Monitoring Pesticides - A Review

A Report to the

Environmental Protection Authority

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Perth, Western Australia
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by
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1. INTRODUCTION

For centuries man has been controlling pests that compete for his food supply, endanger his health or interfere with his comfort. Until the mid-nineteenth century, pest control was effected by mechanical means, which for agriculture necessitated labour intensive operations. Since then, chemical pest control has developed into the multi-national industry it is today.

The first recorded use of a chemical pest control agent was the use of sulphur for fumigating the home in ancient Greece (about 1000 BC). Since that time arsenic has been used by the Chinese to control garden pests, and in 1649, rotenone was used to paralyze fish in South America.

Pyrethrum, lime and sulphur combination, arsenic, sulphur, mercuric chloride and soaps were all introduced in the early 1800s. These and other, largely inorganic, chemicals were in general domestic and agricultural use until 1936 when pentachlorophenol was introduced as a wood preservative (Ware, 1983).

This heralded the beginning of a pest control revolution, in which well known organic chemical pesticides, such as DDT, 2,4-D, captan, and atrazine were developed. In the early days - 1940-1960, most organic pesticides were fairly broad spectrum in their application. Recent years, however, have seen the development of complex organic chemicals which are more target-specific, and also satisfy the community's increasingly strict needs for human and environmental safety.

Pesticides are chemicals designed to kill pests. Because pesticides are biologically 'active', it is inevitable that some environmental effects will result from their use. Many of the environmental effects of pesticides will be minor, and these can usually be accommodated by the environment. Some effects may be beneficial. However, there is no doubt that some pesticide uses produce, either directly or indirectly, significant undesirable impacts on the environment.

In 1985 a Canadian researcher, Catherine Jefferson, who was temporarily employed by the Western Australian Department of Conservation and Environment (now EPA), reported that significant undesirable impacts by pesticides in WA may be occurring, and that monitoring systems, by various State Government agencies, then in place, would be unlikely to detect them.

As a result, the Environmental Protection Authority (EPA) has commissioned this study. The author, Peter Rutherford, is Pesticide Coordinator of the WA Department of Agriculture and was seconded to the EPA for three months, commencing in June 1987.

However, the pesticide residue crisis which hit the beef industry in mid-1987 necessitated the author's return to the Department of Agriculture in mid-July 1987, to assist with the management of the problem. He was not able to complete his secondment until November-December 1988.

The aims of the study were to:

1. Review existing use patterns of pesticides in Western Australia, identifying actual and potential environmental impacts.

2. Review past and current procedures, being conducted by State Government and other agencies, to monitor the environmental impact of pesticides.

3. Discuss the adequacy of existing programmes on an ecosystem basis, and

4. Make recommendations to the EPA regarding future monitoring needs, and any other action that should be taken to eliminate or minimise environmental impacts of pesticides.

The study was confined to:

1. Pesticides, as defined in the Health (Pesticides) Regulations of the Health Act, viz:

   "a substance or compound used or intended for use for agricultural, pastoral, horticultural, domestic, or industrial purposes for controlling, destroying, or preventing the growth and development of, any fungus, virus, insect, mite, mollusc, nematode, plant or animal and includes all preparations and admixtures containing any proportion of any one or more of them;"

   This definition excludes veterinary drugs and fertilisers.

2. The natural and physical environment, including water, soil, air and all natural animals and plants that are part of the environment. The effects of pesticides on man, domestic animals, agricultural crops and any residues in agricultural produce were excluded from the study.

<u>Summary of recent events</u>

The 'beef residue crisis' previously referred to, forced governments, the agricultural industry, and the community at large, to make adjustments to their use of certain pesticides, and to their perception of pesticide use generally. These changes have implications for the direction of this report, so it is relevant to provide the following summary of events and outcomes.

. The US Department of Agriculture detected three high DDT residues in one consignment of beef imported from Australia.

  This discovery, together with some later violative residues of DDT and dieldrin which were found, threatened the $750 million beef export industry to the USA.

. Commonwealth and State governments, and industry, reacted quickly by setting up residue detection screening at all export, and many domestic, abattoirs. This resulted in many beef properties having restrictions placed on their beef cattle sales and movements. This is ongoing in all States.

. State governments completely banned all remaining uses of DDT, and removed all registered agricultural uses for dieldrin, heptachlor and chlordane.

  In WA, DDT was deregistered on 27 July 1987, and the other organochlorines were restricted to the control of termites in the building industry, and in the case of heptachlor, also for Argentine Ant, and Singapore Ant control, in September 1987. The availability of these chemicals was also limited to licensed pest control operators.

- In February 1988, the State Government temporarily suspended the use of heptachlor for Argentine Ant control because of public concerns over human health and environmental contamination. The EPA was requested to review the use of heptachlor for the control of Argentine ants and subsequently released a discussion paper (EPA Bulletin 325) which sought public comment.

  The review was later extended to include the use of heptachlor for termite control. The EPA published its report to the Minister for Environment, after considering public submissions, as Bulletin 354, in October 1988. The main thrust of this report was that Heptachlor should not continue to be registered for Argentine Ant control, but that its registration as a termiticide should remain. The State Government agreed to this recommendation and the Commissioner for Health, acting on the advice of the Pesticides Advisory Committee, removed the registration of heptachlor for Argentine Ant control in late 1988.

  The outcome of these events is that the only registered use for Heptachlor, chlordane, aldrin and dieldrin are as termiticides in the building industry. In addition these events have considerably increased public awareness of the uses of pesticides in the production of food, and in the control of urban pests. This increases the need for Government agencies to be more accountable regarding pesticide uses, and to be more aware of public health and environmental impacts.

2. RECOMMENDATIONS

1. The Government should give consideration to expanding the scope of the Dangerous Goods (Road Transport) Regulations 1983 to include those additional pesticides which are deemed by the Environmental Protection Authority to be of environmental concern.

2. The Recommendations of the Stored Chemicals Sub-Committee, presented in its final report of February 1986, should be implemented as soon as possible.

3. The Department of Agriculture should carry out an extension programme on the safe storage of pesticides on farms and other private property.

4. The Health Department, in conjunction with the Department of Agriculture and the Environmental Protection Authority, should draw up guidelines for the disposal of pesticide containers on farms, and on Local Authority tipsites. These will complement amendments to the Health (Pesticides) Regulations which came into effect on 1 January 1989.

5. The Government should investigate ways of encouraging the use of pesticide drum-crushing contractors as a means of disposing of unwanted used containers.

6. The Roadside Conservation Committee should continue to investigate reports of herbicide damage to native vegetation, and if necessary, recommend ways of minimising the problem.

7. The Department of Conservation and Land Management should re-introduce a monitoring programme for pesticide residues in the Australian Magpie (<u>Gymnorhina tibicen</u>).

8. The Agriculture Protection Board, in conjunction with the Department of Agriculture, should investigate the possibility of using the European Wild Rabbit (<u>Oryctolagus Cuniculus</u>) as a means of monitoring organochlorine (and other) pesticide residues in WA land and vegetation.

9. The Water Authority of Western Australia should extend its pesticide residue monitoring programme to include all major river systems which drain agricultural land.

10. The Environmental Protection Authority and Waterways Commission should continue to monitor pesticide residue levels in water, sediments and indicator organisms in estuaries.

11. A research project into the levels of pesticides found in rainfall over the coastal plain should be carried out by an appropriate body, such as the Chemistry Centre of WA, Murdoch University or CSIRO.

12. The Health Department should extend the analysis of water samples, taken from permanent bores at rubbish tips, to include pesticide residues, particularly the organochlorine insecticides.

13. The Department of Conservation and Land Management, as the manager of Western Australia's fauna, in conjunction with other managers of wetlands, should monitor wetlands for pesticide residues, and their effects on wetland ecology.

14. The Department of Marine and Harbours should extend their harbour water sampling programme to include sediments, and analysis for pesticide residues.

15. A Coordinating Committee for Environmental Monitoring of Pesticides should be established and serviced by the Department of Agriculture. It may be appropriate for the Committee to report to the WA Advisory Committee on Hazardous Substances (WAACHS).

16. The Department of Agriculture should increase its commitment of financial and human resources for the adequate monitoring of pesticides and the effects in the rural environment.

3. CLASSIFICATION OF PESTICIDES

There are many ways of classifying pesticides, such as by chemical type, or use pattern, or by mammalian toxicity. Each of these methods is useful in certain situations.

The most useful classification for the purposes of this Report is by use, and within uses, by chemical type.

Most pesticides fall into three main groups according to their use:

. Herbicides - control weeds.
. Fungicides - control plant diseases.
. Insecticides- control insects, nematodes and mites.

Pesticides which do not fall into these three groups can be conveniently called Miscellaneous Pesticides. They include:

. Rodenticides - control rodents and vertebrate pests.
. Plant Growth Regulators - regulate plant growth.
. Algicides - control algae (eg swimming pools)
. Molluscicides - control snails and slugs.
. Fumigants - fumigate soils, plants, produce etc.

Herbicides

This is a very large group of chemical types which vary in the way in which they are absorbed by the weed, how selective they are, how persistent they are in the soil, and their degree of volatility.

Some of the more important types are:

- phenoxys : eg 24-D, 245-T, MCPA.
- ureas : eg diuron, linuron, ethidimuron.
- uracils : eg bromacil.
- aliphatics : eg glyphosate, 2,2-DPA, acrolein.
- sulphonylureas : eg chlorsulphuron.
- triazines : eg atrazine, simazine, hexazinone.
- bipyridyls : eg paraquat, diquat.
- dinitroanilines : eg trifluralin.
- nitriles : eg bromoxynil.
- benzoics : eg dicamba.
- miscellaneous : eg amitrole, picloram, triclopyr.

Only the ester formulations of the phenoxy herbicides, and picloram, triclopyr and dicamba are sufficiently volatile to potentially damage non-target vegetation at some distance from the site of application.

In addition, only a relatively few herbicides are considered to be soil-persistent, for example diuron, ethidimuron, atrazine, hexazinone, bromacil and chlorsulphuron.

Fungicides

Fungicides are important in horticultural industries, and considerable use is still made of older inorganic fungicides, as well as more modern synthetic organic chemicals.

The main types are:

- inorganic : eg sulphur, copper.
- dithiocarbamates: eg mancozeb, maneb, ziram.
- aromatics : eg chlorothalonil.
- phenols : eg pentachlorphenol, dinocap.
- systemics : eg benomyl, thiabendazole, carboxin.

Fungicides generally are biodegradable, are of short persistence and are relatively insoluble in water. Mercury-based fungicides are extremely persistent, as well as being ecotoxic, but have not been used in WA for some years.

Insecticides

This is an important group of pesticides that probably account for most of the environmental problems attributed to pesticides. The important types of insecticide are:

- inorganic : eg arsenic, sulphur.
- botanicals : nicotine, pyrethrum, rotenone.
- dinitrophenols : eg dinoseb, binapacryl, DNOC.
- petroleum oils : eg kerosene and other hydrocarbon oils.
- organochlorines : eg DDT, dieldrin, heptachlor.
- organophosphates : eg malathion, fenitrothion, chlorpyrifos.
- carbamates : eg carbaryl, propoxur.
- synthetic pyrethroids : eg cypermethrin, deltamethrin, fenvalerate.

Insecticide types vary considerably in the characteristics which may affect the environment. The organochlorines are largely insoluble in water, are soluble in lipid materials, resist biodegradation, and are readily bioaccumulated. The other insecticide types exhibit almost opposite characteristics to the organochlorines. They are more water soluble, less persistent and most are readily biodegradable. Fenitrothion and chlorpyrifos are two of the more longlasting of the organophosphates, with half-lives measured in weeks. The organochlorines, on the other hand, have half-lives which are measured in years.

Miscellaneous Pesticides

These pesticides perform important functions but are of relatively minor importance in terms of the quantities used. This is not to say that the effects on the environment of some of these chemicals are not significant. Examples of the different types are:

- rodenticides : eg warfarin, bromodiolone.
- plant growth regulators : eg paclobutrazol, NAA, ethephon.
- algicides : eg benzalkonium chloride.
- molluscicides : eg metaldehyde, methiocarb.
- fumigants : eg methyl bromide, phosphine.

There are several excellent sources of information which will give much more detail than can be included here. These are listed at end of this report in Section 7.

4. PESTICIDE "LIFE-CYCLE", DESCRIPTIONS AND ENVIRONMENTAL IMPACTS

4.1 INTRODUCTION

The use of synthetic organic chemicals as pesticides in Western Australia, as in other States, can be traced back to the end of the Second World War which saw the introduction of herbicides such as 2,4D, and insecticides such as DDT. Early acceptance of these and other chemicals by farmers paved the way for the growth of the agrochemical industry, which sold in excess of $70 million worth of pesticide products in this State in 1987.

Table 1. Pesticide Sales (WA) ($000s)

	1978	1980	1982	1984	1986	1987
Herbicides	7,386	18,517	29,616	52,769	46,338	58,460
Insecticides	2,664	3,274	4,489	4,731	5,900	6,877
Fungicides	925	1,458	2,130	3,101	2,614	3,388

Table 1 gives the breakdown of pesticide sales for selected years since 1978. In addition to herbicides, insecticides and fungicides, there are a few other chemical types, such as fumigants, plant growth regulators and home garden products, not itemised separately. Table 1 shows that herbicides have accounted for most of the growth in sales experienced in recent years. Insecticide and fungicide sales have risen slowly, but have declined as a proportion of the total pesticide market.

While agriculture has been, and will continue to be, the primary justification for the development of new pesticides, the non-agricultural use of pesticides has become significant. An estimate of the significance of these two main sectors of the pesticide market is shown in Table 2.

Table 2. Estimate of the percentage of 1987 pesticide sales attributable to each sector.

	HERBICIDES	INSECTICIDES	FUNGICIDES
Agricultural	>95%	>80%	>99%
Non-Agricultural	<5%	<20%	<1%

These tables show that a significant proportion of insecticides is used for non-agricultural uses. These are largely confined to urban pest control and control of biting and nuisance insects in urban wetlands.

Table 3. Numbers of pesticide active constituents registered in WA on 31 December 1986 devoted to agricultural, non-agricultural uses and dual use.

	HERBICIDES	INSECTICIDES	FUNGICIDES	TOTAL
Agricultural	50	56	46	152
Non-agricultural	32	39	16	87
Both	6	21	8	35
TOTAL	88	116	70	274*

* In addition, there are 45 miscellaneous pesticides registered that are not included here; for example - swimming pool chemicals, dairy sanitizers. The total number of registered active constituents is 319.

Some of these non-agricultural uses are significant enough to justify the development and registration of specific pesticides, without the need to have additional agricultural uses. Examples are the industrial herbicides, bromacil and ethidimuron. In some cases, the use patterns have declined over the years, from widespread agricultural and non-agricultural uses, to a few specific non-agricultural uses. The cyclodiene organochlorines, dieldrin and heptachlor are, as mentioned previously, now registered only as termiticides in the building industry.

The following sections of the report analyse the different components of the 'life-cycle' of pesticides, ie, manufacture and formulation, storage and transport, agricultural and non-agricultural use, and disposal, identifying any environmental impacts. Not every pesticide is discussed in detail, but many are used as examples to illustrate the various use patterns.

4.2 MANUFACTURE AND FORMULATION

The manufacture of pesticides has never been a major activity in Western Australia. Only one company based at Kwinana manufactures pesticide active constituents.

Several companies are involved in formulating pesticides. This involves the conversion of a technical active constituent into a form which can be used by the consumer. Formulation involves dilution with a solvent (which may be water), and the addition of "additives", such as emulsifiers, stabilisers, and surfactants. In the case of pesticide products which contain several active constituents, the formulation process may be complex.

A few companies repack already formulated products into either their own labelled container, or into smaller pack sizes for the domestic and home garden market.

Nevertheless, most pesticide products are formulated in other States and transported to WA ready for use.

All manufacturing/formulation/repacking takes place in metropolitan Perth.

Actual and Potential Environmental Impacts

1. The pesticide manufacturing plant at Kwinana under the original owners and operators, caused significant contamination of groundwater in the area with 2,4,5-T and 2,4-D phenoxy herbicides. While 2,4,5-T is no longer made in WA, the plant continues to manufacture 2,4-D, together with other pesticides.

