review of the registration of agvet chemicals registered by the states and “grand fathered” into the national scheme existing prior to the establishment of the NRA;
- the undertaking of special reviews of agvet chemicals in the light of new information or adverse events;
- compliance monitoring of chemical products to ensure that chemicals in the market place are NRA registered products and comply with their stated (registered) formulation and labelling;
- the granting of permits to provide for a variation of the registered label to allow off-label use (and minor uses) of chemicals under state legislation; and
- a system, with both mandatory and voluntary components, for reporting adverse experiences with veterinary chemical products. A reporting system for adverse experiences with agricultural chemicals is currently under consideration. (see Hazlehurst *et al.*, July 1999).
- recording on a confidential basis the extent of imports, manufacturing and exports of individual agricultural and veterinary chemicals in Australia.

### **7.2.2. Legislative and Regulatory Framework**

The National Registration Scheme operates through an adoptive legislative framework. The necessary elements of the scheme were created by the Commonwealth enacting a number of pieces of legislation. The central Acts are the *Agricultural and Veterinary Chemicals (Administration) Act 1992* and the *Agricultural and Veterinary Chemicals Code Act 1994*. The 1992 Act establishes the National Regulation Authority for Agricultural and Veterinary Chemicals as a statutory authority and gives it power to administer the necessary Commonwealth laws such as the Agvet Code and also to administer laws of the states and territories as such powers are conferred under their own legislation. Corresponding state law, a Ministerial Agreement (i.e., intergovernmental agreement), regulations and various codes complement the scheme.

*The Agricultural and Veterinary Chemicals Code Act 1994* makes provisions for the evaluation, registration and control of agricultural and veterinary chemicals. The Agvet Code exists as a schedule to this Act. Each state and the Northern Territory then has an Agricultural Code as law in that state or territory and authorises the NRA to administer that law. In the ACT, the Commonwealth *Agricultural and Veterinary Chemicals Act 1994* applies the Agvet Code directly.

A Ministerial Agreement dated 29 September 1995 between the Commonwealth, states and territories provides further support to the scheme. The Ministerial Agreement reaffirms the commitment of each party to the scheme and requires any party to give substantial notice of any intention to withdraw from or modify the scheme as it operates in their jurisdiction.

The Ministerial agreement also confirms that before any proposed amendments to the Agvet Code are introduced into the Commonwealth parliament, they are firstly subject to unanimous agreement by the relevant state and territory Ministers comprising ARMCANZ (now PIMC).

The framework for changing the Code under the Ministerial Agreement is a critical element of the co-regulatory structure adopted. The Commonwealth did not simply take over responsibility for agvet chemicals when the scheme was created. Rather, it involves all the states and territories pooling registration into a common statutory body (the NRA), which as it happens is located within the Commonwealth domain. Any state or territory thus retains the right to withdraw from the scheme and substitute its own registration process and body.

Moreover, any changes to the scheme – including policy directions – are implemented through agreement amongst the signatories to the Agreement. This situation has represented a conundrum for SCARM. Under SCARM, AVCPC was charged with responsibility for developing and progressing policy matters, relating to agvet chemical issues, of concern to both Commonwealth and state governments. Whilst it is the nine government jurisdictions only that make final policy decisions, the NRA and other parties had been represented at, and participated in, AVCPC meetings. The size of the resultant committee was difficult for AFFA to manage, leading to the recent restructuring of the committee, albeit the NRA still provides technical advice.

### **7.2.3. Key Features of the NRA's Administration**

- The National Regulation Authority for Agricultural and Veterinary Chemicals is overseen by a nine-member Board, including a part-time Chair and eight part-time Directors, all of whom are appointed for three year terms which may be renewed. The Board defines key NRA policy, sets strategic direction and guides operations. The Board bears responsibility for the NRA's performance. The Parliamentary Secretary to the Minister for Agriculture, Fisheries and Forestry, has direct portfolio responsibility for the NRA.
- Under the *Agricultural and Veterinary Chemicals (Administration) Act 1992*, the NRA Board membership is required to encompass a range of experience including knowledge of:
  - regulation of chemical products at state or territory level (currently two members);
  - the agvet chemicals industry (currently two members);
  - primary industry (currently one member);
  - consumer protection (currently one member);
  - occupational health and safety (currently one member);
  - the development or administration of Commonwealth government policy, statutory authorities or the operation/management of a Commonwealth statutory authority (currently one member).
- The CEO and Deputy CEO of the NRA, whilst not members of the NRA Board, are largely responsible for preparing the agenda for Board Meetings and actively participate in meetings.
- The NRA (see NRA, 2000c) is effectively funded by users on a full cost recovery basis through the payment of a combination of agvet chemical product registration application fees (14%), registration and renewal fees (22%), levies predominantly on sales of registered products (56%), and other revenue (8%).
- The NRA had staff at 30 June 2000 of 113 and at total budget of \$18.5 million.
- The NRA has eight consultative committees: The Community Consultative Committee, Industry Liaison Committee, Registration Liaison Committee, Industry Technical Committee, Residue Advisory Committee, Meat Consultative Committee, NRA Manufacturers' Licensing Scheme Liaison Committee, and the National Chemical Registration Information System (NCRIS) External Users Group.
- Three committees, in particular, namely, the Registration Liaison Committee, the Industry Liaison Committee and the Community Consultative Committee provides opportunities for State government agencies, industry and the community respectively, in its decision making. The NRA is not legislatively bound to follow the advice of any consultative committee.



- People interested in the activities of the NRA now have access to a number of NRA publications, including 11 *NRA Facts/Information* (published between February 1999 and August 2000), *NRA Newsletters*, the monthly *NRA Gazette* and the *NRA Annual Report*. General information, the *NRA Gazette*, and some earlier issues of the *NRA News* (though surprisingly, not recent issues as at February 2002), may also be obtained by visiting the NRA website at <http://www.nra.gov.au/>

#### **7.2.4. Registration Process for Agricultural Pesticides**

For the purpose of registration, an agricultural chemical product is defined in Section 4 of the Agvet Code as including any substance(s) used to:

- destroy a plant or modify its physiology;
- modify the effect of another agricultural product; or
- attract a pest for the purpose of destroying it.

The above encompasses most herbicides, insecticides and fungicides used in agriculture.

There are over 6,000 agvet chemical products with around 2,000 active ingredients currently registered in Australia by the NRA. Internationally and domestically, the breakdown of plant protection use areas is roughly of the order of two thirds (66%) herbicides, (22%) insecticides, (7%) fungicides and (4 %) others. More complete definitions of precisely (legally) what constitutes and what does not constitute an agricultural chemical product appear in the Agvet Code, scheduled to the *Agricultural and Veterinary Chemicals Act 1994*, and in the *Agricultural and Veterinary Chemicals Code Regulations (no.27 of 1995)*. Under the National Registration Scheme, all agvet chemicals have to be registered by the NRA before they can be manufactured, supplied or sold in Australia. The registration process is a rigorous one. Section 14 of the Agvet Code describes the matters that the NRA must satisfy itself of before granting registration. This includes the fact that the proposed use of the chemical product would not cause an undue hazard with respect to:

- public health;
- occupational health and safety;
- environmental impacts; and
- trade or commerce.

The NRA must also be satisfied that a chemical product's claimed efficacy is correct and appropriate. In satisfying itself of the above matters, the NRA reviews data lodged by the applicant seeking registration. For new chemical products with new active constituents, the required data includes: chemistry and manufacture, toxicology, residues, occupational health and safety, environmental studies and efficacy. Fewer data are required to register a product that does not contain a new active constituent or a product that is not intended for use on food-producing animals.

The applicant may be asked to supply additional data if the data lodged do not satisfy the NRA. The NRA may also require the applicant to provide a sample of the proposed chemical for the purpose of conducting further analysis.

In satisfying itself of the above matters, the NRA obtains expert advice from a number of agencies, with which it has service contracts, including:

- *Health*: from the Commonwealth Department of Health and Ageing which advises on human toxicology and first aid and safety directions;
- *Residue and dietary intake issues*: from the Australian and New Zealand Food Authority;
- *Occupational Health and Safety*: from Worksafe Australia (National Occupational Health and Safety Commission) which determines the safe handling and use practices in the workplace (at manufacturing, distribution and end-use levels);
- *Environment*: from the Commonwealth Environment Australia's Environment Quality Division which assesses the environmental toxicology, chemistry and fate of the product, and makes recommendations to the NRA on how the potential environmental impact of the chemical's use can be minimised;
- *Efficacy*: from state departments of agriculture/primary industries and universities which evaluate that the product is effective for the purpose claimed with respect to target plants and animals;
- *Current and Good Agricultural Practice*: from state departments of agriculture/primary industries.

Other Commonwealth agencies and a range of expert panels or committees also may be requested to provide advice as the NRA sees fit.

The NRA appears to satisfy itself that use of a chemical product would not cause an undue trade hazard on the basis of its own internal evaluation. Although the current protocol was cleared with AFFA, given the export orientation of Australian Agriculture and the ever increasing international sensitivities, the use of a rigorous and effective procedure to evaluate trade risks, both for existing agvet chemicals under review and for new chemicals, is essential. To improve transparency of such assessments, the NRA and AFFA should jointly re-examine the potential to develop a more rigorous procedure on a regular basis for appraising the trade risk associated with the registration of an agvet chemical, based on independent expert advice on appropriate risk assessment procedures.

The Agvet Code requires the NRA to publish notice of any proposal to grant registration of an agvet chemical. This provides the broader community with an opportunity to make public comment and thus make an input into the decision making process.

The output of the NRA registration process is a label which provides user directions, based on current good agricultural practices that are designed to minimise adverse impacts on health, the environment, crops and livestock and international trade. The information contained on a farm chemical label includes the active constituents, directions for preparing and applying the farm chemical, procedures for avoiding

unintended off-target damages, a withholding period to avoid unacceptable chemical residue levels in produce, instruction for correct storage, ‘clean-up and disposal’ and safety and first aid instructions. The label also indicates that additional hazard information is contained on a Material Safety Data Sheet (see next section) which is available from the supplier of the chemical product.

However, it would be erroneous to consider that NRA label directions arising from the hazard assessment process during registration are sufficient in themselves to protect the environment in all cases. Such assumptions imply that there is no need to apply other measures to protect the environment, such as quantitative guidelines (eg. water quality guidelines, ANZECC & ARMCANZ 2001a), best management practice guidance and control of use legislation. Relying on label directions alone assumes that they are detailed enough to cover all possible application situations and contingencies, and that they are always accurately followed. Secondly, it also assumes that the generic hazard assessment prior to registration is based on faultless data and is applicable to every site at which the chemical is likely to be used and to every specific environment. The assessment of hazard during registration is an effective tool, but ARMCANZ (1998) recognised that it is also necessary to monitor whether the label directions and other registration controls are effective in the situations of use.

The information placed on-label is therefore a contentious issue, in particular due to differing control of use legislation between states, and is currently under review. The label relating to issuance of an NRA Permit is a simpler matter, insofar as the permit document is effectively the label.

The NRA review and assessment of an agricultural chemical for registration, or for the purpose of issuing an NRA permit, is a procedure of risk assessment. That is to say, the likely impact of a particular pesticide with respect to public health, occupational health and safety, environmental impacts, and trade is determined according to the likelihood of problems occurring. If the NRA is satisfied that the specified criteria for registration, or for issuing a permit, have been met it must grant registration, or grant a permit.

Most NRA permits are issued for “off-label” uses for chemical products or active constituents which are registered for other on-label uses. However, the NRA has the power to issue a permit in circumstances where no previous application has been made for approval of the active constituent or registration of a chemical product. While most off-label pesticide use is confined to minor crops and activities, it represents in aggregate a significant proportion of the total volume of pesticide application.

Providing that the NRA has complied with the criteria specified in the Agvet Code for registration of a chemical product, or for issuing of a permit, neither the NRA or its officers will be liable with respect to the granting of registration, or a permit, or reliance on registration, or a permit by a third party. However, if the NRA or its officers were shown to have acted negligently or wilfully with respect to non-compliance with the Agvet Code, issues of liability would arise.

### **7.2.5. Efficacy**

The effect of Section 14(3)(f) of the Agvet Code is to require the NRA to determine both what the level of effectiveness should be and whether the agvet chemical meets that level. Efficacy review services have normally been purchased by the NRA from state agriculture authorities. The current regulations applying to efficacy restrict competition insofar as they set minimum product standards. In some states (e.g. Victoria), regulation of a product standard is identified as being one of the principal forms of restriction on competition. Such regulations reduce the range of products available and as a consequence are likely to discriminate against particular sectors or end uses. The National Farmers Federation, for instance, pointed out to the National Legislation Review that:

‘In a horticultural crop anything less than 99.5 per cent control may be regarded as ineffective yet the same chemical used on a broad acre basis may be only required to achieve 30 per cent control because of other factors in crop management.’

Similarly, the appropriate level of effectiveness for controlling some insect pests in forestry, is fairly low (L. Wilson, Pricewaterhouse Coopers, pers. comm.).

Pest resistance management is an important part of agvet chemical use. However, the National Legislation Review stated that:

‘... the Review Team discovered considerable debate over the science of resistance management. As a result of the uncertainty the Review Team is unable to ascertain whether the current system of efficacy review creates a benefit or disbenefit in respect of resistance management (op.cit. pp.44-45).

The Review Team stressed the need for flexibility in levels of pesticide efficacy to meet differing needs. The appropriate level of efficacy for each type of pesticide application should be left to the end users and the market to determine, rather than the NRA or its efficacy review service providers. To this end, the recommendation was made that: Section 14(3)(f) of the Agvet Code be amended to specify that efficacy review extends only to ensuring that the chemical product meets the claimed level of efficacy on the label’ (op.cit. p.46). In the event, this recommendation was not supported.

### **7.2.6. Cost Recovery**

The issue of the appropriate level and method of cost recovery for an authority such as the NRA is an important one, but largely beyond the scope of this report.

The Productivity Commission is currently reviewing cost recovery arrangements across Commonwealth regulatory, administrative and information agencies. The scope of the inquiry includes that the Commission report on where cost recovery arrangements should be applied and whether in the light of the public benefits (if any) of an agency’s activities, and other characteristics of the services provided, the degree of cost recovery should be full, partial or zero. The draft report of the inquiry (Productivity Commission 2001) records that in 1999-2000, the NRA achieved a direct cost recovery of \$17.6 million. Its total recovered revenue represented 108% of its operating costs. Costs are recovered through application fees, an annual

registration renewal fee for each registered product varying between \$200 and \$1 000 depending on the value of the product's gross sales in the previous year, together with levies on the product's gross sales (then exclusive of sales tax) where the gross sales exceeded \$100 000. In addition, in 1999-2000, the NRA received a Federal government appropriation of \$108 000 to help facilitate processing of applications for minor chemical uses.

The final report of the Productivity Commission was signed by the Commissioners on August 16 2001 and delivered to the government.

It should also be noted that the National Legislation Review considered the issue of the appropriate fee/levy structure, assuming that full cost recovery would continue. The recommendation was made that the levy be changed to a simple flat rate levy (on sales as at present), but with no exemptions or caps. Furthermore, it was recommended that the annual renewal fee should be abolished and a nominal minimum levy liability (per registered chemical product) set instead, and that application and other registration service fee should be made cost reflective.

### **7.2.7. Data Protection**

The NRA may ask an agvet chemical manufacturer, or other party, to provide particular information on a chemical product to support continuation of its registration. When the required information relates to the interaction between the chemical and the environment or living organisms or naturally occurring populations, including human beings, it may be protected. Part 3 of the Agvet Code establishes a system of compensation for third party access to such information when the chemical under review has come out of patent or will come out of patent within the period of information protection.

Data protection has a significant influence on investment in agvet chemical research and innovation, the on-label availability of agvet chemicals and the price of agvet chemicals. The essential goal of an effective system of data protection is to determine levels of compensation which will generate an appropriate social balance between the level of generation of information and the level of its utilisation. Without data protection, the ability of third parties to free ride on information would reduce the incentive to generate it. On the other hand, if the level of compensation that must be paid by third parties is set too high, the level of utilisation of existing protected information will be socially sub-optimal.

The National Legislation Review recommended that the data compensation provisions contained in the Agvet Code be modified to adopt the procedures and principles for determining third party access pricing under the various codes in operation under Part IIIA of the Trade Practices Act. In August 2000, AFFA circulated a policy paper on a proposed data protection scheme that it had prepared in response to a joint proposal from Avcare, the Veterinary Manufacturers' and Distributors Association and the National Farmers' Federation. This was being followed up in late 2001 by a review of the possible impact of a data protection scheme on the pricing and availability of agricultural chemicals. After much deliberation, the revised paper has been agreed upon by the three non-government organisation parties only. The Commonwealth has

not endorsed the policy paper. It is envisaged that an improved data protection scheme will be put in place eventually.

#### **7.2.8. Information Technology**

An alternative to relying exclusively on the pesticide container label for information is to make complementary use of information technology. In Queensland, a state-based pest data bank and computerised system, named 'Infopest', was developed over a decade ago. The scope of Infopest is national and it provides information on pests and pesticides to retailers, consultants and farmers throughout Australia. In the mid-1990s, a small group in the Farm Chemicals Program in South Australia developed a customer focussed national pest and pesticide, computerised data base, named 'Infinder'. The information technology services on pests and pesticides provided by Infinder are sold to clients throughout Australia. The major group of clients is farm chemical retailers and pest consultants, rather than farmers (J. Kassebaum, PIRSA, pers. comm.). Infinder utilises the NRA public data sheet and effectively converts it into a user-friendly information technology service on appropriate pesticide use for a wide array of pests and crops.

More recently, a private company, Crop Protection Approvals Ltd., has developed a user-friendly computerised information system of the off-label permit status of a wide array of minor crops, utilising raw NRA data. New permit documents are obtained from the NRA on a fortnightly basis. Crop Protection Approvals Ltd provides this 'public good' information free of charge on its website <http://www.cpaltd.com.au> (P. Taylor, Crop Protection Approvals Ltd, pers. comm.).

It is notable that the development of a national information technology service for pests and pesticide use has been due to the enterprise of small groups within two state government departments and a small private company. It is also noteworthy that the two state government departments charge their clients for the information technology services they provide whereas the private company does not. Regardless of the undoubted high quality of Infopest, Infinder and Crop Protection Approvals Ltd information technology service, it is pertinent to ask why such services were not provided for at a national level under the auspices of NRA with input from the AVCPC, given the public good nature of the product. While it has been asserted that an "advisory" role is outside the current legislative remit of the NRA, there would be merit in the NRA and/or the AVCPC reviewing the current information technology situation and determine whether or not the current scope of the services provided is adequate for potential pesticide users, including those with a non-English speaking background.

#### **7.2.9. Material Safety Data Sheets**

A Material Safety Data Sheet (MSDS) provides information on hazardous substances for the purpose of users in the workplace having access to appropriate information in handling the chemical product; the MSDS does not provide information on the application of the final spray mixture or resulting residues in the environment or the treated commodity. The provision of a MSDS is one of the mandatory information requirements of the NRA and the Agvet Code requires that NRA registered chemical products include an on-label statement referring to the MSDS for the product. Whilst

MSDSs are submitted they are not “approved” by the NRA. Nevertheless, MSDSs provide the chemical industry with some degree of protection against litigation.

As also discussed in chapter 5, under state Workplace Health and Safety legislation (for example, the Queensland Workplace and Safety Act 1989) it is a requirement that an MSDS be made available to farmers, on-farm workers and other persons using pesticides. Farmers are required to hold a complete set of MSDSs for all agvet chemicals applied or stored on farm, and also to make them available to any employees. Farmers and other agvet chemical applicators are thus faced with two separate documents – a (usually) extensive product label and an MSDS. The latter may be up to eight pages in length containing detailed technical information. Chemical product labels are changed quite frequently as products are modified and improved through time. MSDSs are updated much less frequently which commonly leads to a degree of mismatch between the information on-label and that contained in the MSDS. Moreover, there is commonly, a significant overlap of information on-label and on MSDS. It has been suggested that the current arrangements result in counter-productive information over-load that does not lead to a safer workplace. In practice, it appears that farmers collect and file the MSDS only to meet the legal requirements. Farmers currently obtain any information they consider to be useful on occupational health and safety information from the labels and attachments affixed to the product container (see Pricewaterhouse Coopers 1999 and AVCARE 1998). The current system is flawed. In practice, many farmers do not even collect the MSDSs and those that do rarely read them. If MSDSs are to make any real contribution to making the farm workplace safer there is a need for a much simpler document which is submitted to, and approved by, the NRA. One approach which appears to have merit would be to provide a plain English summary MSDS for each chemical product on laminated A4 paper. A farmer could keep such a document in a prominent place in the farm shed in which chemicals are stored and handled (W. Cornish, NFF, pers. comm.). Consideration should also be given to providing access to similar simple summaries in the principal vernacular languages of those from a non-English speaking background. (There are many participants, often employees, with a non-English speaking background in some areas of agriculture, particularly in the intensive horticulture industries.) Whilst the issue of provision of MSDSs to employees is that of the employer, the practical reality is that the issue should initially be addressed by the AVCPC.

#### **7.2.10. Residue Evaluation and Monitoring**

The Agvet Code requires the NRA to be satisfied that there will not be any appreciable risk from residues to consumers arising from use in accordance with Good Agricultural Practice. Thus the NRA also evaluates the significance of chemical residues in food and recommends maximum residue limits (MRLs) to the Australia New Zealand Food Authority (ANZFA) and publishes these MRLs. The MRL is the highest concentration of a particular chemical in a particular crop or commodity that is legally permitted in a food or animal feed (see also section 5.5.4). The NRA seeks to ensure that the MRLs for agvet chemicals are set at levels that result in human exposure to the chemical as consumed through the total diet below the acceptable daily intake (ADI). The ADI is the average amount of chemical present in food as a composite of all its commodity sources that it is considered may be consumed everyday over a lifetime without causing an appreciable risk to health.

The NRA determines an MRL after an evaluation of a chemical product's chemistry, metabolism, analytical methodology and residue trial data. Based on the residue trial data the NRA sets appropriate withholding periods. Withholding periods are the time elapsing between the last treatment with a chemical and the harvest of a commodity, or slaughtering of an animal for meat. Withholding periods permit the chemical residues in plant or animal products to deplete naturally to levels below the MRL.

Before an application for registration of a new agvet chemical or a major extension of use for an existing chemical product is determined, the NRA undertakes a public consultation process. During the consultation phase (for a minimum period of 28 days) any person may comment or raise concerns about proposed MRLs and dietary exposure, or any other relevant matter relating to the intended use of the chemical product.

Following a review of the public comments received, the NRA may register the chemical product or subject it to further review and amendment or reject the application. When a chemical product is registered, the MRL is gazetted in the *NRA Gazette* and entered into the MRL Standard (available on the NRA web site).

ANZFA operates a public consultation process with various stakeholders including consumers, primary producers, state Health Departments and the World Trade Organisation. The ANZFA consultation process is separate to that of the NRA. However, the NRA and ANZFA attempt to work together to run both processes in parallel. When ANZFA is satisfied that a NRA recommended MRL does not pose an unacceptable risk to public health, it makes a recommendation to the Australian New Zealand Food Standards Council (ANZFSC) for incorporation of the NRA determined MRL into the Standard A14 of the Food Standards Code. The Health Ministers of each Australian jurisdiction and New Zealand have been members of ANZFSC, but it was restructured from 31 July 2001 to provide that Ministers from other relevant portfolios such as agriculture and consumer affairs could also participate to ensure a whole of food chain approach to food safety regulation.

Apart from the domestic market, residue monitoring is often a trade requirement either mandatory or as an expectation of importing countries allowing market access to Australian Food Products. The Australian Quarantine and Inspection Service (AQIS) is the Commonwealth body responsible for inspecting Australia's exports of primary produce, and foods imported into the country. Produce is sampled and a wide range of tests are undertaken, including testing for pesticide residues. State, territory and Federal governments have a number of agencies to monitor residues in agricultural produce (previously discussed in section 5.3.1). In addition, industry groups such as AWB Ltd, state dairy food safety bodies, dried fruit and rice growers co-operatives, fruit and vegetable market organisations and meat processors also conduct targeted residue testing programs. Increasingly, retail food stores are requiring testing of produce for chemical residues as part of quality assurance programs. The most prominent residue survey is the National Residue Survey, already discussed in chapter 5, and commonly referred to as the NRS. It is conducted by the Commonwealth Department of Agriculture, Fisheries and Forestry's Bureau of Rural Sciences, which monitors around 30 000 randomly selected samples for residues each year (see AFFA, 2000). The results demonstrate a low occurrence of pesticide residues in those products monitored by the National Residue Survey in



recent years. The meat and grain commodities are well represented in the National Residue Survey, but few horticultural commodities are monitored. For example, over the survey period 1 January to 30 June 1999, the only horticultural commodities appearing in the National Residue Survey were apples and pears, onions, macadamia nuts and pecan nuts (AFFA 2000). Australia's National Residue Survey programs are scrutinised and approved by agricultural authorities in the United States, Canada and the European Union.

An important issue which needs to be resolved is that there are sometime significant delays before NRA-recommended MRLs are incorporated into the Standard A14 (now standard 1.4.2 under the new *FSANZ Act*) of the Food Standards Code (see Section 7.5 on Quality Assurance). Effectively, this means that without the MRL in the Food Standards Code in place at the time of registration, any legitimate residues occurring might be illegal due to the permitted level being at zero by default. Following a recommendation in the recent Federal government's Food Regulation Review, the NRA and ANZFA are attempting to streamline the technical processes. AFFA and the Department of Health and Ageing are the agencies with policy responsibility for the MRL issue.

However, a recent NRA proposal to ANZFA suggested that NRA MRLs should be listed as provisional in the ANZFA code until ANZFA administrative processes were complete. This change would make NRA permits immediately useful to producers. Delegation of the task of approving MRLs to the professional officers in ANZFA would serve as a means of improving timeliness.

In the light of the restructuring by the Council of Australian Governments of the Primary Industries, Natural Resources Management, Australian and New Zealand Food Standards, and Environment Protection and Heritage Ministerial Councils in June 2001, the time is opportune to encourage greater collaboration and coordination among Ministerial Councils on pesticide issues.

#### **7.2.11. Existing Chemical Review Program**

When the NRS commenced in March 1995, the NRA inherited over 5000 agvet chemical registrations granted under the earlier state and territory registration processes. Some chemical products have been registered for over 40 years, dating back to times when the standards for safety were less stringent than today. Over the years, vast amounts of new data have been generated for chemicals that have been on the market for many years; however, some of these data have not been taken into account when maintaining some of these old registrations. The transfer of registration into the NRA provided an ideal opportunity for a rigid reassessment to determine whether or not the chemicals comply with current standards of safety and performance. In addition, overseas regulatory agencies including the US Environmental Protection Agency, have restricted the use of, or completely withdrawn, some older chemicals due to concerns about health and environmental issues.

The Agvet Code empowers the NRA to reconsider the registration of active ingredients, chemical products and labels and to require certain information to be provided. Consequently, it set up the Existing Chemical Review Program (ECRP).

Consultation with the community, industry and farmers has been a feature of this program. Following input from these groups, the NRA formed a 'priority list' of around 80 chemicals. From this list between five and seven chemicals have been selected to make up each review cycle within the program. The ECRP is currently in its third review cycle. All chemicals within a review cycle are assessed in terms of their effects on human health, occupational health and safety, the environment and implications for trade. The ECRP is a complex, contentious and slow process (R.Eichner, NRA, pers. comm.). Assessment of a chemical in the ECRP review cycle may take up to two years to complete. Despite the consultation process, the way in which chemicals are listed for priority review in the ECRP continues to be contentious. All the chemical products thus far subjected to ECRP review have been out of patent. Most ECRP reviews depend heavily on new scientific data generated overseas. Sometimes when complementary domestic trials are required, a chemical product (eg parathion) has been removed from use under the ECRP because the chemical industry was not prepared to fund the necessary trials in Australia.

Final decisions on the future use of chemicals under review in the ECRP are made by the NRA Board after receiving recommendations from NRA management. The endpoint of a review may be a proposal for the complete withdrawal of the product or severe restrictions placed on its use. The act of taking away a product that people have been used to having access to for many years is inevitably a sensitive issue, particularly as it will commonly result in foregone profits for the farmers as well as the chemical manufacturer(s). However, where new information points to the continued use of an older chemical now involving a substantial risk to trade, it is easier to achieve acceptance among stakeholders regarding withdrawal of the chemical product.

This ECRP decision process contrasts with the procedure followed by the NRA for registration of new agvet chemicals where decisions are made by NRA management under powers delegated by the Board. However, the CEO of NRA will consult with the Chair of the Board if there are matters of concern relating to registration of a new chemical product.

Many decisions relating to new registrations involved proposals for alternative chemical formulations with no new active constituents. For a chemical product with a new active constituent, a comprehensive information and scientific data base is available to be drawn upon by the NRA and opportunities for public participation exist. To inform the public about new chemicals or new active constituents being considered for registration, the NRA places a notice in the *NRA Gazette*, which is published monthly.

However, some have still argued that to be consistent, the same NRA decision process should be adhered to both for registering new pesticide products particularly those with new active ingredients, and removing (or restricting) 'old' pesticides. That is to say, the NRA Board should delegate decisions about both to NRA management, or neither. Ultimate responsibility for the NRA performance rests with the Board, and its membership should and does contain expertise that enables informed judgements to be made on pesticide use issues relating to health risk, environmental risk and trade risk.

### **7.2.12. Special Chemical Review Program**

The Special Review Program (SRP) was established to allow the NRA to immediately begin a review of a chemical if issues arise that may alter the terms of its registration. The SRP is thus a reactive targeted program which enables the NRA to rapidly respond to a situation in the light of the findings of new research, or the availability of other new information, or concerns about the use or safety of a chemical. Because special reviews are usually highly targeted towards, for instance, a particular health concern, they usually take less time to complete and rely on a smaller amount of data than chemicals in the ECRP.

Numerous chemical products have been withdrawn or have had severe restrictions placed on their use in recent years under the ECRP and SRP provisions. This includes endosulfan, persistent organochlorines, mercurial fungicides, parathion, dithiocarbamates such as ferbam, maneb and nabam, and the nitrofurans. Included in forthcoming reviews are sheep pesticide products from several pesticide classes used for lice and blowfly control, mainly due to concerns over residues in wool (NRA Bulletin No. 99/13, September 1999).

### **7.2.13. Chemical Review Program**

The Existing Chemical Review Program (7.2.11.) and the Special Review Program (7.2.12.) have recently been integrated into a single program called the Chemical Review Program

### **7.2.14. Compliance**

Manufacturers and distributors of agvet chemical products have specific responsibilities under the National Registration Scheme. The NRA's National Compliance Program seeks to ensure that all products on the Australian market satisfy registration requirements and regulations. Under the Code, manufacturers, wholesalers and retailers must:

- have any product requiring registration registered by the NRA; and
- use only the NRA approved label on registered products.

There are a number of avenues by which the NRA may pursue remedy for a breach, including by prosecution, usually when other administrative actions have failed; that is, prosecution is the avenue of last resort when discovering a breach of the legislation. Registration compliance activities have generally been undertaken by state authorities funded in part by the NRA. There have been recent moves by the NRA to take on more of the compliance program itself. The NRA now undertakes all compliance programs in New South Wales, Western Australia, Tasmania and Northern Territory. The NRA has recently appointed a number of people with detective/policing experience to assist with the compliance program. The NRA compliance surveillance and enforcement team operates both independently and in conjunction with other Commonwealth, state and territory investigative bodies. The NRA has the power to search and seize chemical products when investigating cases of suspected non-compliance. The level of risk to human health and safety, the environment, trade and crops and livestock posed by a particular non-compliance is

an important factor in determining the action NRA surveillance and enforcement officers will take. Other factors considered by the NRA before proceeding with a formal investigation and prosecution include the availability of resources and the likely success of the investigation. Between January 1997 and November 2000, the NRA received 400 agvet chemical compliance complaints, which resulted in 24 prosecutions, encompassing eight prosecutions in Queensland, six in Western Australia, five in Victoria, three in NSW and one each in South Australia and the Northern Territory. Around one third of the prosecutions were for illegal use of veterinary products, particularly hormonal growth promotants (S. McDonald, NRA, pers. comm.).