2. Soil and groundwater contamination as a result of spillage at any facility that manufactures or formulates pesticides.

3. Air pollution resulting from operational malfunction or fire at a pesticide manufacturing and formulating facility, and at distributor and retail storages.

4.3 TRANSPORT AND STORAGE

Transport and storage are important activities in WA because the use of pesticides is so widespread, particularly in agriculture, and because the source of chemicals is in Perth.

Transport

Pesticides are transported into WA from other States and overseas. They are transported to distributors' warehouses, thence to retailers' stores, particularly in rural areas, and from there to the user.

Because of the large quantity of pesticides transported in WA, the potential for environmental damage is high in the event of a major spill. The pesticide, the quantity spilled and the location of the spillage will largely determine the seriousness of a spill in environmental terms.

All phases of pesticide transport in WA are controlled by the provisions of the Dangerous Goods (Road Transport) Regulations 1983 administered by the Explosives and Dangerous Goods Division of the Mines Department. This applies only to those pesticides classified as Dangerous Goods.

These regulations provide for different levels of care in transport based on potential human toxicity of the pesticide in the event of a spill. However, the regulations do not address the question of environmental toxicity. Many pesticide products are not subject to the Regulations because they are insufficiently toxic to humans. However, some of these pesticides may be potentially environmentally damaging, because of, for example, soil persistence, or extreme toxicity to aquatic life.

Storage

Pesticides are stored in large quantities in warehouses, stores and on farms throughout WA, in addition to small quantities stored in domestic premises in urban areas. These storages do not present an environmental threat unless they leak from the container, or are affected by fire or other such natural disaster, such as floodwaters, storm damage etc. The potential for such events may be enhanced by poor storage facilities, or the storage of incompatible materials in close proximity. The regulatory changes proposed by the stored chemicals report of the one time Community Consultative Committee on Chemicals would provide great improvement in the control of many chemical stores. However, many private chemical stores, especially on farms, would be untouched by any regulations, and their safety, both in terms of occupational health, and the environment, would depend on the commonsense and level of knowledge of the owner.

Actual and Potential Environmental Impacts

1. Soil and groundwater contamination as a result of spillage during transport and storage of pesticides.

2. Air pollution resulting from the spillage of pesticides during their transport and storage.

RECOMMENDATION 1

The Government should give consideration to expanding the scope of the Dangerous Goods (Road Transport) Regulations 1983 to include those additional pesticides which are deemed by the Environmental Protection Authority to be of environmental concern.

RECOMMENDATION 2

The recommendations of the Stored Chemicals Sub-Committee, presented in its final report of February 1986, should be implemented as soon as possible.

RECOMMENDATION 3

The Department of Agriculture should carry out an extension programme on the safe storage of pesticides on farms and other private property.

4.4 AGRICULTURAL USE

As previously mentioned, agriculture accounts for by far the largest proportion of pesticide usage, in both quantity and range of chemicals. Statistics provided by the Australian Bureau of Statistics (ABS) show that of the nearly 16 million hectares of land cleared for agricultural use in WA, almost 4.6 million hectares were treated with pesticides in 1985/86.

The proportion of this area treated which can be apportioned to broadacre and horticultural use can only be estimated, but it is safe to say that the vast majority of the 4.6 million hectares would be allocated to broadacre agriculture.

"Broadacre" is an extensive form of agriculture involving cereal, legume or oilseed cropping, and is usually associated with livestock grazing on rainfed pastures.

Most of the "broadacre" hectares receive one pesticide application per year (usually a herbicide), with some receiving two or more applications. However, horticultural land receives multiple pesticide applications every year.

The following sections give details of the use of pesticides by the various components of agriculture.

4.4.1 BROADACRE CROPS AND PASTURES

Description and Location

This component of the agricultural sector uses the widest range and the largest quantity of herbicides, although insecticides, and to a much lesser extent, fungicides, are also important.

Description and Location

Activities included in this component are the production of cereals, protein crops (lupins, peas), oilseed crops (rapeseed, linseed), fodder crops (lucerne), and annual and perennial pastures - both irrigated and rain fed.

These activities take place on the largest proportion of agricultural land in WA. Cereal cropping extends over the lower and medium rainfall areas of the wheatbelt, but becomes limited in higher rainfall areas west of the Albany Highway. Lupin cropping predominates in the lighter soils north and east of Perth, and oilseed cropping is limited to south coastal areas between Albany and Esperance.

Irrigated lucerne growing is restricted to sandy soils between Mandurah and Bunbury, with a small industry developing in the Gingin district. Perennial pastures are restricted to high rainfall coastal areas, servicing the dairy industry. Annual (rainfed) pastures are common throughout the whole South West region of WA.

Methods of Application

All pesticides can be applied by boomspray to both crops and pastures, and this method of application accounts for over 88% of the area covered by all pesticide applications in the agricultural sector (ABS statistics).

Application by mister accounts for almost 8% of the area of all pesticide applications in this sector. However, in broadacre agriculture it only seriously rivals the boomspray in the application of insecticides to pasture, accounting for almost 40% of the area covered by applications, compared to almost 57% for boomspray applications. Applications by mister are restricted, on broadacre agriculture, to certain ester formulations of the phenoxy herbicides, and some oil-based insecticides.

Many pesticides can be applied by aircraft, however, some herbicide formulations are not easily applied by air, and some individual chemicals are prohibited from aerial application, for example, paraquat/diquat formulations.

Aerial application accounts for just over 3% of the area covered by all pesticide application in agriculture. However, its biggest contribution is in the application of herbicides and insecticides to cereal crops where it accounts for 3.2% of the area covered. In certain districts, aerial application predominates, for example in the South-Eastern statistical division, aerial application of insecticides accounts for almost 65% of the 34,000 ha treated in 1985/86.

Of the three application methods discussed, the mister is the least accurate, but is also the least expensive and quickest. The boomspray is the most accurate method of application and is preferred for most herbicide application to crops. The aircraft is reasonably accurate, costs much the same as the boomspray, but does not damage the crop with wheel tracks. Where accuracy of application is not critical, and large areas have to be covered quickly, the mister is satisfactory. However, the drift potential from poor application technique when using a mister is much greater than from a boomspray.

Actual and Potential Environmental Impacts

1. Contamination of water bodies, particularly with DDT. DDT was used extensively in the cereal growing areas for control of Webworm (Hednota spp) for well over twenty years until its deregistration in July 1987. DDT usage in WA for this purpose peaked in 1983 when an estimated 216,000 kg active DDT was used. Although it was registered for webworm control at 500 g active per hectare, most farmers used it at 250 g active per hectare, with every crop.

2. Contamination of water courses with herbicides by run-off from agricultural land.

3. Loss of roadside and on-farm trees as a result of drift from the ground and aerial application of herbicides to crops, and to a lesser extent, pastures.

4. Decline in bird numbers and diversity of species through indirect and direct effects of the use of pesticides. Indirectly through tree decline (see 3 above) and due to the loss of insects for food through insecticide treatments in crops and pastures. Directly by exposure to treated crops and pastures. This may be more critical for ground-living and/or grain-eating bird species.

   There is also the possibility of decline in numbers of birds of prey due to the biomagnification of DDT used on farms (see 1 above).

5. Reduction in soil erosion. This is a positive environmental impact following the widespread use of the bipyridyl herbicides in cereal establishment since the early 1970s as an alternative to multiple cultivations of wheatbelt farms.

4.4.2 HORTICULTURAL CROPS

Horticultural enterprises do not use the wide range of herbicides used in broadacre farming, but use a large number of insecticides and fungicides.

Horticulture is intensive agriculture, where both inputs, and productivity are high. As previously mentioned, many horticultural crops, particularly vegetable row crops, receive multiple application of pesticides over the production life of the crop. Thus the environmental challenge per unit area of land by pesticides is relatively high.

4.4.2.1 Fruit Trees and Vines

Description and Location

This is an important component of horticulture, and covers the production of pome, stone, citrus and nut tree fruits, as well as grapevines for both wine and tablegrape production.

The total area under fruit trees is over 5,800 ha. Most fruit trees are grown in the hills area east of Perth, and in various localities of the south west, such as Donnybrook, Manjimup and more recently, Gingin.

Grapevines are grown principally in the Swan Valley, Margaret River/ Busselton, and Mt Barker, Albany and Denmark. Some vineyards are also established at Gingin. The total area under grapevines exceeds 2,100 ha.

All activities are expanding, in particular, vineyards at Margaret River, and citrus and nut trees at Gingin.

Pesticides used.

Herbicides are not used extensively, except in vineyards where a few herbicides are used selectively for weed control. Most common are the non-selective herbicides paraquat, diquat and glyphosate, particularly in orchards.

Insecticides and fungicides are heavily used, both in terms of quantity and range of chemicals. In orchards, until recently, DDT was registered for Dimple Bug control and was the preferred chemical even though alternatives are registered. In vineyards, some growers have used dieldrin (illegally) at planting to protect the young vine from termite attack. Other insecticides used are organophosphates, carbamates and synthetic pyrethroids.

Methods of application

In orchards, herbicides are applied by boomspray or, in small areas, by knapsack. Insecticides and fungicides are invariably applied by airblast sprayers.

In grapevines, pesticides may be applied by both boomspray or single-nozzle sprayer, either tractor mounted or hand held.

4.4.2.2 Vegetables

Description and Location

Vegetable growing is of equal importance, in terms of pesticide use, to fruit trees and vineyards. ABS statistics show that over 7,500 ha of vegetable crops were planted in 1985/86. However, over 18,000 ha were sprayed with pesticides! This indicates that most crops were treated twice, and some three or more times.

Vegetable crops are grown in the Wanneroo, Balcatta and Spearwood areas of Perth, as well as at Harvey, Bunbury, Donnybrook, Bridgetown, Manjimup and Mt Barker/Albany. Tomato crops are grown at Geraldton and Carnarvon. Carnarvon also produces significant quantities of melons and onions. Kununurra is developing as a producer of vegetables. Potatoes account for over 30% of all vegetable plantings, with around 2,000 ha. These are grown principally in the Bunbury, Bridgetown, Manjimup and Albany districts.

The vegetable industry is expanding slightly overall, although the plantings of individual vegetables fluctuates considerably. Potato plantings, because of their production is under quota from the Potato Marketing Board, are relatively stable.

Pesticides used

Many types of herbicides, fungicides and insecticides are used in vegetable production. Of the 18,000 ha sprayed, 4,000 ha was sprayed with herbicides, 6,000 ha with fungicides and 8,000 ha with insecticides. Of the organochlorine insecticides, heptachlor was registered, and used, in potato cropping. However, its use in agriculture has been terminated. Chlorpyrifos (an organophosphate) is becoming widely adopted as a replacement.

Methods of application

All pesticides would invariably be applied with a boomspray. However, some aerial application is carried out, (up to 2,000 ha) mostly in the South West, the Albany area and in the Kimberleys.

4.4.2.3 Floriculture and Turf Production

Description and Location

This is a rapidly growing horticultural industry and comprises the following activities:

- cut-flower (exotics) production - both in open fields and in green houses;
- native flower production;
- wholesale and retail nursery stock production, and
- wholesale and retail production of turf.

Floriculture

The cut-flower industry, primarily producing greenhouse roses, and greenhouse and field carnations for domestic consumers, uses the greatest quantity and range of pesticides of any floriculture activity.

The wholesale nursery trade uses some pesticides, however, pesticide use in the expanding export orientated, native flowering plants is minimal.

Most cut-flower production is located in or around Perth. In contrast, the native flower industry is developing in two directions, between Bunbury and Albany and between Perth and Geraldton. Proteas, Geraldton Wax and other wildflower species predominate.

Pesticide application in the field is by boomspray or knapsack, while applications in greenhouses are by a variety of means, including knapsacks, single nozzle lance applicators, and in some bigger operations, fixed overhead nozzles.

Commercial Turf Production

Commercial turf farms are also expanding, with almost 200 ha under grass at present. Pesticide use in this industry is variable, but many growers would use bromoxynil/dicamba/MCPA herbicide mixtures for broadleaf weed control. Not much fungicide or insecticide is used.

The majority of turf farms are north of Perth, around Wanneroo (the largest property of over 100 ha is at Carabooda), but others are at Boyanup, Mandurah, Jandakot and Wattle Grove.

All pesticide use is by boomspray.

4.4.2.4 Tropical Agriculture

Description and Location

This is an important, and expanding, agricultural activity. It involves the production of both field crops and traditional horticultural crops, both fruits and vegetables.

Specific components include:

- tree crops eg Avocados, bananas, cashews;
- field crops eg Sorghum, sunflowers, peanuts, soybean, mungbean;
- vegetable crops eg melons, beans, cabbages, carrots, onions, potatoes, tomatoes.

The major centres of tropical production are Carnarvon and Kununurra, however, some horticultural development is occurring in the Pilbara, and at Broome and Derby. Carnarvon is the major centre for the production of bananas, melons, mangoes, pawpaws, sweet potatoes and some citrus and stone fruits. Kununurra is still a developing area, but produces commercial quantities of soybean, sorghum, maize, chickpea, mung beans, peanuts and some other vegetables.

<u>Pesticides used</u>

Because the sub-tropical and tropical conditions at both Carnarvon and Kununurra respectively are favourable to rapid weed and pest growth, pesticide use is relatively high.

The insecticides used are organophosphates, carbamates and synthetic pyrethroids. No organochlorines are registered for these uses, but dieldrin was used on bananas at Carnarvon, and heptachlor on peanuts and other crops at Kununurra, prior to the recall of these chemicals from farming properties in August 1987.

<u>Method of Application</u>

At Carnarvon, pesticides are invariably applied by boomspray, with the occasional use of hand-lead or knapsack equipment. At Kununurra, most pesticides are applied by air; less than 20% of applications would be by boomspray.

<u>Actual and Potential Environmental Impacts</u>

1. Groundwater pollution. The presence of a large proportion of our horticultural industry on the coastal sandplain creates a potential source of pesticide residues in underlying ground water.

2. Air pollution. Many market gardens and orchards are in close proximity to suburban dwellings. There are several cases on record of complaints about alleged overspraying.

3. Bird deaths. The heavy use of insecticides in orchards has the potential to cause deaths in species of birds which are fruit eating or which nest in fruit trees.

4. Waterway pollution. The use of the organochlorine insecticides in horticultural production has been the source of contamination of major river systems in the South West (Atkins 1982).

4.4.3 ANIMAL HUSBANDRY

<u>Description and Location</u>

This activity involves the control of parasites, both internal and external, on domestic animals. In effect, this covers the control of lice, fleas, ticks, fly maggots etc on both agricultural livestock, and domestic pets, and the control of internal parasitic worms.

This is a substantial industry, with product sales approaching $5 million annually, the greater proportion of this amount being spent on agricultural livestock.

In agriculture, the ectoparasiticides (for external pests) are applied to animals in yards, or by driving them through plunge or shower dips. The frequency of application is usually once per year, particularly with sheep, which are usually treated immediately after shearing. In the case of pigs or poultry, which are often housed, more frequent application may be carried out.

In the agricultural areas, most farmers treat their own stock with their own facilities. Plunge, and to a lesser extent, shower dipping has given way in recent years to a back-line pour-on treatment in mustering yards.

In the pastoral areas, stock are usually plunge dipped on the station. In the case of cattle sold for slaughter at southern abattoirs, dipping takes place in a plunge dip at the point of loading the ship, for example, at Broome.

With domestic pets, ectoparasiticides are applied either as a powder, brushed into the animal's coat, a washing solution for use in a bath, or as a collar or medallion worn continuously by the animal.

The endoparasiticides (for internal parasites), are usually applied as an oral drench with a special applicator gun. Some of these products are also formulated to be applied as a subcutaneous injection.

Pesticides used

A wide range of organophosphate, carbamate and pyrethroid insecticides are registered for ectoparasite control on livestock and pets. However, not all pesticides are used on both types of animals, as the following lists show:

Table 4. Insecticides registered for use on livestock and pets for ectoparasite control

LIVESTOCK	PETS	BOTH LIVESTOCK AND PETS
cyromazine	allethrin	coumaphos
amitraz	carbaryl	diazinon
chlorfenvinphos	cythioate	fenthion
chlorpyrifos	dichlorophen	malathion
ethion	dichlorvos	pyrethrins
temephos	iodofenphos	rotenone
cyhalothrin	propoxur	
cypermethrin	trichlorfon	
deltamethrin		

Table 5. Some Endoparasiticides registered for use on livestock

albendazole	ivermectin
arsanilic acid	levamisole
avermectin B1	mebendazole
carbadox	niclosamide
closantel	oxfendazole
dichlorophen	piperazine citrate
diethyl carbazine citrate	rafoxanide
febantel	thiabendazole
fenbendazole	

Actual and Potential Environmental Impacts

1. Contamination of a waterbody by dumping dip solutions into a creek, or onto land where the water table could be affected.

2. The use of avermectin and ivermectin drenches can lead to reproductive failures in dung beetle populations at certain times of the year. The adult beetles are not affected directly by residues of these chemicals in fresh dung from treated animals (T.J Ridsdell - Smith, 1988)

4.4.4 MISCELLANEOUS

4.4.4.1 Stored Grain Protection

Grain production is a major industry in WA, and as the majority of grain production is sold for export, grain storage is also extensive. This presents problems of protection from insect pests.

Stored Grain Protection can be examined in two parts - on, and off the farm.

On-farm grain protection

Most cereal grains harvested are immediately delivered to Cooperative Bulk Handling, therefore any grain stored on farm is usually destined for sowing the following crop or for stockfeed. Farmers have traditionally used malathion as a grain protectant, added when the grain is first placed in storage. In recent years, with the development of malathion - resistant insects, farmers and are successfully storing grain in air-tight storages and keeping it insect-free by fumigating with phosphine gas (generated from aluminium phosphide tablets). A new protectant, not an insecticide, called "Dryacide" has gained wide acceptance. This product, composed of amorphous silica, coats the grain, and abrades the outer skin of the insect, leading to its eventual dehydration.

Fenitrothion is registered for use by farmers as an insecticide for the control of grain insects in farm machinery and to clean out storage units prior to adding the grain. Farmers are not allowed to use fenitrothion on grain, as this use is restricted to Cooperative Bulk Handling, but there is no doubt that many farmers do, as fenitrothion-resistant insects are also found on farms. This practice could present CBH with problems of grain insect control in bulk storages.

Off-farm grain protection

The bulk of WA's grain production is delivered immediately after harvest to receival bins owned and operated by Cooperative Bulk Handling (CBH). CBH is responsible for receiving, storing, handling and shipping grain to overseas buyers. It therefore has a major grain protection responsibility to ensure that grain delivered is as insect-free as possible, certainly within the tolerance limits of the purchasing country. CBH's problems are compounded by the length of time that they may have to hold stored grain, much of it in remote country locations, before it is delivered to the port for loading.

The following pesticides are used by CBH for grain protection:

- fenitrothion - all incoming grain is treated (except lupins, and grain into 'sealed' storage);
- chlorpyrifos -methyl - all lupins received (except into 'sealed' storage);

- dichlorvos - for infested grain when outloading;
- bioresmethrin - limited usage;
- pyrethrum - limited to grain containing fenitrothion resistant insects;
- phosphine gas - sealed storages - widely used;
- carbon dioxide - sealed storages - seldom used.

Application Methods

All insecticides added to grain are applied to the grain on receival, before admixture in the store.

Fumigation is carried out by allowing aluminium phosphide tablets, added to a bulk quantity of grain by probing, to produce phosphine gas after absorbing moisture from the grains.

Fenitrothion is applied to harvesting machinery and storages on farms with a single nozzle spray applicator, or by a 5% admixture to compressed air in cylinders, sold ready for use with an applicator gun.

Actual and Potential Environmental Impacts

The disposal of waste grain dust, known to contain relatively high levels of organophosphate insecticides, could be environmentally hazardous.

4.4.4.2 Declared Plant Control

Description and Location

This is an important use of pesticides by a Government agency, and involves the control of plants declared under the Agriculture and Related Resources Protection Act. This Act is administered by the Agriculture Protection Board (APB).

The role of the APB is to see that landowners, including the Crown, comply with the requirements of the Act regarding their responsibilities to control declared plants. Thus, the APB encourages the landowner to control his or her) own weeds (and animals, see next section), and will only directly undertake control measures if contracted to do so, or where they are obliged to under the Act, in the event of negligence by the landowner.

Even so, the APB is a major user of pesticides, mainly herbicides. Most herbicides are applied by spot spraying, either by knapsack, or more likely, by a power-driven, hand-held, single-nozzle spray. This limits the area of land treated by the herbicide.

Declared plants are widely distributed throughout the State, but are more numerous, and more rigorously controlled in the South West. However, active spraying programmes are also carried out in the Pilbara, Kimberley and all agricultural areas.

Pesticides Used

The herbicides most widely used by the APB (and by landowners treating their own plants) are:

2,4-D (various formulations)
chlorsulfuron
amitrole/atrazine mixtures
amitrole

triclopyr
picloram
paraquat/diquat
glyphosate

Other herbicides used in limited quantities include 2,4,5-T, diuron, hexazinone, ametryne (trials only) and metsulfuron (trials only), dicamba, bromoxynil, bromacil, and 2,4-DB.

Methods of application

As previously mentioned, herbicides for declared plant control are applied with hand-held single-nozzle equipment. However, some broadacre treatments (for example, for Saffron Thistle) may use a boomspray, or a mister.

Actual and Potential Environmental Impacts

1. Damage to non-target species of plants. This is much more likely to occur on road verges, national parks and other public land supporting native vegetation, than on farming properties.

2. Contamination of streams and waterways with herbicide following treatment of blackberry infestation.

3. The eradication or control of weeds in national parks. This is another example of where a pesticide use can result in an environmental benefit.

4.4.4.3 Declared Animal Control

Description, location and method of application

The Agricultural Protection Board (APB) is responsible for the control of Declared animals under the Agriculture and Related Resources Protection Act. A number of vertebrate and invertebrate pest animals are "Declared" in different categories of control, depending on their distribution, and the threat they pose to agriculture, the environment and the community.

Some control activities do not involve the use of pesticides, for example, donkeys, starlings, feral goats, camels and emus are controlled either by shooting or by fencing.

In the case of rabbits, dingoes, grain weevils, European Wasp, feral pigs and plague locusts, some pesticide application is involved, in a variety of ways.

Rabbits: controlled by the use of 1080 (Sodium fluoroacetate) baits, applied either by the landholder or APB officers. Pindone impregnated baits are becoming increasingly popular as a means of rabbit control in urban areas and in adjoining rural land.

Dingoes: controlled by aerial baiting and the laying of fresh meat baits, largely strychnine based, but some 1080 baits are also used.

Feral pigs: these are a pest animal in many areas of the State, from Northampton to Denmark, and in areas of the Pilbara and Kimberleys.

They are predominant in forests in the higher rainfall areas. While shooting and trapping occurs, baiting with strychnine is also used extensively.

Grain weevils: these insects have been declared following the finding of widespread malathion resistance on farms. Dryacide [R], a diatomaceous earth with amorphous silica dessicant, is becoming a widely used "pesticide" for grain weevil control on farms. In addition phosphine-generating tablets are encouraged, in conjunction with the use of gas-tight sealed silos, for storage of grain destined for delivery to Cooperative Bulk Handling.

This activity occurs wherever grain is stored or handled, ie in agricultural areas throughout the State.

European Wasp: the relatively few nests that are found, mostly in the Albany, and Perth areas are eradicated with dichlorvos (DPVP) applied as a gas with compressed CO_2 ("Insectigas D").

Plague locusts: outbreaks of these insects occur almost every year in Spring and early Summer, numbers fluctuating widely from year to year. Severe infestations, which occur anywhere in the agricultural areas of the State, are controlled by APB and landholder applications of fenitrothion insecticide. These applications are often made by aircraft or mister, although boomsprays are also used.

Pesticides used

As already mentioned, the following pesticides are used for Declared animal control.

Sodium fluoroacetate (1080)
Strychnine
"Pindone"
Phosphine-generating tablets
Fenitrothion
"Dryacide"

Actual and Potential Environmental Impacts

1. Non-target animal poisoning with 1080. This is much more of a problem with domestic animals, than with native animals and birds, as native species have some built-in resistance to 1080.

2. Contamination of soil, waterways, and the death of birds and non-target insects from large-scale fenitrothion application to control plague locust outbreaks.

4.4.4.4 Forestry Protection

Description, location and pesticides used

The Department of Conservation and Land Management (CALM) is involved in the production of both hard and softwood forests, the reafforestation of agricultural land in certain catchment areas, the maintenance of National Parks and the production of nursery stock. In all these activities there is significant pesticide use. Some of the uses of pesticides, for example, the use of herbicides for firebreaks, is more appropriately covered in Section 4.5.1.1 (Non-farm Industrial Weed Control).

In this section, the use of pesticides for forestry establishment and protection will be considered.

Significant areas of land, from north of Wanneroo to the south coast, are devoted to the production of hard and softwood forests. In these areas, herbicides are used to control regrowth of unwanted or "weedy" tree species, and for thinning developing stands of hardwood to the correct density. Glyphosate is the preferred herbicide. Relatively small quantities of hexazinone, atrazine and amitrole have been used in a few locations.

In addition, amitrole and atrazine are used in significant quantities to kill pasture plants prior to planting eucalypt and pine seedlings in reafforestation areas of catchments.

At Kununurra and Karratha, small quantities of glyphosate are used to control grass weeds in local arboreta.

The use of pesticides in nurseries is significant in terms of the range of chemicals used. Nurseries are situated at Wanneroo, Narrogin, Manjimup, and Broome. Small quantities of nine herbicides, ten insecticides and seven fungicides are used to protect nursery stock from pest and weed attack.

Methods of application

In nurseries, pesticides are usually applied by boomspray, as are application to firebreaks.

Almost all of the herbicide use in plantations is hand-applied by either cut stump, notching or foliar spray to individual unwanted trees. These trees are usually treated before they become 3 metres high.

Boomsprays are also used to apply herbicide to pasture on catchment areas prior to planting eucalypt suckers.

Actual and Potential Environmental Impact

Contamination of water courses with residual herbicides by run-off from reafforestation areas and firebreaks.

4.5 NON-AGRICULTURAL USE

Non-agricultural use of pesticides has become increasingly important over the last twenty to thirty years. Chemicals that were once used solely in agriculture have become useful in solving non-agricultural pest problems. In some cases, the need for a chemical control method has allowed the development of specific pesticides, for example the rat poisons warfarin and bromodiolone.

Table 3 in Section 4.1 illustrates the relative importance of non-agricultural uses. It is interesting to note, in comparing Table 3 with Table 2, that the proportion of Registered active constituents devoted to non-agricultural uses is much higher than the equivalent proportion of pesticide sales. This suggests that the non-agriculture market is supplied with a wide range of relatively low volume products.

The following Sections give details of the major non-agricultural uses in Western Australia.

4.5.1 INDUSTRIAL WEED CONTROL

Description and Location

Industrial Weed Control (IWC) involves the use of herbicides for the control of weeds in non-agricultural situations. These cover a variety of situations ranging from where weed control is essential to minimise the danger from fire, such as on firebreaks, and around oil storage areas, to amenity areas such as footpaths, where weeds are controlled for aesthetic reasons.

In all cases, non-selective weed control is carried out, as total vegetation control is required. This limits the choice of herbicides.

IWC is often carried out by Government agencies, on land under their control, but also covers certain weed control practices on the farm, for example, on firebreaks and dam catchments, and the control of weeds on private industrial land.

Special areas of operation are as follows:

Railways: All railways in WA, under Westrail control, are treated with herbicide annually, for annual and perennial weeds. This includes the standard gauge and narrow gauge rails, and all sidings and railway yards. Herbicides that have been used are amitrole/atrazine, diuron, bromacil and to a much lesser extent, ethidimuron. Up to 3 metres each side from the centre line of track is treated. The work is all done by contractor.

Private railways, owned and operated by mining companies in the Pilbara, are also treated with herbicide. In the Pilbara, perennial tufty grasses such as Spinifex, are a problem and longer-term residual herbicides are used. Examples are bromacil and ethidimuron. Again, up to 3 metres each side of the track centre line is treated.

Roads: Main Roads Department is responsible for maintenance of the verge and the reserve of all main roads in WA. Almost all the road shoulders (up to 600 mm from the bitumen) in the South West of the State are treated annually with amitrole/atrazine or simazine for winter annual weed control. In addition, many road verges are also treated with glyphosate for summer perennial grass control, such as Lovegrass (Eragrostis curvula).

Eucalypt suckers growing too close to the road are usually cut and the stump treated with triclopyr and/or picloram. Only those suckers which are capable of exceeding 150 mm trunk diameter are removed.

There is little herbicide use on the batters of the table drains, or in the reserve itself unless there is a specific need, for example to reduce fire hazard, or to control Declared plants.

Roads under Local Government control are rarely treated with herbicides, except in townsites. This is covered in more detail below.

Footpaths: Many Local Government authorities use herbicides to control both winter and summer weeds growing in pavements and kerbs. Amitrole/atrazine mixtures are invariably used to control winter annuals, with glyphosate being used for summer weeds, particularly if they are perennial grasses, such as Couch (Cyanodon dactylon). Spraying contractors are used by many authorities, particularly in the Perth Metropolitan area. The APB provides a contract weed control service in some rural areas.

Local authorities also use selective herbicides, and some insecticides in recreational areas, for example, turf and parks. This is covered in more detail in Section 4.5.3.

Pipelines: The Water Authority of WA maintains the country water supply pipelines which carry water from Wellington, and other dams, to various towns and farms. Part of this maintenance involves the control of weed growth under the pipeline which could interfere with painting, and mechanical repairs, as well as creating a fire hazard in summer. Herbicides used are amitrole/atrazine, glyphosate, dalapon, and occasionally, hexazinone.

Irrigation and storm-water drainage channels: In the higher rainfall areas of the State, channels which supply water for use in irrigated dairy pastures and drainage channels are often sprayed with herbicides to prevent weed growth, reducing the efficiency of the channel. Commonly used herbicides are glyphosate, amitrole and atrazine, karbutilate, and bromacil. There would also be some herbicide treatment of channel banks on private farming properties in these areas.

Electric Power Installations: The State Energy Commission, as part of the maintenance programme for various installations, applies residual herbicides to soil within the boundaries of sub-stations, and within a few metres radius of fuse poles in rural areas.

The herbicides used are ethidimuron (in granule form) and glyphosate. Picloram and triclopyr are used to control woody regrowth in transmission pylon rights-of-way.

Grain Receival Depots: In rural areas, the surroundings of all Cooperative Bulk Handling receival points area sprayed with herbicides, usually atrazine mixtures, forweed control.

Fire-breaks: The use of herbicides for firebreaks has become increasingly popular with government departments, farmers and other landowners who need to maintain vegetation-free buffer zones for fire protection.

The herbicide firebreak provides an important advantage over the conventional cultivated one, in that it minimises soil erosion. In many situations, the operation is less expensive because one application of a soil-residual herbicide may give the same protection as several cultivations needed to control successive germination of weeds.

Herbicide firebreaks are applied to farms, research stations, many national parks, and to hardwood and softwood plantations.

The herbicides most commonly used are amitrole and atrazine, glyphosate, paraquat and diquat, and to a lesser extent ethidimuron and bromacil. Triclopyr and/or picloram may also be used if the firebreak contains significant numbers of native woody brush species.

General non-selective weed control — Many other weedy situations are treated with non-selective herbicides. For example, farm dam catchments, industrial sites, landscape areas, carparks, and gardens. The choice of herbicide would depend on the need for residual action. Herbicides most commonly used are glyphosate, paraquat and diquat, amitrole and atrazine, diuron, bromacil, ethidimuron, 2,2-DPA, and simazine.

Methods of of application — Most herbicides in this activity are applied with either a small boomspray, for firebreaks, roadside and railway use; or by hand-lead, where small areas are treated or spot spraying is required.

The SEC uses granular herbicides that are applied by a hand-held applicator.

Actual and Potential Environmental Impacts

1. Non-target vegetation damage. This is always a possible outcome of the use of soil residual herbicides, irrespective of where the herbicide is used. Tree damage has already been observed where road and rail reserves are treated, particularly where they are adjoining, and where herbicide fire-breaks are sprayed.