### **7.2.15. NRA Permits**

When manufacturers seek NRA registration of a new chemical product, typically they will limit the scope of the application to the envisaged major uses (market) for the chemical. The wider the scope the greater will be the overall cost of the application to the manufacturer due to higher costs of data generation, particularly chemical residue data for food crops and animals. The fees for maintaining such a registered product relate to product sales and the number of states in which the product is registered. Manufacturers will generally not make the investment to develop, register or maintain products for 'minor' markets where there is judged to be an inadequate net economic return. The Australian agvet chemical market represents less than three per cent of the world market and it is spread over a wide array of temperate, tropical and semi-arid produced agricultural food and fibre commodities. Moreover, greater emphasis on food-based quality assurance schemes, such as SQF2000, means that illegal use of pesticides cannot be sustained.

The NRA issues off-label permits that allow use of pesticides in ways that differ from the uses specified on product labels. A separate more detailed section on off-label use follows the overview of state and territory Legislative and Regulatory arrangements contained in the next section. Using the off-label permit system is currently the main avenue for meeting Australian minor use requirements. "A permit is only required if the off-label use is an offence against a state's control-of-use laws. Only those states where use is to occur and where the use is an offence will be included in the permit." (NRA Information Sheet, "Understanding Off-Label/Permits", May 1999 p.1.).

A permit will sometimes allow the supply of an unregistered product for grower use. Before issuing a permit, the NRA is required by law (Part 7, Agvet Code) to be satisfied that the permitted use would not be likely to have a harmful effect on humans or an unintended harmful effect on the environment. Additionally, the NRA must be satisfied that the use will be effective and that it will not unduly prejudice Australia's trade. In making its determination for off-label permits, the NRA takes into account both known and at times, relatively uncertain scientific factors. "While the NRA makes every effort in exercising its statutory duty, the issuing of a permit by the NRA cannot be taken as a guarantee that the use will be effective to the extent expected by users, that no crop or animal damage will not jeopardise trade." (op cit p.2).

The NRA gives the highest priority to genuine emergency uses, where permits are usually processed within five to ten days. The majority of applications take between

three months to a year. No fee is charged for emergency permits or for applications received from primary producers or government agencies. All other applications for permits attract an NRA fee for evaluating and processing.

The NRA recognises that there are problems and limitations within the NRA's current permit system. In 1998, the NRA established a Minor Use Steering Committee to develop long term strategies. The Committee believes that there is no 'quick fix' to the minor and off-label use problem and that a workable solution requires a cooperative partnership between farmers (growers), the chemical industry, Commonwealth and state/territory governments and the NRA.

The NRA for instance, is examining ways to encourage chemical manufactures to include more minor uses into product labels through the normal registration process. However, it seems pertinent to ask why a chemical manufacturer would volunteer to pay the additional fees required to register minor uses of its chemical products on-label if the manufacturer believes that the same minor usage of its product will be attained via the issuing of off-label permits, for which it does not pay. Moreover, pesticide manufacturers may not be able to be held liable for any adverse effects resulting from the use of their products for off-label use. It is true that the chemical manufacturer indirectly bears some costs of off-label uses of its products because the NRA is fully funded from industry fees and levies. However, the cost of the NRA determination for off-label use of a chemical product is effectively borne by the chemical industry as a whole. As a consequence, following registration of its chemical products, a manufacturer has an incentive to communicate to growers the value of its product for minor uses. Similarly, since primary producers pay no fees for off-label permit applications, they have a strong incentive to make permit applications. Given the current structure of incentives, it is perhaps not surprising that pesticide use in some fairly substantial agricultural industries, such as the pineapple and avocado sectors, operate on the off-label permit system.

Finally, it is pertinent to note that NRA permit applications increased from about 55 per month in 1996 to 82 per month in 2000. During the same period the number of unprocessed permits increased by 300 per cent. The main reason for the increase in delays appears to be a lack of resources devoted to minor uses within NRA (P. Taylor, Crop Protection Approvals Ltd, pers. comm.). The NRA has moved to address this issue (G. Hooper, NRA, pers. comm.).

### **7.3. STATE / TERRITORY LEGISLATIVE AND REGULATORY ARRANGEMENTS**

Beyond the point of retail sale, the control of use of agvet chemicals is governed by the individual regulatory arrangements of each state. The regulatory and institutional arrangements vary widely between states and territories. There seems to have been no previous attempt to summarise all the regulatory arrangements relating to the use of agricultural chemicals for every state and territory. This is perhaps not surprising, given that there are currently over sixty Acts and Regulations relating to pesticide supply and use, taking the Commonwealth, states and territories legislation as a whole.

### **7.3.1. Victoria**

In Victoria, Section 33 of the *Agricultural and Veterinary Chemicals (Vic) Act 1994*, the “Victorian Enabling Legislation” has the effect of making sections 6 and 19 of the *Agricultural and Veterinary Chemicals (Control of Use) Act (Vic) 1992* (the “Victorian control of use legislation”) eligible laws for the purposes of the Agvet Code (section 109). The effect of sections 6 and 19 of the Victorian Control of Use Act, when taken together is that no permit is required in Victoria for uses of agvet chemicals unless the use is expressly prohibited on the label or if the use is at a greater rate, or shorter interval between use, than is prescribed on the label. All specific prohibitive statements on labels must be complied with. In contrast to the Victorian legislation, the starting point of the other states and territories is that permits are required for any off-label use of a registered agvet chemical. In Victoria, the pesticide user is effectively responsible for undertaking a risk assessment of any proposed off-label use of a pesticide and is also responsible (liable) for any adverse outcomes. The effect and possibly the intent, of the Victorian agvet legislation is to minimise the potential liability to the state government and personnel of any adverse outcomes arising from use of agvet chemicals.

The major administering agency for agricultural chemical use in Victoria is the Department of Natural Resources and Environment (DNRE). The DNRE prohibits the off-label use of all agricultural chemicals which it considers to be in a higher risk category (around 25 products). The DNRE also restricts methods, or times, of applications of some chemicals in defined problem areas. The DNRE may also restrict or prohibit some chemical products or particular uses of some products throughout Victoria at all times. Any agricultural chemical placed by the NRA into its restricted category is also placed in the Victorian restricted schedule thereby ensuring on label use only. The DNRE controls licensing of aerial pesticide applicators and commercials ground applicators working in agricultural situations. All commercial applicators must be trained and licensed and keep records of all their chemical applications. All users of the restricted schedule chemicals must be trained, have an Agricultural Chemical User Permit and keep records of the use of those chemicals.

The Victorian Environmental Protection Agency (Vic EPA), through the *Environment Protection Act 1970*, sections (39-45), deals with pesticide concerns in the environment through local environmental officers. The Victorian Department of Human Services, under the ‘nuisance’ provisions of the *Health Act (1958)*, deals with complaints about chemicals, through local government, where human health is of concern. The Victorian Authority Workcover controls occupational health and safety concerns relating to hazardous substances in the workplace, including farms, under the *Occupational Health and Safety Act (1985)*.

### **7.3.2. New South Wales**

Regulatory controls are provided under the NSW *Pesticides Act 1999* which empowers the NSW Environment Protection Authority (NSW EPA) to control the use of agricultural chemicals (and ectopara silicide veterinary chemicals) through regulatory mechanisms. The *Pesticides Act 1999* aims to prevent harm from pesticide use by:

- preventing use of pesticides that are not registered by the NRA;
- requiring pesticide use in accordance with the NRA, approved on-label directions or NRA issued permit conditions, excepting use of a pesticide at a lower application rate than is recommended on the label, unless the label instructions or an NSW EPA pesticide control order specifically prohibits use of lower rates;
- requiring pesticides to be kept in a container with a NRA approved label;
- all aerial operators of aerial pesticide spray businesses and all spray pilots must be licensed under the *Pesticides Act*. All pest control operators are required to be licensed under the Occupational Health and Safety legislation.

Regulations are currently being drafted to provide mandatory training and pesticide record keeping standards for all commercial operators and farmers.

The NSW EPA, under the Protection of the *Environment Operations Act (1997)* regulates general pollution and waste matters in NSW, including pesticide run-off. For example, fish kills caused by pesticide residues in waterways are generally investigated under this Act.

NSW Agriculture regulates stock foods (under the *Stock Foods Act (1940)* and the *Stock (Chemical Residues) Act (1975)*). It also administers the *Noxious Weeds Act (1993)*.

Under the *Occupational Health and Safety Act (1983)* (OHS Act) and the NSW *Workcover and Safety Act (1983)* (OHS Act), NSW Workcover seeks to protect workers (including farmers) in the workplace. Regulations under the OHS Act control hazardous substances including most pesticides. The most recent and important of these is the *Occupational Health and Safety (Hazardous Substances) Regulation 1996*. The regulation covers identification of hazardous substances (including pesticides) in the workplace and the assessment and control of risks. Workcover has developed the Code of Practice for the Safe Use and Storage of Chemicals (including pesticides and herbicides), and the Code of Practice for the Safe Use of Pesticides, including herbicides in Non-Agricultural Workplaces.

Other regulations under the OHS Act cover occupational health and safety matters related to pesticide use which are currently being consolidated into a single regulation. Workcover is responsible for regulating the classification, packaging, labelling, use and storage of dangerous goods. Many pesticides because of their combustibility or toxicity are classified as dangerous goods. Workcover is responsible for regulating the transport of such goods on private roads. While dangerous goods are being transported on public roads they are regulated by the NSW EPA under the *Road and Rail Transport Dangerous Goods Act (1997)*.

NSW Health advises on and assesses situations relating to pesticides and public health. It contributes to the Australian Total Diet Survey (previously known as the Market Basket Survey). NSW Health laboratories also test for pesticide contamination in drinking water samples, in accordance with the 1996 Australian Drinking Water Guidelines (published by NHMRC and ARMCANZ). Under the *NSW Food Act (1989)*, NSW Health routinely monitors residues of pesticides and

other chemicals in food for sale, to ensure compliance with the National Food Standards Code.

The National Parks and Wildlife Service, the NSW Department of Land and Water Conservation and local government councils also have planning, regulatory and monitoring roles relevant to pesticide use. Local councils, for example, are responsible for noxious weed control within local government areas and have an important role in zoning for appropriate adjacent land uses.

The NSW Rural Lands Protection Boards are responsible for the supply and distribution of pesticides for controlling vertebrate pests, plague locusts and wingless grasshoppers. The vital job of detection and control of plague locusts is coordinated on a national basis by the Australian Plague Locust Commission.

### **7.3.3. Queensland**

In Queensland, there are currently two Acts concerned with control of use of agvet chemicals. The relevant legislation is contained in the *Agricultural Chemicals Distribution Control Act 1996* (ACDC Act) and the *Chemical Usage (Agricultural and Veterinary) Control Act 1988* (Chem Use Act).

The Chem Use Act confines the use of agvet chemicals to NRA registered products that are used according to registered label instructions or by NRA issued permits. This Act also provides for a number of control mechanisms when MRLs of agvet chemicals are exceeded in agricultural produce.

The ACDC Act contains provisions for licensing agricultural pilots to apply pesticides from aerial equipment and commercial spray operators to distribute herbicides from ground equipment and regulates how these operators may apply pesticides.

Under Queensland's current agvet legislation there is nothing to prevent local governments making local laws to impose supplementary licensing or generic controls over users of agvet chemicals. However, the existing State legislation would override any such local laws when there is any inconsistency with State legislation. Currently, there are no local laws relating to generic controls or licensing of agvet chemicals.

In some circumstances agvet chemicals may be used at variance with registered label instructions providing that the label does not specifically state that the variation is not permitted. The current permitted variations to label include:

- at a concentration or rate lower than stated on the label;
- less frequently than that stated on the label;
- for control of a pest or disease in a plant or stock not stated on the label;
- for control of a plant in a crop not stated on the label; and
- by mixing the chemical with another chemical.

The intent of these variations is to allow some flexibility in the management of agvet chemicals in a way that would not normally be expected to result in violative residues.



The above Queensland legislation is under review. Progress with the review included a discussion paper and invitation for public submissions (QDPI 2000); an evaluation of the public submissions received (QDPI 2000a); and a confidential report containing recommendations for future legislation to control the use of agricultural and veterinary chemicals in Queensland, presented to the Minister for Primary Industries and Rural Communities, June 2000.

In determining the recommendations, the Review Committee took cognisance of:

- the objectives and strategic actions in the National Strategy for the Management of Agricultural and Veterinary Chemicals commissioned by the Agricultural and Resource Management Council of Australia and New Zealand, and
- the recommendations relating to controls over the use of agvet chemicals arising from the National Competition Policy Review of Agricultural and Veterinary Chemicals Legislation.

The Review Committee's terms of reference did not provide for a re-examination of agvet chemical legislation of other Queensland agencies such as Health, Workplace Health and Safety, and the Environmental Protection Agency (see Appendix C for relevant Acts and Regulations). However, representatives of other government agencies such as Health, Workplace Health and Safety, and the Environmental Protection Agency (see Appendix C for relevant Acts and Regulations) were included on the Review Committee to ensure that the review process took into consideration all relevant issues concerning agvet chemical use in Queensland.

Drafting instructions for new legislation are in preparation.

#### **7.3.4. South Australia**

The major legislation relating to agvet chemical use in South Australia has been under review for some years. The current legislation is over 45 years old and is recognised as not dealing well with current issues relating to the use of chemicals. In October 1998, the South Australian government published a draft Review and Consolidation of Legislation Relating to the Regulation of Agricultural Chemicals and Stock Foods. Three pieces of legislation relating to the regulation of agvet chemicals were reviewed:

- *Agricultural Chemicals Act 1955*, which was enacted to regulate the sale and use of agricultural chemicals.
- *Stock Food Act 1941*, which was enacted to regulate the sale of stock food products.
- *Stock Medicines Act 1939*, which was enacted to regulate the sale of stock medicines.

All of the above legislation is currently administered by the Farm Chemicals program, Primary Industries and Resources, South Australia (PIRSA). Other more recent legislation of some relevance to the South Australian (SA) review process and

pesticide use is listed in Appendix C. The *SA Agricultural Chemicals Act (1955)* incorporates agricultural fertilisers which do not form a part of the national agvet registration scheme. Nevertheless, it is intended that fertilisers will be incorporated in the proposed new agricultural chemical legislation and will continue to be administered by the Farm Chemical program in PIRSA.

The purpose of the SA review recognises the need for seamless integration with the NRA; the desirability of reasonable uniformity between states and territories in their control of use legislation; and the need to satisfy the government's obligations to the NCP. The proposed new legislation on chemical management aims to manage the risks of pesticide use in terms of threats to market access, environmental and public health and damage to non-target organisms, but operate only in those areas of market failure that require a legislative approach.

Major *proposed* initiatives include:

- The classes of off-label use not requiring a permit will be:
  - (i) Use of a chemical product at less than the maximum rate indicated on the label and/or less frequently than indicated on the label.
  - (ii) For a crop which is on the label, use of the chemical to treat a pest which is not on the label providing that all other label conditions are adhered to.
  - (iii) Use with similar methods of application to those on the label provided the application rate is not exceeded and there are not specific restrictions on the label.
- Other off-label uses which would require a permit obtained from the NRA or Minister of Primary Industries and Resources (SA) include:
  - (i) Use of a chemical product at a rate higher than the on-label maximum rate or at intervals more frequent than the on-label intervals.
  - (ii) Use of a registered chemical product on a crop not listed on the label.
  - (iii) Use of a chemical product in a manner or for a purpose if that use is specifically prohibited by label directions.

The intent of the proposed new legislation relating to off-label use is also to restrict the liability of the State government with respect to the issuing of permits on behalf of the NRA and by the Minister.

- The proposed new legislation would make it an offence to fail to observe the withholding period stated on the label of a chemical product.
- Under the proposed new legislation the Minister will retain the power to prohibit certain agricultural chemicals and chemical uses and be given new power to apply specific restrictions with respect to the use of certain chemicals within prescribed areas. Thus the Minister would have the ability to proclaim chemicals within prescribed areas and so ameliorate (or avoid) conflicting land uses. Within the

proclaimed areas certain agricultural chemicals or chemical uses would be restricted for the purpose of protecting susceptible plants and stock, public health and the environment.

- The proposed new legislation would require that persons using prescribed classes of chemicals, such as some or all Schedule 7 substances, or prescribed methods or application, meet specified qualification and training standards. The legislation was before the Parliament in November 2001.

### **7.3.5. Western Australia**

Regulation of control of use of agricultural chemicals in Western Australia (WA) has a different appearance to the other states because the main legislative controls come under the *Health Act 1956*. Other control of use matters are dealt with through a number of Acts administered by Agriculture WA, Worksafe WA, and the WA Department of Minerals and Energy.

The *Health (Pesticides) Regulations 1956* (which arise under the Health Act) cover matters including:

- the use and application of agricultural pesticides
- premises permitted to be used for manufacturers and packaging of pesticides
- acceptable procedures for disposal of used pesticides and containers;
- licensing of pest control operators and fumigators

The principal Regulation (20C), makes it an offence to use an unregistered pesticide and to use a pesticide at a higher rate or frequency of application than is specified on the label. In addition it is an offence to use a pesticide for an unregistered use, or contrary to any directions or precautions on the label, unless it is in accordance with an NRA permit.

The *Poisons Act (1964)* administered by the WA Health Department provides for the classification of substances (including some pesticides) into poison Schedules, which have different levels of control of supply and use based on risk to human safety. The Act also provides labelling and packaging controls over poisons and some Schedules require specific licenses to sell and use them.

The following agricultural chemicals legislation is administered by Agriculture WA:

- *Aerial Spraying Control Act (1966) and Regulations*  
The Act and regulations exert controls on aerial spraying through requirements for a pilot chemical rating certificate; pilot records of pesticides applied; prescribed hazardous areas; and a requirement of insurance cover.
- *Agricultural Produce (Chemical Residues) Act (1983)*  
This Act controls residue affected produce and property through quarantine and direction notices.

- *Agricultural and Related Protection (Spraying Restrictions) (1979)*  
These regulations relate to restrictions of use of prescribed herbicides in the vicinity of prescribed crops.

The other relevant Acts and Regulations are:

- *Occupational Safety and Health Act (1994) and Regulations (1996)*. This Act controls occupational safety and health of chemicals in the workplace.
- *Explosive and Dangerous Goods Act and Regulations (1998)* - Department of Minerals and Energy. This Act covers storage and transport of chemicals on farms.
- *Dangerous Goods Transport Act and Regulation (1998)* - Department of Minerals and Energy. This Act covers transport of chemicals on public roads.

The large number of legislative provisions in disparate Acts and regulations in Western Australia has the effect that the question of when a permit is necessary is complex and does not flow naturally from the provisions of the Agvet Code. The National Legislation Review Team observed that even officers of Western Australian state-based authorities and who have expertise and responsibilities in relation to the legislation governing the use of agvet chemicals, had disparate views as to the circumstance in which permits issued by the state-based authorities may be required. The observation was also made “..... by virtue of Regulation 4 of the Western Australian enabling regulations a permit does not relieve a person from liability for breach under the Poisons Act or the Occupational Health, Safety and Welfare Act.” Moreover, the Review Team concluded that with respect to pesticide applications at lower rates or frequencies than on the label, the interpretation in Western Australia that such use was as of right is incorrect. The Review Team concluded that any off-label use (whether less or greater than on the label) requires a permit. The power to issue state permits has not been used in Western Australia.

A draft Code of Practice for the Use of Agricultural Chemicals in Western Australia (September 2000) outlines a comprehensive range of duty of care responsibilities for farm owners/managers and spray operators. The objective of the Code of Practice is to provide practical and specific guidance for the safe and responsible use of agricultural chemicals. The matters covered by the Code of Practice include choice of agricultural chemicals, transport, storage, occupational safety and health, minimising residues in agricultural produce, environmental protection, spray drift minimisation and record keeping.

A number of the provisions of the draft Code are currently enforceable under the existing Commonwealth or State law. Code provisions not covered explicitly by Commonwealth or State law come under a common law ‘duty of care’ to ensure that no harm is done to yourself, any other person, or their property.

### **7.3.6. Tasmania**

Regulatory controls for the use of agvet chemicals in Tasmania are imposed through application of the *Agricultural and Veterinary Chemicals (control of use) Act 1995*.

The Act was implemented following the establishment of the National Registration Scheme and was designed to complement the scheme. The 1995 Act, taken together with section 33 of the *Agricultural and Veterinary Chemicals Act (Tas) 1994* (the Tasmanian enabling legislation), effectively prohibits any off-label use of a pesticide unless a permit (usually NRA) has been issued. Only a few such permits are issued each year and these relate largely to the use of particular chemicals that are specifically restricted under Tasmania's control of use legislation (J. Mollison, DPIF Tasmania, pers. comm.).

The key characteristics of Tasmania's strong control of use system are:

To impose controls in relation to the handling of agvet chemical products for the purposes of:

- Protecting human health
- Protecting the environment
- Protecting the health and welfare of animals
- Protecting domestic and export trade in agricultural produce and stock
- Maintaining and enhancing economic viability of the State's agricultural and forest industries.

To impose controls in relation to agricultural spraying and to provide protection against loss caused by damage to, or detrimental effects on, plants and stock from agricultural spraying.

To impose controls in relation to the production of agricultural produce to avoid the presence of chemical products in food for human consumption, feed for animal consumption and drinking water supplies.

To impose controls over the conditions of storage for the sale, distribution or handling of agvet chemical products for the purpose of preventing or minimising the risks of:

- Contamination of stock and agricultural produce;
- The presence of chemical products in the environment; and
- Hazard to persons

### **7.3.7. Northern Territory**

The current legislation governing the control of use of pesticides in the Northern Territory is the *Poisons and Dangerous Drugs Act* (1983) administered by the Territory Health Services. The view has been expressed that this Act is not a suitable vehicle for a modern control over use of pesticides. Drafting of a new Bill for control of use of pesticides in the Northern Territory is nearly complete.

The main features of the new control of use legislation are:

- Agvet chemicals control of use will be administered by the Northern Territory Department of Primary Industries and Fisheries (NT DPIF) (now the Primary Industry and Fisheries agency within the NT Department of Business, Industry and Resources Development).

- legal use of agricultural chemical products off label will be permitted for uses which are considered by NT DPIF to be acceptable low risk uses;
- all other off-label uses will be permitted only under the NRA permits.

Low risk legal off-label uses will include application of a pesticide at a concentration or rate lower than stated on the label, applied on another pest for a crop listed on the registered label for another weed in the same situation, and mixed with other products including fertilisers. In addition the Northern Territory does not require a pesticide user to heed the state heading in the Directions for Use table of a registered label, except if the registered label states 'not in the Northern Territory'.

### **7.3.8. Australian Capital Territory (ACT)**

As noted earlier, the Commonwealth Agricultural and Veterinary Chemicals Act 1994 applies the Agvet Code directly in the ACT. There is no separate ACT enabling legislation. The use of agvet chemicals in the ACT is controlled by the Environment Protection Regulations which are given force under Regulation 15 of the Environment Protection Act 1997.

Agvet chemical products applied in the ACT must be NRA registered on-label uses, or used under and according to directions of an NRA issued permit.

## **7.4. OFF-LABEL USE**

The extent of the ability to use agvet chemicals for purposes other than those for which the chemical is registered (off-label use) is arguably the most important and contentious aspect of the states' control of use legislation. An understanding of off-label use issues requires knowledge of this aspect of each state's control of use legislation. The provision of each state and territory's legislation expresses when a permit is required to legalise a pesticide use which would otherwise be prohibited. The manner in which off-label use can occur currently varies markedly between states. Thus, pesticide users in different states and territories have differing degrees of access to off-label uses.

The strict legal interpretation of the states' control-of-use legislation is extremely complex. The Review Team that recently conducted the National Competition Policy legislation review of agvet chemical legislation in Victoria, Queensland, Western Australia and Tasmania (Pricewaterhouse Coopers 1999) states that it experienced '...a significant degree of misunderstanding by state authorities both in terms of off-label use in other states and in terms of their own off-label use provision.' The Review Team provides an independent and detailed legal interpretation of the legislative basis of off-label use for the states included in their review in Appendix D of its Report.

The differences between state control of use legislation, relating to off-label chemical use, essentially reflect different approaches to risk management. The overall objectives of the states control of use legislation are generally consistent with the objectives of the National Registration Scheme.

It may be argued that off-label use allowed by right, as occurs in Victoria, is unlikely to have been subject to the same degree of risk assessment as that involved in NRA registration. As a consequence, off-label use may result in unacceptably high levels of chemical residues in food or the environment. Avcare, for instance, commented in its submission to the National Legislation Review, that off-label use as occurs in Victoria:

“creates potentially unacceptable risks (efficacy, crop/animal safety, health, environment and trade) where agvet products may be used for purposes for which they were not intended and for which the core regulatory criteria may not have been evaluated.”

Avcare also observed that off-label uses allowed by right

“place growers in the unenviable position of needing to second guess complex matters....”

However, NRA permit based off-label use also poses risks. While the issuance of a permit entails a specific risk assessment by the NRA the assessment is usually not as rigorous as that for registration. Thus the National Farmers Federation (NFF) commented in its submission to the Review that with the reduced risk assessment for permits compared to registration, the:

“potential for environmental damage and untenable residues in produce is increased”

Both Environment Australia and the Department of Workplace Relations and Small Business have expressed concern that they were required to give advice on clearance (registration) on the basis of uses according to the proposed label, notwithstanding the fact that off-label mechanisms exist that could permit other uses. Both agencies were particularly concerned as to situations like that in Victoria where off-label uses occurred as a right.

The problem with a full NRA permit system, such as exists in Tasmania, is that it invites frequent law-breaking. The Review Team noted that no true administrative cost estimates of operating a full or near full permit system are available because no state or territory really enforces such a permit system. Some states have inadequate knowledge of actual user compliance with pesticides control of use regulations.

The wide variation between states arising from current off-label use systems imposes major costs and results in confusion for agvet chemical users, food retailers and others, especially those whose growing or trading activities cross state borders. All major stake-holders recognise the virtue of a system of uniform control of use regulatory arrangements for agvet chemicals between states.

A risk management assessment and management approach for off-label use which is nationally consistent and integrated with the NRS, is required.

‘As of right’ off-label uses would be based on a categorisation of acceptable risk. The model in operation in Queensland appears to follow this approach. South Australia proposes to develop its control of use legislation along similar lines. Variations of use from registered label instructions posing no significant risks are commonly identified as:

- use of a chemical product at *less* than label rate;
- use of a chemical product *less* frequently than advised on the label;
- use of a chemical product to treat a crop on the label for a pest not so stated, providing that all other label conditions are adhered to;
- use of a chemical product by similar methods of application to those stated on the label, providing that there are no specific label restrictions applying to such methods and the maximum application rate is not exceeded.

Variations of use from registered label instructions which may pose significant risk are likewise commonly identified as:

- use of a chemical product at *higher* than the label rate;
- use of a chemical *more* frequently than the label rate;
- use of a chemical product contrary to a label prohibition;
- use of a chemical product on a crop or situation not mentioned on the label;
- use of a chemical product by a different method of application than that stated on the label.

In 1996, a process of off-label use harmonisation was attempted under the auspices of an Agricultural and Veterinary Chemicals Policy Committee working group (under SCARM). However, the working group failed to reach an agreed position. An ARMCANZ control of use task force, appointed in early 2000, to develop (among other matters) a nationally consistent approach to off-label use has not yet resolved the issue. South Australia, Northern Territory, Tasmania and possibly NSW and WA seem prepared to move toward a Queensland type of off-label system. In Victoria, however, powerful interests, including the VFF, are opposed to significant changes to Victoria's off-label use legislation.

In defence of the current approach to off-label use in Victoria, a number of arguments have been advanced. First, it has been suggested that the Victorian approach is 'outcome' focussed whereas the other states approaches are largely 'input' (or process) focussed. Second, as benefits an outcome focussed approach, Victoria adopts a strong state residue monitoring and auditing program. Third, the less legislatively intrusive and lower time and administrative burdens imposed on farmers, by the Victorian approach to off-label use, is claimed to have had no detrimental effect relative to other states. It is also of note that in Victoria significant restrictions are placed on farmers with respect to their use of a broad range of chemical products. Use of products, which are listed in a schedule to the legislation, requires training to be completed and an Agricultural Chemical Users Permit to be obtained. Specific records of all use of these products are also mandatory and they can only be used strictly in accordance with the label (P. Bailey, DNRE Victoria, pers. comm.).

The relative performances of each state and territory's agvet chemical control of use regulatory arrangements could be empirically tested. For example, AQIS currently informs each state only of its own situation relating to pesticide (and other) residues found in exports of primary produce. Analysis of AQIS data, say over the most recent five years, for each state and territory would provide some useful 'outcome' oriented information on relative regulatory performance. Similarly, comparative state/territory regulatory performance could be tested by analysing food residue data from the National Residue Survey and other residue surveys. In principle, state-based data on



adverse environmental, health and OHS could also be analysed to provide some empirical measures of interstate/territory regulatory performance. There does not appear to be any research aimed at comparative measurement of the pesticide regulatory outcomes of the states/territories. Some research in this area would be useful. Of course, considerable care would need to be taken in interpreting comparative results. In particular, a researcher(s) would need to be cognisant of any bio-physical differences between states and territories that influenced real costs and/or benefits of pest control. A full benefit-cost analysis of each state's agricultural chemicals regulatory structure and performance would be required to obtain a more definitive measure of comparative performance. This is currently seems unlikely to happen. Nevertheless, it is important that in making decisions about future pesticide regulatory arrangements, some focus is given toward an expected outcome oriented approach that, at least, generates data to assist in risk management decision making and utilises the cost benefit framework. This would facilitate the identification of priority issues and the selection of the appropriate management tool including, where relevant, regulatory processes relating to pesticide use.

## **7.5. FOOD SAFETY AND QUALITY ASSURANCE SCHEMES**

Consumers, in many cases strongly influenced by the media and pressure groups, are dictating changes in national and global food supply chains. Increasingly, a paddock to plate quality assurance philosophy is being internationally embraced as a means of ensuring the integrity of food and food production processes at every point in the supply chain (Todd, 2000). International credibility now demands that a country's claims about having a 'clean-green' agricultural sector are underpinned by hard evidence for such claims.

This section of the paper reviews the growth in quasi-regulations in the form of food safety and quality assurance (QA) schemes. The following chapter considers farm environmental management systems (EMS).

In 1993, the FAO/WHO Codex Alimentarius Commission published guidelines for the application of the Hazard Analysis Critical Control Point (HACCP) System (Bauman 1995). The Codex Alimentarius Commission nominated the application of HACCP as the tool of choice for managing food safety in the implementation of quality management systems, such as the ISO9000 series (Code 1997). The International Standards Organisation for standardisation's ISO 9000 series adopted by Australia has become the most widely recognised international management system. The ISO14000 environmental management systems series outlined in the next section has been developed so that it meshes with the ISO9000 quality management series.

In 1994, the Commonwealth Government announced a Food Quality Program initiative which provided funding for, and highlighted the importance of, quality assurance in the future development of the Australian Food Sector. As the Food Quality Program progressed there were other concurrent moves at Commonwealth and State level to introduce more stringent government regulations relating to food safety and hygiene. This had the effect of bringing together food quality, safety and hygiene within the Program and it became apparent that HACCP - based systems would need to satisfy requirements in all three areas.

In parallel with the government Food Quality Program initiative, multinational food companies and large retailers were implementing HACCP-based quality systems for their operations and insisting that their suppliers do the same. Thus, the food retailer Woolworths, developed the Vendor Quality Management Standard in 1996 based on the HACCP system.

In response to an array of forces, including customer and regulatory demands, food safety and quality assurance schemes have proliferated across the Australian agri-food industry in recent years. "What initially looked as a fairly simple choice is now a mind-boggling mire of partly incompatible systems". (Fabiansson, 2000, p.29). The Commonwealth's Bureau of Rural Sciences is developing a database of standards and guidelines for agricultural food quality systems and associated information which it will make available through the Internet.

The HACCP-based food quality systems, now adopted by most major supermarkets in Australia, apply the ANZFA Standard A14 of the Food Standards Code with respect to maximum residue limits for pesticides. A recent study has identified approximately 650 anomalies for agvet chemicals in food commodities between the NRA MRL Standard and the ANZFA Food Standard A14 (Norton and Hamilton, 2000). This is currently a major problem for growers when products they have produced which comply fully with NRA requirements, including its MRL standards, do not meet the ANZFA Food Standard A14 at the point of attempted sale. Nearly one third of the anomalies arise from the situation where an NRA MRL has no corresponding ANZFA MRL for the commodity in question, or for the chemical compound. It has been recommended (Norton and Hamilton 2000) that the Australian Government should issue a single standard for maximum residue limits for food and livestock. This single standard should at a minimum have the features of timeliness and general correctness of the current NRA MRL Standard.