   This problem is much more acute in the South West and Agricultural Areas of the State, as road, rail and pipeline reserves are often the sites of remnant vegetation. In the North West, where herbicides are used on mining railways, the problem does not exist due to the almost total absence of trees and other substantial species near the railway line.

   Cases of tree damage in rural townsites have also been recorded following the use of residual herbicide to control footpath weeds. In addition, farmers have used the adjoining road, rail or CBH siding as a catchment for water to fill a dam. In some cases, the water has been used to irrigate the garden, causing damage to plants.

2. Waterways contamination. The use of herbicides for channel bank weed control can lead to localized water contamination. Non-target tree damage may also result where an inappropriate residual herbicide is used, as the irrigation channel may be their only source of water.

4.5.2 AQUATIC WEED CONTROL

Description and Location

Aquatic Weed Control is the direct application of herbicides to bodies of water, either flowing or static, to control weed growth in the water.

In general, aquatic weeds are not a major problem in WA, however, specific water bodies have been affected by weed problems in recent years. Herbicides have been used to control aquatic weeds in both urban and rural areas of WA.

- Acrolein is used in the main irrigation channels of the Ord River Irrigation Area (ORIA) to control aquatic weeds. It is applied by specially trained operators through direct injection methods;

- glyphosate and amitrole have been used to control weeds such as Cumbungi (Typha spp) in lakes and ponds in many areas of the State, both rural and urban;

- hexazinone has been used successfully by the APB to eradicate infestation of Salvinia (a Declared plant) from several outer metropolitan and South West lakes, for example, Lake Eudoria, Gosnells;

- diquat has been used by the APB to control Water Hyacinth in lakes in the northern suburbs;

- farmers have used copper sulphate, and simazine to control algae in farm dams;

- many years ago, 24-D was applied successfully, by aircraft, to control Water Hyacinth in Lake Monger.

Methods of application

Applications to water bodies are limited by what is practicable. In many cases, application by a boat-mounted spray unit is suitable, unless the water-body is small enough to be able to be treated from land. Some cases of aerial application have been known (such as on Lake Monger), and this method could be suitable for treating large areas of water.

The use of direct injection for acrolein in the Ord River Irrigation Area is necessitated by the relative instability of the chemical, and the need to provide a constant level of chemical in contact with the weeds in a flowing body of water.

Actual and Potential Environmental Impact

1. Deaths of fish and aquatic organisms. This is always a secondary problem with aquatic weed control, where the weeds or vegetation in the waterbody, killed by the herbicide, break down rapidly in the water, causing transient de-oxygenation. The herbicides themselves are of low to moderate toxicity only and are unlikely to directly result in deaths of aquatic animals, although the effects of these chemicals on many species, including phytoplankton and other invertebrates, is unknown.

4.5.3 COMMERCIAL TURF : PEST AND WEED CONTROL

Description and Location

This activity involves the control of weeds, insects and fungal diseases on areas of commercial turf. Three specific situations can be identified:

- passive recreation turf: eg foreshores, parks, and other general public turfed areas. The use of pesticides is minimal, restricted to an occasional herbicide treatment for Onehunga weed. Most pesticide treatments are too costly for this type of turf. Weed control is obtained by mowing;

- sporting and playing fields: eg football ovals, school ovals; cricket pitches and many tennis courts. These are often treated with bromoxynil/dicamba/MCPA mixtures for Onehunga and broadleaf weed control. Occasionally atrazine is used for Parramatta grass control. Insecticide and fungicide control is limited due to the cost of treatment;

- specialised areas of recreation turf: eg bowling greens, golf courses (especially the greens) and to a lesser extent, tennis courts. These areas are intensively managed and are subject to many treatments of herbicides, insecticides and fungicides. These treatments are often prophylactic, applied as part of a pre-determined program of management.

Pesticides used

The most commonly used herbicides on passive and sporting turf are bromoxynil/MCPA and possibly dicamba. No wintergrass control is carried out, with propyzamide, because of cost.

A range of all pesticide types are used on bowling greens and golf courses. Most important are propyzamide, endothal and ethofumisate herbicides, diazinon and fenamiphos insecticides, and a number of fungicides such as triademefon, benomyl, and chlorothalonil.

Heptachlor (an organochlorine) has been widely used in the past for black beetle control, especially on bowling and golf greens. This use has been terminated recently. Fenamiphos is becoming increasingly popular as a replacement.

Methods of application

Almost all applications of pesticides to turf are by boomspray. The exception would be the use of granular fenamiphos on small turfed areas.

Actual and Potential Environmental Impact

1. Deaths of birds. The potential exists for bird deaths following the use of pesticides on bowling greens and, more likely, golf courses. Diazinos and fenamiphos insecticides, bromoxynil herbicide, and benomyl fungicide are all highly toxic to birds. The use of fenamiphos is particularly hazardous when the granular formulation is applied, as these are easily picked up by ground feeding birds.

2. Groundwater contamination. With the intensive use of pesticides on recreational turf, and the concentration of these areas in the Perth metropolitan area, there exists the potential for groundwater contamination.

   Until 1987, heptachlor was used widely on recreational turf. This use would have contributed to the levels of heptachlor found in groundwater, and the wetland lakes into which the water drains.

4.5.4 COMMERCIAL PEST CONTROL

Description and Location

This is a major industry involving the use of insecticides for pest and vermin control in buildings in mainly urban areas. Specific areas of activity can be identified:

- termite control: this involves the use of the cyclodiene (organochlorine) insecticides, aldrin, dieldrin, heptachlor and chlordane in either pre- or post-treatment of buildings for termite protection. All treatments are prescribed by the Health (Pesticides) Regulations and Australian Standards AS 2057 and AS 2178. In terms of quantity of chemical used, the most important component of this activity is the pre-treatment of new domestic and commercial buildings by the application of chemical as a termite barrier to the sand pad immediately prior to the laying of the concrete floor. Aldrin and heptachlor are most widely used.

  A Sub Committee of the Western Australian Advisory Committee on Hazardous Substances (WAACHS) has examined the use of organochlorine insecticides for termite control. The Committee's report entitled "Organochlorine Use as Termiticide" contains a number of recommendations which further restrict the use of these chemicals, and their application by licenced pest control operators. This report is currently before State Cabinet.

  These chemicals have also been used by the State Energy Commission of WA to protect wooden power poles in rural areas from termite attack. This source of insecticide has contributed to the residue problem which has affected the beef industry.

  Arsenic trioxide is used to treat wooden structures, for example, door frames, roof timbers, and floorboards, that have already been attacked by termites. The chemical is applied as a powder, and is puffed into the intercepted termite galleries.

  Chlorpyrifos, an organophosphate insecticide, is also used, to a limited extent, as an alternative to the organochlorines in the preventative treatment of existing buildings for termites, by sub-surface injection of the soil.

  Chlorpyrifos is one of the more persistent organophosphate insecticides which, under some conditions, may remain active as a termiticide for up to three years. However, it is not nearly so persistent as the organochlorines, whose termiticidal activity is likely to exceed 15 years;

- general insect pest control: this involves the use of a range of organophosphates, carbamate and synthetic pyrethroid insecticides for the control of, for example, cockroaches, spiders, fleas, ticks, silverfish, and flies in domestic and commercial premises. Properties commonly treated are private homes, schools, restaurants, hospitals, and industrial premises;

- rodent control: this activity often occurs in conjunction with general insect control, and involves the use of rodenticides, usually in bait form, to control rats, mice and other vertebrate pest animals. A wide range of private and public buildings are baited for rat and mouse control. Commonly used rodenticides are warfarin, bromodiolone and brodifacoum;

Because the bulk of the States' population lives in Perth and the major regional centres, most pest control activity is urban-based. However, pest control treatments are often carried out in rural areas, including farms and farm buildings.

Pesticides Used

aldrin	diazinon
dieldrin	propoxur
heptachlor	deltamethrin
chlordane	permethrin
arsenic trioxide	dichlorvos
warfarin	chlorpyrifos
bromodiolone	bendiocarb
brodifacoum	carbaryl
coumatetralyl	fenitrothion
	maldison

Methods of application

Almost all chemicals used in commercial pest control are either injected into the soil, in the case of post-construction termite treatments, or sprayed with a hand-held lance, in the case of pre-treatment with termiticides and general pest control products.

Rodenticides are usually applied as baits, and arsenic trioxide is applied as a powder, puffed into termite galleries.

Actual and Potential Environmental Impacts

1. Groundwater and wetland contamination. There is no doubt that most of the organochlorine and organophosphate insecticide residues found in groundwater, and in urban wetlands, originate from pest control activities in the Perth metropolitan area (Davis & Garland 1986).

2. Contamination of watercourses. The use of organochlorines around the base of power poles in rural areas is likely to have contributed to pesticide levels in waterbodies. This source would be indistinguishable from the same chemicals emanating from their use in horticulture in the South West of WA.

4.5.5 DOMESTIC PEST AND WEED CONTROL

Description and Location

This involves the use of pesticides in the home and garden by domestic consumers. A very large range of chemicals is available to the market, sold in packs up to 1 litre.

Predominant in this market are the aerosol fly sprays and surface sprays for crawling insects. Pet care products, such as flea collars, insecticidal washes, and powders are also an important component.

In the garden, a range of herbicides, insecticides and fungicides is available. Snail pellets, based on metaldehyde, are widely used, and are responsible for a substantial proportion of illness and death in dogs.

All pesticides used in the garden for plant protection are derived from agricultural use by reformulation into dilute mixtures and repacking into small packs.

Of the organochlorines, chlordane was available in a 500 ml pack until mid 1987, and was used as a termiticide for "small" infestations, such as wooden fence-posts, woodheaps and pergola posts.

<u>Actual and Potential Environmental Impacts</u>

These chemicals are likely to make some contribution to ground water contamination in Perth.

4.5.6 ARGENTINE ANT CONTROL

<u>Description and Location</u>

Until November 1988 control of Argentine Ants was the responsibility of the Agricultural Protection Board, acting under the powers given by the Argentine Ant Act 1968.

The circumstances surrounding the State Government's decision to abandon Argentine Ant control activities are explained in the Introduction to this report. However, a summary of the programme as implemented over the last several years is provided as background information to any environmental impacts.

Argentine Ant control took place in the summer months, from October to April as the ants are most active in the warmer weather. It involved the detection of ant trails and laying down a chemical 'grid' over the area infested.

Since the late 1940s - early 1950s when the programme started, dieldrin was used exclusively, however in the early 1970s this was replaced by heptachlor. In agricultural areas, where the use of heptachlor may have led to undesirable residues in livestock products, chlorpyrifos was used with reasonable success after 1985.

Argentine ants have been found in many areas of the South West of the State, particularly in the higher rainfall areas. Thus significant infestations have been treated at Esperance, Albany, Bunbury, Busselton and in Perth. Smaller infestations in many wheatbelt centres have also been treated in the past.

The majority of infestation which remain untreated are in the Perth metropolitan area. They are centred around the shores, and adjacent suburbs, of the chain of freshwater lakes north of Perth. The Herdsman's Lake infestation is the largest of these infestations.

<u>Method of application</u>

In most situations, dilute (0.5%) heptachlor emulsion was applied in a grid pattern across the infested area using a hand-held, low pressure sprayer, applying a band a few centimetres wide.

In some instances, blanket spraying has been necessary over a limited area.

Environmental Impacts

1. Contamination of groundwater and wetlands. The use of dieldrin, and latterly heptachlor, for Argentine Ant control has, like pest control operations, contributed to organochlorine residues being found in groundwater and wetlands.

2. The external application of heptachlor (or any organochlorine) on the soil surface has the potential to affect non-target animals.

3. Death of aquatic species. Use of heptachlor around Perth's wetlands has caused significant but transitory reductions in aquatic invertebrate numbers (Davis and Garland 1986).

4.5.7 MOSQUITO/MIDGE CONTROL

Description and Location

The control of mosquito and midge insects in wetlands that border urban development largely involves the application of temephos granules to the waterbody during the summer. This insecticide is used as a larvaecide to reduce the 'flush' of insects that emerge as biting and nuisance adults during the summer.

In addition, insecticides such as malathion (maldison) and, to a lesser extent, bioresmethrin are used to fog areas between homes and the wetland, as well as the wetland itself, to directly control adult swarms of these insects.

These activities are under the control of Local Government, however, officers of the Health Department and CALM provide advice on request. The extent to which these treatments are carried out each year depends on the wetland in question, the season, the number of complaints received by the Council, and cost.

Most pesticide use on wetlands for insect control occurs in the Perth metropolitan area. At least a dozen lakes and wetland areas in and around Perth are regularly treated. In country areas, temephos and malathion are used in the Leschenault and Peel estuaries and in the Kimberleys, particularly at Broome and Derby.

Application methods vary from aerial spreading of temephos granules to fogging applicators for malathion.

Actual and Potential Environmental Impacts

1. Bird deaths. Temephos is moderately to highly toxic to birds, and is formulated as a granule which can easily be picked up by a ground or shallow water feeding bird. Hundreds of Red Stints died at Lake Forrestdale in 1984 as a result of temephos granules applied to the rapidly drying lake.

2. Alteration of the ecology of the wetland. There is evidence that each treatment affects the ecological balance of the wetland by killing non-target species of invertebrates.

4.6 DISPOSAL

The final phase of the "life-cycle" approach to pesticides is the disposal of surplus chemical and the containers in which they were sold.

Surplus pesticide

This is not a major problem at the present time as most pesticide is used by the purchaser. However, every user eventually accumulates old stock which requires disposal. Individually, the disposal of old pesticides into "a hole in the ground" may not present a potential environmental problem, as the quantities are not great. This is a matter which is difficult to police and full reliance must be placed on the education of the user to be environmentally responsible. In recognising this, the Pesticides Advisory Committee has drawn up new regulations for the disposal of surplus pesticide and containers. The regulations, which are effective from 1 January, 1989, describe the conditions under which pesticide wastes can be disposed of by landfill. A copy of these regulations is presented in Appendix 3.

Actual and Potential Environmental Impacts

The continued use of considerable quantities of DDT and other organochlorines on farms each year, posed a threat to the environment. As part of its response to the pesticide residues in beef crisis, the Department of Agriculture, in conjunction with the APB, recalled all organochlorines from farms and other outlets. In all, over 150,000 litres of DDT were collected, together with about 6,000 litres/kilograms of other organochlorines. These chemicals were decanted into new 200 Litre drums and placed in storage at Wongan Hills, Merredin and Katanning.

The State Government has decided to proceed with the high temperature incinerator in the Mt Walton area, in the western goldfields, as part of the Integrated Waste Disposal Facility and to include the DDT stocks, with the existing PCBs, for incineration.

Containers

Current pesticide use, mostly as a result of agricultural uses, generates upwards of 100,000 containers per year. Most of these are 20 litre containers, with some 200 L drums and other assorted sizes. The containers are either plastic or metal drums, with a few paper containers, largely restricted to smaller pack sizes used in horticulture and domestic uses.

No satisfactory method of disposing of the enormous number of containers has been devised. Some 200 L drums are returned to the supplier and re-used. The smaller pack sizes (less than 2 litres) are usually disposed of in household rubbish at a landfill rubbish site. It is the large quantity of 20 L containers that remains the problem.

Some farmers dispose of them on the property (and this is preferred option for disposal), either by burying (flattened or entire) or by using them for some other purpose, for example, tree guards (by cutting off tops and bottoms) or machinery stands etc. These uses would be approved by the Commissioner of Health under the proposed new regulations. Many drums lie about in rusting heaps on farms, near roadsides and on town rubbish tips. Some Local Government Authorities are coming to grips with the problem by providing special disposal sites in strategic places in the shire or by allowing the containers to be placed on the rubbish tip. Many do nothing and are exacerbating the problem by not providing a site for container disposal.

The problem of empty containers on rural rubbish tips would be considerably reduced if local Government authorities regularly compressed and covered the tip with soil, say about every three months.

A private Western Australian contractor has developed a drum crushing machine, in which the drum is emptied and crushed to a fraction of its original bulk, thus allowing for improved efficiency of disposal. This service has met with limited success with Local Government largely due to their perceptions of the cost. However its adoption should be encouraged.

RECOMMENDATION 4

The Health Department, in conjunction with the Department of Agriculture and the Environmental Protection Authority, should draw up guidelines for the disposal of pesticide containers on farms, and on Local Authority tipsites. These will compliment amendments to the Health (Pesticides) Regulations which came into effect on 1 January 1989.

RECOMMENDATION 5

The Government should investigate ways of encouraging the use of pesticide drum-crushing contractors as a means of disposing of unwanted used containers.

5. ENVIRONMENTAL MONITORING - REVIEW OF PAST AND PRESENT PROGRAMMES

5.1 INTRODUCTION

Over the last twenty years or so, WA Government agencies have conducted many monitoring studies designed to examine the impact of pesticides on various components of the environment. The majority of these have been 'ad hoc' since they were reacting to a specific perceived problem.

In this review, only true monitoring studies have been described, based on the dictionary definition of "monitor" viz, "a device which checks, controls, warns or keeps a record of something". Thus any study which seeks to determine how much pesticide is in a substrate, and then draws conclusions from that finding, is included.

Research work where a specific effect of the presence or absence of a pesticide level is measured, usually carried out in the laboratory or glasshouse, is not included in the review.

Definitions

In this chapter frequent references are made to "EPA criteria" and "MRL for potable water". These terms are explained as follows:

"EPA CRITERIA"

"EPA criteria" is a short way of referring to "Marine and Estuarine water quality criteria for maintenance and preservation of aquatic ecosystems". These criteria are specified in Schedule 7 of DCE Bulletin 103 (April 1981) entitled "Water Quality Criteria for Marine and Estuarine Waters of Western Australia", and are presented in Appendix 2.

It is important that the concept of criteria is understood. They are not legal limits. They can be defined as:

- scientific yardsticks upon which a decision or judgement may be made concerning the ability of water of a given quality to support a designated beneficial use.

The criteria used here are not absolute and unchanging yardsticks of water quality. The criteria for the organochlorine insecticides are based on the United States EPA quality criteria for water, which have been derived from laboratory studies with aquatic organisms. They are not based on Australian data.

"MRL For Potable Water"

The "MRL for Potable Water" figures are the Maximum Residue Limits for potable (ie drinking quality) water established by the National Health and Medical Research Council. As these figures have been incorporated into the Food Standards Regulations of the Health Act of WA, they are legal limits. They are listed in Appendix 1.

The following sections describe, and review, the studies which have been carried out, in alphabetical order of the responsible agency.

5.2 WESTERN AUSTRALIAN GOVERNMENT AGENCIES

5.2.1 AGRICULTURE

The Department of Agriculture is committed, amongst other things, to "develop agricultural technology to increase farm productivity and help rural industries to adjust to changing economic conditions and natural hazards (1986 Annual Report)". With this background, the Department has always put significant resources into research programmes which will assist farmers with pest control problems. This has necessitated a good deal of research into the use of pesticides in agriculture, although research into mechanical and biological pest control is important, and increasing. Research into the agricultural use of pesticides has considerable "spin-off" value for the use of these chemicals in non-agricultural areas, and this has assisted the development of, for example, home garden pest control, and industrial weed control.

Almost all of this research has been orientated towards the efficacy of the product. Little environmental research has been carried out, beyond the work necessary for agricultural production, for example, the effect of herbicide residues on following crops, and the effect of drift on adjoining or nearby susceptible crops.

The following is a summary of pesticide environmental monitoring projects conducted by the Department of Agriculture.

1. Airborne 2,4-D and tomato damage at Geraldton (Gilbey et al 1984)

   A series of studies were conducted between 1979 and 1982 to monitor the airborne levels of 2,4-D in the Geraldton region. The work was coordinated by Des Gilbey, Weed Research Officer, assisted by a team of officers from several government departments.

   The work was done in response to complaints over many years that tomato growers in and around Geraldton were suffering crop damage as a result of 2,4-D spray drift caused by wheat growers further east. It was originally assumed that volatile 2.4-D ester vapour from several kilometres away was responsible. This may or may not have been so, but the monitoring study coincided with a change in Restricted Spraying Regulations, when the use of high volatile 2,4-D esters was prohibited within 50 km of Geraldton, instead of the 19 km permitted before 1979.

   The study showed that tomato crop damage was more likely to have been caused by short distance droplet drift of 2,4-D amine (which is allowed to be used within 50 km of Geraldton), and to a lesser extent droplet and vapour from 2,4-D ester applied within the prohibited area.

   This study has implications for the problem of herbicide drift and damage to non-target vegetation. The study found that, with the monitoring equipment and resources available, it was not possible to identify individual spraying events - and thereby pin-point the source. Neither could the monitors distinguish between a high concentration for a short time, and a constant low level during the weekly monitoring interval. Short duration, say hourly, monitoring would be needed to detect peak concentrations.

2. Long-term effects of herbicides in cropping systems (unpublished report)

This project, conducted between 1982 and 1985 by Terry Piper, Weed Research Officer, attempted to identify the effect of any actual or potential residues on subsequent crop or pasture growth in the wheatbelt resulting from the use of nine herbicides.

The herbicides measured were, simazine, diuron, trifluralin, dicamba, 2,4-D, diclofop-methyl, chlorsulfuron, picloram, and propyzamide. These herbicides were applied as recommended, and at five times recommended rates of application to small (3 m x 3 m) plots, replicated at each of two sites, Wongan Hills Research Station (Sandy soil) and Avondale Research Station (Loamy soil) 190 km north east and 140 km east of Perth respectively. Wheat and Lupins were planted at the appropriate times. The plots were soil sampled throughout the season for residue analysis.

Despite seasonal and logistical difficulties experienced at both sites, sufficient data were obtained to show that simazine decays exponentially with a half-life of 2.5 weeks at Avondale and 4.5 weeks at Wongan Hills. In addition, trifluralin did not decay exponentially, but degraded faster initially. In both cases insufficient residue was carried over into the following season to cause crop or pasture damage. The only other herbicide analysed to date is picloram, which showed that the time of application greatly influenced the decay curve.

This work supports the general supposition that herbicide residues are not important in annual cropping systems in normal seasons. However, in 1985, rainfall was so low in some areas (eg only 150 mm fell on Newdegate Research Station 400 km south east of Perth, after June) that wheat growth depression was observed in the 1986 season. Other herbicide residue carryover reports were also received that year. While not conclusive, the 1985 experience indicates that herbicide residue carryover may be a problem in dry years.

From an environmental point of view, this work is limited to the agricultural information it has generated. Measurable residues of these herbicides were detected some considerable time after application, and their disappearance to ground water cannot be ruled out. Further work is needed to determine the effects of rainfall and other factors, on the potential for these herbicides to contaminate groundwater.

3. Levels in soil, pasture and water at Lake Neerabup (unpublished data)

This monitoring study evolved from the treatment of a pasture adjoining Lake Neerabup, about 50 km north of Perth for Argentine Ant control in early 1982. Shortly after the pasture was sprayed, stock were returned to the pasture. Several cattle and horses died, as a result of acute heptachlor poisoning. Repeat treatments at different parts of the Lake occurred in 1983 and 1984.

The Entomology Branch of the Department has been regularly monitoring heptachlor and chlordane levels at a number of location in Perth and in rural areas, in pasture, soil and water since that time.

While no results have been published, the study has provided much information on the degradation rates of these chemicals in the metropolitan environment. The results show that the initially high levels of heptachlor and chlordane in herbage fall to less than 1 mg/kg within 12 months of application, but that residues after that time decline extremely slowly, and are likely to be detectable for some years to come.

4. <u>DDT levels in soil, crop and pasture, water and sediment, as a result of its use in cereal cropping</u> (unpublished report)

Mr C Sharpe, Pesticide Advisor, conducted a monitoring study from December 1983 to May 1985 to assess the levels of DDT found in agricultural soils, in crops and pastures growing in those soils, in water draining from the soils and thence to a permanent lake and the Avon River, and in sediments at the bottom of the water bodies.

The report was prepared for the Pesticides Advisory Committee. The results of the study are summarised as follows:

- The soil DDT levels showed a rapid rise after spraying. They then fell over a 2-week period after which there was little or no DDT loss. This provides a new 'base' for a future DDT application.

- Pasture levels of DDT, even one year after spraying in the crop, still exceeded the Maximum Residue Limit for DDT in animal feeds (0.05 mg/kg). Crop residues were lower, but could contribute to a grazing animal's body burden.

- DDT levels in the water and sediments fluctuated with the times of peak flow in winter. The water levels frequently exceeded the EPA criteria.

This study appears to be the only one which has attempted to monitor the effects of a persistent insecticide in the wheatbelt. It is of particular value in that regard.

5. <u>Insecticide residues in agricultural soils</u> (unpublished data)

In mid-1987, the beef industry was faced with the problem of excessive residues of organochlorine insecticides in beef exported to the USA. Massive industry and government resources were committed to solve the problem by:

- detecting violative animals at the point of slaughter, and if possible, on the farm.

- detecting and removing the source of contamination on individual properties.

This latter activity involved the taking of thousands of soil samples, by officers of the WA Department of Agriculture, from properties designated "at risk" by virtue of their agricultural history, or whether violative animals from the property had been detected at abattoir.

The results of the analysis of the samples are presented in Table 6:

Table 6. <u>Levels of organochlorine insecticides found in some agricultural soils of the south west of WA</u>.

CONCENTRATION (mg/kg)	NO. OF DETECTIONS (% of 11,248 SAMPLES) CHLORDANE	DDT	DIELDRIN	HEPTACHLOR
0 - 0.09	858 (7.6)	1080 (9.6)	1521 (13.5)	924 (8.2)
0.1 - 0.49	1007 (9.0)	1575 (14.0)	1860 (16.5)	934 (8.3)
0.5 - 0.99	162 (1.4)	780 (6.9)	610 (5.4)	190 (1.7)
> 1.0	50 (0.4)	1023 (9.1)	407 (3.6)	73 (0.6)
TOTAL DETECTIONS	2077 (18.4)	4458 (39.6)	4398 (39.0)	2121 (18.8)

In this Table, all samples were analysed for all four organochlorines, however, not all samples <u>contained</u> all of these insecticides.

It must also be remembered that these samples were taken from selected properties where residue levels were expected. These results are not representative of soil residue levels of the South West generally.

These results also exclude samples from experimental plots and from "hot spots", for example, near State Energy Commission power poles.

6. <u>Miscellaneous monitoring work</u>

The Department of Agriculture, over many years, has taken many hundreds of samples of soils, vegetation and water for analysis for pesticide residues. Many of these samples have been taken for health or agricultural reasons, but collectively they provide a body of knowledge about how pesticides act in the physical environment.

For example:

- 19 samples of ground water were taken from Burswood Island in 1986, by the Entomology Branch, to assess the effects of Argentine Ant treatments. All samples were found to contain <0.01 μg/L of any organochlorine except one sample containing 0.09 μg/L of heptachlor.

- Samples of water from farm dams, house rain-water tanks, and town water supply dams in the eastern wheatbelt in 1984 and 1985 were taken as a result of publicity about possible effects of herbicide spraying in the area. No detectable residues of diuron, 2,4-D, chlorsulphuron, trifluralin, triallate, paraquat, diquat or glyphosate were found.

In addition to these small residue analyses, the Department has carried out many trials with both new, and already registered, pesticides, in new situations. While a discussion of this work is outside the scope of this study, much supplementary knowledge of the likely environmental effects of using these chemicals is being amassed.

5.2.2 AGRICULTURE PROTECTION BOARD

The Agriculture Protection Board (APB) is the government agency which is empowered, under the Agriculture and Related Resources Protection Act 1976, to control those weeds and vermin which are actual or potential threats to agriculture. It is a major user of pesticides, mainly herbicides, and its activities are examined in detail in Chapter 4.

Research on the control of "declared animals" is carried out by the Research Branch of the APB based at Forrestfield. Research into the control of "declared plants" is the responsibility of the Weed Science Branch of the Department of Agriculture, although funding is provided by the APB.

Because they are introduced, many declared plants, and declared animals are as much a threat to the natural environment as they are to agriculture. Control measures, particularly those in non-agricultural situations are therefore implemented with consideration for the environment.

Declared Plants

Only one environmental monitoring project has been carried out with respect to Declared plant control.

1. Herbicide residues in flowing streams (unpublished report)

A large proportion of Blackberry infestations occur very close to streams or waterbodies. Therefore, herbicide control measures have the potential to contaminate the water body, at the time of spraying, and soon after. This project was designed to measure the potential of glyphosate, triclopyr and picloram herbicides to contaminate the Brunswick River after a simulated Blackberry spraying operation.

Samples of water and sediment were taken at the site of application and 20 m downstream at 1 minute intervals to 5 minutes after spraying, then 20, 60 and 120 minutes after, and 1 week later.

Analysis of the samples showed that no detectable glyphosate or picloram residues were present in either the water or sediment, and that triclopyr was not found in the sediment. Triclopyr residues were found in the water, 1 minute after spraying and 20 m downstream at a maximum level of 0.6 μg/L. These levels declined to <0.02 μg/L (Limit of Detection) after sixty minutes.

Declared Animals

1. Non-Target Fauna - effect of dingo baiting (King, 1988)

   For many years, the APB has conducted research into the toxicity of sodium fluoroacetate (1080), used in both rabbit and dingo baits, to a number of native animals. This work has largely involved laboratory studies with various species to determine their respective LD_{50} for 1080. The work has found that many local native species of birds, reptiles and mammals are naturally more tolerant to 1080 than their counterparts from other States. This is due to their exposure over the centuries to species of *Oxylobium* and *Gastrolobium* plants which contain naturally high levels of 1080.

An extension to this work has just been completed. A field study was conducted to determine the actual hazard posed to the Northern Quoll (Dasyurus hallucatus) by aerial baiting with 1080 dingo baits. This species had been identified in laboratory studies as being the species in the pastoral areas which was most at risk from baiting programmes for dingo control.

The study concluded that as all 10 animals originally trapped, fitted with radio collars and released, had survived the baiting, then any other native species of even lower risk should also survive the baiting operation.

2. Fenitrothion levels in the environment after locust spraying campaign, 1982 (unpublished report)

From October to December 1982, the Agriculture Protection Board applied or supplied to farmers for their own application 26 000 kg of technical fenitrothion and 26 000 kg of formulated fenitrothion for the control of a major outbreak of the Australian Plague Locust. The infestation occurred in the Great Southern and South Eastern Wheatbelt, and a total of about 117 000 hectares were sprayed (41 000 hectares by air).

Mr C Sharpe, Pesticide Adviser, collected 31 samples of vegetation, water, soil and locusts during the campaign. These were analysed for fenitrothion residues. Residues were found in 3 water, 7 vegetation, 6 soil and 3 locust samples. The highest levels found were 0.7 μg/L in water, 37.0 mg/kg in pasture herbage, 3.8 mg/kg in soil, and 9.6 mg/kg in locust samples.

The study report suggested that the fenitrothion spraying had no effect on agriculture, but was not sufficiently detailed to assist in an assessment of environmental effects. However, freshwater marron living in dams, and birds feeding on locust carcases, may be affected by the fenitrothion levels in water and locusts respectively.

5.2.3 CONSERVATION AND LAND MANAGEMENT

The Department of Conservation and Land Management (CALM) is a large organisation which covers three main activities, Forest Management and Production, National Park Management, and Wildlife Management and Research.

As the manager of large areas of national parks, State forest, and soft wood plantations, CALM is a significant user of pesticides (mostly herbicides) as described in Chapter 3. However, no environmental monitoring studies of CALM's pesticide use has been attempted.

CALM is also host to an advisory body, the Roadside Vegetation Conservation Committee (RVCC) - The aims of the Committee are

"to coordinate and promote the conservation and effective management of rail and roadside vegetation for the benefit of the environment and the people of Western Australia".

The RVCC is embarking on a number of research projects, to be coordinated by its executive officer, Ms Penny Hussey. One of these projects was to investigate the effects of pesticide application, both by rights-of-way managers, and adjoining farmers, on native vegetation in road and rail reserves. A draft report prepared by Murdoch University in November 1988 is before the RVCC, awaiting comments.