In November 2000, the Department of Prime Minister and Cabinet announced that a new independent statutory authority to be known as Food Standards Australia New Zealand (FSANZ) will replace ANZFA. The enabling legislation was passed in June 2001. The intent is that FSANZ will deliver a more streamlined, efficient and nationally focussed food regulatory system for Australia that will enhance public health and safety. It would be most appropriate for FSANZ, in consultation with the NRA, to rapidly develop and issue a single Australian standard for MRLs for food and livestock feeds.

A further issue identified in Victoria, is that the State's control of use legislation authorises farmers as a matter of right to certain off-label uses of a pesticide(s) which are not, in varying degrees, permitted in other states and territories unless a producer has been issued a permit. For the purposes of their QA programs some large supermarkets appear to be taking the view that an NRA permit expressly authorises an off-label pesticide use (rather than by omission or general right, as is the case in Victoria). As a consequence, some Victorian producers have felt a need to seek a NRA permit in circumstances in which the current State legislation does not require them to hold a permit. The legislation governing the NRA only enables the NRA to issue a permit for off label use as required by state legislation. The permit, in effect, makes legal something that would otherwise be illegal. therefore if the State control of

use legislation does not make a particular use illegal there is no requirement for the permit to legalise that use. If it is issued, it is meaningless.

Results from the most recent Victorian Produce Monitoring Survey (work in progress) identifies that some residue violations are occurring in QA accredited systems. As the numbers of samples with respect to QA or non-QA properties in the Survey do not technically constitute true monitoring, it is difficult to draw conclusions from the data. It would appear that QA schemes may be having difficulty in identifying the key critical control points in horticultural systems. A number of shortcomings in these QA systems have been identified by various parties and assumptions made as to where the problems may lie. Lack of true independence of the auditors, and consultants providing 'off the shelf' systems to producers are among the issues which have been identified that should be addressed.

## **7.6. CONCLUSIONS – REGULATORY SYSTEMS**

**The assessment of pesticides by the National Registration Authority for Agricultural and Veterinary Chemicals appears to be an effective and well conducted process.**

**While recognising that the NRA has a close relationship with AFFA for the assessment of the potential for a chemical to cause an undue trade hazard through the use of trade advisory notices, international sensitivities are continuing to increase, in some cases to generate trade barriers. The effectiveness and transparency of the process will be improved if AFFA and the NRA finalise an inter-agency protocol and also set in place a process for regularly reassessing the agreed protocol.**

**While supporting the elevation of AVCPC membership from the technical to the policy level, the effectiveness of the revised arrangements, particularly in the light of the isolation of representatives from other portfolios, and from other organisations into two subordinate bodies, should be reviewed after two years.**

**The NRA and/or the AVCPC should review the currently available pesticide information technology services and determine whether or not the current scope of the services provides an adequate, and sufficiently accessible user-friendly information technology service on appropriate pesticide use for a wide array of pests and crops to pesticide users including those whose first language is not English.**

**The AVCPC should address how simple, robust summary versions of Material Safety Data Sheets, expressed in plain English, and in other community languages might be provided.**

**As part of completing its tasks, the Control-of-Use Task Force should initiate a comparative analysis between the states and territories of the outcomes of effectiveness of current control-of-use mechanisms used in the respective states by evaluating AQIS data for pesticide residue levels found in export produce, food residue data from the National Residue Survey, and states/territories data on adverse environmental, health and OH&S incidents or claims.**

**It would be most appropriate for Food Standards Australia and New Zealand soon after its creation, and in consultation with the NRA, to rapidly develop and issue a single Australian standard for MRLs for food and livestock feeds.**

## **8. PESTICIDE HANDING AND MANAGEMENT**

Farmers are increasingly being encouraged to use pesticides in their production enterprises within an adopted environmental management system which, as well as meeting end-product standards, also takes account of any impacts on the environment. Effective and reasonably uniform state/territory hazardous substance regulations are in place, though some farmers still overestimate their agricultural knowledge and underestimate the health risks from exposure to agricultural pesticides. A national training program for farm chemical users, with a number of training providers, is now in place. Educational standards are improving and evidence of formal achievement can be required before users can access some chemicals. There are consistent licence requirements for aerial pesticide applicators, but ground applicators remain less consistently regulated. Pesticide formulations have been made safer, improved packaging introduced, and programs adopted for the safe disposal of unwanted pesticides and used containers. Research and Development Corporations are sponsoring research into improved application technologies to reduce off-target movement of agricultural chemicals during application. National guidelines to reduce spray-drift are being finalised.

### **8.1. THE CURRENT FARMING FRAMEWORK**

#### **8.1.1. The role of Environmental Management Systems**

The advent of environmental management systems (EMS) represents a shift or extension of focus from the safety and quality of the product to the quality of the production systems. “An EMS is a methodical approach to the planning, implementation and review of an organisation’s attempts to manage its impact on the environment” (Rowland, 2000). The way in which the farmer selects and uses pesticides in relation to the total production system and the end product necessarily falls within environmental management systems. By contrast, previous quality assurance (QA) schemes largely dealt with the quality of the end product, rather than the whole system which led to its production.

In December 1996, Australia and New Zealand accepted the International Standard on Environmental Management Systems, ISO14000 as AS/NZ14000 (AS/NZ ISO14001). ISO 14001 is process or system orientated. It requires a commitment to continual improvement of the environmental management system, but not of environmental performance *per se*. The specific environmental criteria to be met depend on each country’s own environmental policy and standards. As a process rather than a performance standard, ISO14001 does not guarantee good environmental outcomes, but because it is not an environmental performance standard it is more acceptable in international trade (Rowland, 2000). It is the only certification system currently recognised for environmental management in Australia, though there are other systems overseas.

In May 2000, the Sustainable Land and Water Resources Management Committee of SCARM agreed to establish a working group to consider how governments might

facilitate voluntary adoption of EMS and maximise opportunities arising from EMS implementation. A concern with EMS is to avoid the plethora of partly incompatible systems that have evolved in the arena of food QA.

A notable finding in some Western European countries, is that food consumers are giving as much weight to being assured that the production of the food they consume has not had adverse environmental/resource impacts, as they are to being assured that the food does not contain residues harmful to human health. This situation is well illustrated by the policy of Tesco, the United Kingdom's largest food retailer and one of the top ten global food retailers. As a result of considerable consumer research, Tesco places great emphasis on the farmer end of the food supply chain. Tesco has developed a stringent growers code of practice titled 'Nature's Choice', which addresses issues of food safety, environmental management, and occupational health and safety. The company applies this code of practice to wherever its food supplies are sourced (including Australia) and carries out independent audits of growers. Currently, for example, a detailed EMS is being developed for a group of onion growers in Tasmania to meet Tesco's growers code of practice. All Tesco's direct suppliers are required to implement full Hazard Assessment Critical Control Point (HACCP) programs and to meet stringent product-quality standards, in addition to complying with the food safety codes of practice.

A significant Australian initiative is Supermarket to Asia (STA) which is managed through the Supermarket to Asia Council, established by the Prime Minister in 1996, and harnesses the combined expertise and experience of the food industry and government to maximise Australia's food export potential to the Asian region. STA is developing a system of "eco labels" and related value adding concepts that seek to differentiate Australian food destined for Asian markets on the basis that it is produced under a "clean and green umbrella" and that these claims are backed by rigorous certification requirements.

For Australian primary producers, it is inevitable that meeting EMS codes of practice will become as important as food safety and quality assurance schemes. Farmers will find it increasingly difficult to find markets for food produced under management systems that are unable to provide evidence of freedom from harmful environmental pesticide or other impacts.

Both QA and EMS programs represent a form of quasi-regulation which impose hurdles for producers additional to those imposed by the Commonwealth and states pesticide regulations. With respect to pesticide use, the hurdles arise because 'new' production and management systems are being mandated which if properly implemented and managed, ensure that acceptable pesticide standards will be met. In consequence, the overall monitoring system for pesticide residues in food, fibre and the environment, whether set by regulation or demanded by purchasers, will become more rigorous.

### **8.1.2. Regulation of Workplace Hazardous Substances**

The National Occupational Health and Safety Commission, the NRA and the states have worked co-operatively over a period of several years to introduce reasonably uniform and effective workplace hazardous substances regulations in each state and

territory. These regulations have been developed from a national model. The goal of the program has been to minimise the risk of adverse health effects due to worker exposure to hazardous substances, including hazardous agvet chemicals. Good progress has been made toward full implementation of an effective and reasonably uniform set of state and territory hazardous substance regulations, encompassing agvet chemicals.

However, an empirical study by Brush and Clemes (1995) on agrochemical and occupational safety legislation found that significant informational failure led Australian and New Zealand farmers to overestimate their agricultural knowledge. Moreover, the study found that a significant number of farmers underestimated the health risks from agricultural exposure, and consequently undervalued the implementation of protective practices. This is likely to act as a considerable barrier to farmers' voluntary participation in agrichemical training and educational programs.

Evidence of this nature provides strong support for agrochemical training to be made compulsory. Further support to the benefits of agrochemical training participation is given in a study by Sutherland (1994). In this study it was found that over 75 percent of respondents who had undertaken farmer chemical user training courses in NSW had modified their farm chemical practices as a result of training participation. Over a half of respondents who had modified their practices indicated they had greatly improved safety measures.

It seems clear that the success of any regulatory processes designed to attain effective and safe use of agricultural pesticides will be greatly influenced by whether or not farmers and other appliers of pesticide have had appropriate agricultural training.

## **8.2. OPERATOR TRAINING AND ACCREDITATION**

The national training and accreditation program for farm chemical users was established in the early 1990s by the NFF and the Rural Training Council of Australia (RTCA) to develop and co-ordinate training to raise competency levels of users of agricultural and veterinary chemicals.

The program, formerly known as Farmcare Australia, is now known as ChemCert Australia. The agricultural and veterinary chemical industry also has a national training and accreditation program. It is known as Agsafe Accreditation. Commercial Operator Training and Accreditation programs are also in place or are being developed for commercial operators who apply agricultural chemicals, both aerial and ground operators.

All of the programs regularly enhance standards with higher requirements for training and accreditation of chemical users.

### **8.2.1. ChemCert Australia and other training providers**

ChemCert Australia is a national non-profit incorporated organisation. ChemCert is recognised by industry and government as the peak body for the coordination and delivery of training and accreditation in farm chemical management (Kent 2000).

ChemCert Australia was first located at Charles Sturt University at Wagga Wagga but moved to Canberra where the Rural Training Council of Australia is located.

There are a number of other training providers, some associated with the Technical and Further Education institutes in the various states.

The aims of these national programs are:-

- to improve the knowledge and skills of farm chemical users
- to influence attitudes and behaviour towards responsible farm chemical use
- to assist users meet standards for farm chemical management, and the present and future regulatory, duty of care and quality assurance obligations
- to assist users of farm chemicals to sustain profitable production

Since the ChemCert® course was introduced, the Australian national training framework has been introduced, defining competency standards for workers in all industries, including the rural industries, and including competencies relating to handling and use of pesticides in the rural industries. Competency standards relate to the tasks to be undertaken and to the level of responsibility of the worker in an enterprise. The Chemical Units in the Rural Training Package are currently being revised, and training providers for the rural industries, including Chemcert® and a number of other training providers, will provide training in line with these requirements.

ChemCert had issued over 130 000 certificates to both agricultural and non-agricultural farm chemical users by the end of 1999. It is a critical element of, or complementary to the quality assurance (QA) programs, Agsafe farm chemical accreditation, Farmsafe and drumMUSTER container management.

The acceptance of ChemCert training and accreditation in farm chemical management and other similar programs such as the Level 3 Smart Train Course in New South Wales, is demonstrated by the stipulation by the NRA that only holders of such training certificates can purchase and use certain restricted pesticides. It is also demonstrated by the acceptance of these certificates to gain a permit to use the more hazardous pesticides in Victoria and by the requirement by state government bodies for users of pesticides in certain situations to hold an appropriate certificate. Specific examples are for mouse baiting in Victoria and for the use of herbicides near water in New South Wales.

These requirements are expected to proliferate in the future. The providers of accredited national training programs including ChemCert have a key role in helping farm chemical users meet those requirements.

### **8.2.2. Agsafe accreditation**

Agsafe Ltd. is a non-profit public company wholly owned by Avcare, the National Association for Crop Protection and Animal Health (Avcare) but it operates separately having its own Board and memorandum of articles. Agsafe is required by the Australian Competition and Consumer Commission (ACCC) to undertake statutory activities in its memorandum of articles. The Commission has issued a draft



determination proposing to authorise an agricultural and veterinary chemical industry self-regulation compliance program overseen by Agsafe.

Agsafe accreditation is the program ensuring duty of care and regulatory compliance within the agricultural chemical and animal health product industry from manufacturer to re-seller. The program is implemented through training, initially a basic 2 to 3 day course. The skills acquired through that training require re-accreditation every 3 years. Agsafe also accredits premises.

Nationally, there are 10 assessors and 25 course providers who usually work and offer courses through TAFE campuses. Each year, Agsafe trains about 1000 individuals. It also re-accredits about 1000 industry workers each year.

Agsafe is totally funded by the agricultural chemical and animal health products industry. It costs about \$1 million per year to run.

Manufacturers and re-sellers who do not wish to be members of Agsafe must, under ACCC authorisation, demonstrate they are complying with all the Agsafe accreditation standards (V. Keighley, Agsafe Accreditation, pers. comm.).

### **8.2.3. Training of commercial pesticide applicators**

Pesticides are often applied to crops by commercial operators who contract their services to farmers. These commercial operators fall into two categories, viz. those who apply pesticides from aircraft and those who apply pesticides through ground rigs.

#### **8.2.3.1. Aerial operators**

Each state has its own licensing procedures and requirements for commercial aerial operators, a far from ideal situation, but one which the aerial operators and their farmer clients have to accommodate.

Agricultural pilots must have the appropriate Commonwealth and state licences to operate in each state. They also have to meet state requirements including the various mandatory insurance policies, the spray application records to be kept, the specific requirements to apply pesticides in various regions within the state, the requirements to apply specific pesticides and the communication or notification requirements associated with aerial application of the various pesticides.

The Aerial Agricultural Association of Australia Ltd. is the national body representing agricultural pilots. This association recently introduced “Operation Spray Safe,” which in effect is the industry’s code of practice. It includes an accreditation program for aircraft operators.

This accreditation program includes the issuing of a “Certificate of Approval” on the successful completion of an examination based on the “Pilots and Operators Manual” prepared by the Gatton University Centre for Pesticide Application and Safety (CPAS). This manual provides all relevant information on aerial application of pesticides including the products being applied, their fate in the crop and in the wider environment and on the avoidance of off-target contamination.

### **8.2.3.2. Ground operators**

There is far greater variation in the current procedures and requirements for ground spraying operators. In some states, ground rig operators are not required to be licensed. In other states, licences are only required for ground application of herbicides.

The National Competition Policy Review of agvet chemical legislation made a recommendation (Recommendation 17) which addressed the need for a licensing system for all jurisdictions. This stated:-

“The Review Team recommends that an appropriate business licensing system for agvet chemical spraying businesses (ground or aerial) would entail no more than the relevant state agvet authority issuing a licence subject to

- maintenance of detailed records of chemical use
- using only appropriately licensed persons to perform application activities and
- the provision of infrastructure to enable persons to operate at the appropriate competency level”

A SCARM Task Force has been addressing the review recommendations pertaining to control of use of agricultural and veterinary chemicals. It has also been examining the regulatory responsibilities of the NRA and the control-of-use responsibilities of the states with the goal of integrating the national management of those chemicals.

## **8.3. PACKAGING, TRANSPORT AND DISPOSAL INITIATIVES**

### **8.3.1. Formulations**

There has been a trend away from use of traditional formulations in recent years in response to transport and packaging imperatives.

The reduction in the use of hydrocarbon solvents in pesticide formulation has greatly reduced the number of products with a “Dangerous Goods” classification. This has assisted in minimising restrictive transport and storage requirements for many pesticides.

Emulsifiable concentrate and oil based ultra low volume (ULV) formulations are being replaced by water dispersible granules or other granular formulations, as well as suspension concentrates and water based liquid formulations.

The new formulations are often more concentrated than those previously used and provide considerable savings in transport and packaging costs. The same amount of active constituent can be contained in a smaller volume of formulated product reducing the need for packaging material and increasing the amount of active ingredient which can be transported in the same volume.

An example of the increases in formulation concentrations is the conversion of a 500g/L suspension concentrate formulation of the herbicides, atrazine and simazine to a 900g/kg water dispersible granule formulation. Such a change in formulation reduced what was a 10 000 000 litre market to one of just over 5 000 tonnes. Similar changes to the formulation concentrations have occurred with the herbicides trifluralin and glyphosate.

Recent and current trend data on the volume of pesticides used in crop production systems can be confounded by changes in formulations such as these unless expressed in terms of Technical Grade Active Ingredient (P. Chalmers, Crop Care Australasia, pers. comm.).

This reduction in the overall volume of pesticide product being sold does not necessarily mean a reduction in the amount of pesticide being used. The rates of active ingredient being applied are frequently the same (P. Waterhouse, Crop Care Australasia, pers. comm.).

As a result of previous spray drift incidents, there has also been a move away from the use of ultra low volume (ULV) formulations in aerial spraying. Effective coverage of crops using ULV formulations requires the production of fine droplets with a high drift potential. Emulsifiable concentrate formulations must be diluted with water before application and the higher volume allows effective coverage by application of large droplets with a lower drift potential.

### **8.3.2. Packaging**

In recent years there have been significant changes to the packaging in which pesticides have been supplied. These changes have been prompted in the main by disposal difficulties associated with empty containers, particularly in the broadacre industries, where there have been significant increases in the number of containers requiring disposal.

These increases have stemmed from a number of sources including increased use of herbicides in field crop conservation tillage programs and increased areas planted to cotton. Horticultural cropping systems do not require the same volumes of pesticides as cotton and winter cereals because the areas being treated in the fruit and vegetable industries are much lower.

### **8.3.3. Management of Unwanted Pesticides and Used Containers**

Local authorities have struggled with the disposal of 20 litre and 200 litre containers in particular, and many of these authorities have been ill-equipped to deal with either the quantities or the types of containers requiring disposal. High density polyethylene and polypropylene containers are the most difficult to dispose of because of difficulties in properly crushing such containers prior to burial at local authority landfills.

In response to this situation, a number of container collection programs have targeted both on-farm use and the disposal of pesticide containers.

There are a number of government and industry initiatives which seek to collect and safely dispose of on-farm stocks of old unwanted agvet chemicals; ensure that such stocks do not build up again; and promote the use of a refillable chemical containers and safe recycling procedures for non-returnable agricultural chemical containers. These programs are discussed below. Taken together, the programs provide an encouraging sign that industry and government are taking a more holistic view of agvet chemical management and the need for the chemical industry to display some “stewardship.” However, the potential still exists for government to assume a stronger role to ensure that the programs are well coordinated and that outcomes are effectively monitored.

#### **8.3.3.1. ChemCollect**

ChemCollect (Anon 2000h) is a nationally coordinated, jointly funded collection scheme to ensure unwanted and de-registered agricultural and veterinary chemicals are safely collected from rural areas throughout Australia without charge to farmers, and are destroyed in a socially and environmentally acceptable manner.

ChemCollect is funded by each state providing half the funding for its collections and the Commonwealth government providing matching funding up to a maximum of \$13.5 million. It is a one-off scheme scheduled for completion by the end of 2002.

#### **8.3.3.2. ChemClear**

To ensure stocks do not build up again, ChemClear will begin in each state after ChemCollect has finished. ChemClear will be an on-going program for regular collections of registered farm chemicals which are otherwise non-returnable.

ChemClear is a joint initiative involving Avcare, the Veterinary Manufacturers and Distributors Association (VDMA) and the National Farmers Federation (NFF).

#### **8.3.3.3. Industry Waste Reduction Scheme**

ChemCollect and ChemClear are complemented by an Industry Waste Reduction Scheme (IWRS) (Anon 2000h) which is an agricultural and veterinary chemical industry initiative. This scheme has two objectives, viz:-

- a reduction in the amount of packaging at source by encouraging manufacturers to adopt alternative containers such as bulk or re-fillable packs, new packaging technology such as water soluble sachets, and new formulations such as gel packs and granules
- ensuring that non-returnable crop protection and animal health chemical containers have a defined route for disposal that is socially, economically and environmentally acceptable.

The scheme aims to reduce the weight of container packaging by 32% and the weight of containers currently going to landfill by 68 % by 2001.

A number of chemical companies have introduced 110 litre refillable containers, and 1 000 litre refillable containers. One of these companies promotes the 110 litre container as an “Envirodrum” and the 1 000 litre container as “Envirotank.”. Under

this closed chemical transfer system, a number of pesticides are supplied in containers which when empty, are returned fully sealed to the place of purchase and then to the company for refilling. To encourage farmers to return these specially manufactured containers, a deposit is incorporated in the purchase price, redeemable on the return of the container (G. Healy, Nufarm Ltd, pers. comm.).

An estimated 4 million non-returnable agricultural chemical containers are sold every year to Australian farmers.

#### **8.3.3.4. “drumMUSTER”**

To implement its IWRS, the chemical industry has instituted a system of container management known as drumMUSTER (Anon 2000h).

This national program aims to collect and recycle empty, cleaned, non-returnable agricultural chemical containers. It is managed by Agsafe Ltd for the NFF, Avcare, the VMDA and the Australian Local Government Association.

drumMUSTER is funded from a levy of 4 cents per litre or kilogram on crop protection and on-farm animal health products sold in non-returnable chemical containers of over 1litre or 1kilogram in content. The 110 litre and 1 000 litre refillable containers are exempt from the drumMUSTER levy.

Farmers deliver empty, cleaned containers to collection centres on designated collection days. These centres are run by participating local councils and shires. The participating councils inspect and process containers through re-use, recycling, energy recovery or other environmentally approved methods.

The program aims to recover 66% of empty, clean, rinsed chemical containers and to supply 50% of raw materials in recyclable or returnable packaging.

### **8.4. RECENT TRENDS IN METHODS OF APPLICATION**

#### **8.4.1. Application technologies**

With respect to technique of pesticide application, there is evidence in Australia and overseas that application equipment can commonly be inefficient or defective. As a consequence, more pesticide is often used than necessary. A mandatory scheme of regular pesticide equipment testing would be one approach to this problem.

More generally, Zilberman *et al.* (1996; 1991) argue that there is great potential for the development and adoption of high-precision technology in the application of pesticides and other farm inputs. These techniques would be firstly more efficient in terms of productivity because of greater utilisation of the input applied, and secondly, their impact on the environment is more benign. The use of drip technology systems for applying irrigation water is a good example of a precision technology. It is also relevant to pesticide use insofar as the more common practice of flood irrigation is a technology which can have a consequence of transporting pesticides into waterways.

New pesticide application technologies are readily transferable. Equipment manufacturers, equipment merchants, industry organisations, individual farmers and pesticide application contractors rapidly introduce into Australia, overseas developed innovations. Examples of recent changes in technologies adopted by agricultural industries were outlined in Chapter 4 in the description of pesticide use by the apple and pear, and the cotton industries.

The Centre for Pesticide Application and Safety (CPAS) at the University of Queensland, Gatton, is the pre-eminent national centre for research on pesticide application technology. Other agricultural R&D agencies in Australia also are developing pesticide application technology for specific crop industries almost invariably, as with CPAS, with financial support from industry based Research and Development Corporations.

Community and industry concern over pesticide usage has catalysed research and development (R&D) in Australia in all crop industries for improvements in pesticide application technologies.

One of the major challenges facing Australian farmers is the off-target movement of agricultural chemicals during application. High monitoring costs of non-point environmental damages caused by off-target pesticide use will commonly make the method of application of a pesticide or a complementary input an appropriate incentive target. Off-target movement can arise in a number of ways including drift and run-off.

#### **8.4.2. Spray Drift**

As indicated in Section 7.1.2, a SCARM Working Party is finalising publication of national guidelines to reduce spray drift of agricultural chemicals. Draft guidelines were released for public comment in 2000 and a final report had been completed for publication. These guidelines present a comprehensive coverage of the scientific, technical and other information which needs to be addressed in the planning stages of any application of agricultural chemicals. (K.Priestly, QDPI, pers. comm.).

## **8.5. CONCLUSIONS – PESTICIDE HANDLING AND MANAGEMENT**

**For Australian primary producers, meeting EMS codes of practice will become as important as food safety and quality assurance schemes. These are currently reflected in certification for AS/NZ14001. Farmers will find it increasingly difficult to find markets for food produced under management systems that are unable to establish certification for environmental performance standards including providing evidence of freedom from harmful environmental pesticide or other impacts.**

**There have been significant improvements in the levels of educational achievement by producers and contract applicators in pesticide handling and management over the past ten years. These are increasing required before users can gain access to some pesticides, thereby generating benefits for both pesticide users and product purchasers.**

**A range of jointly industry-government sponsored programs have significantly reduced the risk of environmental damage from the unsafe disposal of surplus chemicals and their containers.**

## **9. THE POTENTIAL IMPACT OF GENETIC MODIFICATION TECHNOLOGIES ON PESTICIDE USE**

Genetically modified crop varieties have the potential to assist farmers improve production efficiency and can offer enhance product quality and even nutritional benefits for consumers. The extent to which these varieties are adopted will ultimately be determined by the market-place. Initial emphasis has been towards “pest protected” and “herbicide tolerant” crop varieties, though future improvements are being directed to many other characteristics such as flower colour, fruit ripening characteristics and nutritional value. Although use of genetically modified varieties is yet small in Australia, they had been adopted on over 35 million hectares of production systems world-wide by 2000. Approximately 30 per cent of Australia’s cotton crop is currently sown with varieties containing a single gene for insect pest protection, and on these areas, insecticide use has been reduced by nearly half, leading to an overall reduction across industry of 12-15 percent. Since the risk of inducing resistance in the insect pest population should be reduced, cotton with two insect protection genes, anticipated by 2003, may allow a 70-80 per cent reduction in insecticide use on such crops. Use of genetically modified varieties has also facilitated increased use of Integrated Pest Management in cotton-growing. Crops with naturally-bred herbicide tolerance are already in use, notably canola, and genetically modified varieties are in the “pipeline”. These can allow more effective weed control in crops through use of specific herbicides, and have the environmental benefit of allowing the withdrawal of herbicides with residual activity, but will require careful attention to the likely risk of resistance build-up in the weed population

### **9.1. AN ALTERNATIVE APPROACH TO PEST MANAGEMENT**

Biotechnology has dramatically increased the range of characteristics we can incorporate into our crops (NRC 2000). This technology offers an alternative approach to aspects of pest management in production agriculture quite independently of other aspects of the potential use of **genetically modified** (often abbreviated as **GM**) crops.

Australian agricultural commodity production systems tend to be lightly subsidised and growers are price takers on world markets. In such a system, a genetically modified crop variety which increases yields, reduces costs or encourages the production of a crop in regions where there was previously little incentive to grow it will probably result in increased areas being planted to that crop.

This has been the case with a version of non-genetically modified, **herbicide tolerant (HT)** canola in Australia. The area of canola has increased tenfold in recent years through increased use as a “break” crop in cereal production, a role which has become increasingly necessary because of disease and weed problems in cereals, and which has been facilitated by **triazine tolerant (“TT”)** canola. Such a change in the crop rotation/production system will have implications for aggregate pesticide use. Australian agriculture typically competes on world markets by being efficient, which



often means large-scale, low-input techniques practiced in marginal environments. Any genetic modifications which improve this competitive position will increase crop areas in the Australian environment, and therefore may in some circumstances, increase aggregate pesticide use. Other genetically modified crop varieties which allow the extension of pesticide-using crops into zones which are currently too arid or too saline might have a similar effect.

### **9.1.1. Factors influencing pesticide use**

#### **9.1.1.1. *Who makes the decisions?***

In general, any alternative or additional method of pest control, whether derived from genetic modification techniques or not, could logically be expected to change pest management practices, and alter the extent to which pesticides are used. Whether the introduction of one pest management practice results in the reduction of another will depend on relative suitability, effectiveness and cost, as well as social and ethical factors. Evaluating whether new crop varieties will change pesticide use requires a clear understanding of who makes pesticide decisions and what their options are. The decision makers include producers, consumers and government regulators.

Ultimately, it is the consumers who make the final decisions on use of a commodity, based on market forces, but they also influence and are influenced by governments on what is acceptable. Some consumers may have a perception that there is an excessive use of pesticides in Australia. Such consumers can influence pesticide decisions by lobbying governments to change the regulations impacting on producers. They can also apply pressure via market forces, for example choosing products produced without pesticides. Third parties may complain if they perceive a risk of pesticide exposure to them or their property (eg. excessive wind during spraying causing drift). They may also see environmental damage, possibly linked to pesticides, (for example dead fish in rivers). It is ironic that consumer dissatisfaction with standards of product appearance may lead to increased pesticide use, contradicting other consumer demands for reduced pesticide use.

Generally, producers base decisions on economics, together with their perceptions of the health and environmental risks that may impact on themselves and their product markets. Within the regulatory limits set by the NRA, there is considerable scope for producers to decide on the extent of pesticide use, but they are limited in their ability to respond to long-term environmental health issues in the face of short term profitability imperatives. Such economic pressures may colour their longer term perceptions. Perceptions can vary considerably between industries and between individuals. Some producers actively avoid pesticides and promote alternative pest control strategies.

#### **9.1.1.2. *Public perceptions of GM technology***

Genetically modified organisms have attracted considerable public debate. The general community acceptability of this technology will have an overriding influence on the applicability of the conclusions of this report. It has been argued that promoters of GM technology made a major strategic mistake in leading with organisms intended primarily to increase the profitability of farming systems. Those that might have provided a more identifiable consumer or community benefit may

have been a better choice, such as, say, technologies leading to improved human health or to help solve environmental problems like waste-site contamination or agricultural soil degradation (Walker and Lonsdale 2000). Even in the case of those genetically modified crops which provide genetically built-in pest protection and are therefore expected to decrease pesticide use, emphasis has been on cost savings to farmers rather than potential environmental benefits. Taking the profitability approach has nurtured public disquiet, because it has been perceived that the public will bear all the potential risks of this new technology, while farmers in the developed world and multinational companies will enjoy all of the gains.

Public disquiet about genetically modified crops may provide markets for Australian produce from those demanding non-GM material. Some are concerned that we are already jeopardising markets by continuing to register GM crop varieties even for trials (Clark 1999b). Communities in two major economic centres of world trade, the USA and Europe, have taken widely differing positions in this debate. It is in these circumstances that the potential adoption of genetically modified crops in Australia is being considered. A more detailed general discussion of the policy implications of the use of GM crops is beyond the terms of reference of this review which is concerned with the specific relationship between GM crops containing herbicide tolerance or pest control genes and the use of chemical pesticides.

### **9.1.2. Biotechnology and genetic engineering**

#### **9.1.2.1. Some definitions**

“Genetic engineering” has been defined as a component of biotechnology for modifying the properties of organisms. It has been further defined as “the transfer of one or a few genes into a cultivar with the use of *Agrobacterium tumefaciens*, microprojectile bombardment, electroporation, or microinjection” (NRC 2000). It is now possible to transfer genes which code for an enormous range of characters across the ‘species boundary’ (Regal 1999). The first transfer of bacterial DNA from *Agrobacterium tumefaciens* to a plant occurred in 1980 (Hernalsteens *et al.* 1980). This heralded a huge range of potential possibilities for modification to plant varieties.

Previously, genes which governed the characters of a species (plant or animal) and its continued fertility could only be transferred in conventional plant breeding between members of the same species. This meant that the store of characters available to breeding programmes was limited to those present in the genome of any given species. Put simply, a species represented the gene store and sexual reproduction provided the means of mixing those genes to produce a variety of individuals. After mixing, selection of superior individuals provided the parent plants of new crop varieties.

Although this method has contributed tremendously to the improvement of plant varieties, including the production of varieties resistant to pests, selection based on sexual reproduction on such a basis, has limitations. Sexual gene transfer occurs randomly at each mating, so desirable genes might not concentrate in the same individual. Many generations, meaning years of crop breeding programs, are usually required to obtain useful results. Therefore, despite their success, traditional methods

of plant breeding have been limited by the range of characters available within sexually compatible individuals, and the intrinsic imprecision of the sexual gene transfer (Royal Society of Canada 2001).