CALM's Wildlife Research Centre, has conducted three major monitoring projects on the effects of pesticide residues on birds.

1. <u>Organochlorine Residues in the Western or Australian Magpie</u> (unpublished report)

   A total of 114 Australian Magpies were collected between December 1970 and April 1973. The majority of the birds (70) were collected within the Perth-Albany-Cape Naturaliste triangle during mid 1971. The other 44 birds were obtained from a variety of sources, including the Perth Metropolitan Area, Pinjarra, Mingenew and other agricultural areas.

   The bird samples were, when possible, dissected in the field at collection, and the liver and pectoral muscles forwarded for analysis. In some cases, the whole bird was frozen and submitted for dissection in the laboratory.

   The results of this study, conducted by Dr R Prince, have not been analysed in detail, but it appears that:

   - only DDT and dieldrin residue levels are reported;
   - there is little difference between residue levels in the liver and the pectoral muscle;
   - the residue levels are very variable, but birds from the Perth Metropolitan area, and the eastern hills orchards and forest areas contain the highest residue levels. Maximum levels found in these areas were 33 mg/kg of DDT (liver) and 12 mg/kg dieldrin (liver). In agricultural areas, the levels found were almost all less than 1 mg/kg, with many as low as 0.01 mg/kg of either DDT or dieldrin.

   The Australian Magpie was selected as an indicator species because it is widespread and numerous throughout the south west, largely insectivorous, long-lived, sedentary and territorial. This makes it an ideal species for an assessment of pesticide contamination of the terrestrial environment.

2. <u>Pesticide levels after Plague Locust spraying operations -</u> (unpublished data)

   In 1971, the Agriculture Protection Board was involved in spraying agricultural land near Mingenew with malathion for Plague Locust control. Officers from the Wildlife Research Centre took a total of 57 bird samples from an area not treated with maldison, and 53 bird samples from a treated area. Samples of both live and dead locusts were also taken from the treated area.

   The analysis of these samples showed that no malathion was detected in any bird tissue, even after treatment. Malathion residues were detected in live (0.4 mg/kg) and dead locusts (1mg/kg).

   The birds were also found to contain DDT, Dieldrin and Hexachlorobenzene in many tissues (mainly liver) at levels around 0.01 mg/kg for each chemical with occasional samples containing up to 0.6 mg/kg of one of the pesticides.

3. Miscellaneous residue levels in birds

Several samples of different species of birds, and eggs, from a wide range of localities were collected and analysed during the early to mid 1970s. Samples ranged from Ospreys at Shark Bay to Owls at Mandurah. Almost all samples contained low levels of organochlorine insecticides, up to a maximum of 60 mg/kg of DDT in an Owl from Lake Argyle and 14 mg/kg of dieldrin in a Mudlark from Karratha (this sample taken in 1983).

5.2.4 ENVIRONMENTAL PROTECTION AUTHORITY

One of the primary functions of the Environmental Protection Authority (EPA) is "to ensure that environmental quality is maintained" (1985/86 Annual Report). It carries out this function by coordinating the efforts of other organisations and agencies that are directly responsible for the management of various parts of the environment.

This has been the case for the following pesticide monitoring studies coordinated by the EPA. Much of the work has been conducted by other organisations, for example, Murdoch University, as part of a study group established by the EPA to examine a specific problem.

1. Pesticide Residue Level in Cockburn Sound (Chegwidden 1979)

A number of specific studies were carried out in the mid-1970s, leading to the production of the Cockburn Sound Environmental Study, 1976-1979 published by the then Department of Conservation and Environment (Report No 2). One of these studies investigated the presence of pesticide residues in water, sediment and mussels of several localities in Cockburn Sound.

Levels of total organochlorine insecticides found in the sediments and mussels of Cockburn Sound were less than 0.001 μg/kg. Sediments from one sampling station in Owen Anchorage contained 4 μg/kg of dieldrin while the effluent from Anchorage Butchers contained 15 μg/kg of dichlorvos insecticide. No pesticide residues (in fact, no chlorinated hydrocarbons of any sort) were found in samples of the common mussel *Mytilus edulis* taken from the Sound. The study concluded that the extent of pesticide contamination could not be inferred from one sample, and recommended that "a survey be taken to quantify the extent of sediment and biota contamination by pesticides, particularly in Owen Anchorage".

2. Study to establish baseline levels of contaminants and nutrients in marine waters of WA (Chegwidden 1981)

This study was conducted as part of the marine quality assessment programme (Map 15) in 1980/81. The site chosen for the study was the CSIRO Rottnest Island 50 m station. This was in 50 m of water, 3.3 km due west of Cape Vlaming, Rottnest Island.

Water samples were taken at this site on 11 occasions between April 1980 and January 1981, from the surface and at depths of 1.5 and 20 m. 10 percent of the 120 samples gave positive results for dieldrin and DDT plus metabolites. The highest levels found were 0.027 μg/L for dieldrin and 0.01 μg/L for DDT and metabolites. The analytical limit of detection was 0.001 μg/L for both pesticides. Most levels detected just exceeded that limit.

The author concluded that organochlorine pesticides were present in the waters off Rottnest Island.

3. Preliminary study of pesticide residues in rivers and estuaries of WA - (unpublished report)

Water and sediment samples were collected over two sampling periods from several estuaries and their associated rivers in mid-1987. The samples were analysed for all organochlorine and organophosphate insecticides and selected herbicides.

The sediments did not contain detectable quantities of pesticides, with the exception of the Denmark River containing 0.1 mg/kg chlordane and the Sleeman River which contained 0.04 mg/kg dieldrin. Unfortunately, the limit of detection in sediments (0.01 mg/kg) was four orders of magnitude higher than the limit in water (0.001 μg/L).

In the estuarine and river waters, no herbicides or organophosphorus residues were detected. Organochlorine residues were found in all samples. Levels which exceeded the EPA criteria predominated at the first sampling time (after the first river flows for the season). The highest level of each chemical found is shown in Table 7, with the source of the sample.

Table 7. Highest levels of OC Pesticides found in SW rivers sources.

PESTICIDE	LEVEL μg/L	SOURCE
DDT	0.026	mouth, Blackwood River
heptachlor	0.007	upper Blackwood River
chlordane	0.021	" " "
dieldrin	0.009	mouth, Denmark River

On the basis of the number of samples which exceeded the EPA criteria for at least one of the above pesticides, the most contaminated river systems were the Blackwood, Denmark, and Hay. The Harvey, Carbunup, Sleeman, Austin, Serpentine, King, Robinson and Scott were much less contaminated. No samples exceeding the EPA criteria were found in the Murray and Kalgan river systems.

5.2.5 FISHERIES DEPARTMENT

The mission of the Fisheries Department is "to manage the fish resources of Western Australia for the benefit of the community" (1986/87 Annual Report). In order to achieve their objectives, the Department must, amongst other things:

- develop the aquaculture industry, and under-developed fisheries; and
- conserve fish habitats and fish species.

Studies into pollution and the environment as they affect marine fisheries and aquaculture projects are carried out by research officers of the Department. For example, research into heavy metal pollution in estuarine and marine waters are major projects.

Two projects involving pesticides monitoring, one past and one current, are attributable to the Fisheries Department. The first one, on pesticide residues in fish from the Ord River Irrigation Area, was completed in 1978. It was part of a collaborative project of the then Department of Fisheries and Wildlife, the then Public Works Department, the Department of Agriculture and the then Government Chemical Laboratories. This latter organisation prepared a report on the whole project, which is further described under the Chemistry Centre of WA.

1. Pesticides in Marron

   This is a new project to be undertaken in 1989. It involves the sampling of marron, water, sediment and feeds (where applicable) from three rivers, six marron farms and the Pemberton Hatchery.

   The samples will be analysed for organochlorine and organophosphorus insecticides.

   The project also involves the laboratory study of low (sub-lethal) levels of organochlorines in feed on the growth, development and reproduction of marron.

2. Miscellaneous pesticide monitoring

   The Fisheries Department continues to conduct 'ad-hoc' sampling of fish species for pesticide residues. These are usually in response to specific requests. For example, five species of fish (24 specimens) were sampled in Wilson's Inlet near Denmark in 1988. Unexpected residues of chlorpyrifos were found in 11 of the samples ranging from 0.01 mg/kg (the limit of detection) to 0.18 mg/kg.

5.2.6 CHEMISTRY CENTRE OF WA

The Chemistry Centre (formerly the Government Chemical Laboratories) is part of the Mines Department and provides professional chemical and analytical services to the State Government.

The Centre consists of a number of Laboratories, which specialise in different areas of chemical analysis, such as mineralogy, and forensic chemistry. The Environmental Chemistry Laboratory, and in particular, the Pesticides Laboratory have been responsible for assisting State Government Departments in the analysis of samples from pesticide monitoring projects. They also provide expert advice on the chemical feasibility of projects, correct sampling procedures, and the interpretation of results. This advice should be sought at the planning stage of any project involving the pesticide analysis of samples.

Thus the Chemistry Centre has been heavily involved in most of the projects reported in this review. The Centre has also published two significant reports on work they have carried out on their own and others behalf.

1. Report on Pesticide Residue Sampling for the Ord River Irrigation Area 1964-1978 (Gorman 1979)

   This report was prepared for the Ord River Ecology Sub-Committee, and consists of a collation of results of several ad hoc monitoring exercises conducted by several departments, notably the WA Departments of Agriculture, Fisheries and Wildlife, and Public Works.

It covers the analysis of water, silt (sediments), soils, foods, pastures, stockfeeds, cattle, birdlife and fish for organochlorine and organophosphorus residues arising out of their widespread use for cotton production. Cotton production stopped in 1974 when insect pest resistance to the insecticides used became insurmountable. With the demise of cotton, the use of organochlorines fell dramatically. Their use in the Ord River Irrigation Area was so high, however, that residues in the environment continued long past 1974, and are still detectable today, albeit at much reduced levels.

2. Dieldrin Residues - A Western Australian Study (Shewchuk 1981)

This report is a compilation of all residue analyses of dieldrin in a wide range of substrates from the mid 1960s on. It covers the dieldrin levels in foods, the environment and such things as cigarettes. A useful summary of the history of dieldrin in Western Australia is provided, together with a description of its manufacture, properties and toxicology.

5.2.7 WATER AUTHORITY OF WA

The Water Authority of WA (WAWA) "plans and manages water services and water resources throughout Western Australia for the continuing benefit of the community" (Annual Report 1986).

An important component of this role is the commitment to ensure that the consumer is supplied with potable water of the best possible quality. To ensure that potable water, whether it be from surface or groundwater sources, is not contaminated with pesticides and other chemical contaminants, water monitoring programmes have been implemented.

1. Catchment Studies

Specific catchments are sampled fortnightly to monthly for up to twelve months. The water samples are analysed for a range of organic contaminants, including the organochlorine and some organophosphorus pesticides. Current catchment studies which are due for completion in early 1989 are the lower Helena, Logue Brook and Waroona catchments.

The levels found are well below the Maximum Residue Limits for the various chemicals in potable water, but many of them exceed, sometimes markedly, respective EPA criteria.

2. Reservoir monitoring

The major supply Reservoirs for the Metropolitan area are sampled and analysed for organic contaminants, including pesticides, on a yearly or twice yearly basis. The levels of pesticides found in the 1988 sampling are all below the EPA criteria, and are well below the MRLs for potable water.

3. Monitoring groundwater production bores

Sampling and analysis for a wide range of chemical and microbiological contaminants is conducted annually for all groundwater production bores. Since 1974, 130 bores have been found to contain well below the respective MRLs for potable water. However, a significant proportion of the samples have been found to contain pesticides at levels in excess of the EPA criteria. These elevated levels are predominantly from samples taken in the last few years, as shown in the Table 8.

Table 8. Number of samples of water taken from groundwater production bores, since 1974, that exceed the EPA criteria.

YEAR	(a)	(b)
1974	3	-
75	10	-
76	24	-
77	31	-
78	26	-
80	19	-
81	2	-
82	18	3
83	31	3
84	34	3
85	41	13
86	59	8
87	47	28
88	39	21

(a) No of water samples taken in that year.
(b) No of samples containing one or more organochlorine pesticide levels in excess of the EPA criteria.

Many of the numbers shown in column (b) contain more than one pesticide level in excess of the EPA criteria. For example, in the 1987 sampling, a total of 42 individual pesticide levels exceeded the EPA criteria.

These levels are not of concern with respect to the quality of the water for human consumption (the highest level found was 0.011 μg/L). However, they are useful as indicators of the possible increasing contamination of Metropolitan groundwater from organochlorine insecticides. DDT and dieldrin provide most excessive levels with 45 and 34 respectively; only 8 heptachlor and 3 chlordane levels exceed the EPA criteria. As Perth's groundwater is recharged by direct infiltration of rainfall over the coastal plain (Ventriss 1988), these pesticide levels are likely to have originated from their previous agricultural and urban use, and to a much lesser extent, from the rainfall itself.

4. Monitoring WA Rivers and Basins

Since about 1980 WAWA has intermittently sampled four river basins - the Warren, Preston, Collie and Swan Coastal - for pesticide residues. These samples have been taken either at permanent stream gauging stations, or at other marked points along the river.

The analysis of these samples has shown the consistent presence of dieldrin and DDT residues (except in the Collie River where no residues were found). Some heptachlor levels were also found; one extreme level of 0.170 μg/L was detected in Lefroy Brook (a tributary of the Warren River, near Pemberton) in December 1981. A significant proportion of the DDT and dieldrin residues exceeded the EPA criteria. The highest dieldrin level found was 0.019 μg/L - also from Lefroy Brook in June 1982.

5. Monitoring Waste Disposal Sites

Only one sample of water has been taken from a waste disposal site for analysis for pesticide residues. In February 1979, a sample of water from the Gnangara Liquid Waste site was found to contain DDT at 0.030 μg/L.

6. Groundwater monitoring at CIK (Kwinana) Pty Ltd

In the late 1970s, routine sampling and analysis of water from shallow aquifers in the BP (Australia) Ltd site at Kwinana found elevated levels of 24-D and 245-T herbicide. Further sampling of the area found some extremely high levels of these herbicides in ground water, particularly from the pesticide manufacturer CIK (Kwinana) Pty Ltd. This company operated on a site adjacent to BP on the east.

Investigation showed that a considerable area of shallow (20 m) groundwater was contaminated with these chemicals to varying degrees. Some of the levels were well over the MRLs for potable water. The source of the contamination was the pond into which CIK (Kwinana) discharged its manufacturing and formulation wastes.

It was eventually decided that CIK (Kwinana) should dispose of its wastes by injection into a deep bore, in excess of 1 000 - 1 200 m. This was done, but not until 1986, and by then the company had been taken over by Nufarm Ltd.

Routine monitoring of all the bores in the area has been taking place over the last ten years, and is continuing, with samples to be taken at 3 monthly intervals.

7. District monitoring projects

Several WAWA districts carry out water system monitoring projects within their areas of responsibility. These projects are shown in Table 9 and are aimed at maintaining the quality of the water source for potable uses, and include analysis for pesticide residues.

Table 9. WAWA District Water Monitoring Projects

DISTRICT	WATER SYSTEM	SAMPLING
COLLIE	Preston River Irrig. scheme Lefroy River (Pemberton)	Monthly during Irrig. season (Nov-May) Twice annual (Dec + May (or when run-off starts
KUNUNURRA	Ord River	Twice annually along river and drainage outlets
ALBANY	Scotsdale Creek (Denmark)	Fortnightly during flow period
MANDURAH	Dwellingup Water Supply	Three times per year
NORTHAM	Mundaring Catchment	Occasionally - after CALM spraying operation
CARNARVON	Town Water Supply	Occasionally - by Health Department

8. Pesticide levels in soil in south west

During late 1987, when the beef cattle industry was grappling with the problem of organochlorine pesticide residues, the Water Authority assessed all its sites where organochlorine had been applied, and which could possibly be accessed by grazing animals.

A number of sites were sampled adjacent to wooden bridge structures and pumping facilities which have been previously treated for termites. All these sites were grazed by cattle, albeit intermittently in most cases.

The samples were shown to contain dieldrin at rates ranging from less than 0.01 mg/kg to 98 mg/kg. Those sites containing dieldrin at 0.1 mg/kg or greater were immediately fenced from stock access.