Genetic variation can also be increased by mutation. Mutations generally occur at a very slow rate but can be accelerated through enhanced mutation rates using radiation or chemicals. This is not regarded as genetic engineering because the process might occur naturally, though some observers do not see it as any different from genetic modification techniques, in terms of regulatory issues.

Whether modern gene transfer techniques have, so far, increased the rate of production of genetic varieties is debatable. Genes must be sought, successfully introduced to the recipient DNA and must then perform (be expressed) at desirable levels. Such biotechnology projects usually have been concerned with introducing a single trait to an already successful line. The process must work for that particular plant variety, and this is not always achieved. Furthermore, single-gene constructs introduced for biological defence against a pest can result in pressure to select for resistance in the pest population, leading to a rapid build up of resistance and loss of genetic effectiveness of the technology.

Some characters may require additional supporting genes that code for components needed at earlier stages in a biochemical process. For example, blue roses require several extra genes to be introduced before the desirable colour is expressed. That has taken at least ten years, and efforts are still continuing. Successful gene transfers still involve a great deal of trial and error, eventually requiring the more tedious traditional plant breeding practices to introduce the new character into existing, otherwise well-adapted and desirable varieties. Relatively simple transfers can reach commercial use much faster, as has occurred with the production of a single protein operating in a relatively isolated way in *Bacillus thuringiensis* (Bt) gene-containing crops. The transfer of Bt from a bacterium to crop varieties could never have been achieved by conventional techniques. Even introducing this single gene into Australian commercial cotton varieties has taken 10-15 years (Pyke and Fitt 1998). However the rates of success for gene identification and transfer are almost certain to improve as biotechnology advances (TJ Higgins, CSIRO, pers. comm.). In addition, mapping of entire genomes may allow desirable traits to be expressed by manipulating the existing genome of a crop, through gene regulation rather than gene addition or removal.

The major advantage of genetic modification techniques over selective breeding is to dramatically increase the range of characters that are potentially available. For example, it is conceivable that a salt tolerance mechanism from a saltbush species might be available to crop and pasture species, or that antifreeze characteristics of certain insects might be introduced to fruit or vegetable crops to increase frost tolerance.

#### **9.1.2.2. Transgenic crop varieties**

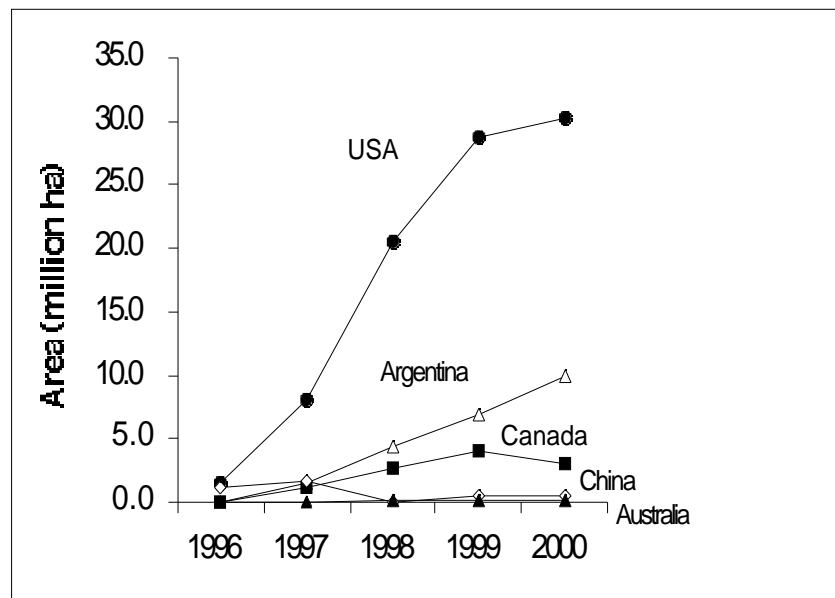
The first applications of gene transfer technology for commercial crop varieties have been directly aimed at pest control. These form a category of genetically modified crops being referred to as “pest-protected” or “herbicide tolerant” crops. Some 90% of varieties of genetically modified crops currently in commercial use confer insecticidal

properties on plants to kill pest insects that feed on them (for example, Bt corn and Bt cotton), and/or herbicide tolerance properties to the crop so that a particular broad-spectrum herbicide can be used to control a wide selection of weeds within the crop without damaging the crop itself (for example Roundup Ready canola and Roundup Ready® soybeans) (NRC 2000).

### 9.1.2.3. Area of GM crops world wide

It can be seen from Figure 7 that Australia has proceeded slowly in planting genetically modified crops compared with the USA, Argentina, and Canada. The date of the first introductions of genetically modified crop varieties in the United States is shown in Table 39.

**Figure 7.**  
The adoption of genetically modified crops by four major countries: USA, Argentina, Canada and China in relation to Australia.



(Source: Lonsdale plotted from James, 2000)

**Table 39:**  
**Pest-protected crop varieties released in the USA. and Australia.**

Crop	Resistance	Release in USA	Release in Australia
<b>Insect resistance</b>			
Potato	Bt IR	1995	
Corn	Bt IR	1995	
Cotton	Bt IR	1995	1996
Corn	Bt IR	1995	
Corn	Bt IR	1996	
Corn	Bt IR	1996	
Potato	Bt IR	1996	
Corn	Bt IR	1997	
Cotton	Bt IR, HT	1997	2000
Corn	Bt IR, HT	1997	
Tomato	Bt IR	1998	
Corn	Bt IR, HT	1998	
<b>Virus resistance</b>			
Potato	Bt IR, VR	1998	
Potato	Bt IR, VR	1999	
Squash	VR	1996	
Papaya	VR	1996	

Abbreviations: IR = Insect Resistant, VR=Virus Resistant, HT=Herbicide Tolerant, Bt = *Bacillus thuringiensis*.  
Source:- NRC 2000,- data source USDA 1999

#### **9.1.2.4. US experience with GM crops**

US farmers have readily adopted genetically modified crops (Table 40). One fifth of the corn acreage, over half the soybean acreage and almost one third of the cotton acreage were changed over to genetically modified varieties between 1996 and 2000.

Carpenter & Gianessi (2001) concluded that Bt corn has led to little reduction in actual insecticide use because pesticides had had only limited use since they were not been very effective on the main target of Bt corn (the European Corn Borer, *Ostrinia nubilalis*). The main benefit has been yield increases brought about by reduced losses to this pest, but an added benefit for consumers has been the virtual elimination of mycotoxin contamination in corn modified for insect resistance. Carpenter and Gianelli (2001) also concluded that, as in Australia, US cotton growers have reduced pesticide use with Bt cotton. With genetically modified varieties of soybean (mostly involving the Roundup Ready herbicide tolerance gene), growers reported significant reductions in herbicide treatments. However, the adoption levels for Bt potatoes have been low (2-3% of industry in 2000).

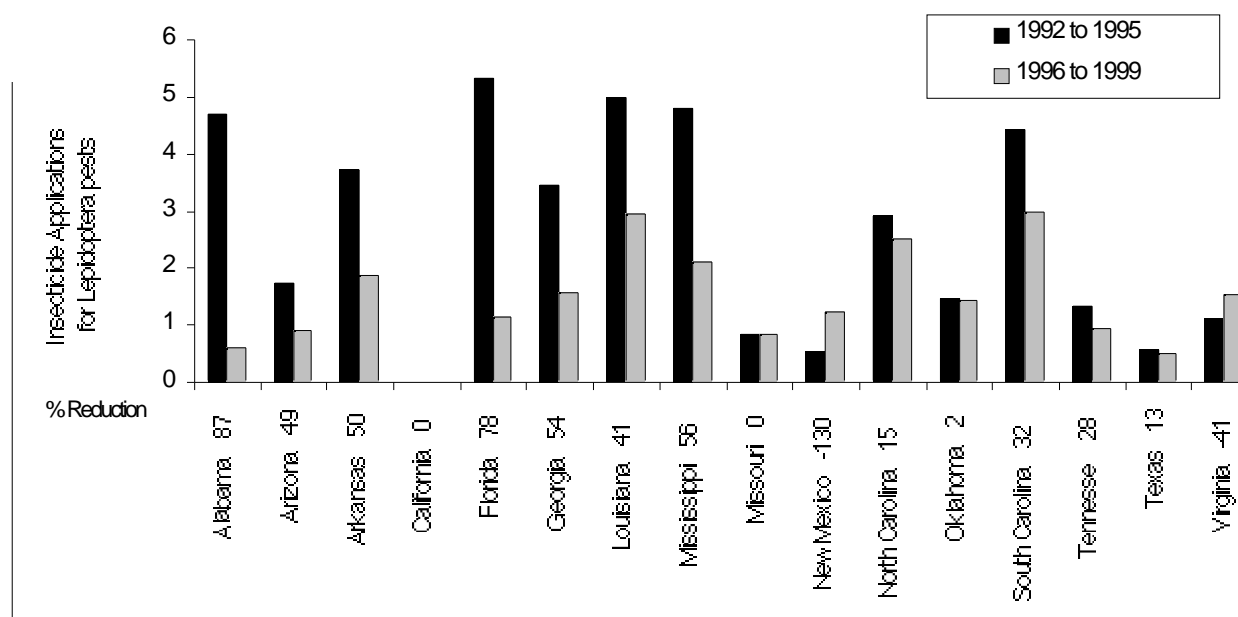
**Table 40**  
**Adoption rates of genetically modified crop varieties in the USA since introduction,**  
**expressed as a percentage of the total crop.**

Variety	1995	1996	1997	1998	1999	2000
Bt corn	-	1	6	18	26	19
Bt cotton	-	12	18	23	32	39
Bt potatoes	-	1	2.5	<4	<4	2-3
RoundupReady® cotton	-	-	4	21	37	54
RoundupReady® soybeans	-	2	13	37	47	54
Bromoxynil tolerant cotton	0.1	0.1	1.2	5.8	7.8	7.2

Source: Carpenter & Gianessi, 2001.

The reports of pesticide reductions across large industries in the USA are difficult to interpret (eg. Carpenter & Gianessi 2001 and USDA 2000).

**Figure 8**  
**State by state (USA) comparison of the average number of insecticide applications**  
**directed at pests that are targeted by Bt, for the four years previous to Bt variety**  
**introductions (1992 to 1995) and the four years after (1996 to 1999).**



(Source: Carpenter & Gianessi 2001).

It is clear that not all US states have benefited as much as others from the Bt technology (Figure 8), because some do not apply much pesticide targeting *Lepidoptera* in the first place. Adoption rates for Bt cotton also reflect where the protection with Bt will be most effective. Highest acreage adoption (1999) occurred in Alabama (66%), Mississippi (67%), Arizona (63%) and Louisiana (61%) but very little in California (3%), Missouri (2%), Virginia (7%) and Texas (8%) for example.

## **9.2. PROGRESS OF GM TECHNOLOGY IN AUSTRALIA**

### **9.2.1. Current and future availability of GM crop varieties**

Australian authorities have allowed three commercial releases genetically modified crop varieties, Bt cotton, blue carnations and Roundup Ready (herbicide tolerant) cotton (Table 41). This table shows also shows the approximate times to and likelihood of use of genetically modified crop varieties in Australia to assist our projections on pesticide use. The number of traits being considered is increasing

The extent of the impact of genetically modified varieties on pesticide use will depend on the types of genetic modifications which are being used.

Many crop improvements in the future will not be directed at pest management. Genes coding for quality traits such as flower colour, fruit ripening characteristics and staple length in cotton may have no impact on the survival of pests or the extent of pesticide use. Nevertheless some characters (such as colour, nutrient level or the timing of ripening) could conceivably change pest status. The change may be direct, by perhaps improving attractiveness of the plant to the pest, or increasing pest population growth rates. Alternatively, it may be indirect, by increasing the value of a product, which economically justifies more pesticide applications to ensure product quality. These considerations do not differ from those considered in traditional plant breeding.

Genetic modification technology may allow more precise addition of genes without removing defence mechanisms which were sometimes lost in traditional methods. In recent decades, some crop yield improvements have been accompanied by reduced natural plant resistance. Some conventionally-bred varieties have been deliberately selected for reduced resistance because the resistance factor has had undesirable effects which restricted the end uses of products. In cotton, for example, the terpenoid gossypol (an important contributor to insect resistance in primitive cotton varieties) has been reduced because it makes cotton seed meal unsuitable for consumption by monogastric animals such as pigs and poultry. In other crops, continual yield assessment in variety trials conducted under the protection of insecticides has selected for genotypes which have reduced natural insect pest resistance. The greater precision of gene transfers with genetic modification technology should allow progress in improving important production traits such as yield and quality criteria without the risk of defence losses. Such technology could even facilitate the return of ancient defence genes to high yielding varieties.

The former Genetic Manipulation Advisory Committee (GMAC) used to provide a list of genetically modified crop varieties under review on its no-longer accessible website. Subsequent reviews conducted by the Office of the Gene Technology Regulator are to be found at [www.health.gov.au/ogtr/index.htm](http://www.health.gov.au/ogtr/index.htm). A summary of the genetically modified plant varieties, their characteristics and expected time to introduction, if acceptable, is presented in Table 41.

**Table 41.**  
**Approximate times to and likelihood of use of genetically modified crop varieties in**  
**Australia in the near future.**

<b>Crop</b>	<b>Genetic Modification</b>	<b>Technical Status</b>	<b>Approximate year expected commercial in Australia</b>
Cotton	insect resistance	achieved	current
	herbicide tolerance	achieved	current
	Waterlogging tolerance	research phase	5-10
	fusarium wilt tolerance	research phase	>10
	fibre quality (strength, colour)	research phase	>10
Canola	herbicide tolerance & hybrid vigour	achieved	2- 3
	resistance to fungal pathogens	research phase	5-10
	insensitivity to photoperiod	research phase	5-10
	reduced glucosinolate	research phase	5-10
	dwarf cultivars	research phase	5-10
Sugarcane	reduced pod shatter	research phase	5-10
	modified sucrose metabolism	research phase	>10
	juice colour	research phase	>10
	resistance to leaf scald disease	research phase	5-10
	resistance to mosaic virus	research phase	5-10
Wheat	herbicide tolerance	achieved in USA	>8
	grain qualities	research phase	5-10
Barley	resistance to yellow dwarf virus	research phase	5-10
Oilseed Poppy	pharmaceutical content	research phase	5-10
Clover	herbicide tolerance	-	unlikely to be used
	nutritionally enhanced	-	unlikely to be used
Lupins	herbicide tolerance	-	unlikely to be used
	virus resistance	research phase	5-10
Field Peas	nutritionally enhanced	research phase	5-10
	nutritionally enhanced	research phase	>5
	insect resistance	achieved 2-3	
Lentils	blight resistance	research phase	>10
	herbicide tolerance	-	unlikely to be used
Tomatoes	fruit ripening	achieved in USA	5-10
	flavour development	research phase	5-10
	herbicide tolerance	research phase	5-10
	insect resistance	research phase	5-10
Potatoes	virus resistance	research phase	5-10
	tuber production	research phase	5-10
	non-browning when cut	research phase	5-10
Pineapples	control flowering and ripening	research phase	5-10
Grapes	non-browning of dried fruit	research phase	5-10
Papaya	virus resistance	achieved in USA	2- 5
Apples	marker gene testing	-	N/A
Carnations	colour	achieved	current overseas
	extend vase life	achieved	current overseas
	resistance to fungal pathogens	achieved	5-10
Chrysanthemums	petal colour	research phase	5-10
Roses	petal colour	research phase	5-10

Source: Crops and genetic modifications from GMAC public information sheets Dec 1999. Approximate times to and likelihood of use have been estimated by Dr. T. J. Higgins, CSIRO Plant Industry (pers, comm. 2001).

As shown in this table, the lead time to produce such varieties is in the order of ten years. Progress over the next five years or so in Australia can be relatively well predicted (if we discount political and social factors) because any such crops must



come from those currently being developed and tested in Australia or being introduced from other countries. Therefore the candidates are known. Some may fail to gain registration. It is predicted that over time, those varieties which are only pest protected will give way others which also include more output-oriented traits.

### **9.2.2. Pest resistant crops**

#### **9.2.2.1. Australian Experience with Bt cotton**

Bt cotton, released in Australia in 1996, was initially planted over approximately 10% of the cotton-growing area. Today it represents about 30% of the total crop. Its use is held at this point by the need for adequate resistance management, rather than by lack of demand from producers (Fitt and Wilson 2000). Currently, cotton is the only broad acre crop in a high pesticide-use industry having varieties with a genetically modified pest-protected attribute which enables comparison with non-genetically modified varieties.

Following trials to ensure acceptable agronomic performance, minimal outcrossing risk of GM cotton carrying the Bt gene, and absence of off target impacts, Australian regulators allowed limited release of Ingard® cotton (licensed by Monsanto) on a commercial scale for the 1996/97 season (Fitt 2000). Currently, Monsanto's Cry1A(c) gene is the only Bt gene in commercial Australian cotton. It has been incorporated into elite cotton varieties marketed by the two major seed producing companies in the Australian cotton industry, Cotton Seed Distributors and Deltapine Australia. This incorporation has not led to any yield penalties or disadvantageous agronomic characteristics, though inconsistent variation in yields between Bt and non-Bt varieties grown under the same conditions has been sometimes recorded. Economic analyses showed that there have yet to be any consistent increases in returns to growers, since reductions in the costs of insecticides were roughly balanced by the cost of the license fee paid to Monsanto (Long and Boyce 1997, Long and Boyce 1998, Long and Boyce 1999). Partly in response to these considerations, the license fee was progressively reduced over the first three seasons.

The Bt gene was chosen for its efficacy against lepidopteran pests (larvae of moths and butterflies). The main targets of the technology are two species of *Helicoverpa* (*H. armigera* and *H. punctigera*), in the subfamily *Heliothinae* of the family *Noctuidae*. These are the key pests of Australian cotton. Approximately 75% of insecticide applications to cotton in Australia are directed at these two pests. It is useful to note, for later comparisons, that the American cotton industry also has two serious heliothine pests.

As a specific control measure directed at lepidopteran pests, the impact of Bt cotton can be judged by its replacement of insecticides directed at those pests. Statistics on insecticide use on Bt cotton versus conventional cotton of comparable varieties in similar agronomic conditions are presented in Table 42. The information was collected from cotton consultant surveys and published through the Cotton Research and Development Corporation (CRDC) in its Occasional Papers series (Pyke and Slack-Smith 1997, Clark 1998, Clark 1999a, and Kwint 2000). An occasional Paper has been produced for each of the four growing seasons that GM cotton has been grown. Surveys covered 46%, 20%, 9% and 28% of the Bt cotton crop from 1996/7 to 1999/2000 respectively.

Initial small-scale trials suggested that a 40-50% reduction in pesticide applications directed at *Helicoverpa* spp. was possible on Bt cotton crops in Australia, relative to conventional cotton varieties (Fitt *et al.* 1994). This has subsequently been confirmed by the industry-wide studies of the Cotton Research and Development Corporation (1997, 1998, 1999, 2000; Table 43). The reduction in use of insecticides on Bt cotton during the four seasons for which data are available has ranged between 43 and 57% for *Helicoverpa* spp. sprays and between 38 and 52% for all sprays. The overall influence on the industry of Bt cotton adoption is based on figures supplied by ABARE (2001).

**Table 42.**  
**Reductions in insecticide use (number of sprays) for *Helicoverpa* spp. and in total on Bt cotton varieties, and the level of adoption of Bt cotton, 1996/1997 to 1999/2000.**

Season	Reduction to insecticide applications for <i>Helicoverpa</i> spp. (%)	Reduction to overall insecticide applications (%)	Total Area of Cotton ('000 ha)	Area of Bt cotton ('000 ha)	Proportion of Crop Bt cotton (%)	Reduction of Insecticide Overall (%)
1996/97	57	52	396	30	8	4
1997/98	44	41	438	64	15	6
1998/99	43	38	562	85	15	6
1999/2000	47	40	464	130	28	11
Average	48	43				

Sources: CRDC Occasional papers (Pyke and Slack-Smith 1997, Clark 1998, Clark 1999a, Kwint 2000) and ABARE (2001)

An industry limitation (or cap) recommended by the National Registration Authority restricted the adoption of Bt-containing varieties to 30% of the sown area to minimise any risk of development of Bt resistance in the pest. The actual adoption level in 2000/2001 was close to the maximum permitted 30%. On this basis, and assuming that spray reductions for 2000/2001 are similar to the average of the past four seasons, the current overall reduction of insecticides for the industry is in the range of 12-15%.

Realised pesticide reductions, in terms of the absolute numbers of sprays, depend on the pest pressure because high numbers of the pest in any particular year lead to higher pesticide use. High seasonal pest pressure (as, for example, in 1997/8 and 1998/9 compared to 1999/2000) appears to slightly reduce the difference between Bt cotton and conventional varieties.

The current GM varieties of cotton with single gene for Bt expression, provide good efficacy over the first two thirds of the growing season but diminish in pest control effectiveness over the last third (Fitt *et al.* 1998). It might therefore be expected that there would be a greater reduction in insecticides used mostly early in the season, compared to late-season sprays. Table 43 shows, in percentage terms, the reductions achieved in the use of various chemical groups.

**Table 43.**  
**Percentage reductions in the average number of insecticide applications for key chemical groups directed at Heliothine and other pests on Bt cotton varieties compared with conventional cotton varieties, 1996 to 2000.**

Season	Endosulfan	Carbamates	Ovicides	Organo-phosphates	Synthetic pyrethroids	Miticides	Granular systemics	Other
1996/97	86	64	75	16	50	NA*	NA*	NA*
1997/98	81	43	34	25	29	4	-7	69
1998/99	70	62	63	24	35	-23	0	44
1999/2000	71	50	58	29	45	14	NA*	47
<b>Average</b>	<b>77</b>	<b>55</b>	<b>58</b>	<b>24</b>	<b>40</b>	<b>-2</b>	<b>-4</b>	<b>49</b>

\* Not Available. Sources: Pyke and Slack-Smith 1997, Clark 1998, Clark 1999a, and Kwint 2000.

In particular there has been a 77% reduction in endosulfan applications. Endosulfan is an insecticide which has been widely used early in the season against *Helicoverpa* spp. It has had a problematic history with regard to contamination of waterways, and recent residues in beef cattle (via insecticide drift onto nearby pastures) disrupting Australia's export beef markets (NRA News 2001). Reductions in the use of this chemical, which decrease the probability of such episodes, are a major benefit of Bt cotton.

On the other hand, reductions in the use of organophosphates have been relatively limited. These chemicals are largely used late in the season, and often against non-lepidopteran pests such as aphids and mites which are not affected by the Bt toxin. In the case of systemic granular insecticides, and miticides, which are directed at pests not affected by the Cry 1A(c) toxin in INGARD® cotton, there have been no consistent changes. This suggests that cotton farmers are not, as might perhaps be expected, increasing their proportionate use of insecticides against other pests in order to protect their investment in the licence fee required to grow the Bt crop.

The presence of only a single gene leaves current Bt varieties vulnerable to inducing insect resistance problems (Fitt 2000). Hence, adherence to the resistance management strategy is reinforced by the conditions of the label on the seed and of the licence required of growers who buy and plant Bt cotton seed. Over the next few years, two-gene cotton is expected to become available. This will consist of genetically modified varieties which express two different Bt toxins. With two (pyramided) genes, the selection pressure for populations of the pest which are resistant to the cotton variety are greatly reduced (Roush *et al.* 1998). This may see the relaxation of the area limit and greatly increase the impact of genetically modified varieties on pesticide reduction across the whole cotton industry. Initial trials of two-gene cotton indicate that it also has improved efficacy which implies even fewer insecticide treatments, particularly later in the year (Fitt 2000).

Current research suggests a 70-80 per cent reduction in insecticide applications may be applicable and that 70-80 percent of the total crop area is likely to be approved for the two-gene varieties. However, if the present single gene varieties were to continue in use and lose efficacy in the later crop years, the two-gene cotton would effectively present as a single gene cotton. Current thinking is that the two-gene varieties might

enter commercial use in a transitional year 2003, with full adoption from 2004, from which time the single gene varieties would be withdrawn (G. Constable, Cotton CRC, pers. comm.).

Reduced treatments, particularly with broad-spectrum insecticides over the early half of the season, have revealed the contribution by natural mortality factors to pest control. This has boosted the interest in, and application of IPM strategies which, in turn, encourage changes in insecticide types and number of treatments.

The development of new insecticides continues, complicating the evaluation of Bt cotton. The 1999/2000 season saw an increased use of spinosad, a chemical which is regarded as “softer” on beneficial insects (Murray and Lloyd 1997). “Softer” refers to pesticide applications which are more specifically targeted and relatively less disruptive to non-target species. It has been noted that the use of several insecticides, including biopesticides such as the *Helicoverpa* virus, Gemstar<sup>®</sup>, which are consistent with IPM strategies, has increased relative to more traditional pesticides on both Bt and non-Bt cotton. This reflects the greater realisation of natural mortality observed in parallel with the reduction of pesticide use, particularly over the early half of the season, coinciding with the most effective protection period of the Bt gene. Accordingly, growers are substituting “softer” chemicals to extend the period of natural enemy impact. This is occurring on both conventional and Bt cotton, but more so on Bt cotton where the natural enemy conservation can be maximised. However, the extent of adoption of the IPM approach is not yet uniform across the industry.

The introduction of new insect pests continues to threaten Australia’s crops. Despite Australia’s best quarantine endeavours, there is likely to be a continual flow rate of new pest introductions which will always add a level of instability to the pest management equation in Australia. The silverleaf whitefly (*Bemisia argentifolia* or *B. tabaci* Type B) which is a major pest in other countries was introduced to Australia in 1994. It is not yet clear how important it will be in future cotton pest management, though some researchers believe there is considerable potential for damaging populations to develop (Gunning *et al.* 1995). Being hemipterans, whiteflies are not susceptible to current Bt varieties. Genetically modified crops which have been developed specifically for particular pests may cease to be effective upon the establishment of a new pest. On the other hand, it is conceivable that a new “pest-protected” variety using Bt or another resistance character could be developed to control these problems (Fitt 2000). What this uncertainty indicates is that pesticides, as the only immediate “fire fighting” intervention available, will continue to have a role well into the future. However, this role may become considerably less significant than currently, and use chemicals which are far more specific and environmentally benign.

New cotton varieties, involving genes for toxins or characters unrelated to Bt, are also in the early development stages. Using several genes with differing modes of action within the same crop variety can reduce the probability of resistance in the pest population, increasing the time to control failure (Roush *et al.* 1998, Fitt 2000).

### **9.2.2.2. Bt cotton and integrated pest management (IPM).**

Integrated Pest Management (IPM) is an approach to pest control in agriculture which recognises that maximum control of pests is likely to require several methods used in concert, including maximising the use of natural responses in the crop which have come to be encompassed within the term “ecosystem services”.

The cotton industry in Australia has gained an important tool in Bt cotton which allows a broader contribution of pest control tactics, that is, which facilitates improved IPM (Fitt 2000). Cotton growers are fully aware that insect pest populations can be extremely damaging. In a few days, *Helicoverpa* spp. can arrive in numbers capable of reducing a profitable cotton crop to an enterprise-threatening loss. The various means of reducing the pest population include.

- Plant varieties resistant to pests, (whether of genetically modified or conventional origin). For example, varieties with the okra leaf characteristic provide considerable resistance to mites.
- Allowing natural mortality factors to impose losses. Like many noctuid moths, *Helicoverpa* spp. produce large numbers of eggs, of which only a very few survive. Most succumb to the weather, wind, rain or desiccation, or are eaten by other insects such as predatory beetles or parasitic wasps.
- Cultural control, such as “pupae busting” (cultivating to disrupt buried *Helicoverpa* spp. pupae) , and
- Measures designed to increase the abundance of natural enemies such as strip planting with lucerne.

Prior to the introduction of Bt cotton, prospects for IPM were not promising. There were fewer effective pesticides, because the resistance of pests was increasing. Pyrethroid resistant insects could often be killed but only if insecticides were applied when eggs had only just hatched. This forced a situation where growers perceived that they could not afford to wait and see if a certain level of eggs produced a damaging level of larvae. They had to estimate if an egg lay had the potential to cause damage and if so apply insecticide, targeting hatch.

In Bt cotton, it is paramount to wait until the crop has had time to reduce the pests in the crop before pesticides are considered. There is no point in introducing a crop which kills larvae when they feed on it, only to spray it with insecticide on hatch. This has produced a waiting period in pest management. While the grower waits for Bt cotton to kill larvae, wind, rain, heat, predators and parasites are also having an impact. The waiting will often lead to a decision not to use an insecticide and predators and parasitoids will be maintained and perhaps increased for the next influx of *Helicoverpa* spp. Predators will also impact on secondary pests, such as aphids and mites. The key point is that adoption of Bt cotton has allowed weather, and predators and parasites to make a greater contribution. Relying so much on natural mortality (environmentally clean, free pest control) was more difficult to justify in economic terms 10 years ago. This meant that very few growers were prepared to leave crops unsprayed to find out the contribution of natural mortality factors. Even if they did, the large areas being treated with insecticide by neighbouring farmers diminished

beneficial populations in the area. Within this new farming system, conventional (non-Bt) cotton is often receiving fewer sprays than 10 years ago, and yielding at levels comparable to GM crops (I. Macpherson, pers. comm. ). Recent economic studies quantify improvements in gross margins associated with the use of “soft” insecticide regimes, ranging from 5-6% for conventional cotton and 5-25% for Bt cotton. Increased industry awareness of these results will further increase the adoption of IPM based on the combination of Bt cotton and natural enemies (Hoque *et al.* 2000, Johnson *et al.* 2001).

It is not claimed that Bt cotton alone has been responsible for an increase in the adoption of IPM practises, even for conventional cotton varieties. Failure of existing pesticides, use of new insecticides which retain natural enemies of the pest, and grower willingness to test the boundaries of IPM have all made important contributions. However, the general reduction in insecticide use on a wide-scale throughout the early and mid season, on both conventional and Bt cotton, has been strongly influenced by the introduction of Bt cotton and this has provided a major step toward recognising the contribution of other factors to pest management. Cotton thus provides us with an example of a farming system in which the contribution of genetically modified varieties towards reducing pesticide use has been much greater than might be expected by simple comparisons of the number of sprays it requires compared with its conventional equivalent.

#### **9.2.2.3. Resistance management**

The introduction of Bt cotton has highlighted to importance of industry-wide pesticide resistance management. The actions of a group of farmers allowing the development of insect resistance populations could have a serious impact on the viability of other growers. Such developed resistance may reduce the effectiveness of a pesticide to zero. Simply removing a pesticide from use for a few years will not return the chemical to effectiveness. In a climate of reduced availability of insecticides and very high costs of developing new ones, industries can easily be faced with diminishing options for pest control. In recent years, a comprehensive voluntary resistance management scheme based on rotation of chemical groups (discussed in Chapter 2, and outlined in tables 6-8) has delayed the development of resistance to many groups of insecticides in eastern Australia. This has been successful in extending the use of certain insecticides, especially synthetic pyrethroids, for over 17 years, bringing substantial benefits to the Australian cotton industry (Cox and Forrester 1992).

Resistance management is particularly important in genetically modified varieties which use a single gene for pest protection as they impose a high selection pressure on insects to overcome a protection mechanism which depends on a narrow genetic basis. Such a variety exposes every insect in the field to a single mode of action based on that single gene, all season long.

Resistance management schemes are necessary to minimise this selection pressure. Currently the area of Bt cotton is restricted to 30% of the total cotton area. The other 70% is non-Bt cotton, of which a certain proportion is refugia and must not be sprayed with foliar Bt insecticides under the guidelines of the resistance management strategy. The refugia area produces Bt-susceptible insects which, on mating with resistant types coming from the Bt cotton, will minimise the proportion of homozygous resistant insects in the next generation, in effect diluting resistance. For

every 100 ha of Bt cotton, farmers must provide 10 ha of unsprayed cotton, or 100 ha of conventional (sprayed) cotton, or various other equivalents in corn, sorghum or pigeon pea, to ensure enough susceptible *Helicoverpa armigera* to mate with any surviving resistant moths. Future Bt varieties will have two or more genes, and if there is minimal cross resistance between them, this will greatly delay resistance build up.

Without complementary resistance management strategies in other industries, we may see the collapse of genetically modified varieties before their potential for reducing pesticide use is fully realised. Similarly, if Bt cotton led to resistance in *Helicoverpa armigera*, Bt-based insecticide sprays might become ineffective. This would remove one of the most environmentally friendly insecticides (and one of the few insecticides available to organic producers of other crops) from the arsenal of pest control. However, recent research (Gahan, Gould and Heckel 2001) suggests that efficient DNA-based screening for resistance gene containing heterozygotes in pest species may provide a mechanism for early monitoring of the risk of evolving Bt resistance.

Resistance to the current Bt toxin may not necessarily develop into an immediate problem. There are several Bt variants, and while effective variants are available, new crop resistance mechanisms may be developed. This could however place farmers in a similar position to the old “pesticide treadmill”, where they remain reliant on the future technological releases from pesticide companies to remain viable.

#### **9.2.2.4. Potential for cotton in northern Australia**

The environmental benefits of genetic modification technology may allow the expansion of an industry into regions previously considered too environmentally sensitive. For example, proposals to expand cotton production in northern Australia (Strickland *et al.* 1998) depend on the exclusive use of two-gene Bt varieties, together with other changes such as winter (dry season) cropping. This is to avoid repeating the disasters of the past, such as the collapse in the 1970s of the cotton industry in the Ord River region of NW Western Australia due to rapid build-up of resistance in insect populations to previously effective insecticides. This two-gene system should require much less pesticide than previously used, and possibly less than contemporary cotton systems in southern Australia. By those standards it may be environmentally sustainable – but if a substantial increase in plantings occurs, it may lead to an increase in aggregate pesticide use, together with changes in the types of pesticides being used, compared with how agricultural land is currently used in northern Australia.

The area of cotton grown in southern Australia is largely limited by the availability of water and competing demands for it, such as environmental flows. In the regions of northern Australia, there are large reserves of water, along with irrigable lands, which are not used for intensive cropping at present. Although the Ord River disaster of the 1970's provides a cautionary note for potential developers of these areas, new pest management systems which rely extensively on Bt cotton show considerable promise. Trials on areas of up to 1 000 ha in the Ord River, and smaller trials in other northern regions, show that high yields can be achieved with lower pesticide inputs than in earlier schemes.

Bt cotton is not the only pesticide-reducing component of the production system. Dry season (winter) cropping means that the crop is grown when insect activity is low. Damaging pests such as pink bollworm (*Pectinophora gossypiella*) and armyworm (*Spodoptera litura*) are avoided. New systems for exploitation of beneficial insects and cultural control methods may also contribute. Nevertheless, Bt varieties are a critical component of the Integrated Pest Management system proposed for cotton in the north.

If there is sufficient commercial interest in growing cotton in the north, an additional 100 000 ha of cotton (about 20% of the current Australian area) might eventually be produced in these regions. The extent to which the industry develops is likely to reflect public and government perceptions of the economic benefits versus the environmental impacts, including those associated with pesticides, as well as direct market opportunities.

Australian estimates of insecticide application reductions on Bt cotton are in the region of 40-50%, Translated to the whole industry, this represents a 12-15% reduction because of the 30% planting area limit. Though similar reductions on a per hectare basis are reported for many regions of the USA, reports of reductions in insecticide use at the overall scale are much lower than 12-15%, and are in the region of 7%. The difference may be due to the fact that the Australian industry relies much more heavily on insecticides to control its lepidopteran pests. On average, 6.5 insecticide applications occur on conventional cotton for *Helicoverpa* control (Kwint 2000). The comparable average in the USA is 2 to 3 (Carpenter and Gianessi 2001).

### **9.2.3. Herbicide Tolerant Crops**

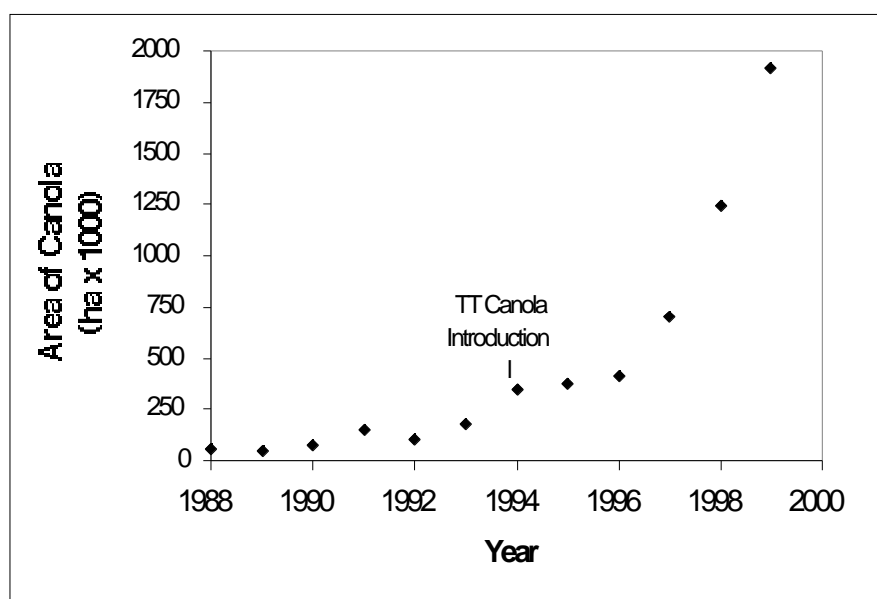
#### **9.2.3.1. Triazine-tolerant ("TT"), a herbicide-tolerant canola in Australia**

Triazine-tolerant ("TT") canola varieties currently grown commercially in Australia have not been generated by genetic modification. "Canola" was developed with conventional genetic breeding technologies from rapeseed (*Brassica rapa* or *B.napus*) primarily to lower erucic acid levels and glucosinolates to produce a source of edible oil, but hybridisation with related wild relatives has also resulted in some varieties possessing herbicide tolerance characteristics similar to those which are now being increasingly generated by genetic modification. Triazine tolerant canola has been available for commercial production for six years in Australia and so represents an example of the anticipated responses of herbicide tolerant varieties of crops that might be alternatively developed by genetic modification. The analogy is not complete because some of the legislative restrictions on varieties generated by genetic modification have not applied to TT canola.

TT canola was introduced in 1994 and was adopted readily. Three years prior to TT canola introduction, the area of the canola crop was steady at around 150,000 hectares. Subsequently, partly in response to an attractive overseas canola market, it increased to current levels of near 1.9 million hectares (Figure 9).



**Figure 9.**  
**Area of Canola in Australia indicating the introduction of TT canola, a non-genetically modified herbicide tolerant canola type.**



(Source: Australian Bureau of Statistics 2000)

Western Australia grows 50% of the canola area and 80-90% of that is TT canola. The remaining 50% is mainly grown in NSW, Vic and SA of which 30-40% is generally thought to be the TT type (R. Colton, NSW Agriculture, pers. comm.). Prior to the advent of TT varieties, cropping, particularly of cereals, was being limited by an increasing frequency of soil-borne crop diseases, but also in some areas by the presence of weeds that were difficult to control because of herbicide resistance. While the initial increase of canola was due to having overcome susceptibility to the canola disease “blackleg” by conventionally bred resistant varieties (Colton and Potter 1999), later, varieties of canola which were triazine-tolerant became rapidly built into cereal rotations as a break crop (Rieger *et al.* 1999), particularly in WA, where herbicide resistance was especially severe. The most popular and effective has been the Victorian variety “Karoo” which has an approximate 10 to 15% yield penalty compared with non-TT varieties. Yields of only 1 tonne/hectare in the dry cropping belt of WA can be profitable if weed control can be achieved cheaply. It is against this very cheap weed control in TT canola, based on atrazine and simazine, that other new varieties of canola will be compared for profitability. Growers consider that weeds generally impose a reduction on conventional varieties anyway, making expected yield effectively similar or only slightly lower (R. Colton, NSW Agriculture, pers. comm.). A similar but alternative approach to triazine tolerance is now available using one of two imidazolinone tolerant (“imi”) varieties offering under the Clearfield® banner for use with Cyanamid-marketed herbicide in a package agreement contracted with growers. These varieties do not have the yield and oil variability penalties of TT varieties.

#### **9.2.3.2. Conventional canola vs. TT canola with herbicide use**

A comparison of typical herbicide application schedules for TT and conventional canola is given in Table 44. Note that there are many other schedules of herbicides

used by canola producers, depending on farmers' particular circumstances. These include the types of weeds they have, the density of their weed populations, the herbicide resistance levels in those weed populations (particularly for ryegrass) and other environmental aspects of their location.

**Table 44.**  
**An example of herbicide usage scenarios in conventional and TT canola in typical farming systems of WA grainbelt (2000).**

Timing	Conventional Canola	Rate L/ha	TT Canola	Rate L/ha
<b>Field preparation</b>	Glyphosate or (paraquat+diquat) Cultivate	0.5 to 1	Glyphosate or (paraquat+diquat) Atrazine	0.5 to 1 1 to 2
<b>Pre-planting</b>	Trifluralin	2	Trifluralin: 20% probability, particularly where herbicide resistance is prevalent	2
<b>At planting</b>	metolachlor (in high rainfall districts) for control of <i>Crassula</i> spp. etc.	0.5		
<b>Post-emergent</b>	Capeweed, clover & doublegee control (eg. clopyralid)	0.3	atrazine	2
<b>Followup</b>	grass selective herbicide (eg. clethodim + haloxyfop-ethoxyethyl mix): 95% probability.	0.15	grass selective herbicide (eg. clethodim): 10% probability.	0.15
<b>Yield and weed control comments</b>	Conventional canola crops are not weed free. Therefore some yield loss caused by weeds is always expected. Preparation for conventional canola needs to be more rigorous to minimise losses due to weed competition.		In a weed free situation TT canola generally yields 15 to 20% lower than conventional canola but because of the excellent weed control atrazine provides in many situations, this yield penalty is often overcome.	

(Source: P. Carmody pers. comm. 2001).

In the majority of cases the total cost of herbicides used on a TT canola crop will be 40 - 50% lower than for conventional canola herbicide treatments, even though the total volume of herbicide application is about 25% greater, as can be deduced from Table 45 (P. Carmody, pers. comm.). The situation in Australia is that TT canola has been very successful as a cheap production system to overcome herbicide resistance in ryegrass relative to alternatives, while also allowing use of canola as a break crop in disease management of cereal rotations. To what extent future genetically modified canola is adopted in place of TT varieties will depend on the economics of the introduced system and its genetic characteristics.

It should be noted that atrazine and simazine represent herbicides in the higher risk categories of environmental impact. As discussed in Chapter 6, though their mammalian toxicity is low, they are more toxic to aquatic organisms and more persistent than alternatives such as glyphosate. Since they do not bind as strongly to soil particles as glyphosate, they are more likely to enter groundwater. Widespread adoption of a genetically modified glyphosate tolerant crop variety would almost certainly cause the substitution of glyphosate for triazine chemicals. On purely health

and environmental grounds this would appear desirable (Sutherland 2000). Genetically modified glyphosate tolerant varieties may become available in the near future but whether they are readily adopted will depend on their agronomic performance, yield and disease resistance, and other costs such as seed and licensing costs charged by suppliers. Glyphosate is more effective on grasses than triazines, so glyphosate resistant crops may result in less use of trifluralin, another persistent herbicide which is toxic to aquatic organisms. Generally, growers in the USA and Canada have reported lower use of herbicides, on an industry wide average per acre basis, with the introduction of glyphosate tolerant crops (Canola Council of Canada 2000). Although it is difficult to be certain, the environmental risk status of atrazine and simazine appears to have had little impact on the adoption of TT canola. This would suggest that growers are unlikely to accept or reject genetically modified herbicide-tolerant crop varieties primarily on the basis of the relative environmental consequences of the herbicides in question. Reluctance to use genetically resistant crops due to ethical or marketing constraints is more likely to influence choices and these factors are yet to be resolved. For a grower, any registered chemical is a viable choice. Economic merits of alternative agricultural options may have a larger impact on herbicide use than environmental consequences. The amount of herbicide used will be that which maximises the gross margin and manageability of the respective production systems while minimising the risk perception of the farmers.

#### **9.2.3.3. Managing GM herbicide resistant varieties**

Canola with genetically developed tolerance to glyphosate (eg. Roundup Ready ® canola Monsanto), released in North America, has exhibited a very similar adoption pattern to that of the non-genetically modified TT canola varieties in Australia. Canola is now regarded in the US as one of the easiest crops to manage in regard to weeds (I. Heap, International Survey of Herbicide-Resistant Weeds, pers. comm.). This shows the potential for farmers to adopt a profitable and highly manageable option. Trials have been conducted for several years in Australia with Roundup Ready ® canola. Varieties tolerant to glufosinate-ammonium (Basta ) are currently being developed by Aventis, which aims to come to the commercial market with hybrid canola varieties. It is hypothesised that in the longer term 50-60% of plantings will move to hybrids with 10-25% increase in harvest yields.

The need for resistance management strategies is equally necessary for “naturally” selected varieties like TT canola as for genetically modified varieties. The lack of a formal resistance management strategy associated with the release of traditionally bred TT canola lines may influence the extent or adoption of future herbicide-tolerant varieties. However, resistance in weeds to the triazine herbicides may develop relatively quickly, rendering this cheap option ineffective. This could preclude existing products from competing with the emerging genetically modified, herbicide tolerant varieties, hastening their adoption rates, and associated changes in herbicide use.

The availability and efficacy of herbicide tolerant crop varieties, whether genetically modified or not, will depend on the successful application of effective resistance management strategies. This is well recognised by the governing bodies in Australia. The former Genetic Manipulation Advisory Committee proposals for the release of GM varieties include a requirement for comments on proposed resistance management strategies, and insisted that acceptable levels of management were to be

in place before releases were made. The details involved with each farming system affect the practices which can be applied or are necessary for each variety. No genetically modified canola varieties have yet been commercially released in Australia.

Requirements addressing resistance management in weeds affecting genetically resistant, herbicide tolerant crops would include avoidance of using the same herbicide resistance gene in different crops within the same rotational system in the same region. Increasing repetitive applications of the same chemicals would increase the selection pressure on weeds growing in the same area. The use of alternative methods of weed control for weeds or crop volunteers following the genetically modified, herbicide tolerant crop is therefore necessary.

#### **9.2.3.4. Roundup Ready® cotton**

Glyphosate tolerant (Roundup Ready ) cotton is the first genetically modified, herbicide tolerant crop to be registered for commercial use in Australia. Present weed management practices involve several herbicide treatments over winter to remove weeds which would otherwise add to the seed bank and spread seeds via reticulated drainage water. Cultivations can also achieve equivalent control but many farmers practice minimum tillage to retain moisture, soil structure and reduce soil erosion and are therefore reluctant to use cultivation. Glyphosate is commonly used to clear weeds in minimum till operations. Following this, high rates of prophylactic pre-emergent residual herbicides are applied to protect seedling establishment from weed competition (Charles *et al.* 1995). This includes chemicals such as trifluralin and fluometuron.

In cotton, the aim is to present a virtually weed free zone in the crop. Growers are prepared to pay hand hoe operators (“cotton chippers”) to remove all weeds that the mechanical and herbicide practices miss. In essence, chipping is likely to continue a long time into the future, but growers aim to reduce the chipping cost, which is currently between \$20 and \$300 per hectare. (G. Charles, NSW Agriculture, pers. comm.)

The introduction of a crop tolerant of a herbicide capable of controlling a very wide spectrum of weeds could conceivably replace some or all pre-season and pre-emergent herbicide treatments used in cotton production. Roundup Ready cotton (with glyphosate tolerance) from Monsanto was the first genetically modified, herbicide tolerant cotton to be used in limited commercial trials, with 14 000 ha planted in 2000/2001. Unfortunately the herbicide tolerance is only effective against over-the-top herbicide applications for the period to the 4<sup>th</sup> leaf stage, about 4 weeks after emergence. Adverse weather or other problems may prevent an application within the short time available. However, RoundupReady® cotton remains tolerant to contact by the herbicide on vegetative (non-reproductive) structures. Directed or shielded applications can be used until the flowering stage with a relatively low risk of damaging the crop, compared to conventional cotton (Roberts 1999). Therefore, the potential exists for growers to reduce the use of pre-emergent residual herbicides but the extent to which this occurs will depend on the attitude of the grower to the risks involved with these application methods and the extent of their weed problems. It is generally considered that pre-emergent herbicides will remain necessary to bring fields with a high weed load to a point where glyphosate applications and other post-

emergent controls can cope (G. Roberts, Cotton CRC, pers. comm. 2001). However, it is expected that in about the year 2005, a new transgene offering protection up to the twelfth leaf stage is expected (G. Roberts, Cotton CRC, pers. comm. 2001) and this will provide greater scope for growers to avoid the pre-emergent residual herbicides and perhaps reduce cultivation or chipping effort in relatively clean fields (G. Charles, NSW Agriculture, pers. comm.).

The prospect of reducing the use of residual herbicides and therefore avoiding their greater environmental impacts by using glyphosate would represent a net environmental gain. An ideal genetically modified, herbicide tolerant variety which allows glyphosate applications all season could reduce cultivations and reduce chipping considerably. However, the need to kill surviving weeds in order to contain resistance to glyphosate will almost certainly see cultivations and chipping continuing. If weeds can be reduced to the point where a very quick pass with a chipping team is sufficient (nearer to the \$20 end of the chipping costs per hectare scale), this would be very attractive to growers (G. Charles, NSW Agriculture, pers. comm.).

The use of computer guidance systems for applying herbicide directly to weeds is a competing technology to the use of herbicide tolerant crop varieties, but the entry cost of such technology may slow adoption. Shielded spray rigs (with large skirting panels around each spray nozzle to shield the cotton plants from herbicide droplets) are also available which allow in-crop application of broad-spectrum herbicides. How this compares in price to the Roundup Ready cotton system will be important. Currently, many growers consider the shielded spray technology to be too risky.

Some cotton growers are concerned about the Roundup Ready cotton becoming a weed problem in subsequent years. Given that Roundup Ready and Bt cotton could eventually be combined in the same varieties, there is also the complication that volunteer Bt/ Roundup Ready cotton may occur in fields which next year might be intended for conventional refugia cotton, thus presenting an obstacle for the Bt resistance management strategy. The alternatives are paraquat, a less environmentally friendly chemical with high mammalian toxicity, or glufosinate ammonium, a far more expensive option. In essence, price and effectiveness will be the primary influence on the adoption of herbicide tolerant cotton. These are factors which can be hard to predict. Initial trials of herbicide tolerant varieties have produced highly variable results. One field might have the range of weeds that justifies the use of Roundup Ready cotton, in another it might be unnecessary. Adoption of even the most effective genetically modified variety will depend on a major string of variables, not the least being the price set on licences to growers by companies, and the price for the genetically modified product in the market.

#### **9.2.4. Principles, Recent Developments and the Outlook**

##### ***9.2.4.1. The principles***

It can be concluded from table 41 which summarises proposals for release, that among the genetically modified varieties likely to become available, those with pest protection or herbicide tolerance are likely to predominate. It is convenient, although somewhat simplified, to assess their impact on pesticides at two levels; on a per

hectare basis and on the total area of the crop. Applying the simple two level analysis to pest protected versus herbicide tolerant crop varieties reveals different characteristics which are important for making generalisations about their impact on pesticide use.

Genetically modified, pest protected varieties act in a similar way to a pesticide, usually reducing the population of the pest arthropod or pathogenic organism. The relative efficacy of the pest protected variety will be judged against available pesticides. At the per hectare level, a pest protected variety may simply reduce the need for an alternative pesticide leading to a reduction per unit area of pesticide for production. The overall impact is then the reduction multiplied by the area of influence. As will be clear from the discussion on Bt cotton, that area of influence may be strongly limited by the need to avoid the development of pest resistance. To maintain the effect of the pest protection mechanism, a resistance management strategy must be effective. Currently with Bt cotton, large areas of refuge are used to manage resistance and this significantly reduces the area of influence on pesticide reductions to 30% of the industry. Future resistance management may allow a larger area of influence, for example through gene pyramiding. Also of fundamental importance is the potential for a genetically modified pest-protected variety to remove a limitation on the growth of an industry. For example, the advent of Bt cotton may mean that cotton can be grown over a larger area of Australia. A reduction in pesticide use at the unit area level could be offset by increased pesticide use overall, when other pesticides used in association with cotton production are included over the new area. In the Australia cotton industry, a 40-50% reduction in *Helicoverpa* spp. pesticides on Bt cotton represents a large proportion of the insecticide used on cotton. However, even with the 30% limit on the area of influence, the net insecticide reduction of 12-15% over the whole industry has led to a net environmental gain (on an unit area basis) via changes in the types of pesticides used and in the revitalised IPM approaches that aim to minimise pesticide use in other ways.

A genetically modified herbicide tolerant crop variety differs in its application. Use of a specific pesticide is intrinsic to the use of such a variety. Therefore the unit area analysis depends on how this pesticide substitutes for currently used pesticides. As for the pest protected varieties, if other pesticides are not available for the purpose, no substitution is possible and an increase pesticide use will ensue. However there may be circumstances where other pesticides are replaced, possibly by more desirable products. The total area analysis is somewhat different for herbicide tolerant varieties. The maintenance of the efficacy of these crops is also dependent on resistant management strategies but refuge areas are not used. Timely changes in weed control tactics are more effective. Therefore the effective area of a herbicide tolerant crop is not usually reduced by any refuge requirement. However, an initial apparent decrease in pesticide use may be undone by a requirement to kill potentially resistant weeds or even volunteer crops at a subsequent time. This should become apparent in the unit area assessment of changes in pesticide uses.

The next question is whether the genetically modified crop variety will remove a limitation which might allow a larger area of the crop to be grown. Whether there is an increase in pesticide will depend on both whether there is an increase in area sown, but also upon the previous pesticide use for the enterprises the expanding crop is replacing. This effect is amply demonstrated by the example of TT canola in

Australia where the ability to control certain weeds has contributed to a tenfold expansion of the industry. This has been accompanied by a general increase in triazine herbicides per unit area.

These principles are equally applicable to any crop varieties exhibiting pest protection or herbicide tolerance characteristics, regardless of whether the varieties are produced by conventional breeding (as has thus far been the case with triazine tolerant canolas), or by genetic modification. However, the probability is that genetic modification technology will become the dominant source of such characteristics in future varieties.

#### **9.2.4.2. *The past five years***

In summary, the past five years have seen the global introduction of genetically modified crop varieties. Around 90% of these are pest protected and herbicide tolerant. This has had direct implications for the use of pesticides but has not necessarily resulted in reductions in pesticide use. Dissecting the aggregated US analysis (USDA 2000) clearly shows that some regions and practices register reductions or at least substitution of pesticides, but the overall analysis is confounded. Certainly expectations of obvious reductions on a country wide scale have not eventuated. The technology is new and its initial application management may not have occurred in the most effective circumstances for each trait on every occasion.

A clear obstacle to pest protection efficacy is resistance in the pests to the particular defence introduced to the plant. The development of pest populations resistant to control methods based on single chemicals or modes of action is generally regarded as inevitable.

#### **9.2.4.3. *The next five years***

Proposals for releases already registered with Australian gene regulators including the former Genetic Manipulation Advisory Committee, together with experience from other countries with similar production systems (such as the USA) suggest that in the next five years, an increased number of pest protected or herbicide tolerant crops will become available. This will impact on pesticide use, particularly where genes are pyramided and resistant management strategies can be varied to allow a larger proportion of the total crop to be planted to genetically modified varieties.

Adding more transgenes to current crop varieties is expected to continue rapidly because the genes and technology are already available. Combining genes with herbicide tolerance for different herbicides might disrupt resistance management but combining other traits could be desirable, eg. insect resistance and herbicide tolerant characteristics to confer multiple benefits. Pyramiding (combining traits to confer the same characteristic, eg. two types of Bt toxin produced in the same plant directed at the same pest) will also play a role in this five year period. The impact of this will depend on the efficacy of the traits and the ability to increase the area of GM cropping within resistance management strategies. As previously discussed, two-gene cotton may allow much greater than 30% of the Australian cotton crop to be planted to transgenic varieties, thereby potentially increasing the area from which pesticide reduction can be maximised.

Despite the insecurities of some consumers, the suitability of genetically modified crops as food sources is beginning to gain recognition. The Australian and New Zealand Food Authority has drafted recommendations that amendments be made to the *Food Standards Code* to give approval for the sale of oil from bromoxynil-tolerant canola and food from insect protected and glufosinate ammonium tolerant corn (ANZFA 2002a, 2002b).

#### **9.2.4.4. The long term**

The scope of current genetically modified varieties of crops is extensive. Future proposals could only be expected to increase the number and range of possibilities. Which modifications will be considered beneficial and of sufficiently low risk for introduction is yet unknown, and will be influenced by the standards established by Australia's new gene technology regulatory system. There are likely to develop other beneficial characteristics from genetic modification, including frost tolerance, water use efficiency, drought tolerance and enhanced nutritional composition. Some of these characteristics could significantly increase the production range of crops. Whether the crop opens up new areas or substitutes for other enterprises, there may be an increase or decrease pesticide use.



### **9.3. CONCLUSIONS – GENETICALLY MODIFIED ORGANISMS**

The introduction of genetically modified crop varieties as an alternative to some insecticide use has already been shown to reduce dependence on pesticides and reduce the levels of application. Furthermore, it has encouraged a greater appreciation of the potential for Integrated Pest Management to contribute to agricultural and horticultural crop production, thereby further reducing pesticide use.

Evidence suggests that insecticide application reductions of 40-50% have been achieved on those areas to which Bt cotton has been introduced, representing an overall pesticide-use reduction of 12-15% across the entire cotton industry.

New multi-genic insect-resistant varieties are likely to allow an increase to 70–80% in the proportion of the total crop which can be sown the varieties with genetic modification to insect attack, allowing a reduction in insecticide use of up to 80 % after 2004.

The continued availability and effective use of herbicide-tolerant crop varieties, whether genetically modified or not, will depend on the application of effective resistance management strategies in target weeds.

In the next five years, an increased number of pest protected or herbicide tolerant crops will become available. This will impact on pesticide use, particularly where genes are pyramided and resistant management strategies can be varied to allow a larger proportion of the total crop to be planted to genetically modified varieties.

It is essential that newly-appointed Gene Technology Regulator and the Chief Executive of the NRA jointly make known the respective roles and responsibilities of each organisation so that their roles and their methods of risk assessment are transparently evident to plant breeders, industry organisations, pesticide companies and product users alike.

## **10. ADVANCES IN PESTICIDE MANAGEMENT IN AUSTRALIAN AGRICULTURE**

There has been an increase in both the value and amount of pesticides used in Australia in the past ten years. Herbicides represent by far the major pesticide group used. The 40% increase in insecticides used was primarily to do a 70 % increase in the area of land planted to cotton. Pesticide use is strongly influenced by the fluctuations in agricultural commodity prices, technological changes in production systems and meeting the demands of the international market-place. There has been a notable move away from broad spectrum “hard” pesticides to more target-specific and generally less toxic “soft” chemicals. There has been increased adoption of Integrated Pest Management strategies. Australian farmers have access to world class pesticide application technologies, though adoption rates vary. There are strong and effective incentives to ensure Australian farmers meet pesticide residue standards on export markets. Farmers are increasingly conscious of the impact of pesticides on production systems, product quality the environment and the community. The handling of pesticides by the chemical industry and users has greatly improved. Australia has an assessment process managed by the National Registration Authority that is generally rigorous, but there is little public appreciation of the role it serves and its effectiveness deserves to be better known. Nevertheless, there is yet to be developed a fully integrated policy approach to pesticide assessment, regulation and management by the Commonwealth, the states/territories, the pesticide industry and producers.

### **10.1. THE PESTICIDES USED**

Despite the inexorable decline in the terms of trade of Australia’s rural industries, rural industry productivity continues to increase. The value of crop production has increased threefold in constant dollar terms over the past 40 years. In 1998-9, the rural sector contributed \$31.5 billion to the Australian economy. The largest contributor to production in the rural sector is the industrial and other crops industry which contributed \$8.7 billion, or 28.3% of total rural production. The value of the exported component of industrial and other crops sector’ production approached nearly \$6 billion. (AFFA 1999). The availability and use of pesticides has contributed significantly to agriculture’s continuing productivity

A number of important and pertinent conclusions about use of pesticides in agriculture can be derived from this report on Pesticide Use in Australia. They include :-

Pesticide use in Australian crop production systems is increasing and the rate of increase has accelerated during the 1990s. That increase has occurred in both the amount of pesticides used and in the value (\$) of pesticides used.

The quantity of pesticide active ingredients used in crop production in Australia increased annually by 10 to 15 % in the period 1996-1999. At

the same time, the real cost to producers increased by some 7% (inflation adjusted) annually.

Herbicides are by far the major pesticide group used in Australian crop production systems. As is the case in agricultural production systems elsewhere, the quantity of applied herbicide active ingredients is some six times that of applied fungicide active ingredients and approximately twice that of applied insecticide active ingredients. The quantity of plant growth regulators used is comparatively small, being some 20% of the quantity of applied fungicides.

The quantity of herbicides and plant growth regulators used in the study period 1996-1999 fluctuated only slightly from year to year, reflecting the relatively constant annual impact of weeds in farming systems. However, the volume of herbicides used has very likely been understated in this analysis due to the increase in the concentration of formulations used, particularly, but not exclusively that of glyphosate, now by far the most widely used pesticide in Australia.

Significant increases in insecticides (40%) and fungicides (46%) used were recorded during the study period.

It is noted that the 40% increase in insecticides used from 1996-1999 was largely the result of extremely high insect pest pressure in the 1998-99 cotton season and the 70% increase in the area planted to cotton between the 1995-96 and 1998-99 seasons. Insect resistant (Bt/INGARD) cotton has also been accessed and used by industry since 1998. The outcome of these influences and of cotton industry efforts to reduce dependence on synthetic pesticides is that while overall pesticide quantity increased, insecticide application per unit area of cotton declined during the study period.

The 46% increase in the volume of fungicides used ensued largely from significant changes in broadacre crop production systems particularly in the southern and western grain growing regions. These changes included a 230% increase in the area sown to canola and a 100% increase in the area planted to other oilseed crops. These newer crops require fungicides to control the diseases which attack the crops as currently-used varieties do not yet have genetic resistance to many of those pathogens.

There is likely to be greater between-season variation in the threats to crops from insect pests and fungal diseases than from weeds.

Decisions concerning the use of pesticides in Australian agriculture are made by producers. The quantities of pesticide active ingredients used in Australian agriculture depend strongly on the prevailing market prices and the anticipated returns by growers from alternative commodity options, each of which may have different pesticide needs. Other factors affecting producer decisions include technological changes in agricultural production systems and practices. These factors need to be seen in the

larger context of maintaining the international competitiveness of Australian agriculture, meeting the QA requirements of purchasers and enhancing labour efficiency.

In the second half of the 1990s, there was a noticeable movement away from broad spectrum generally more toxic or 'hard' pesticides to those which are more target pest specific, more efficacious and generally less toxic and therefore 'soft'. These 'soft' pesticides are usually still under patent and hence more expensive. This movement from 'hard' to 'soft' pesticides led to the annual increase in the cost of pesticides being applied by Australian farmers during the study period.

Australian farmers are adopting integrated pest management (IPM) strategies and practices, albeit the extent of adoption varies between industries. Several influences are driving this significant change in farm practice. They include community concerns over pesticide residues and other product quality issues and farmer and industry concerns over the development of pesticide resistance in weed, disease and insect populations. Farmers and their industry organisations are also concerned over the cost and efficiency of spray schedules, the availability of pesticides and non-target pesticide contamination.

The movement towards greater use of integrated pest management is being underpinned by R & D, funded to a significant extent by industry through the various Research and Development Corporations.

The adoption of a genetically modified insect resistant variety by the cotton industry has also had the effect of ensuring greater recognition and adoption of integrated pest management practices. This has resulted in reduced pesticide usage per unit area, further supported through its "Best Management Practices" program and other related initiatives, while accommodating the major industry expansion and the extreme insect pressure of the late 1990s.

The area sown to winter cereals increased by 17%, including a 25% increase in the area sown to wheat during the study period. Although herbicide use has declined, increased quantities of fungicides are being applied to wheat, barley and other winter cereals as the suite of diseases attacking those crops expands. The expansion in the risk of diseases attacking the crops derives largely from the introduction of stubble mulching, minimum and zero tillage practices as techniques to facilitate greater environmental sustainability by reducing soil erosion.