Some of the sites sampled were along the banks of irrigation channels. These, plus the bridge structure sites may be the source of some environmental contamination.

5.2.8 WATERWAYS COMMISSION

The Waterways Commission was established in 1976 to administer the Waterways Conservation Act 1976, and to oversee the activities of three Management Authorities (Swan River, Peel Inlet and Leschenault Inlet) established under the Act.

Section 23 of the Act outlines the duties of the Commission, which amongst other things includes:

- to preserve and enhance the quality of the environment and amenities of the waters and of the associated land to which the powers of the Commission apply, and;

- to provide advice and disseminate knowledge on the conservation and good management of river, inlets, and estuaries and of associated land.

In their pursuit of these objectives, the Commission has initiated a number of monitoring surveys involving pesticide residues (amongst other things) in rivers under their control.

1. Heavy metals in sediments and mussels of the Swan River system - (Chegwidden 1980)

2. Heavy metals and pesticides in surface sediments near slipping facilities on the Swan River - (Chegwidden 1981)

   These two studies were aimed at determining the extent of environmental contamination of the Swan River by mainly heavy metals and, to a lesser extent, organochlorine pesticides.

   The first study concentrated on selected drain sites in the Swan, and the second study, slipping facilities, with the aim of gauging the impact of anti-fouling paints on the riverine environment.

The studies found that:

- significant levels of heavy metals were being accumulated in the surface sediments at the drain sites selected, compared with presumed background levels found in the upper reaches of the river;

- elevated levels of copper and zinc (but not chromium and tin) were found in sediments at slipping facilities. Significant DDT levels were found in all sampling sites, from Jane Brook to Chidley Point. The levels of DDT ranged from 0.01 mg/kg to 4.8 mg/kg (at Royal Freshwater Bay Yacht Club). In addition, Dieldrin was detected at 0.01 mg/kg in Freshwater Bay Yacht Club.

The second study in particular, showed that the use of anti-fouling paints (containing the pesticide tri-butyl-tin) by boat owners was leading to residues in the river environment. Also that DDT was widespread throughout the river sediments, possibly reflecting its historical use in urban Perth, and much more recent use in agricultural areas.

Unfortunately, no water samples were taken at this time.

3. Swan-Canning Estuarine System - Environment, Use and the Future - (Thurlow et al 1986)

This report, was the culmination of a two-year study into the Swan-Canning River system.

Chapter 6, Section 311 was concerned with pesticide contamination, and reported the results of analysis of quarterly water samples taken from the Causeway and Fremantle Traffic Bridge.

The mean organochlorine pesticide levels found at the two sampling points are shown in the table below. These results are not significantly higher than the EPA criteria. However, the mean figures mask some peak residue levels in winter, the highest recorded levels also being shown in Table 10.

Table 10. Seasonal Means (µg/L) and peak level recorded of Pesticide Levels in the Swan Estuary (May 1974 - March 1985)

	CAUSEWAY		FREMANTLE TRAFFIC		PEAK LEVEL
	SUMMER	WINTER	SUMMER	WINTER	
Aldrin	0.001	0.003	0.001	0.003	0.018
Chlordane	0.001	0.001	0.001	0.001	0.006
DDT & Metabolites	0.002	0.002	0.002	0.004	0.030
Dieldrin	0.005	0.005	0.003	0.005	0.035
Lindane	0.001	0.001	0.001	0.001	0.020
Heptachlor	0.001	0.003	0.001	0.003	0.060

These peak levels have been derived from a series of graphs in the Report (pages 127, 128). Some interesting points can be made from these graphs:

1. Sampling commenced in 1974. By winter of 1975, levels of all pesticides had fallen significantly, possibly implying that levels before 1974 were much higher than from 1975 onwards.

2. Despite this decline, the peak levels for aldrin, dieldrin and heptachlor all occurred in the winter of 1982.

3. The peak level for DDT occurred in 1975, with some smaller peaks in 1976. Since then DDT levels have been very low.

No sediment or biota residue levels have been taken.

Quarterly sampling is continuing.

4. <u>Organochlorine Pesticide Residues in the Preston River (Atkins 1982</u>)

This study was conducted in 1980 and 1981 to monitor the possible effect of the use of organochlorine pesticides in the Preston River catchment on water, sediment and biota levels in the river and Leschenault Inlet.

Of the 88 samples of water taken, dieldrin was detected in 78. DDT, aldrin and heptachlor were detected in 34, 25 and 5 samples respectively.

Between 22% and 67% of the dieldrin detections exceeded the EPA criterion depending on the site. DDT detection exceeded the EPA criterion between 11% and 33% of the time, depending on the sampling site. Aldrin and heptachlor detection were only occasionally above their respective EPA criteria.

The dieldrin levels were amongst the highest in rivers in the south west of WA, but were low when compared to other Australian rivers.

No organochlorines were detected in sediment samples, the limit of detection being 0.01 mg/kg.

Three specimens of fish were sampled from the lower reaches of the Collie River. Less than 0.01 mg/kg of DDT were found in all three, and only in one did the dieldrin level equal 0.01 mg/kg.

This Report compared dieldrin levels with those found in the Preston River, by various other researchers, since 1974. The author concluded that no significant reduction in dieldrin levels in that time had occurred, even though the number of registered agricultural uses for dieldrin in the area had declined markedly. This could be due to the very high level of retention of dieldrin by soils, in which the slow "release" of this chemical, as soil is eroded into the river, masks the decline in dieldrin use. Alternatively, (and perhaps, additionally), dieldrin was continuing to be used illegally.

5. Organochlorine Pesticide Residues in the Preston River (Klemm 1988-) (unpublished)

This is a follow-up to the previous study by Atkins (1982). The main objective of this study was to monitor the predicted reduction of dieldrin residues reaching the Preston River. In addition, the study aimed to detect any increase in other pesticide residues, and to detect any accumulation of organochlorines in Leschenault Inlet.

The study area, as in the previous one, extended from Glen Mervyn Dam to the Glen Iris Road Bridge on South West Highway, a 60 km section of the Preston River. The ten sampling sites used by Atkins (1982) were again used for this study. Sampling took place between December 1985 and May 1986.

It was found that organochlorine residues in the Preston River had decreased. Dieldrin was still the predominant pesticide, but the mean level had fallen from 0.006 to 0.003 μg/L since the Atkins (1982) study. In addition, the percentage of recordings that exceeded the EPA criterion of 0.003 μg/L had declined from 58% in the 1982 study to 13% in this study.

DDT levels had also fallen from a mean of 0.004 to 0.002 μg/L, with a fall from 46% to 8% of the recordings exceeding the EPA criterion.

Heptachlor, and for the first time, chlordane were found more frequently, and the proportion of heptachlor readings that exceeded the EPA criterion increased from 8% to 13% (chlordane from nil to 12%).

These changes have reflected the change in use-pattern of the chemicals. Dieldrin lost all agricultural registration in 1982, with heptachlor replacing dieldrin for potato production and in some orchards.

No organophosphorus residues were detected in the samples.

Levels of organochlorines in the twenty samples of freshwater mussel did not exceed the limit of detection (0.001 mg/kg) and therefore do not indicate any bioaccumulation.

Organochlorine residues in the Preston River are now generally comparable with other river systems. The range of dieldrin residues is similar to the Swan and Serpentine Rivers' systems, but levels are still higher than other South West Rivers.

6. Ongoing monitoring work in the Preston and Collie River (unpublished data)

The Waterways Commission has been taking one water sample each three months from December 1977 to December 1985 from both the Preston and Collie Rivers. This sampling has been independent of the sampling of the Preston River for the Atkins (1982) study. Unfortunately no samples have been taken since December 1985, however, the Commission has advised that quarterly sampling will recommence in 1989.

While the levels found have been many orders of magnitude below the Maximum Residue Limits for potable water, many of them have exceeded the EPA criteria, particularly between 1977 and 1981, and 1984/85. There is no obvious explanation for the noticeable absence of excessive residues between April 1981 and June 1984. This phenomenon holds true for all the organochlorine pesticides in both the Collie and Preston Rivers.

7. Avon River System Fact Finding Study (Hansen 1986)

This study was conducted by the Avon River System Management Committee, in late 1985.

The study was intended to:

- identify the main environmental values of the riverine ecosystem;
- examine the main alterations that are occurring to these ecosystems;
- suggest measures that may be taken to alleviate these alterations.

The report also sought to point out areas where inadequate knowledge is preventing an understanding of many longer term alterations that are occurring.

The report discusses the problem of point and non-point sources of pollution, and the potential for pesticide contamination of the river system, resulting from the use of pesticides in agriculture.

The only pesticide residue study reported was the very limited Sharpe (1985) unpublished work, which has been described earlier under the Department of Agriculture.

No other pesticide residue work was undertaken. This is unfortunate, given the importance of the study, and the opportunity it presented to provide much data on the effects of the use of pesticides in broad-hectare agriculture on the river system.

5.3 OTHER INSTITUTIONS

5.3.1 CURTIN UNIVERSITY OF TECHNOLOGY

For some years, Curtin University has had an Environmental Studies Group, comprising interested members of the Biology and Chemistry Departments. This group publishes a series of occasional research papers on various subjects of environmental interest.

One of these papers, ESG Report No 7, is described below.

Pesticide Residues around Swan Coastal Plain Lakes (Ford & Stacey, 1983)

This study was initiated as a result of the death of a kangaroo which had strayed into a section of Yanchep National Park, which had been treated with heptachlor for Argentine Ant control.

Twelve samples of grass and surface soil were taken from various locations within and close to the treated area.

No pesticide residues were found in any of the samples.

5.3.2 MURDOCH UNIVERSITY

The School of Biological and Environmental Sciences at Murdoch University is a leading centre of research into many areas of environmental concern to Western Australia.

One of the major areas of expertise being developed is on the effect of urban development on the wetlands of the Swan coastal plain. As part of this research a number of specific projects relating to the effects of pesticides on wetlands have been conducted in recent years.

1. Herdsman Lake Pesticide Study - Interim Report (Davis & Garland (1986): plus subsequent studies

   (a) This study was carried out to investigate the environmental effects of spraying to control the Argentine Ant at Herdsman Lake, in March/April 1986. The Department of Agriculture's programme to control Argentine Ants in Herdsman Lake commenced in the mid-1950s with the use of dieldrin. Heptachlor replaced dieldrin in 1970. The perimeter of the Lake has been treated every year except from 1983 to 1985, when public concern at the possible threat to wildlife resulted in a cancellation of the spraying programme for those seasons.

   A sampling programme was carried out when the spraying programme recommenced in the summer of March/April 1986 to establish the level of various organochlorines and organophosphates in the water, sediments, and two species of aquatic fauna, the mosquito fish (Gambusia affinis) and the corixid (Micronecta robusta). Samples were taken prior to spraying, one week after spraying, and after the first heavy rains following spraying, from six sites in the Lake itself, and two from control sites in an adjoining and separate waterbody. Quantitative sampling of aquatic invertebrate was also carried out at each sampling.

   The results showed that almost all components of the ecosystem of the Lake were contaminated, to varying degrees, with the organochlorine insecticides. Heptachlor and chlordane were not detected before spraying, suggesting that post-spraying levels found were due to that season's spraying activity.

   Dieldrin, and to a much lesser extent, DDT, were found in all samples, including those taken from drainage water entering the lake. This indicates that dieldrin has been present since its last use in 1970, in addition to any additional chemical entering via drains from surrounding urban areas.

   Fish and insect samples contained all organochlorines when taken post-spraying, but only dieldrin and DDT pre-spraying.

   Chlorpyrifos was found in post-spraying water and sediment samples only. Temephos was not detected in any samples.

   Insect (corixids) numbers decreased significantly after spraying. A dead pelican was found to contain elevated levels of all organochlorines, but far below those necessary to be the cause of death.

(b) Further sampling of pesticide levels in the water, sediments, fish and invertebrate fauna of Herdsman Lake took place in October 1986, from the same sites. Additional sites, near the Herdsman Industrial Park, and three drains, were also sampled.

This sampling showed that water levels of pesticides generally fell and became more uniform between sites, since the post-rain sampling in May. The levels of heptachlor and chlordane in sediments increased dramatically, and may partially account for the decline in water levels. Levels of pesticide found in one drain were higher than the Lake itself, and this must be considered a source of chemical.

Levels of pesticides in fish and invertebrates were much lower than the post-spraying high levels of May 1986, but were still higher than the pre-spraying levels. It was not possible to draw conclusions from the apparent "mortality" amongst fish and corixids immediately post spraying as animals from other parts of the lake probably recolonised the sprayed areas between May and October.

Pesticide levels in water birds were well below LD_{50} values for acute toxicity, but were high enough to be of concern.

(c) As a follow-up to this work, twenty one samples each of water and sediment were taken from seven Metropolitan Lakes with a history of Argentine Ant treatments, in December 1986.

This was to enable comparisons of pesticide levels in Herdsman Lake to be made with levels in lakes elsewhere in the Perth region, and to reveal possible rates of decline over longer time scales.

These results have not yet been written up, but my interpretation of the residue data is that Lakes Carabooda, Neerabup and Goolellal are significantly more contaminated with pesticides than Herdsman, both in the water and the sediments.

2. Forrestdale Lake Chironomid Study (Davis et al 1987)

This study, conducted between September 1985 and January 1986, was initiated by CALM to investigate the problem of midges (chironomids) at Lake Forrestdale, and effects of the pesticide temephos on their control, and the ecosystem of the Lake.

The report of the study concentrated on the biology of the various chironomid species found, and the effectiveness of temephos treatments on chironomid numbers. However, the report does cover some of the observed effects of the temephos applications on the invertebrate and insect species of the Lake. These effects were not quantified, nor was any attempt made to obtain pesticide levels from the water and sediments.

3. Investigations into more effective control of nuisance chironomids (midges) in metropolitan wetlands, Perth, WA (Davis et al 1988)

A Midge Research Steering Committee was established in August 1987 to oversee research into more effective and environmentally acceptable methods of reducing the nuisance caused by non-biting midges to nearby residents of Perth's major wetlands. The Committee was formed in response to concerns about the decreasing effectiveness, increasing cost and potentially harmful environmental effects of midge control methods.

The study almost entirely concentrated on the biology of the various midge species, and laboratory and field testing of several pesticides for control measures. Some assessment of the effects of the various pesticides on the environment was made within the enclosures used in the experiements, but these were not reported in detail.

5.3.3 CSIRO

The Division of Water Resources of CSIRO carries out scientific work aimed at improving the utilisation and quality of Australia's water resources.

Dr Robert Gerritse of the Division of Water Resources in Perth conducted a study in 1988 into the mobility of organochlorines in a Bassendean sand. This work was commissioned by the EPA.

The study was largely laboratory based, but one part involved a field monitoring exercise.

<u>Organochlorine Residues in Sediments and Soils in and around Lake Goolellal (Gerritse 1988 in EPA Bulletin 354)</u>

Lake Goolellal is one of a number of natural wetlands in the coastal plain, situated amongst the northern suburbs of metropolitan Perth. It has been treated with organochlorine insecticides on a number of occasions for Argentine Ants.

The Study involved the analysis of samples of soil, sediments and lake water taken from six points along each of two transects into the Lake, starting from the road (Lakeway Drive). Levels of all organochlorines peaked about 50 m from the shore line, and were found within 4 cm of the soil surface. No dieldrin or heptachlor was detected in the sediments of the lake.

Based on information on the use of these chemicals for Argentine Ant control, their half-lives in this situation were tentatively estimated to be much less than one year for heptachlor and chlordane - considerably less than is reported in the literature.

6. DISCUSSION OF THE ADEQUACY OF EXISTING PROGRAMMES, AND FUTURE NEEDS

6.1 INTRODUCTION

This chapter will assess the adequacy of existing monitoring programmes, for each component of the environment, in the light of the perceived environmental threats from pesticide use in that component. This discussion will lead to a number of recommendations.

It is convenient to divide the Western Australian environment into three main ecosystems, ie air, land and water. The aquatic ecosystem is further divided into freshwater (specifically, rivers and streams, groundwater and wetlands), and marine ecosystems.

The question of coordinating future monitoring needs and programmes will also be discussed.