Herbicide use in winter cereals did not expand during the study period at the same rate as the increase in the area planted. This again underlines farmer and industry concerns over the development of pesticide resistance. It also reflects the positive impacts on pesticide use of IPM and related initiatives and on the increase in the concentration of herbicide formulations being marketed.

Insecticide and herbicide use in the potato industry, and insecticide and fungicide use in the apple and pear industry appear to have increased at a greater rate than the expansion of those industries, despite an aspiration in the early 1990s by industry to reduce pesticide usage. The increase occurred despite the development and extension of IPM technologies by both industries. If these increases are real (and more reliable figures would need to be compiled than were available to this investigation before a firm conclusion could be reached), these industries need to further examine those activities and modify them where appropriate with the objective of reducing the use of pesticides in line with previously-set industry targets.

The information available on pesticide use by the various agricultural industries appears inadequate.

Australian farmers have access to world class pesticide application technologies. There is evidence it is being adopted, perhaps not as rapidly as desired in some industries. Significant crop production efficiencies can be achieved through improvement in pesticide application methods. Unfortunately, a major crisis such as the 1995 cotton pesticide contamination of beef is sometimes necessary to trigger industry-wide adoption of appropriate technologies. This may reflect a degree of ‘market failure’, and some encouragement from governments in the interest of the entire society to diminish any risks may be justified.

Australian primary producers have particularly strong incentives to meet pesticide residue standards on export markets. Grains, meats and wine grapes are three important groups of primary commodities that now have particularly effective systems. In the case of wine grapes, the structure of the industry is such that cooperative arrangements between growers and a small number of large wine producing buyers have evolved with minimal government action to provide a very efficient means of meeting strict pesticide residue standards for Australian wine on export markets. Very low pesticide residue status is also now efficiently achieved in the grain and meat industries, by a more centralised industry-government approach.

The incentives to control pesticide residues in domestically consumed foods have arguably not been as strong as they have been for export markets. However, the comparatively recent introduction of Quality Assurance (QA) schemes by the large food retailers in Australia provides a potentially powerful force toward improving the pesticide residue status of domestically consumed foods, particularly horticultural commodities. As is perhaps inevitable in a new system of accreditation, some problems have been identified in QA schemes. These include difficulty in identifying the key critical control points in horticultural systems, lack of independence of auditors, and, the simple provision of ‘off the shelf’ systems to producers by some consultants. Another weakness of the QA system is that it currently comprises a myriad of partly incompatible systems, rather than a single system.

However, it must be recognised that in recent years, Australian farmers have made significant and positive changes to pesticide use in their production systems. Farmers have enhanced their skills in pesticide use and handling. They are now more

conscious of the impact of pesticide use on farm production systems, on farm product quality, on the on-farm and the off-farm environment and on the community in which they live. That consciousness has resulted in marked changes in farm practices. IPM programs are being adopted across Australian agriculture. As a result, there have been some important recent advances particularly reduced insecticide use per unit area of cotton planted and reduced herbicide use per unit area of winter cereals planted. The cotton industry is the largest purchaser of insecticides nationally while the winter cereal industry is the largest purchaser of herbicides, so these achievements are significant in the broader context of pesticide use in Australian agriculture.

## **10.2. PESTICIDE HANDING AND MANAGEMENT INITIATIVES**

To the direct gains achieved in agriculture must also be added the benefits of a number of recent public and private sector pesticide handling and management initiatives which have also impacted positively on pesticide use in Australia.

These include:-

- changes in packaging
- changes in pesticide formulations
- changes in the collection and disposal of empty containers
- changes in the administration of pesticide registration
- assessment of the likely impact of pesticides on international trade
- review of the registration standards of older chemicals including label information
- use of registration and labelling provisions to effect changes to pesticide use patterns
- increasingly mandatory operator training and accreditation
- greater assessment of the fate and transport of pesticides after application and their impact on the environment.

## **10.3. AUSTRALIA'S PESTICIDE REGULATORY SYSTEM**

The Australian legislative and regulatory arrangements relating to the supply and use of pesticides are numerous and complex, reflecting to a degree the nature of the Australian constitution and our Federal system of government. The National Regulatory Authority for Agricultural and Veterinary Chemicals (NRA), a Commonwealth statutory authority, administers (on behalf of the states and territories) the assessment, registration, and regulation of pesticides up to and including the point of retail sale. Beyond this point, the control of pesticides is governed by the individual legislative and regulatory processes of each state and territory. The latter legislation varies substantially between the jurisdictions. There are over sixty separate legislative acts and regulations governing pesticide supply and use in Australia. Taken together, the current legislative acts and regulations have reasonably consistent goals/objectives and are reasonably, but not completely, comprehensive in their coverage. Institutions, such as the NRA, are highly technically proficient by international best practice standards. It is essential that they be empowered to maintain their proficiency.

Most of the individual parts of the current regulatory system controlling the supply and use of agricultural pesticides are reasonably open to public scrutiny. However, scrutiny is extremely difficult in practice because there is a very large number of parts. The interfaces and linkages between them are not transparent.

There is a need for the effective implementation of a comprehensive overarching national agricultural and veterinary chemical strategy – such as that envisaged in the promotion of the national program described in the Chapter 11 - to provide a coherent framework for seamless integration of pesticide management and regulatory processes between the Commonwealth and the states/territories. Until this is achieved and communicated to the public, the view of the processes controlling pesticide supply and use in Australia, as a whole, will continue to be opaque.

This lack of transparency is largely due to the sheer number of disparate acts, regulations, and government agencies with responsibilities relating to pesticides. To some degree, the management of pesticide supply and use is innately complex. This is reflected in the large number of fact and information sheets that individual agencies, such as the NRA and NSW EPA, distribute as they seek to provide helpful information to stake-holders and make their activities and processes more accessible for public scrutiny. The existing information is extensive, but it is in ‘bits and pieces’. No single agency currently has the responsibility to look at the problem of pesticide use and management in Australia in its totality and succinctly communicate an overall perspective to the public.

Serious consideration should be given to developing an integrated policy approach to pesticide assessment, regulation and management by the Commonwealth, states/territories, pesticide industry and producers in a similar way to that in which responsibility for domestic animal and plant quarantine policy advice has been transferred to joint government/industry bodies in the form of Animal Health Australia and Plant Health Australia.

It may be argued that there is a strong potential for a regulatory authority to be captured by the peak industry body it is regulating, particularly if that industry is also the agency’s source of funding and has conspicuous potential for providing policy advice. However, the NRA has an array of consultative committees and it also contracts expert advice on public health and environmental issues. The memberships of these bodies are responses to the need to have a committee structure and composition that provides an appropriate balance of agricultural and veterinary chemical technical expertise, policy issue identification and analysis expertise, consumer and community input, and authority to implement agreed policies.

Compared with, say, the Environment Protection Authority in the United States, or the Australian Competition and Consumer Commission in Australia, the very existence of the NRA – let alone its functions – remains largely unknown to the Australian public. This has been confirmed by the NRA itself in a program of research into the levels of awareness of, and prevailing attitudes to the NRA. This established that awareness of the NRA and its role was extremely low within the general community. Awareness among producers had reached 9 per cent. Some 74 per cent of the community sample admitted having some concerns about agricultural and veterinary chemicals, mostly for health and environmental reasons (NRA 2001c).

Particularly if domestic and overseas consumers of Australian food and fibre are seeking assurances about the safety and quality of Australian produce and production processes, an overall perspective of and confidence in Australia's pesticide regulatory system is essential. It is considered that the NRA should increase public understanding and awareness of its role to ensure greater public confidence in the integrity, effectiveness and limitations of pesticide management in Australia.

Taking into account the passage of the *Gene Technology Act 2000* which clarifies the regulatory role for genetically manipulated organisms of the Office of the Gene Technology Regulator from that of the NRA for pesticides, that ten years has elapsed since the creation of the NRA, and that there are still inconsistencies between the Commonwealth and the states/territories in their management of responsibilities for pesticides in Australia, it is considered that an independent review of the NRA should be jointly commissioned by the Federal and state Ministers of Primary Industries/Agriculture. The review should address whether the current composition of NRA Board membership; the structure, composition and secretarial support of the NRA consultative committees; and the division of responsibilities between the NRA Board and management are appropriate; whether the implementation of its objectives as defined in its Act are being efficiently and effectively met, and whether its communication policies with pesticide users, industry and the community are adequate. In addition, the review should consider whether there might be scope for a more appropriate and effective provision of policy advice to governments to facilitate the integrated and seamless oversight of pesticide use in Australia. Support from industry has been evidenced for such a review.

#### **10.4. CONCLUSIONS – ADVANCES IN PESTICIDE MANAGEMENT**

**There have been significant advances in pesticide management over the past ten years, accompanied by increases in the quantities of insecticides and plant growth regulators used, and a maintenance in the quantities of herbicides used, but accompanied by a reduction in the risks associated with their use.**

**Australian farmers have made positive changes to pesticide use in their production systems. Farmers have enhanced their skills in pesticide use and handling. They are now more conscious of the impact of pesticide use on farm production systems, on farm product quality, on the on-farm and the off-farm environment and on the community in which they live. That consciousness has resulted in marked changes in farm practices. IPM programs are being adopted more widely across Australian agriculture. As a result, there have been some important recent advances, particularly reduced insecticide use per unit area.**

**The assessment of pesticides by the National Registration Authority for Agricultural and Veterinary Chemicals appears to be generally a rigorous process that uses internationally accepted principles of risk assessment. In particular, assessments reported in the full texts of recent reviews of products under the Existing Chemicals Review Program are indicative of a careful scientific approach and use of all available information and literature in the assessment. There is nevertheless an imperative to maintain leading-edge proficiency in its assessments.**



**The NRA should endeavour to have its role better known and more transparent to the general community, to engender greater awareness of and confidence in the Australian pesticide regulatory system.**

**It is ten years since the NRA was established. While its activities were encompassed within the National Competition Policy Review, and its efficiency has been audited by the Australian National Audit Office, it is considered that an independent review of the NRA should be jointly commissioned by the Federal and states/territories Ministers of Agriculture/Primary Industries. The review should encompass the operations, management, governance, efficiency and effectiveness of the NRA and the legislation under which it operates.**

**There are still ambiguities in the role of the NRA *vis à vis* other Federal and state agencies.**

**The continued variation between the states/territories in their management of the control of use of pesticides is of concern. To ensure that overseas trade competitors do not identify these mechanisms as inconsistencies in the production of export commodities, these pesticide use-policies should be harmonised and be seen to be harmonised as a matter of urgency and priority by ensuring the jurisdictions have legislation which achieves similar outcomes. Whilst identical states/territories legislation which is exactly complementary to that of the Commonwealth is unlikely to be achieved, nor is it necessary, it is recommended that legislation which achieves harmonised outcomes should be sought as a matter of principle. The legislation should be established to agreed standards using a set of parameters which are capable of consistent adoption and enforcement. These parameters and their descriptions and interpretations should be posted in a common agreed form on the web-sites of all the Commonwealth and states/territory agencies responsible for pesticide management.**

## **11. THE NATIONAL STRATEGY FOR AGRICULTURAL AND VETERINARY CHEMICALS**

The then Agricultural and Resource Management Council of Australia and New Zealand developed and endorsed a National Strategy for Agricultural and Veterinary Chemicals in 1998. Although there some progress is being made, there has been only limited achievement towards its implementation. It should be progressed.

### **11.1. IMPLEMENTATION**

ARMCANZ (1998) developed a National Strategy for Agricultural and Veterinary Chemicals which is summarised in Appendix B. The intent of the Strategy is to “maximise the benefits from the use of agvet chemicals while minimising the risks of undesirable side-effects”. The Strategy outlines a number of objectives to move towards achieving this intent. These objectives aim to:

1. promote integrated farm, forest and natural resource management;
2. reduce reliance on chemicals;
3. increase the efficiency and effectiveness of chemical assessment and approval processes;
4. reduce the risks associated with use of chemicals (including best management practices);
5. better understand potential impacts of chemical use on human health and reduce adverse effects;
6. better understand potential impacts of chemical use on the environment and reduce adverse effects;
7. maintain acceptable residue levels in food and fibre;
8. enhance market access for primary produce; and
9. ensure safe disposal of unwanted chemicals and containers.

The National Strategy is the major national pesticide policy in Australia, but there appears to be little current impetus toward progressing the National Strategy toward implementation. Nevertheless, some progress is taking place and a number of observations arising from this review are discussed against the strategy’s objectives.

#### **11.1.1. Strategy Objective 1: Adopt integrated planning and management**

*To promote the further development and adoption of integrated farm, forest and natural resource planning and management systems that minimise adverse impacts and use chemicals only as needed.*

This objective seeks to encourage management practices that will ensure that a chemical is only used when necessary. To encourage this, Best Management Practices (BMPs) are being introduced into agricultural industries, notably the cotton industry in eastern Australia. As an example of benefits arising, these practices (which are in part aimed at minimising off-target contamination), along with tighter regulatory

controls, have led to a reduction in endosulfan contamination of the north-western rivers of NSW in 1999-2000 (Muschal 2001).

Progress on uptake of industry BMPs into other some agricultural areas and sectors has been slow. Some agricultural sectors lack an influential coordinating industry body to drive the implementation of BMPs. By themselves, individual growers will not solve all pesticide problems, and it is essential that peak industry and regulatory bodies maintain the momentum across an industry after a BMP regime is introduced.

Environmental issues remain secondary to many primary producers, given their many pressures, but effective management and control of pesticides is important for an industry's economic and biological sustainability. Improved user education is needed on pesticides issues, as they relate to the environment, with particular emphasis on development of information that is convenient for growers coming from a non-English speaking background.

#### **11.1.2. - Strategy Objective 2: Reduce chemical reliance – encourage IPM**

*To reduce reliance on chemicals through the development and implementation of Integrated Pest Management (IPM) programs and alternatives to chemicals.*

Many industries are working within an IPM framework and the registration process takes into account compatibility with IPM strategies. Still more work is required along the lines of that recommended by ARMCANZ (1998) to ensure wider adoption of IPM.

Use of IPM technologies can be further encouraged in association with adoption of genetically manipulated crop varieties. However, initial reliance on single gene transgenic crops and bio-pesticides may provide only short-term gains, as these can readily lead to pests developing resistance. Growers must understand the risks associated with pesticide use and the risks associated with adoption of genetically manipulated crop varieties having insect pest or herbicide resistance.

#### **11.1.3. – Strategy Objective 3: Improve chemical assessment processes**

*To increase the efficiency and effectiveness of chemical assessment and approval processes in making available efficacious products that have minimal risks to health, the environment and trade.*

Strategic actions under this Objective encompass: assessment and approval processes; lower-risk products; review of existing chemicals; minor use; emerging uses; and compliance. The NRA processes for assessing new pesticides and reviewing existing chemicals appear to be effective in highlighting issues of concern and identifying need for additional controls. The NRA is investigating means to expedite outstanding existing chemical reviews. Efforts are continuing to improve international harmonisation of approval processes. The Strategy recognises that controls on use do not obviate the need for appropriate monitoring of environmental residues or biological impacts.

#### **11.1.3.1. Assessment & approval processes**

Probabilistic risk assessment is a useful tool in higher tiers of the environmental assessment process, and for *post-hoc* assessment, provided that it enhances the ability to make clear decisions and that procedures are applicable to Australian conditions. Risk assessment needs to quantify uncertainties and assumptions in a transparent manner, so that changes in circumstances or additional data can be effectively incorporated. Risk assessments need to be quantitative whenever possible and to avoid subjective, qualitative analysis. Current procedures for pesticides are meeting these requirements.

A limitation is that current hazard or risk assessments are chemical-specific, and do not adequately consider the effects of chemicals found as mixtures in the environment or cumulative effects. Local data are required on the transport, behaviour and fate of many pesticides in specific Australian environments. Further investigation may be required on appropriate leaching tests for pesticides in soils. Major changes in land use emphasise the need to reassess pesticide hazard or risk in the specific environments. Changing soil characteristics such as increasing salinity, acidity and sodicity (NLWRA 2001), together with agricultural responses that further affect soil chemistry, such as liming, need to be considered when evaluating the potential fate of pesticides in Australia.

#### **11.1.3.2. Review of existing chemicals:**

Some of the issues highlighted for new pesticides are also applicable to existing chemicals. Pesticide assessments often identify areas where more data are required and uncertainties remain. Some of these require follow up, but processes currently do not exist to ensure that such follow up occurs. There is evidence that voluntary provision of follow-up data by industry after registration approval has often been slow.

Further information is required on the environmental impact of some existing chemicals. Examples include

- the potential adverse effects of fipronil on Australian soil invertebrates;
- the susceptibility of eastern Australian native mammals to 1080 baits;
- the impact of some veterinary chemicals, such as synthetic pyrethroids, on dung beetle populations;
- risks from many widely dispersed sheep-dip sites throughout Australia; and.
- maintaining a watching brief on second-generation anti-coagulant rodenticides.

There is often very little information on pesticide fate and effects following intensive usage. A mechanism is required to allow access to the data presented during registration on the fate and effects of pesticides in the environment, to enable the use of these end points, for example, in deriving water quality guidelines.

#### **11.1.3.3. Genetically manipulated organisms**

Proposals for releases previously registered at GMAC and the experience from other countries with similar production systems (like the USA) suggest that in the next five years, more genetically manipulated crop varieties will become available. Risk assessments of alternatives to pesticides (eg. GMOs) need to be conducted in the same rigorous and quantitative manner as those for pesticides wherever possible.

Adding more transgenes to current crop varieties will continue rapidly because the genes and technology are already available. Combining separate genes for tolerance to different herbicides might disrupt resistance management but combining genes for other traits could be desirable, eg. insect resistance and herbicide tolerant characteristics to confer multiple benefits. Combining traits to confer the same characteristic, eg. two-gene cotton may allow much greater proportion than 30% of the Australian cotton crop to be Bt transgenic, thereby increasing the area upon which pesticide reduction can be maximised.

The extent of the resistance problem, and the rate that new solutions to pest attacks can be generated depends on the rate of identification of insect resistance genes or of herbicide tolerance genes, and their insertion into new varieties, combined in the case of herbicide tolerance with generating an arsenal of alternative pesticides.

#### **11.1.4. – Strategy Objective 4: Reduce handling and environmental risks, adopt BMP**

*To reduce the risks associated with handling and applying agvet chemicals – [including] to the environment (including non-target organisms); ..... through best practice management of chemical application.*

Strategic actions listed under this Objective include: *best practice in the use of chemicals; effective control of use; training and education; and communication.*

Steps have been initiated towards harmonising control of use regulation between states and territories throughout Australia, but thus far there has been little progress. Urgent attention should be given to resolving this issue, both from the perspective of community confidence within Australia and before overseas trade competitors identify it as an inconsistency in the production of export commodities

There has been little agreement on how to approach the collection of accurate data on the use of agricultural and veterinary chemicals and monitoring the effectiveness of compliance programs and to make them available. Information on geographical distribution of use of pesticides is critical for setting priorities for pesticides monitoring, assessing exposure, establishing effectiveness of management schemes and supporting management decisions. The agricultural chemical industry, primary industry organisations and government need to consult in the development of a national pesticide use database.

Best Management Practice guidelines have been partly discussed above under Objective 1. It has recently been established that half of the total profit of Australian agriculture, when calculated at full equity, comes from industries using irrigation, yet these industries occupy only 0.5 per cent of Australia's land area (NLWRA 2002). The irrigation industries are major users of pesticides. Their management practices can have significant environmental impact. There is a need to control storm water run-off from agricultural lands wherever possible. Care is required when using some of the more persistent herbicides near waterways and alternatives need to be found for weed control in riparian zones.

### **11.1.5. Strategy Objective 5: Minimise health risks**

#### *Minimise risks to human health*

A primary question is how safe is our food? Is the health of the people of Australia safe from being harmed by pesticides in use in agriculture and horticulture?

The Australian regulatory process that assesses pesticides for their potential to harm human health is comparable to that of most advanced Western Countries, although there will always be differences based on the needs of this continent.

Australia has a robust national registration process for agricultural and veterinary chemicals that includes assessment of the toxicology and potential public health and occupational health risk associated with use, using internationally accepted procedures. That process is complemented by states' regulatory frameworks which control use of pesticides, and states' occupational health legislation that regulates for safe work practice. Increased attention to risk management on farms is occurring, including to the management of pesticides, in the context of Farmsafe Australia provided training and management tools, and in the context of the requirements of commodity quality assurance programs. However, the lack of consistency in the application of control of use legislation is of concern as discussed elsewhere.

A particularly sensitive issue has been any on-going impact of organochlorines on infant nutrition. Although organochlorines can be found in human milk, likely to derive from termite treatments applied to building sites in urban areas rather than from agricultural uses which ceased many years ago, to date, no deleterious effects on infant health at the levels of generally found in human milk have been demonstrated. Health authorities throughout the world are of the opinion that any risk that pesticides in breast milk may pose to an infant is far outweighed by the immunological and nutritional benefits obtained from breast-feeding.

The food monitoring programs in place in Australia are impressive by international standards. Results from these monitoring programs provide assurance that levels of pesticide residues in Australia's food chain do not raise major human health concerns. Available research and survey information shows low risk of exposure of harmful levels of pesticides through ingestion of food and water.

There is no evidence that pesticides exposure is a major public health problem for Australia. However, problems on a small scale arise for some users, and some sensitive individuals ascribe their condition to pesticide exposure. Public concern may also be gauged from the growth of the, as yet small, organic food industry.

#### **11.1.5.1. Occupational Health and Safety**

Occupational health and safety risk assessment requirements and processes for registration of pesticides in Australia have steadily become more rigorous over time. The assessment is a rigorous process that uses internationally accepted principles of risk assessment. Assessments reported in the full texts of recent reviews of products under the Existing Chemicals Review program of the National Registration Authority for Agricultural and Veterinary Chemicals are indicative of a careful scientific approach and the use of all available information and literature in the assessment. Conservative safety factors and precautionary principles are used in the absence of

human data so as to ensure the health and safety of workers using products that undergo such assessment.

However, around 80 cases of workers compensation claims are made each year related to injury caused by exposure to pesticides in all states and industries, although the recent trend appears to be downward in terms of the number of claims. Nevertheless, the legislative requirements to protect workers and others from exposure to pesticides during application are complex and overlapping and practical information about how to manage compliance in both major systems could be improved.

Monitoring of exposure of the population to pesticides is still incomplete. The results, currently not readily accessible to the public, should be provided in a more conveniently available form. The regulatory and health authorities need to be continually vigilant to ensure that human health is not compromised by the mis-use of pesticides in agriculture or in the domestic environment.

These issues also indicate that the importance of continuing to address and improve the adequacy of the OHS risk assessment of agricultural and veterinary products for practical risk management on Australian farm workplaces.

One significant gap remains in Australia's agricultural and veterinary chemicals database – that of a capacity to record untoward health incidents that may relate to pesticides.

#### **11.1.6. – Strategy Objective 6: Monitor and assess outcomes of chemical use**

*To better understand the potential impacts of chemical use on the environment, and reduce the adverse effects through best practice procedures to identify and minimise the risks, and to monitor, assess and act on outcomes.*

It is necessary to monitor the effectiveness of management strategies, whether in government or industry, that are designed to reduce environmental contamination. However, such monitoring has rarely been adequately done. Specific techniques for catchment risk assessments in Australia can be particularly valuable tools which can fit into existing environmental risk assessment frameworks.

The interpretation of monitoring results is being limited by the absence of data on usage of pesticides in Australia.. This further strengthens the need for establishing a national database on the use of agricultural and veterinary chemicals.

The recent industry interest in environmental management systems (EMS) represents an extension of focus from the safety and quality of the product (QA) to the quality and environmental integrity of production systems. The growing requirement for producer EMS programs by the global food retailers and other buyers of Australia's primary commodity exports will exert increasing pressure on growers to develop accredited EMSs.

There appears to have been only limited progress on any of the actions listed under research & monitoring under this Strategy objective. An exception is the recent

program by Land and Water Australia, the Cotton R&D Corporation and the Murray Darling Basin Commission to provide some valuable background data on environmental effects of endosulfan in the cotton growing areas of eastern Australia.

Among the broader environmental monitoring programs, that undertaken by the New South Wales Department of Land and Water Conservation in the north-western rivers of NSW has been exemplary and provides probably the only continuous environmentally-based trend data over a ten year period. Even this program is limited by its weekly (at best) sampling of water column concentrations, and limited sediment monitoring. The program is under threat of being scaled down. Other areas of the country have not received a similar level of monitoring and there are some areas where basic data on levels of pesticide contamination is lacking.

More monitoring information is required on potential environmental contamination from common pesticides in areas where they are used intensively. Furthermore, emphasis needs to be placed on monitoring of organisms and ecosystems for effects of pesticides in the field, not just concentrations of contaminants.

Monitoring needs to be strategic and to feed back into management decisions. The overall approach may best be a mix of options but those involving a risk assessment approach combined with monitoring of use by both industry and state/territory agencies may provide the most effective way forward. Funding for any such initiative may need to be tied to registration and/or sales of pesticides

Resources need to be allocated toward developing more comprehensive and effective monitoring systems for chemical pesticides.

More emphasis is needed on understanding the cumulative impacts of pesticides, including those involving mixtures, pesticide metabolites and degradation products on Australian aquatic species and ecosystems, particularly in irrigation areas. In addition, the effects of short-term pulse exposures of many pesticides are not well understood. Understanding of these effects will assist application of water quality guidelines.

More data are required on effects of pesticides on birds under Australian conditions, particularly relating to their survival. There is almost no information on the effects of pesticides on reptiles and their behavioural responses in the wild. Further work is required on the effects of broad-scale locust spraying in inland Australia on invertebrates, mammals, reptiles, amphibians and birds. There are few data on environmental effects of herbicides on aquatic ecosystems, including effects on primary productivity of ecosystems, and on effects of pesticides on estuarine ecosystems.

Rigorous protocols for examining fish kills would assist in assessing the contribution of pesticides to fish kills. Residue analysis of freshly-killed fish would help in confirming the cause of pesticide-related kills. However, often there are few data on the relationship between residues of pesticides in organisms (eg. fish) and effects on individuals, populations or communities.

The increased potential for groundwater contamination by pesticides in areas of sandy soils, such as the coastal plain of WA, requires special consideration.



### **11.1.7. - Strategy Objective 7: Manage any residues**

*Residues in food and fibre –*

There is an ongoing need to monitor residue levels of chemicals that can enter the food chain. Previous experience has indicated that there is still potential for residue contamination in food and water.

The risk management approaches already in place include:

- Use of significant safety factors in establishing MRLs and ADIs, with transparent processes for establishing these (although locating all relevant information is not without difficulty.)
- National monitoring programs (National Residue Survey and the Australian Total Dietary Surveys) that pay rigorous attention to appropriate sampling frameworks and quality of laboratory procedures, and that publish results in well publicised reports.
- Complementary state based targeted approaches that aim to actively seek out breaches of compliance and follow up action to ensure that recurrences do not occur. results of such programs, however, are not readily available
- Quality Assurance and residue testing requirements of individual companies. Results of these are not made public.
- Awareness of changing export market standards with Australia's response being pre-emptive rather than responsive.

Where no MRL has been established for a pesticide in a specific commodity then detection of the pesticide residue at any level of detection constitutes non-compliance. Such a finding can result in major problems in the marketing of the product where no MRL exists in the importing country (Objective 8), although rarely in practice would such finding constitute a potential health problem. However, the process of establishing the MRL for pesticides in each commodity involves consideration of the ADI for the pesticide, consumption patterns of the commodity as well as good agricultural practice. Where no MRL has been established, then such breaches should not be disregarded.

A major outstanding pesticide residue issue is that serious anomalies have long existed between the NRA MRL Standard and the ANZFA Food Standard A14. This issue should be resolved by the introduction of a single standard for maximum residue limits for food and livestock administered by a new independent statutory authority, Food Standards Australia and New Zealand.

### **11.1.8. Strategy Objective 8: - Ensure continued trade and market access**

*Trade and market access –*

In the international policy arena there is a recognition that environmental and health regulations can be used as trade barriers. This has generated international political efforts to harmonise them and to reach a more uniform set of principles for pesticide use and environmental regulation in agriculture. In the mean time, an important issue is the need for a coordinated expert approach toward assessment of trade risk, particularly for local problems such as locust control, where there may be a conflict of

interest between, for instance, crop growers and meat producers. It should also be recognised that a decision which is made at a state level, relating to a pesticide “control of use” matter, may not take account of the risk that the cost of lost trade opportunities to the industry (and nation) resulting from a single serious pesticide residue mishap affecting a major primary commodity export, may be a much greater than the direct cost to the state in which the mishap occurred. This point reinforces the need for an informed and consistent national approach to risk management of agricultural and veterinary chemicals, including their use.

#### **11.1.9. Strategy Objective 9: Management of unwanted chemicals and containers**

*To minimise the risks presented by unwanted farm and household agvet chemicals, and their containers, through measures designed to minimise future wastes and ensure the safe collection and management of unwanted chemicals and chemical containers.*

Pesticide assessments in Australia do not focus on the impact of all life stages of the product. In particular, disposal, and issues relating to disposal of problematic pesticide wastes have not been considered in any detail in assessments. This approach has left the pesticide user without any detailed information on the possible impact from their waste disposal actions. However, recent programs such as ChemCollect, ChemClear and DrumMUSTER have and are helping to ensure removal of the risk of potential environmental hazards from retention and possible improper disposal of surplus unwanted chemicals and their containers.

### **11.2. THE QUESTION OF LIABILITIES**

The lack of commitment to implementing an integrated, overarching national agricultural and veterinary chemicals strategy, has resulted in some important questions not being asked or addressed. For example, does the current system of NRA revenue collection, taken together with the implicit structure of liability sharing for pesticides used on-label vs. off-label uses, lead to excessive off-label use and a potential undermining of the integrity of the NRS? There are strong indications that the answer is ‘yes’.

In principle, there should be an optimal structure between pesticide manufacturers, the NRA, state/territory agencies, contract pesticide applicators, consultants and farmers, for the liability sharing which would optimise the supply and use of pesticides. This is not simply an academic question. Changes in the structure of liability between different stakeholders may have profound impacts on the supply and use of pesticides. The High Court, for instance, has recently been sending strong messages to statutory authorities that it is likely to (or has been in the process of) widening categories of responsibility and narrowing areas of statutory immunity. Such changes have the potential to significantly influence decision-making within the NRA towards a more conservative approach in registering new pesticides and probably a more radical approach to removing or restricting the use of ‘old’ chemicals under the ECRP and SRP. It is noted that in the Helix case, the NRA chose to not take part in any legal proceedings, but rather rely on its statutory immunity. If the Helix or a similar incident were to occur today, it is likely that the NRA would participate in court

hearings or legal proceedings rather than seeking to rely on its perceived statutory immunity as in the earlier case. For example, if a chemical product which were used strictly in accordance with on-label instructions, or in accordance with an NRA issued permit, resulted in an adverse incident which damaged Australia's trade reputation, a focus of interest to a court would be the procedures followed by NRA in assessing risks to trade before registering the pesticide or issuing a permit for off-label use. It is likely that the court would seek evidence relating to the technical (including statistical analysis) resources and expertise and trade risk assessment process. If in a court's view, the NRA had allocated too few resources or inadequate expertise to the decision, the court might well judge the NRA to have been negligent and liable. Pesticide regulators, manufacturers, distributors and users need to be aware of and be able to take responsibility for any liabilities arising from their actions.

Other important issues requiring resolution include the flaws in the current Material Safety Data Sheet (MSDS) system; off-label pesticide use; determining an appropriate method of identification and registration process for 'low-risk' agricultural and veterinary chemicals; and the appropriate structure of NRA fees/levies.

### **11.3. THE FUTURE**

Pesticides, by their very nature, are designated to kill or inhibit the spread of undesirable living organisms. They have the potential for serious effects on non-target species including the human population and biota in the natural environment. Some significant effects may not be detected until well after a pesticide has been released, or even after it has been withdrawn from use. This has led to increasing stringency of regulation and control, and in improved methods of predicting the risk that pesticides pose to human health and the environment.

Responsibly managed pesticide use will remain an important input to ensuring Australian food and fibre remains at the forefront of acceptance in world markets. Formal agreement to and implementation of the Strategy by governments, the chemical industry, producers and processors is necessary to underpin that outcome.

### **11.4. CONCLUSIONS – THE STRATEGY**

**The National Strategy for Agricultural and Veterinary Chemicals provides a sound framework for moving forward in Australia's pesticide management policies and practices, but it is noted that this strategy has now been extant for three years with only limited achievement towards its implementation. This should be progressed forthwith to ensure a consistent national approach to the risk management of agricultural and veterinary chemicals.**

## **12. CONCLUDING OBSERVATIONS**

Pesticides will continue to play an important role in Australia's farm and forestry production systems. There will be a small market for produce grown without synthetic pesticides, there will be continuing effort to reduce pesticide use, but Australia could not move to an economy free of synthetic pesticides. New pest threats continue to evolve, and unwise pesticide use can exacerbate this risk. We must look to continual improvement in our food and fibre production systems to ensure the maintenance of products that are safe and competitive on world markets.

Achieving optimal use of chemical pesticides and other management practices to control pests is one of the most challenging resource management problems because of the array of potential areas of market failure, particularly 'spill-over effects'. In many ways, effective control of pests and management of chemical pesticides is an exercise in informed risk evaluation and management. Substantial advances have been made in the 'safe' use of chemical pesticides in Australia, particularly over the past decade. The standards of control relating to the supply and use of agricultural pesticides in Australia would appear to compare favourably with other major food and fibre producing countries in the western world.

Despite pressure from some consumer and environment groups, and the growth of the organic produce sector, pesticides will continue to play an important role in sustainable agriculture and forestry in Australia and also in a wide variety of other aspects of modern Australian life.

There is a small but important role in Australia for products grown without use of synthetic pesticides, and there needs to be continuing effort to advance approaches that reduce risks by using fewer or no pesticides. As is the case for pesticide research, there are also some areas of market failure in the undertaking of research into pesticide-free production systems, justifying some public investment. Any adoption of new organic systems, as is the case for any technological changes, should be on a basis of overall net benefits including environmental gains. However, the current state of agricultural and forestry technology is such that a rapid change to an economy free of synthetic pesticides could not be accomplished without a dramatic drop in output. This would be associated with increased per unit of production input costs, the potential dilution of current niche "organic" market profit premiums and a probable marked reduction in the standard of living in Australia and in its position in the world economy.

Pesticides are an integral and important input in Australian agriculture. Their use and importance are increasing as farmers and their industry bodies strive to remain internationally competitive. At the same time, those very same industry bodies and an increasing number of their members, recognise market and community demands for crop production systems to be environmentally sustainable. They have responded by increasing funding support for R&D in the development and adoption of superior pest control, pest management, pesticide resistance management and pesticide application technologies. These recent changes in pesticide use are impacting positively on Australian crop production systems.

It is a truism of pest management that new threats to production continue to evolve. We know that in some cases farm practice can speed this evolution through unwise use of pesticides, for example in generating pesticide-resistant strains. Similarly, in the broader sphere of management, new standards are continually being set, new health and environment studies are reported, and consumer attitudes change. As a consequence, new and enhanced pest control methods will need to be developed and adopted in the future if Australia is to retain the markets for its food and fibre products. This management model is known as continuous improvement, and it applies in agribusiness just as much as it does in industrial manufacture or office procedure. It needs to be applied to the entire pesticide pathway.

## **APPENDICES**

### **APPENDIX A: THE PESTICIDE PATHWAY CONCEPT**

Following the release of the 1990 Senate Committee Report, the states became frustrated due to the emphasis by the Commonwealth on the registration process alone and the lack of appreciation that the difficult management issues occurred downstream when Agvet chemicals were *used*. In South Australia, a chemical pathway concept was developed to illustrate the need to clearly identify all the steps of manufacture, sale and use of Agvet chemicals and to recognise the important interdependencies (M. Hirsch, pers. comm.). The essential features of the chemical pathway concept are shown in Table 45.

**Table 45 - The Chemical Pathway Concept**

Step	Action
1.	Active constituents imported or locally made (ie. industry making the basic ingredients).
2.	Manufacturing capability for chemical products (ie. industry formulating the concentrate).
3.	Authority secured for sale (ie. Government assessment, approval and registration).
4.	Packaging and labelling arranged (ie. marketing and production of the final product).
5.	Wholesale distribution.
6.	Retail sales.
7.	On-farm storage and transport.
8.	Mixing and dilution.
9.	Application, appropriately or inappropriately (ie. the ground or aerial application of spray mixture).
10.	Effects, both desirable and undesirable, on both the target and non-target crops/livestock.
11.	Chemical presence as residue in commodity and the environment and impacts on human health, trade and the environment.
12.	Chemical breakdown, decomposition or disposal.

There are 12 steps, from farm chemical cradle to grave, that can be classified into three larger groups.

Some important points to note are that:

- Stages 1 – 7 deals with the handling of a chemical concentrate, in most cases in a secure container with a label attached. The regulatory focus is with the Commonwealth Government. The compliance activities of the chemical registration process (step 3) focus on retail sale (step 6). Other regulations apply to storage and handling, including poison scheduling, and transport of dangerous goods.
- Stages 8 – 11 involve State control of use activities.
- At stage 8 the chemical product is transformed and used on farm. The underlying decision process involves both label information (from step 3) as well as other outside information, particularly in relation to assessment of the pest situation. Off-label use issues arise here.
- At stage 9, operations can go well or not, depending very much on the quality and training of the operator and the standard of spray equipment.

- Stages 10 and 11 are at the nub of successful chemical use; did the pesticide land only where it was intended and did it work? Spray drift, run-off, efficacy, human health, trade and the environment are key issues here.
- Stage 12 focuses on how the chemicals “disappear” out of the system, including appropriate disposal of unwanted chemicals and containers.

Stage 3 can be viewed as a ‘shut-off’ valve; if the chemical is banned, downstream problems will not occur. But there is more to efficient management of Agvet chemicals than this. In order for the registration system to be effective, it needs to be informed about what happens at other stages downstream and determine the conditions for use on the label in the light of such information. In other words, there are important feedback and information loops from downstream (stages 8 – 12) that an Agvet chemical registration system needs to take into account if an effective overall chemical management system is to be attained.

## **APPENDIX B: MANAGEMENT OF AGRICULTURAL AND VETERINARY CHEMICALS – NATIONAL STRATEGY**

Vision and Objectives of the National Strategy for Agricultural and Veterinary Chemicals	
<b>Vision</b>	
<p>The use of agricultural and veterinary chemicals in a way which:</p> <ul style="list-style-type: none"> <li>• minimises the risks to health, environment and trade;</li> <li>• ensures the long term sustainability of agricultural productivity and trade; and</li> <li>• best contributes to national prosperity.</li> </ul>	
<b>Goal</b>	
Best practice management of agricultural and veterinary chemicals to achieve ecologically sustainable and socially acceptable food and fibre production in Australia.	
<b>Objectives</b>	
<ul style="list-style-type: none"> <li>• Integrated Farm, Forest and Natural Resource Management</li> </ul>	To promote the further development and adoption of integrated farm, forest and natural resource planning and management systems that minimise adverse impact and use chemicals only as needed.
<ul style="list-style-type: none"> <li>• Reducing Reliance on Chemicals</li> </ul>	To reduce reliance on chemicals through the development and implementation of Integrated Pest Management (IPM) programs and alternatives to chemicals.
<ul style="list-style-type: none"> <li>• Assessment, Approval and Availability of Chemicals</li> </ul>	To increase efficiency and effectiveness of chemical assessment and approval processes in making available efficacious products that have minimal risk to health the environment and trade.
<ul style="list-style-type: none"> <li>• Risk Reduction in the Use of Chemicals</li> </ul>	To reduce the risks associated with handling and applying agricultural and veterinary chemicals - to the environment (including non-target organisms); to those using the chemicals; to people living in the environs of application; to handlers of produce; and to consumers - through best practice management of chemical applications.
<ul style="list-style-type: none"> <li>• Minimise Risk to Human Health</li> </ul>	To better understand the potential impacts of chemical use on human health, and reduce the adverse effects, through best practice procedures to identify and minimise the risks, and to monitor, assess and act on outcomes.
<ul style="list-style-type: none"> <li>• Minimise Risk to Environment</li> </ul>	To better understand the potential impacts of chemical use on the environment, and to reduce adverse effects, through best practice procedures to identify and minimise the risks, and to monitor, assess and act on outcomes.
<ul style="list-style-type: none"> <li>• Residue in Food and Fibre</li> </ul>	To produce and market food and fibre that meets the needs of customers and enhances Australian's reputation as a supplier of high quality food and fibre, through adoption of production, processing and marketing systems that assure customers (both domestic and overseas) about quality and ensure that primary produce exported from Australia complies with the requirements of importing countries
<ul style="list-style-type: none"> <li>• Trade and Market Access</li> </ul>	To enhance market access for Australian primary produce through the identification and management of potential trade risks related to chemicals, and through constructive engagement with major trading partners and in international forums, to ensure Australia's trade interests are protected.
<ul style="list-style-type: none"> <li>• Safe Disposals of Unwanted Chemicals and Containers</li> </ul>	To minimise the risk presented by unwanted farm and household agricultural and veterinary chemicals, and their containers, through measures designed to minimise future waste and ensure the safe collection and management of unwanted chemicals and chemical containers.



## **APPENDIX C: LEGISLATION AND REGULATIONS**

### **National Registration Scheme**

*Agricultural and Veterinary Chemicals Act (1992)*  
*Agricultural and Veterinary Chemicals (Administration) Act (1992), and Regulations;*  
*Agricultural and Veterinary Chemicals Code Act (1994) and Regulations; and Order*  
*Agricultural and Veterinary Chemicals Code Regulation Act (1995)*  
*Agricultural and Veterinary Chemicals Regulations (1999)*  
*Agricultural and Veterinary Chemicals Code Act (1994); and Regulations (Vic)*  
*Agricultural and Veterinary Chemicals (Western Australia) Act (1995) and Regulations (WA)*  
*Agricultural and Veterinary Chemicals (Tasmania) Act (1994) and Regulations (Tas)*  
*Agricultural and Veterinary Chemicals (New South Wales) Act (1994) and Regulations (NSW)*  
*Agricultural and Veterinary Chemicals (South Australia) Act (1994) and Regulations (SA)*  
*Agricultural and Veterinary Chemicals (Queensland) Act (1994) and Regulations (Qld)*  
*Agricultural and Veterinary Chemicals (Northern Territory) Act (1994) and Regulations (NT)*  
*Agricultural and Veterinary Chemicals Act (1994), and Determination (under Section 23)*  
*Agricultural and Veterinary Chemicals Products (Collection of Levy) Act (1994)*  
*Agricultural and Veterinary Chemicals Products Levy Imposition (Customs) Act (1994) and Regulations*  
*Agricultural and Veterinary Chemicals Products Levy Imposition (Excise) Act (1994)*  
*Agricultural and Veterinary Chemicals Products Levy Imposition (General) Act (1994)*

## **STATE CONTROL OF USE AND OTHER LEGISLATION**

### **Victoria**

#### ***Department of Natural Resources and Environment***

*Agricultural and Veterinary Chemicals (Control of Use) Act (1992); Regulations 1996 and Hormonal Growth Promotants Regulation (1993)*

#### ***Environmental Protection Authority***

*Environment Protection Act (1970), particularly sections 39-45*

#### ***Victorian Workcover Authority***

*Occupational Health and Safety Act (1985)*

#### ***Victorian Local Government***

*Health Act (1958) (Nuisance provisions)*

### **New South Wales**

#### ***Environmental Protection Authority***

*Pesticides Act 1999 (Act became fully operational on 1 July 2000, replacing the older Pesticides Act 1978)*

*Protection of the Environment Operations Act (1997)*

*Road and Rail Transport (Dangerous Goods) Act (1997)*

#### ***NSW Agriculture***

*Stock Food Act (1940)*

*Stock (Chemical Residues) Act (1975)*

*Noxious Weeds Act (1993)*

### **NSW Workcover**

*Occupational Health and Safety Act (1983)*

*Occupational Health and Safety (Hazardous Substances) Act (1996) (and Codes of Practice).*

### **NSW Health**

*NSW Food Act (1989)*

### **Queensland**

*Agricultural and Veterinary Chemicals Distribution Control Act (1966)*

*Agricultural Chemicals Distribution Control Regulations (1998)*

*Chemical Usage (Agricultural and Veterinary) Controls Act (1988)*

*Chemical Usage (Agricultural and Veterinary) Control Regulation (1989)*

*Environmental Protection Act (1994)*

*Workplace and Safety Act (1995)*

*Workplace and Safety Hazardous Substances Regulations (1997)*

*Health Act (1937)*

*Drugs and Poisons Regulations (1996)*

### **South Australia**

#### **Primary Industries and Resources, SA**

*Agricultural Chemicals Act (1955)*

*Stock Foods Act (1941)*

#### **Other legislation of relevance to pesticide use:**

*Dangerous Substances Act (1979)*

*Food Act (1985)*

*Environment Protection Act (1993)*

*Occupational Health, Safety and Welfare Act (1986)*

*Water Resources Act (1990)*

*Meat Hygiene Act (1994)*

*Livestock Act (1997)*

### **Western Australia**

#### **WA Health**

*WA Health Act (1956)*

*Health (Pesticides) Regulations (1956)*

*Poisons Act (1964)*

#### **WA Agriculture**

*Agricultural Produce (Chemical Residues) Act (1983) and Regulations*

*Aerial Spraying Control Act (1966) and Regulations*

*Agricultural and Related Resources Protection (Spraying Restrictions) Regulations (1979)*

#### **WA Worksafe**

*Occupational Safety and Health Act (1994) and Regulations (1996)*

#### **WA Minerals and Energy**

*Explosive and Dangerous Goods Act and Regulations (1998)*

*Dangerous Goods Transport Act and Regulations (1998)*

**Northern Territory**

***Territory Health Services***

*Poisons and Dangerous Drugs Act (1983)*

**Tasmania**

*Agricultural and Veterinary Chemicals (Control of Use) Act (1995)*

***Workplace Standards Tasmania***

*Workplace Health and Safety Act (1995)*

*Dangerous Goods Act (1998)*

*Poisons Act (1971)*

**Australian Capital Territory**

*Commonwealth Agricultural and Veterinary Chemicals Act (1994) applies Agvet Code directly to ACT*

*Environmental Protection Act (1997) – Regulation 15*

## **APPENDIX D: INTERNATIONAL CHEMICAL PROGRAMS**

Concerns which are being expressed worldwide about the impacts of chemicals demands for regulatory and other management systems of sufficient transparency and integrity to assure public confidence in food and fibre production.

In 1992, the **United Nations Conference on the Environment and Development**, also known as the Rio Earth Summit, launched an agreed blueprint for the next century, known as **Agenda 21**. Chapter 19 of the Agenda deals with 'environmentally sound management of toxic chemicals including prevention of illegal international traffic, in toxic and dangerous chemicals. Implementation of Agenda 21 has seen a substantial increase in international activity related to Agvet chemicals including the negotiations of MEAs to which Australia is party.

Domestic and international policies are in place, or under negotiation in relation to the following issues of concern:

- persistent organic pollutants such as organochlorines;
- chemical compounds which deplete the ozone layer, such as the pesticide methyl bromide;
- trade in domestically prohibited goods, including Agvet chemicals; and
- heavy metals (non-pesticides), such as cadmium, which is a significant problem in agricultural production in Australia and elsewhere.

Australia currently participates in a number of international programs aimed at harmonising efforts to address effective management of Agvet chemicals including: membership of the **Codex Alimentarius Commission** and **Food Standards Program administered by the United Nations Food and Agricultural Organisation (WHO)**; participation in the **FAO Code of Conduct on the Distribution and Use of Pesticides**; the **OECD Chemical Accidents Program** and **Pesticide Risk Reduction Project**; the **Intergovernmental Forum on Chemical Safety**; the **Inter-Organisation Program for the Sound Management of Chemicals**; the draft **Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade**; the **Convention on Persistent Organic Pollutants**; and the **Trans-Tasman Harmonisation Scheme**.

## **APPENDIX E – SAMPLE PESTICIDE USE DATA CHART**

**Table 46: Mean annual net use of insecticides (imports + manufacture - exports)**

(Individual cells to highlighted according to distribution of mean annual consumption of insecticide.)

<b>INSECTICIDES</b>				
Net annual tonnes of Active Ingredient used	1 – 10	10- 10 –	10 – 10	> 10
Acephate				
Allethrin 20:80				
Amitraz				
Azinphos ethyl/methyl				
Beta-cyfluthrin				
Bifenthrin				
Bioallethrin				
Bioresmethrin				
Bt aizawai				
Bt israelensis				
Bt kurstaki				
Cadusafos				
Carbaryl				
Chlorfenvinphos				
Chlorpyrifos				
Cypermethrin				
Cypermethrin 40:60				
Cypermethrin alpha				
Cyromazine				
Deltamethrin				
Diazinon				
Dichlorvos				
Dicofol				
Dimethoate				
Disulfoton				
Endosulfan				
Esfenvalerate				
Ethion				
Fenamiphos				
Fenitrothion				
Fenoxycarb				
Fenthion				
Fipronil				

Net annual tonnes of Active Ingredient used	1 – 10	10- 10 –	10 – 10	> 10
Lamda cyhalothrin				
Maldison				
Metham sodium				
Methamidophos				
Methidathion				
Methiocarb				
Methomyl				
Methoprene				
Methyl bromide				
Monocrotophos				
Omethoate				
Parathion				
Parathion methyl				
Permethrin				
Permethrin 25:75 cis:trans				
Permethrin 40:60				
Phorate				
Phosmet				
Pirimicarb				
Pirimiphos methyl				
Profenofos				
Profenofos Q grade				
Propoxur				
Prothiofos				
Spinosad				
Tau fluvalinate				
Tebufenozide				
Temephos				
Terbufos				
Tetramethrin (various)				
Thiodicarb				
Trichlorfon				
Triflumuron				
Vamidothion				

## **APPENDIX F – PHYSICAL, TOXICOLOGICAL AND ENVIRONMENTAL PROPERTIES OF PESTICIDES**

**Table AF 1:** Some basic environmental properties of organochlorine pesticides (most of which are now withdrawn).<sup>1</sup>

	CAS No.	MW	Water Sol mg/L <sup>2</sup>	Log Kow	Log SAC <sup>5</sup>	Water T1/2 <sup>5</sup>	Soil Half-life <sup>7</sup> D1/2	Notes
Aldrin	309-00-2	365	0.027	3.0			30 - 100d	
Chlordane	57-74-9	410	0.10	2.8 <sup>3</sup>	4.3	<10d <sup>6</sup>	4y	
DDE		310	0.04	6.1	3.9 <sup>8</sup>	1-6d <sup>8</sup>	Adsorbs	
DDT	50-29-3	354	0.00	6.4	5.4 <sup>8</sup>	1.5d <sup>8</sup>	15y <sup>9</sup>	
Dicofol	115-32-2	370	0.8	4.3	3.7	47 - 85d	60d	
Dieldrin	60-57-1	381	0.19	n.a	3.9 <sup>8</sup>	14-57d <sup>8,10</sup>	7 - 10y <sup>8</sup>	
Endosulfan <sup>3</sup>	115-29-7	407	0.32	4.8	4.1	2d - 4w	35 - 150d	Log K <sub>oc</sub> = 5 <sup>11</sup>
Endrin	72-20-8	381	0.2	5.6	4.5y <sup>8</sup>	>4y <sup>8</sup>	14y <sup>8</sup>	
Heptachlor	76-44-8	373	0.06	5.4	4.4		0.4 - 0.8y	
Lindane	58-89-9	291	7.3	3.7	3.0		6 - 15 mo	Log K <sub>oc</sub> = 3.04 <sup>11</sup>
Methoxychlor	72-42-5	346	0.1	5.0	4.9	5h - 45d	1w - 120d	
Mirex	2385-85-5	546	“insol”	5.3 <sup>8</sup>	7.4 <sup>8</sup>			
Toxaphene <sup>4</sup>	8001-35-2	414	3	3.3	3.9	0.25	1 - 4y	

1. Data from ANZECC & ARMCANZ (2001), except where indicated; 2. Mostly at 25-27°C, but some at 20°C; 3. Mixture of isomers; 4. Mixture of 175 components; 5. Data from Kamrin (1997) except where indicated; 6. Volatilisation; 7. Tomlin (2000); 8. TOMES database; 9. Nowell et al. (1999); 10. Evaporation only; 11. Kookana et al. (1998); SAC = Soil adsorption coefficient; Gaps in table indicate that no information was found

**Table AF 2:** Toxicities of organochlorine pesticides (mostly now withdrawn) to terrestrial organisms<sup>1</sup>: mg/kg; LD50.

Chemical	Mammals Acute LD50		Birds LD50		Bees <sup>2</sup>
	Oral	Dermal	Oral	Dietary ppm	
Aldrin <sup>5</sup>	39 - 60				
Chlordane	20 - 1720	530 - 780	83 - 860		HT
DDE <sup>6</sup>	825		829	na <sup>3</sup>	
DDT <sup>7</sup>	50 <sup>6</sup> - >1000	2510		na <sup>3</sup>	
Dicofol	420 - 1810	1000 - 5000		1420 - 3010	
Dieldrin	3 - 65	56 - 200	20 - 1200		
Endosulfan	7 - 160	78 - 360	30 - 320	2900	MT <sup>4</sup>
Endrin <sup>6</sup>	1.3 - 36	18 - 75	1.1 - 17		
Heptachlor	30 - 220	120 - 2000	2080	99 - 700	HT
Lindane	60 - 560	300 - 1000	>2000	490 - 880 <sup>3</sup>	HT
Methoxychlor	1850 - 6000	>2000	>2000	>5000	LT
Mirex <sup>6</sup>			2000 - 5000		
Toxaphene <sup>6</sup>	80 - 90	780 - 1075	40 - 160		

1. Data from Kamrin (1997) unless otherwise stated. Refer to original document for further information on tests and treatment of data. 2. And other beneficial terrestrial invertebrates. As quantitative toxicity figures were not always reported, there may be variation in interpretation of NT, MT etc; 3. Eggshell thinning noted; 4. Low toxicity to other beneficials; 5 Merck Index, 12th Ed'n; 6. Tomes database; 7. Tomlin (2000); n = Number of species; n.a = data not available; LT = “Low toxicity”; MT = “moderate toxicity”; HT = high toxicity; Gaps in table indicate that no data were found

**Table AF 3:** Acute toxicities of organochlorine pesticides (mostly now withdrawn) to freshwater aquatic organisms<sup>1</sup>: µg/L; 48-96h LC(EC)50.

Chemical	Fish		Crustaceans & Insects		Aquatic plants & ciliates	
	n		n		n	
Aldrin	16	0.9 - 53	15	0.1 - 50	0	
Chlordane	21	0.8 - 115	11	0.4 - 63	1	360
DDE	3	32 - 240	1	1100	0	
DDT	30	0.45 - 123	24	0.36 - 23	2	4600
Dicofol	13	53 - 4400	2	140 - 650	0	
Dieldrin	9	1 - 79	7	0.6 - 740	0	
Endosulfan	42	0.1 - 63	24	0.1 - 720	2	100 - 700
Endrin	22	0.06 - 31	21	0.08 - 74	1	95 <sup>2</sup>
Heptachlor	13	6.2 - 102	9	0.5 - 80	1	28 - 38
Lindane	27	26 - 800	15	3.2 - 1100	4	1620 - 3200
Methoxychlor	16	1.2 - 75	13	0.5 - 34	0	
Mirex	0		5	40 - 2000	0	
Toxaphene	16	0.8 - 56	11	1.3 - 40	1	380

1. Data from ANZECC & ARMCANZ (2001) unless otherwise stated. Refer to original document for information on screening and treatment of data. Figures significantly exceeding solubility were not included; 2. 36h NOEC growth; n = Number of species; Gaps in table indicate that no data were found

**Table AF 4:** Some basic environmental properties of organophosphorus pesticides.<sup>1</sup>

	CAS No.	MW	Water Sol mg/L <sup>2, 8</sup>	Log Kow	Log SAC <sup>5</sup>	Water T1/2 <sup>2, 5</sup>	Soil Half life <sup>5</sup> D1/2	Notes
Azinphos-methyl	86-50-0	317	28	3.0	3.0	2d <sup>4</sup>	5 - 68d	
Chlorfenvinphos <sup>9</sup>	2701-86-2	360	145	3.8		80 - 170 d		
Chlorpyrifos	2921-88-2	351	1.4	4.7	3.8	3 - 20 d	60 - 120d	
Diazinon	333-41-5	304	60	3.3	3.0	6 mo	2w - 6 mo <sup>3</sup>	
Dichlorvos	62-73-7	221	10000	n.a	1.5	4d	7d	Volatile
Dimethoate	60-51-5	229	24000	0.7	1.3	8d	ca 20d	
Fenitrothion	122-12-5	277	21	3.4		0.25 - 3 d	<7 d	
Fenthion <sup>5</sup>	55-38-9	278	2	4.1	3.2	2w	34d	
Malathion	121-75-5	330	145	2.7	3.3	<1w	1 - 25d	Mod. mobility
Methidathion <sup>5</sup>	950-37-8	302	240	4.7	2.6	n.a.	ca 7d	
Monocrotophos <sup>6</sup>	2157-98-4	223	Soluble	-0.2		66 - 150d	≤7d	Mobile - soil
Parathion	56-38-2	291	11	3.8		130-272 <sup>7</sup>	7 <sup>7</sup> - 260d <sup>2</sup>	
Profenofos <sup>4</sup>	41198-08-7	374	28	4.4			0.25 <sup>4</sup> - 15d <sup>2</sup>	
Temephos	3383-98-8	466	0.03	4.9	5.0	<1w	30d	

1. Data from ANZECC & ARMCANZ (2001), except where indicated; 2. pH dependent (figures around pH7 reported); 3. 185d at pH 7.4 from ANZECC & ARMCANZ (2001); 4. pH9; 5. Kamrin (1997); 6. NRA (2000); 7. Tomlin (2000); 8. Mostly at 25-27°C but some at 20°C; SAC = Soil adsorption coefficient; Gaps in table indicate that no information was found; 9. NRA (2000d) – i.e. the NRA review of chlorfenvinphos

**Table AF 5:** Toxicities of organophosphorus pesticides to terrestrial organisms<sup>1</sup>: mg/kg; LD50

Chemical	Mammals Acute LD50		Birds LD50		Bees <sup>2</sup>
	Oral	Dermal	Oral	Dietary (ppm)	
Azinphos-methyl	4.4 - 230	65 - 220	32 - 262	640 - 1940	HT
Chlorfenvinphos	10 - >5000	30	<10 - 500	3 & 6	
Chlorpyrifos	32 - 1000	>2000	8 - 112	ca 100	HT
Diazinon	300 - 400	540 - >2000 <sup>9</sup>	3 - 41		HT
Dichlorvos	11 - 1090	70 - 206	12	>1100 <sup>9</sup>	HT
Dimethoate	160 - 600	100 - 600	20 - 64	340	HT
Fenthion	88 - 300	330 - 1000	4 - 30	30-230	HT
Fenitrothion	330 - 1340	890 - >2500	100 - 550 <sup>4</sup>		HT
Malathion	4000 - 10000	4000 - 10000	100 - 1500	>2600	HT
Methidathion	18 - 200	90	8 - 225		MT
Monocrotophos <sup>3</sup>	18	354	0.2 - 6.5	2.4 - 32	HT
Parathion <sup>5,8</sup>	2 - 12	50			HT
Profenofos <sup>9</sup>	369 - 700	470 - 3300	70 - >1000		
Temephos	460 - 13000		19 - 240	170 - 1200 <sup>9</sup>	HT

1. Data from Kamrin (1997) unless otherwise stated. Refer to original document for further information on tests and treatment of data; 2. and other beneficial terrestrial invertebrates. As quantitative toxicity figures were not always reported, there may be variation in interpretation of HT, MT etc; 3. NRA 2000; 4. Crisp (1992); 5. NRA (1999); 6. NOEC & LOEC; 7. Story & Cox (in press); 8. TOMES database; 9. Tomlin (2000); LT = "low toxicity"; MT = "moderate toxicity"; HT = "high toxicity"; Gaps in table indicate that no data were found.

**Table AF 6:** Acute toxicities of organophosphorus pesticides to freshwater aquatic organisms<sup>1</sup>: µg/L; 48-96h LC(EC)50.

Chemical	Fish		Crustaceans & Insects		Aquatic plants & ciliates	
	n	LC (EC)50	n	LC (EC)50	n	LC (EC)50
Azinphos-methyl	15	0.36 - 4270	10	0.1 - 88	1 <sup>2</sup>	7150
Chlorfenvinphos <sup>2</sup>	3	270 - 530	1	300	3 <sup>4</sup>	600 - 10000
Chlorpyrifos	16	1.3 - 542	27	0.06 - 10	7	10 - 330
Diazinon	23	22 - 24000	19	0.2 - 140	7	2500 - 20000
Dichlorvos	3 <sup>3</sup>	900 - 11600	1 <sup>3</sup>	4	1 <sup>2</sup>	52800
Dimethoate	16	2.3 - 70800	7	2 - 6400	1	480 000
Fenitrothion	26	1.6 - 12600	25	0.9 - 82	10	800 - 24400
Fenthion	9	1160 - 9300 <sup>3</sup>	1 <sup>2</sup>	5.7	1 <sup>2</sup>	1800
Malathion	24	4 - 39600	14	1.1 - 6000	0	
Methidathion	2	2 - 14 <sup>3</sup>	0		1	22000 <sup>2</sup>
Monocrotophos <sup>2</sup>	3	7000 - 23000	1	23	1 <sup>5</sup>	100 - 300,000
Parathion	14	18 - 3600	22	0.04 - 32	3	2900 - 15000
Profenofos	6	19 - 2500	0		1	2900
Temephos	21	160 - 22750	9	0.09 - 640	0	

1. Data from ANZECC & ARMICANZ (2001) unless otherwise stated. Refer to original document for information on screening and treatment of data. Figures significantly exceeding solubility were not included; 2. Tomlin (2000); 3. Kamrin (1997); 4. NRA (1999); 5 = AQUIRE (1994) Database; n = Number of species; Gaps in table indicate that no data were found.



**Table AF 7:** Some basic environmental properties of carbamate insecticides.

	CAS No.	MW	Water Sol mg/L <sup>2</sup>	Log K <sub>ow</sub>	Log SAC <sup>6</sup>	Water <sup>6</sup> T1/2	Soil Half-life <sup>6</sup> D1/2	Notes
Aldicarb	116-06-3	190	6000	0.05	1.5	1d - 1 mo	Mod.	Mobile-soil
Carbofuran	1563-66-2	221	320	1.5	1.3	8w <sup>3</sup>	30-120d	Mobile-soil
Carbaryl	63-25-2	201	40	n.a.	2.5	10d	7-28d	
Methomyl	16752-77-5	162	58000	1.2	1.9	6d <sup>4</sup> - 25w <sup>5</sup>	14d	

1. Data from ANZECC & ARMCANZ (2001), except where indicated; 2. at 20 - 25°C; 3. At pH 7; 4. In surface water; 5. In ground water; 6. Kamrin (1997), except where indicated; SAC = Soil adsorption coefficient; Gaps in data indicate that no information was found.

**Table AF 8:** Acute toxicities of carbamate pesticides to terrestrial organisms<sup>1</sup>: mg/kg; LD50.

Chemical	Mammals Acute LD50		Birds LD50		Bees <sup>2</sup>
	Oral	Dermal	Oral	Dietary (ppm)	
Aldicarb	0.5 - 1.5		1.8 - 5.3	71 <sup>4</sup>	LT
Carbaryl	100 - 850		>1000		HT
Carbofuran	2 - 19	>1000	0.2 - 746 <sup>3</sup>		HT
Methomyl	10 - 24	5880	15 - 42	1890 - 3680 <sup>4</sup>	HT

1. Data from Kamrin (1997) unless otherwise stated. Refer to original document for further information on tests and treatment of data; 2. and other beneficial terrestrial invertebrates. As quantitative toxicity figures were not always reported, there may be variation in interpretation of HT, MT etc; 3. Many species <12 mg/kg; 4. Tomlin (2000); LT = "low toxicity"; MT = "moderate toxicity"; HT = "high toxicity"; Gaps in table indicate that no data were found.

**Table AF 9:** Acute toxicities of carbamate pesticides to freshwater aquatic organisms<sup>1</sup>: µg/L; 48-96h LC(EC)50.

Chemical	Fish		Crustaceans & Insects		Algae & ciliates	
	n	LC (EC)50	n	LC (EC)50	N	LC (EC)50
Aldicarb	2	1500 - 8800 <sup>3</sup>			1 <sup>4</sup>	>50,000
Carbaryl	2	1300 - 10000 <sup>3</sup>	3	6 - 5700	16 <sup>4</sup>	600 - 2900
Carbofuran	24	80 - 4800	7	0.33 - 86	1	204 500
Methomyl	12	300 - 6800	8	8.8 - 920	0	60,000 <sup>3</sup>

1. Data from ANZECC & ARMCANZ (2001) unless otherwise stated. Refer to original document for information on screening and treatment of data. Figures significantly exceeding solubility were not included; 2. Tomlin (2000); 3. Kamrin (1997); 4. AQUIRE (1994) Database; n = Number of species; Gaps in table indicate that no data were found.

**Table AF 10:** Some basic environmental properties of pyrethroid pesticides.<sup>1</sup>

	CAS No.	MW	Water Sol µg/L <sup>2</sup>	Log Kow <sup>5</sup>	Log Soil Adsorp Coeff	Water T1/24	Soil D1/2
Cypermethrin <sup>3</sup>	52315-07-8	416	10	6.6	5	>50d	4d - 8w
Deltamethrin	52918-63-5 <sup>3</sup>	505	<0.2	4.6	5.7 - 6.2		9d <sup>4</sup>
Esfenvalerate	66230-04-4	420	2	6.2	3.7	21d	15d - 3 mo
Permethrin <sup>3</sup>	52645-53-1	391	2000	6.1	5	<2.5d	30 - 38d

1. Data from ANZECC & ARMCANZ (2001), except where indicated; 2. Mostly at 25°C; 3. Depending on isomer; 4. Kamrin (1997), except where indicated; 5. Tomlin (2000); SAC = Soil adsorption coefficient; Gaps in data indicate that no information was found.

**Table AF 11:** Acute toxicities of pyrethroid pesticides to terrestrial organisms<sup>1</sup>: mg/kg; LD50.

Chemical	Mammals Acute LD50		Birds LD50		Bees <sup>2</sup>
	Oral	Dermal	Oral	Dietary (ppm)	
Cypermethrin	150 - 4120		>4640	>20000	HT
Deltamethrin <sup>3</sup>	135 - >5000	>2000	>4640	>5620	HT
Esfenvalerate	460 - 2500		1312 - 2250		HT
Permethrin	430 - 4000		>9900		HT

1. Data from Kamrin (1997) unless otherwise stated. Refer to original document for further information on tests and treatment of data; 2. and other beneficial terrestrial invertebrates. As quantitative toxicity figures were not always reported, there may be variation in interpretation of HT, MT etc; 3. Tomlin (2000); LT = "low toxicity"; MT = "moderate toxicity"; HT = "high toxicity"; Gaps in table indicate that no data were found.

**Table AF 12:** Acute toxicities of pyrethroid pesticides to freshwater aquatic organisms<sup>1</sup>: µg/L; 48-96h LC(EC)50.

Chemical	Fish		Crustaceans & Insects		Algae & ciliates	
	n	LC (EC)50	n	LC (EC)50	n	LC (EC)50
Cypermethrin	2	1.8 - 8.2 <sup>3</sup>	1	0.2 <sup>3</sup>	0	n.a.
Deltamethrin	2	0.5 - 3.5	2	0.003 - 1	1 <sup>2</sup>	>9100
Esfenvalerate	4	0.07 - 420	1	0.27	0	n.a.
Permethrin <sup>2</sup>	3	1800 - 5400	1	0.6	3 <sup>4</sup>	68 - 5000

1. Data from ANZECC & ARMCANZ (2001) unless otherwise stated. Refer to original document for information on screening and treatment of data. Figures significantly exceeding solubility were not included; 2. Tomlin (2000); 3. Kamrin (1997); 4. AQUIRE (1994) Database; n = Number of species; Gaps in table indicate that no data were found

**Table AF 13:** Some basic environmental properties of insect growth regulators and miscellaneous insecticides.<sup>1</sup>

	CAS No.	MW	Water Sol mg/L <sup>2</sup>	Log Kow	Log SAC <sup>5</sup>	Water T1/2 <sup>5</sup>	Soil D1/2 <sup>5</sup>
<b>Insect Growth Regulators</b>							
Chlorfluazuron	71422-67-8	541	<0.01	5.8 <sup>4</sup>			6w + <sup>4</sup>
Diflubenzuron	35367-38-5	311	0.14	n.a.	5	1 - 3w	3 - 4d
S-Methoprene	40596-69-8 <sup>3</sup>	310	1.4	5.2	n.a.	30 - 40h	10d
Tebufenozide	112410-23-8	352	<1	4.4 <sup>4</sup>	2.5 - 3.0 <sup>4</sup>	4 - 30d <sup>4</sup>	100d <sup>4</sup>
<b>Miscellaneous</b>							
Chlorfenapyr <sup>4</sup>	122453-73-0	408	“v. low”	4.8		15 - 24d <sup>8</sup>	>250d <sup>8</sup>
Fipronil	120068-37-3	437	2.3	4.0		>28d <sup>7</sup>	18 - 310d
Spinosad		732 <sup>3</sup>	0.053 <sup>3,6</sup>	4.2 <sup>4</sup>		>200d	9 – 350d

1. Data from ANZECC & ARMICANZ (2001), except where indicated; 2. Mostly at 25°C; 3. Depending on isomer; 4. Tomlin (2000); 5. Kamrin (1997), except where indicated; 6. pH-dependent, figures at pH 7; 7. Hydrolysis; 8. Environment Australia (1998a); SAC = Soil adsorption coefficient; Gaps in data indicate that no information was found.

**Table AF 14:** Toxicities of insect growth regulators and miscellaneous insecticides to terrestrial organisms<sup>1</sup>: mg/kg; LD50.

Chemical	Mammals Acute LD50		Birds LD50		Bees <sup>2</sup>
	Oral	Dermal	Oral	Dietary (ppm)	
Insect Growth Regulators					
Chlorfluazuron <sup>6</sup>	7000 - >8500	>1000	>2510	>5620	LT
Diflubenzuron	>4640	>4000		>4640	LT
Methoprene	>5000	>2000	>2000	>4640	LT
Tebufenozide <sup>6</sup>	>5000	>5000	>2150	>5000	LT
Miscellaneous					
Chlorfenapyr <sup>3</sup>	440 - 1150		2.2 - 34	8.6 - 132	HT
Fipronil <sup>4</sup>			11 - >2000 <sup>7</sup>	48 - >5000 <sup>7</sup>	HT
Spinosad <sup>5</sup>	>2000 - >5000		>2000	>5000	HT

1. Data from Kamrin (1997) unless otherwise stated. Refer to original document for information on tests and treatment of data; 2. and other beneficial terrestrial invertebrates. As quantitative toxicity figures were not always reported, there may be variation in interpretation of HT, MT etc; 3. Environment Australia (1998a); 4. Environment Australia (1998b); 5. Environment Australia (1998c); 6. Tomlin (2000); 7. Galliform birds (quail, pheasant, partridge) all at lower end of range (<50 mg/kg); LT = “low toxicity”; MT = “moderate toxicity”; HT = “high toxicity”; Gaps in table indicate that no data were found.

**Table AF 15:** Acute toxicities of insect growth regulators and miscellaneous insecticides to freshwater aquatic organisms<sup>1</sup>: µg/L; 48-96h LC(EC)50.

Chemical	Fish		Crustaceans & Insects		Algae & ciliates	
	n	LC (EC)50	n	LC (EC)50	n	LC (EC)50
<b>Insect Growth Regulators</b>						
Chlorfluazuron <sup>2</sup>	1	>300 000	1	908	1	>1800
Diflubenzuron <sup>2</sup>	2	135 000	1	7	1	>300
S-Methoprene	2 <sup>2</sup>	4400 - 4600	1 <sup>2</sup>	360 <sup>4</sup>	2 <sup>7</sup>	20 - 500
Tebufenozide <sup>2</sup>	2	3000 - 5700	2	1400 - 3800	2	≥230
<b>Miscellaneous</b>						
Chlorfenapyr <sup>2,4</sup>	3	7.4 - 500	1	6.1	1	137 <sup>6</sup>
Fipronil <sup>4</sup>	3	85 - 800	1	36 - 190	2	68 - 169
Spinosad <sup>5</sup>	3	5000 - 30000	1	1500 - 93000	4	110 - >110000

1. Data from ANZECC & ARMCANZ (2001) unless otherwise stated. Refer to original document for information on screening and treatment of data. Figures significantly exceeding solubility were not included; 2. Tomlin (2000); 3. Limb regeneration defects in crabs at 50µg/L for 1 week Kamrin (1997); 4. Environment Australia (1998a); 5. Environment Australia (1998b); 6. Environment Australia (1998c); 7. AQUIRE (1994) Database; n = Number of species; Gaps in table indicate that no data were found

**Table AF 16:** Some basic environmental properties of herbicides.<sup>1</sup>

	CAS No.	MW	Water Sol mg/L <sup>2</sup>	Log Kow	Log SAC <sup>6</sup>	Water T1/2 <sup>6</sup>	Soil Half-life <sup>6</sup> D1/2	Notes
<b>Bipyridilium herbicides</b>								
Diquat	2764-72-9	184	700000	-4.6	6 <sup>6</sup>	<2d	>3y <sup>8</sup>	
Paraquat	4685-14-7	186	700000	4.5	6 <sup>7</sup>	0.5d - 23w	>3y <sup>9</sup>	
<b>Phenoxy acetic acid herbicides</b>								
MCPA	94-74-6	202	734 <sup>4</sup>	0.5 <sup>5</sup>	1.3-3	<2w	2-4w	
2,4-D	94-75-9	221	900 <sup>4</sup>	2.8	1.3	ca 1w	<7d	
2,4,5-T <sup>8</sup>	93-76-5		ca 250	4	1.9 - 2.5	15d	14 - 300d	
<b>Pyridine herbicides</b>								
Picloram	1918-02-1	241	430	0.15	1.2	2.6d	90d	Leaches
Triclopyr	55335-06-3	256	440	0.4	2.9	0.5 - 4d <sup>7</sup>	30 - 90d	Mobile
<b>Sulfonyl urea herbicides</b>								
Bensulfuron-Me	83055-99-6	396	120 <sup>3</sup>	0.6 <sup>3</sup>		4 - 6d <sup>11</sup>	4 - 20w <sup>11</sup>	
Metsulfuron-Me	74233-64-6	381	213 <sup>3</sup>	0.02 <sup>3</sup>	1.5 <sup>11</sup>		1 - 5w <sup>5,11</sup>	
Sulfometuron-Me	74222-97-2	364	244 <sup>11</sup>	0.5	1.9	1d - 2mo	20 - 28d	
<b>Thiocarbamate herbicides</b>								
Molinate	2212-67-1	187	88	2.9	2.3	n.a.	5 - 21d	Mobile
Thiobencarb	28249-77-6	258	30	3.4		30d <sup>11</sup>	18d <sup>5</sup>	
Thiram	137-26-8	240	18	1.7	2.8	Rapid	15d	
<b>Triazine &amp; triazole herbicides</b>								
Amitrole	61-82-5	84	280000	Low	2	40d	14d	
Atrazine	1912-24-9	216	33	2.3	2	1.6 - 2.2 <sup>11</sup>	30 - >100d	Mobile
Cyanazine <sup>6</sup>	21725-46-2	241	171	2.2	2.3	35-200d	2 - 14 w	Mobile
Hexazinone	51235-04-2	252	33000	1.0	1.7	n.a.	30 - 180d	Mobile
Prometryn	7287-19-6	241	48	3.3	2.6	>>1 mo	1 - 3 mo	
Simazine	122-34-9	202	6	2.1	2.1	30d	250	Sl. Mobile
<b>Urea herbicides</b>								
Diuron	330-54-1	23	42	2.8	2.7	Rel stable	1 m - 1y	Mobile
Tebuthiuron	34014-18-1	228	2500	1.8	1.9	>>30d	12 - 15mo	
<b>Miscellaneous herbicides</b>								
Acrolein	107-02-08	56	208000	1.1		0.2 - 2 <sup>4,9</sup>	7d - 4w <sup>9</sup>	
Bromacil	314-40-9	261	800 <sup>2</sup>	Low	1.5	2mo	60d - 8mo	Leaches
Glyphosate	1071-836	228	7000 <sup>3</sup>	Low	4.4	12d-10w	47d	
Imazethapyr	81335-77-5	288	1400	1.0				
Ioxynil	2961-62-8	371	50	Low			10d <sup>11</sup>	
Metolachlor	51218-45-2	284	488	2.9	2.3	100 - >200d	15 - 70d	Leaches
Sethoxydim	74051-80-2	328	4700 <sup>3</sup>	1.6 <sup>3</sup>	2	<40d	5 - 25d	
Trifluralin	1582-09-8	335	0.4	5.3	3.9	n.a.	45d - 8 mo	Sediment

1. Data from ANZECC & ARMCANZ (2001), except where indicated; 2. Mostly at 20-25°C; 3. pH-dependent, figures at around pH 7; 4. Acid formulation; 5. At pH 5; 6. Kamrin (1997); 7. Ester; 8. Dibromide; 9. Dichloride; 10. TOMES database; 11. Tomlin (2000) at pH 5; SAC = Soil adsorption coefficient; Gaps in data indicate that no information was found.

**Table AF 17:** Toxicities of herbicides to terrestrial organisms<sup>1</sup>: figures in mg/kg; LD50.

Chemical	Mammals Acute LD50		Birds LD50		Bees <sup>2</sup>
	Oral	Dermal	Oral	Dietary (ppm)	
Bipyridilum herbicides					
Diquat	30 – 230	400 - 500	200 - 560	1300	LT
Paraquat	50 - 150	236 - 235	970 - 980	4050	LT
Phenoxy acetic acid herbicides					
MCPA	550 - 1160	>1000	377		LT
2,4-D	<320 - 1000	ca1 500	270 - 1000		MT
2,4,5-T <sup>5</sup>	100 - 500	1535			
Pyridine herbicides					
Picloram	2000 - 8200	>4000	>2000 - 5000		LT
Triclopyr	630 - >2000	>2000	1700	2935 - 3280	LT
Sulfonyl urea herbicides					
Bensulfuron-Me <sup>4</sup>	>5000	>2000	>2510	>5620	LT
Metsulfuron-Me <sup>4</sup>	>5000	>2000	>5000	>5620	
Sulfometuron-Me	>5000	>2000	>5000	>5000	
Thiocarbamate herbicides					
Molinate	370 - 800	>4000		>5000	
Thiobencarb <sup>4</sup>	560 - 1300	>2000	2630	>5000	
Thiram <sup>4</sup>	210 - 2000	>1000	300 - 695	100 - 5000	MT
Triazine & triazole herbicides					
Amitrole	>5000	>200	2000		LT
Atrazine	750 - 3090	>3000	>2000	5000	LT
Cyanazine	140 - 380	>1200	400->2000		LT
Hexazinone	860 - 1690	>5270	2260	>10000	LT
Prometryn	>2000	>2000	>2150	>10000	LT <sup>3</sup>
Simazine	>5000	>3000	>1780	>5000	LT <sup>3</sup>
Urea herbicides					
Diuron	3400	>2000	5000	1730 ->5000	LT
Tebuthiuron	>200 - 640	>200	>2500	>1000	LT
Miscellaneous herbicides					
Acrolein <sup>4</sup>	7 - 29	231	9 - 19		
Bromacil	>3000	>5000	>10000		LT
Glyphosate	750 - 5600	>5000	>3800 <sup>4</sup>	>4500	LT
Imazethapyr <sup>4</sup>	>5000	>2000	>2150		LT
Ioxynil <sup>4</sup>	110 - 230	>2000	75 - 210		
Metolachlor	1200 - 2780	>2000	>2000	>10000	LT
Sethoxydim	2600 - 3100	>5000	>2500	>5600	LT
Trifluralin	>2000	>2000	>2000		LT

1. Data from Kamrin (1997) unless otherwise stated. Refer to original document for information on tests and treatment of data; 2. and other beneficial terrestrial invertebrates. As quantitative toxicity figures were not always reported, there may be variation in interpretation of HT, MT etc; 3. Low toxicity to earthworms; 4. Tomlin (2000); 5. TOMES database; LT = “low toxicity”; MT = “moderate toxicity”; HT = “high toxicity”; Gaps in table indicate that no data were found.

**Table AF18:** Acute toxicities of herbicides to freshwater aquatic organisms<sup>1</sup>: µg/L; 48-96h LC(EC)50

Chemical	Fish		Crustaceans & Insects		Aquatic plants & ciliates	
	n	LC (EC)50	n	LC (EC)50	n	LC (EC)50
<b>Bipyridilium herbicides</b>						
Diquat	17	750 – 300000	6	19 - 46600	4	19 - 73
Paraquat	10	5200 - 156000	7	1300 - 11000	0	
<b>Phenoxyacetic acid herbicides</b>						
MCPA	5	25000 - 621000 <sup>8</sup>	1	11000 <sup>8</sup>	0	130 <sup>6</sup>
2,4-D	23	1.4 - 4800 <sup>8</sup>	10	1.6 - 144 <sup>8</sup>	1	104 - 485 <sup>8</sup>
2,4,5-T	16	150 - 6100 <sup>8</sup>	5	120 - 88000 <sup>8</sup>	0	
<b>Pyridine herbicides</b>						
Picloram	3 <sup>7</sup>	14500 - 55000	1 <sup>7</sup>	51000	3 <sup>2</sup>	36000 - 54000
Triclopyr <sup>5</sup>	2 <sup>7</sup>	740 - 870 <sup>9</sup>	1 <sup>7</sup>	1170000 <sup>10</sup>	1	45000 <sup>4</sup>
<b>Sulfonyl urea herbicides</b>						
Bensulfuron-Me	2 <sup>4</sup>	>150000	5	802 - 12200	0	
Metsulfuron-Me <sup>4</sup>	2	>150000	1	>150000	1	1560
Sulfometuron-Me <sup>4</sup>	2	>12500	1	>125000	0	
<b>Thiocarbamate herbicides</b>						
Molinate	9	43 - 39500	11	180 - 33200	0	
Thiobencarb <sup>4</sup>	14	110 - 2950	6	200 - 9240	3	17 - 3790
Thiram	10	0.3 - 7500	4	60 - 61000	3	1000 - 5000
<b>Triazine &amp; triazole herbicides</b>						
Armitrole	4	65 - 410	2	22 - 58	1	4 <sup>7</sup>
Atrazine	14	500 - 71000	5	5700 - 54000	2	21 - 377
Cyanazine	2 <sup>5</sup>	7500 -18000	1	>42000 <sup>4</sup>	8 <sup>2</sup>	25 - 207
Hexazinone	8	75 - 1620	1 <sup>4</sup>	442000	0	
Prometryn <sup>5</sup>	4	2500 -10000	1	18900	1 <sup>4</sup>	23
Simazine	7	90 - 66000	5	1000 - 3700	2	160 - 320
<b>Urea herbicides</b>						
Diuron	15	500 - 63000	8	160 - 15500	0	
Tebuthiuron	3	106000 - 290000	1	297000	3	10 - 310 <sup>6</sup>
<b>Other herbicides</b>						
Acrolein <sup>4,5</sup>	4	14 - 125	3	51 - 500	0	
Bromacil <sup>4,5</sup>	1	≥71000	1	119000	0	
Glyphosate	11	11 - 9217	4	3 - 62	2	>380000
Imazethapyr <sup>4,5</sup>	3	240000 - 420000	1	>1000000	0	
Ioxynil	1	3300 - 68000	1 <sup>4</sup>	3900	1 <sup>4</sup>	24000
Metolachlor	1	20 - 8600	1	1950	1 <sup>4</sup>	100
Sethoxydim <sup>4,5</sup>	1	38000	1	1500	0	
Trifluralin	12	8.4 - 2200	14	37 - 4200	1 <sup>4</sup>	12200

1. Data from ANZECC & ARMCANZ (2001) unless otherwise stated. Refer to original document for information on screening and treatment of data. Figures significantly exceeding solubility were not included; 2. AQUIRE (1994) Database; 3. NRA (1997); 4. Tomlin (2000); 5. Kamrin (1997); 6. NOEC endpoint; 7. Photosynthetic effects endpoint; 8. acid; 9. ester; 10. Amine; n = Number of species; Gaps in table indicate that no data were found.

**Table AF 19:** Some basic environmental properties of fungicides<sup>1</sup>.

	CAS No.	MW	Water Sol mg/L <sup>2,3</sup>	Log Kow <sup>3</sup>	Log SAC	Water T1/2	Soil D1/2	Notes
<b>Dithiocarbamate fungicides</b>								
Mancozeb	8018-01-7	266	6		>3.3	1 - 2d	1 - 7d	
Thiram	137-26-8	240	30		3.8		15d	Adsorbs
Zineb	12122-67-7	276	10	<1.3	3	Rapid	16d	
Ziram	137-30-4	306	65		2.6	>2mo	30d	
<b>Organochlorine fungicides</b>								
Chlorothalonil	1897-45-6	266	0.6	4.4	3.1	<10w	1 - 3mo	
Hexachlorobenzene	118-74-1	285	0.005		4.7	<5d	2.7 - 7.5y	
Pentachlorophenol	87-86-5	266	80	5.1	1.5	+/-1 d	45d	mobile
<b>Other fungicides</b>								
Benomyl	17804-35-2	291	2		3.3	<1d <sup>4</sup>	3 - 12 mo	
Captan	133-06-2	301	3.3	2.8	2.3	1 - 2d	1-10d	
Metalaxyl	57837-19-1	279	7100	1.75	1.7	>4w	70d	
Thiabendazole	148-79-8	201	<50		3.4	n.a.	400d	Sediment

1. Data from Kamrin (1997), except where indicated; 2. Mostly at 20-25°C; 3. Tomlin (2000); 3. T<sub>1/2</sub> for metabolite of 2 months; SAC = Soil adsorption coefficient; Gaps in data indicate that no information was found.

**Table AF20:** Toxicities of fungicides to terrestrial organisms<sup>1</sup>: figures in mg/kg; LD50

Chemical	Mammals Acute LD50		Birds LD50		Bees <sup>2</sup>
	Oral	Dermal	Oral	Dietary (ppm)	
<b>Dithiocarbamate fungicides</b>					
Mancozeb	>5000	>5000 <sup>5</sup>		3200->10000	LT
Thiram	210 - 2000	>1000	300 – 695	100-5000	MT
Zineb	1850 - 8900	>2500	2000		LT <sup>3</sup>
Ziram	100 - 1400	>6000	56 – 3350		
<b>Organochlorine fungicides</b>					
Chlorothalonil	>6000	>6000 <sup>5</sup>	5000		LT
Hexachlorobenzene	1700 - 4000			570 - 1450	LT
Pentachlorophenol	27 - 300	40 - 1000	380 – 500	>5100	LT
<b>Other fungicides</b>					
Benomyl	>3400	>5000 <sup>5</sup>	100	>10000	LT <sup>4</sup>
Captan	250 -15000	>4500 <sup>5</sup>	2000 – 5000		LT
Metalaxyl <sup>5</sup>	630 - 790	>3100	920->10000		
Thiabendazole <sup>5</sup>	3100 - 3800	>2000	>2250	>5620	

1. Data from Kamrin (1997) unless otherwise stated. Refer to original document for further information and treatment of data, particularly in context of risk; 2. and other beneficial terrestrial invertebrates. As quantitative toxicity figures were not always reported, there may be variation in interpretation of HT, MT etc; 3. Mites are sensitive; 4. High toxicity to earthworms; 5. Tomlin (2000); LT = “low toxicity”; MT = “moderate toxicity”; HT = “high toxicity”; Gaps in table indicate that no data were found.



**Table AF 21:** Acute toxicities of fungicides to aquatic organisms<sup>1</sup>: µg/L; 48-96h LC(EC)50.

Chemical	Fish		Crustaceans & Insects		Algae & ciliates	
	n	LC (EC)50	n	LC (EC)50	n	LC (EC)50
<b>Dithiocarbamate fungicides</b>						
Mancozeb	4	2200 - 9000	1	>40 000	5 <sup>3</sup>	3000 - 12000
Thiram	3	130 - 4000	3 <sup>2</sup>	210	2 <sup>3</sup>	1000 - 5500
Zineb	1	2000	0		1 <sup>3</sup>	500 - 1800
Ziram	1	5000 -10000	0		70 <sup>3</sup>	<4 - 4000
<b>Organochlorine fungicides</b>						
Chlorothalonil	3	250 - 430	3 <sup>2</sup>	70 - >1000000	4 <sup>3</sup>	170 - 270
Hexachlorobenzene	4	11000 - 50000	0		2 <sup>3</sup>	1 - 10000
Pentachlorophenol	25	18 - 1490	30	55 - 42000	7	80 -10300
<b>Other Fungicides</b>						
Benomyl	4	6 - 14000	1	640 - >100000	4 <sup>3</sup>	0.03 - 145
Captan	3	56 - 72	1	7000 - 10000	6 <sup>3</sup>	1000 – 74000
Metalaxyl	3	>100000	1	12500	1 <sup>3</sup>	140000
Thiabendazole	2 <sup>2</sup>	550 – 19000	1	450	1 <sup>2</sup>	9000

1. Data from Kamrin (1997) unless otherwise stated; 2. Tomlin (2000); 3. AQUIRE (1994) Database; n = number of species; Gaps in table indicate that no data were found.

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## **GLOSSARY OF ACRONYMS**

2,4,5-T	2,4,5-trichlorophenoxyacetic acid
2,4-D	2,4-dichlorophenoxyacetic acid (a systematic post-emergence herbicide)
AAPGA	Australian Apple and Pear Growers Association
AAT	Administrative Appeals Tribunal
AAVCC	Australian Agricultural and Veterinary Chemicals Council
ABARE	Australian Bureau of Agricultural and Resource Economics (within AFFA)
ABS	Australian Bureau of Statistics
ACCC	Australian Competition and Consumer Commission
ACGRA	Australian Cotton Growers Research Association
Ach	Acetylcholine
AchE	acetyl-cholinesterase
ACGRA	Australian Cotton Growers Research Association
ACOEM	American College of Environmental Medicine
ADI	Acceptable Daily Intake
AFFA	Agriculture, Fisheries and Forestry – Australia, a Commonwealth department created in October 1998 as a successor to the Department of Primary Industries and Energy
Agvet Code	Agricultural and Veterinary Chemicals Code
Agvet	Agricultural and Veterinary
AHAH or ALS	acetoxyacid synthetase or acetolactate synthetase
ANZECC	Australia and New Zealand Environment and Conservation Council
ANZFA	Australia New Zealand Food Authority
ANZFSC	Australian and New Zealand Food Standards Council
APIC	Australian Potato Industry Council
APLC	Australian Plague Locust Commission
AQIS	Australian Quarantine Inspection Service
ArfD	acute reference dose
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
ATDS	Australian Total Diet Survey
AVCARE	Avcare, the National Association for Crop Protection and Animal Health (a peak industry body)
AVCPC	Agricultural and Veterinary Chemicals Policy Committee
BHC	hexachloro-cyclohexane
BMP	Best Management Practice
BRS	Bureau of Rural Sciences (within AFFA)
Bt	<i>Bacillus thuringiensis</i>
CCAC	Coordinating Committee on Agricultural Chemicals
CCPR	Codex Committee on Pesticide Residues
CCRVDF	Codex Committee of Residues of Veterinary Drugs in Food
CEO	Chief Executive Officer
COAG	Council of Australian Governments (comprising Prime Minister/Premiers of Commonwealth, States/Territories and Chairman of Australian Local Government Association)
Codex	Codex Alimentarius Commission
CPAS	Gatton University Centre for Pesticide Application and Safety
CRC	Cooperative Research Centre
CRDC	Cotton Research and Development Corporation
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DDE	1,1-dichloro-2,2-bis( <i>p</i> -chlorophenyl)ethylene
DDT	1,1,1-trichloro-2,2-bis(4-chlorophenyl) ethane
DNRE	Victorian Department of Natural Resources and Environment

DO	dissolved oxygen
DPIWE	Department of Primary Industries, Water and Environment (Tasmania)
DT50	median degradation time
EA	Environment Australia
ECRP	Existing Chemical Review Program
EEC	estimated environmental concentration
EMS	Environmental Management System
ERL	Environmental Residue Limit
EU	European Union
EVAO	estimated value of agricultural operations
FAO	United Nations Food and Agriculture Organisation
FSANZ	Food Standards Australia and New Zealand (to replace ANZFA)
GAP	Good Agricultural Practice
GATT	General Agreement on Tariffs and Trade (replaced by WTO)
GM	genetically modified
GMO	genetically modified organism
GRDC	Grains Research and Development Corporation
HACCP	Hazard Analysis Critical Control Point
HCB	hexachlorobenzene
HRDC	Horticulture Research and Development Corporation
HT	herbicide tolerant
IEI	idiopathic environmental intolerances
IFCS	Inter-governmental Forum on Chemical Safety
IFP	integrated fruit production
ILO	International Labour Organisation
IPM	Integrated Pest Management
ISO	International Standards Organisation
IWRS	Industry Waste Reduction Scheme
JECFA	Joint FAO/WHO Expert Committee on Residues of Veterinary Drugs in Food
JMPR	Joint FAO/WHO Meeting on Pesticide Residues
<i>K<sub>d</sub></i>	unadjusted observed soil adsorption coefficient
<i>K<sub>oc</sub></i>	organic carbon partition coefficient
<i>K<sub>ow</sub></i>	n-octanol-water partition coefficient
LC50	median lethal concentration
LD50	median lethal dose
LWRRDC	Land and Water Resources Research and Development Corporation (now Land and Water Australia)
MCPA	(4-chloro-2-methylphenoxy)acetic acid, (a systematic post-emergence herbicide)
MCPES	Minnesota Children's Pesticide Exposure Study
MCS	multiple chemical sensitivity
MDBC	Murray Darling Basin Commission
MEMC	methoxymethylmercury chloride
MIA	Murrumbidgee Irrigation Area
MOE	Margin of Error
MOS	Margin of Safety
MPC	Maximum Permissible Concentration
MRL	Maximum Residue Limit
MSDS	Material Safety Data Sheets
NCP	National Competition Policy
NEPC	National Environment Protection Council (comprised of Commonwealth and States/Territories Ministers)
NEPM	National Environment Protection Measure
NFF	National Farmers' Federation

NHMRC	National Health and Medical Research Council
NICNAS	National Industrial Chemicals Notification and Assessment Scheme
NOEL	no-observable-effect level
NOFS	National Office of Food Safety (now Product Integrity – Animal and Plant Health within Agriculture, Fisheries and Forestry Australia.)
NOHSC	National Occupational Health and Safety Commission (C'wlth), formerly Worksafe
NRA	National Registration Authority for Agricultural and Veterinary Chemicals
NRS	National Residue Survey
NSW EPA	New South Wales Environment Protection Authority
NT DPIF	Northern Territory Department of Primary Industries and Fisheries
OC	Organochlorine Pesticide
OECD	Organisation for Economic Cooperation and Development
OHS	occupational health and safety
OP	organophosphorus pesticide
OPIDP	organophosphate-induced delayed polyneuropathy
PCBs	polychlorinated biphenyls
PIC	Rotterdam Convention on the Prior Informed Consent Procedures for Certain Hazardous Chemicals and Pesticides in International Trade
PIRI	Pesticide Impact Ranking Index
PIRSA	Primary Industries and Resources South Australia
POEM	Predictive Operator Exposure Model
PTWIs	provisional tolerable weekly intakes
QA	quality assurance
QDPI	Queensland Department of Primary Industries
QDNRM	Queensland Department of Natural Resources and Mines
R&D	research and development
RMG	Residue Management Group
SAC	soil adsorption coefficient
SCARM	Standing Committee on Agriculture and Resource Management
SDMP	spray drift management plan
STA	Supermarket to Asia
$t_{1/2}$	half-life
TGA	Therapeutic Goods Administration (Commonwealth)
TGAC	technical grade active constituent (pesticide)
TT	triazine tolerant
ULV	ultra-low volume (spray)
UNEP	United Nations Environment Program
US EPA	United States Environmental Protection Agency
USDA	United States Department of Agriculture
VDMA	Veterinary Manufacturers and Distributors Association
VFF	Victorian Farmers Federation
Vic EPA	Victorian Environment Protection Authority
WAWA	Western Australian Water Authority
WHO	World Health Organisation
WTO	World Trade Organisation

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