6.2 AIR

The air is that component of the environment least affected by pesticides. At Kwinana, where WA's sole manufacturer is based, there is no evidence or suggestion that significant air pollution occurs. Unless a gross manufacturing defect occurs, air levels of all but the most volatile pesticides, such as the phenoxy herbicides, would be negligible. Therefore, monitoring of air pollution for pesticides would be relatively ineffective.

The other source of air pollution is the use of pesticides in the field. The only work that has been carried out to monitor this is the study by Gilbey in 1984. Gilbey found that low levels of phenoxy herbicides could be detected during the few weeks of the year when these chemicals were being applied to cereal crops. That study also confirmed what had been observed in other parts of the wheatbelt and South West, that phenoxy herbicide drift (whether droplet or vapour) affects only susceptible species of plants, and only with a relatively short distance (a few kilometres at most).

Thus, air pollution by pesticides is relatively insignificant and substantial monitoring, from an environmental perspective, is not justified.

6.3 LAND

Pesticides can affect the terrestrial component of the environment by contaminating the soil itself, or by affecting, either directly or indirectly, animal and plant life in or on it.

Most of the pesticides used in WA end up in the soil. This is not necessarily environmentally significant as many of them are degraded rapidly. The organochlorine insecticides, and the residual herbicides, are two groups of pesticides that are persistent in soils. The presence of persistent chemicals in the soil is, in itself, not an environmental threat unless the chemical is leached or eroded from the soil into a waterbody, or in the case of the residual herbicides, the soil is planted with susceptible plants, or the plant up-take and storage of the herbicide is significant.

The Department of Agriculture has found, by recent extensive soil testing, that organochlorine insecticide residues are widespread in rural land in the South West. These residues have resulted largely from the use of organochlorines in potato production, and orchard management.

Very large quantities of DDT have been used in the wheatbelt for thirty years. While DDT is well known as a persistent insecticide, no real attempt has been made to establish levels of DDT in wheatbelt soils, except for the very limited work by Sharpe (1985) in the Avon valley.

DDT has now been deregistered in WA, therefore no further DDT will be entering the environment. This means that extensive monitoring of the agricultural areas for DDT residues cannot be justified, in the absence of evidence of widespread contamination of waterbodies with DDT, or cases of environmental damage. However, some limited work should be carried out, complementing the work by Sharpe (1985) to establish the likelihood of DDT becoming a serious water contaminant.

Soil residual herbicides, while they are persistent in soils, have little effect until susceptible trees or plants are placed in contaminated soil. The use of these chemicals is limited, at rates necessary for total vegetation control, but widespread in agriculture at selective rates in cereals, and more importantly in lupins. Work by Piper in 1985 (unpublished) found some herbicide carry-over to the following season in a low-rainfall year. Further work is needed to determine if any threat to groundwater exists in (for example) a high-rainfall year.

Pesticides used on land can also directly affect vegetation or animals living on the land. For example, the use of herbicides in broadacre agriculture has been blamed, to varying extents, for the death of roadside and ornamental trees. It is alleged that drift from spray equipment is the source of the herbicide.

Gilbey (1984) showed that susceptible crops, such as tomatoes, could be adversely affected by phenoxy herbicide drift. The same cannot be said for herbicides in general on native vegetation. Nevertheless, the problem is potentially serious, and should be investigated.

This potential problem was highlighted by the then Western Australian Advisory Committee on Chemicals in Recommendation 16 of its Report "Legislative Control of Hazardous Substances in Western Australia" (February 1987). This Report was approved, by Cabinet, for implementation, and the Department of Agriculture was charged with the responsibility of putting Recommendation 16 into effect.

Recommendation 16 states "the scope of the Agricultural and Related Resources Protection Act and the Aerial Spraying Control Act be expanded, or new legislation developed, to encompass the protection of areas of non-target vegetation".

This work is well underway, and the Department of Agriculture, with advice of officers of other agencies, will draft new legislation to replace the two Acts named in the Recommendation. The new legislation will, amongst other things, make it an offence to cause damage to non-target vegetation by the application of a pesticide.

The new legislation will cover a gap in the State's legislative control of pesticide usage.

The Roadside Conservation Committee has, amongst others, the objective of preserving native vegetation, particularly on roadsides. It would be an appropriate function for this Committee to maintain a watching brief over the problem.

RECOMMENDATION 6

The Roadside Conservation Committee should continue to investigate reports of herbicide damage to native vegetation, and if necessary, recommend ways of minimising the problem.

Animals (including birds) living on land are difficult to monitor for the purpose of determining pesticide residue levels. However, two species, the rabbit, and the Australian Magpie are so widespread throughout the agricultural areas, that they appear to make ideal indicator species for monitoring the levels of organochlorine insecticides (and DDT in particular) in WA.

The magpie has been successfully used for monitoring purposes (Prince 1970-73).

RECOMMENDATION 7

The Department of Conservation and Land Management should re-introduce a monitoring programme for pesticide residues in the Australian Magpie (Gymnorhina tibicen).

RECOMMENDATION 8

The Agriculture Protection Board, in conjunction with the Department of Agriculture, should investigate the possibility of using the European Wild rabbit (Oryctolagus cuniculus) as a means of monitoring organochlorine (and other) pesticide residues in WA land and vegetation.

The APB has carried out excellent work on the natural resistance of Western Australian wildlife to 1080 poison. This should be continued with field monitoring to ensure that the continued use of 1080 baits does not endanger native animals.

6.4 WATER

The aquatic component of the environment is monitored for pesticide residues much more rigorously than any others. This is because water is used for critical beneficial uses - eg human consumption; it supports organisms which are often very sensitive to pesticide residues; and most pesticides invariably end up in water.

It is convenient to consider the different components of the aquatic ecosystem separately.

6.4.1 FRESHWATER

Fresh water ecosystems comprise rivers and streams (including the estuary), groundwater, and wetlands.

6.4.1.1 Rivers and Streams

Western Australia's rivers are likely to carry significant pesticide loads, particularly of organochlorine insecticides used in agriculture. However, only those rivers in the South West of the State, and the Ord River system in the East Kimberley, have been monitored to any extent.

The Preston River has been the most thoroughly monitored of all South West rivers, being the subject of two separate studies (Atkins 1982, Klemm 1988 unpublished) and ongoing sampling by both the Waterways Commission and the Water Authority. Other rivers which have been monitored to a much lesser extent are the Collie, Swan-Canning (Thurlow 1986) (Chegwidden 1980, 1981), Warren, Lefroy Brook, Scotsdale Creek, Denmark, Sleeman, Blackwood, Hay, Harvey, Carbunup, Austin, Serpentine, King, Robinson, Scott, Murray and Kalgan. These rivers have been variously sampled by the Waterways Commission, WAWA and the EPA.

The Ord River has been the subject of intense sampling up to the late 1970s to monitor DDT contamination following the decline of the cotton industry. Since then, the Ord has been sampled only occasionally.

The Avon River was sampled once (Sharpe 1985) and was the subject of a major environmental review, although, unfortunately, no sampling was carried out (Hansen 1986).

There is a lack of coordination in the monitoring that has been conducted in the river systems of the South West. The Waterways Commission only has "jurisdiction" over the Swan, Peel Inlet and Leschenault Inlet and the rivers which feed those estuaries.

Many of the others have been sampled by the Water Authority, because they supply potable water, or by the EPA as a "one-off" study to see what is there. The need for coordination will be discussed under Section 6.5.

The Water Authority carries out a regular and comprehensive survey of streamflow at its stream gauging stations on all river systems in Western Australia. Given the widespread use of DDT on agricultural soils in the wheatbelt areas of WA, and the dearth of information on DDT levels in rivers which drain this land, it is recommended that:

RECOMMENDATION 9

The Water Authority of Western Australia should extend its pesticide residue monitoring programme to include all major river systems which drain agricultural land.

The contamination of estuaries by pesticides depends on the chemical load being transported by the river systems that feed them. The levels of pesticide (particularly the organochlorines) in the water of estuaries is likely to be lower than in the water of river systems, due to the dilution effect. However, sediment levels may become critical due to the slower estuary flow rate. These sediment levels are important to many bottom-dwelling organisms. The sampling and analysis of estuarine indicator species (eg mussels) is important.

RECOMMENDATION 10

The Environmental Protection Authority and the Waterways Commission should continue to monitor pesticide residue levels in water, sediments and indicator organisms in estuaries.

6.4.1.2 <u>Groundwater and Wetlands</u>

Perth is fortunate in having relatively large quantities of fresh groundwater, in both shallow and deep aquifers, in the coastal plain. This water is important as a supplement to the potable water supply derived from dammed catchments. In addition it supplies all of metropolitan Perth's amenity irrigation needs, and most of its horticultural irrigation requirements.

The Water Authority conducts a comprehensive bore water monitoring programme for pesticides, as well as other physical and chemical properties. While this programme is essentially to satisfy our requirements for <u>potable</u> water, it also provides a useful means of monitoring the quality of groundwater from an <u>environmental</u> point of view.

Perth's groundwater is replenished largely from rainfall received over the coastal plain and the adjoining hills area. No work appears to have been carried out on the levels of pesticides (particularly the organochlorine insecticides) in rainfall. This information would assist in determining the sources of these pesticides in groundwater.

RECOMMENDATION 11

A research project into the levels of pesticides found in rainfall over the coastal plain should be carried out by an appropriate body, such as the Chemistry Centre of WA, Murdoch University or CSIRO.

The Health Department has, for many years, regularly sampled ground water from a series of multiport bores established around Metropolitan land-fill rubbish sites. These water samples are analysed for pollutants which may have originated from the rubbish tip, and be a public health threat. There is no reason why these samples could not also be analysed for pesticide residues, to provide another source of information about the quality of our ground water.

RECOMMENDATION 12

The Health Department should extend the analysis of water samples, taken from permanent bores at rubbish tips, to include pesticide residues, particularly the organochlorine insecticides.

Wetlands

Perth's groundwater provides the basis of the series of wetland lakes and swamps which run more or less north to south from Pinjar to Forrestdale. The environmental quality of these wetlands (with respect to pesticides) depends on the quality of the water supplying them, as well as the quantity of pesticides added for insect control.

There is ample evidence that the pesticide load of these wetlands, particularly the organochlorine insecticides, has increased in recent years, both as a result of their use in urban pest control, and in Argentine Ant control. Recent studies have shown that these levels could be responsible for changes in the invertebrate ecology of these lakes (Chambers J M & Davis J A 1988).

The organochlorines are no longer used in agriculture nor for Argentine Ant control, but their use in the building industry continues. It is therefore important that these pesticides continue to be monitored in wetlands to ensure that levels do not increase further, nor that further environmental degradation takes place.

RECOMMENDATION 13

The Department of Conservation and Land Management, as the manager of Western Australia's fauna, in conjunction with other managers of wetlands, should monitor wetlands for pesticide residues, and their effects on wetland ecology.

6.4.2 MARINE

The marine component of the environment is by far the least understood from the pesticide contamination point of view. Only two attempts have been made (Chegwidden 1979 and 1981) to determine pesticide residue levels in WA marine waters.

Given the relatively low residue levels of organochlorine insecticides in our rivers and estuaries, one would expect that levels in sea water would be virtually undetectable. However, both of Chegwidden's reports have found levels of dieldrin, for example, up to 0.027 μg/L in water, and in Cockburn Sound, 4 μg/kg of sediment.

Regular sampling of marine waters is carried out by the Department of Marine and Harbours, particularly in boat harbours. Samples are taken for analysis for nutrients, heavy metals and physical properties. It would not be difficult or expensive to extend this sampling to include sediments as well as water, and arrange for their analysis for organochlorine pesticides.

RECOMMENDATION 14

The Department of Marine and Harbours should extend their harbour water sampling programme to include sediments, and analysis for pesticide residues.

6.5 GENERAL DISCUSSION

There is no doubt that the organochlorine insecticides pose the greatest environmental threat of all pesticide types. These chemicals, with their lipophyllic properties, and their ability to biomagnify, are found at varying levels in almost all parts of the environment.

The organochlorines have now been withdrawn from agriculture, but remain for use as termiticides in the urban environment. Because their use in agriculture has been declining over the last 10 years or so, residues in agricultural produce have fallen markedly over the same period, notwithstanding the problem with the beef industry in 1987.

The same is not true for organochlorine residues in the environment. While these have declined in some situations, (for example the South West river systems) in response to their disappearance in agriculture, residue levels in urban groundwater have risen. Organochlorine residues in the environment are going to be with us for many years, therefore it is important that we maintain an accurate understanding of their levels.

Coordination

Agriculture still accounts for most pesticide use in Western Australia, and the Department of Agriculture is the source of most technical expertise in pesticides, their use and environmental effects. However, most of the undesirable environmental effects of pesticides, occur in areas of the environment managed by other Government agencies, for example, Water Authority, CALM and Waterways Commission.

In addition, the need for coordination has already been discussed in relation to residue monitoring in watercourses. All pesticide monitoring work, with the possible exception of the work carried out on the Ord River by the Ord River Ecology sub-committee, has been carried out by individual agencies with no relation to work being carried out by other agencies. Therefore:

RECOMMENDATION 15

A Coordinating Committee for Environmental Monitoring of Pesticides should be established and serviced by the Department of Agriculture. It may be appropriate for the Committee to report to the WA Advisory Committee on Hazardous Substances (WAACHS).

The Committee, which would meet infrequently would be concerned with:

1. Setting priorities for programmes of environmental monitoring of pesticides.

2. Ensuring that departmental programmes complement each other.

3. Reviewing environmental monitoring programmes.

In many ways, the Committee would continue the work of this Review, by providing an on-going overview of the monitoring work of State Government agencies. The membership of the Committee would comprise those government agencies whose work is described in the Report, ie, those agencies who manage some section of the environment.

Work on the efficacy of pest control systems will always be a necessary part of the Department of Agriculture's research effort. However, as the Government agency primarily responsible for the "management" of agriculture, the Department must assume increasing responsibility for those activities carried out by agriculture which affect the environment of Western Australia. The Department is already assuming this responsibility with respect to soil and water conservation. It must now do so with pesticide use.

RECOMMENDATION 16

The Department of Agriculture should increase its commitment of financial and human resources for the adequate monitoring of pesticides and their effects in the rural environment.

This would bring the Department of Agriculture into line with other Government agencies who put considerable efforts into monitoring their sector of the environment for pesticide residues imposed by the use of these chemicals in agriculture.

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Finally, I wish to express my gratitude to the EPA and the WA Department of Agriculture for the opportunity to undertake this consultancy.

REPPARPES

P A Rutherford

MAXIMUM RESIDUE LIMITS (MRL) FOR PESTICIDES IN POTABLE WATER.

Compound	*Maximum Residue Level (micrograms per litre)***	*Compound*	*Maximum Residue Level (micrograms per litre)***
Acephate	20	Fenvalerate	40
Alachlor	3	Flamprop-methyl	6
Aldrin	1	Fluometuron	100
Amitrole	1	Formothion	100
Asulam	100	Fosamine (ammonium salt)	3000
Azinphos-methyl	10	Glyphosate	200
Barban	300	Heptachlor	3
Benomyl	200	Hexaflurate	60
Bentazone	400	Hexazinone	600
Bioresmethrin	60	Lindane	100
Bromacil	600	Maldison	100
Bromophos-ethyl	20	Methidathion	60
Bromoxynil	30	Methomyl	60
Carbaryl	60	Metolachlor	800
Carbendazim	200	Metribuzin	5
Carbofuran	30	Mevinphos	6
Carbophenothion	1	Molinate	1
Chlordane	6	Monocrotophos	2
Chlordimeform	20	Nabam	30
Chlorfenvinphos	10	Nitralin	1000
Chloroxuron	30	Omethoate	0.4
Chlorpyrifos	2	Oryzalin	60
Cyhexatin	200	Paraquat	40
2,4-D	100	Parathion	30
DDT	3	Parathion-methyl	6
Demeton	30	Pendimethalin	600
Diazinon	10	Perfluidone	20
Dicamba	300	Permethrin	300
Dichlobenil	20	Picloram	30
3,6-Dichloropicolinic acid	1000	Piperonyl butoxide	200
Dichlorvos	20	Pirimicarb	100
Diclofop-methyl	3	Pirimiphos-ethyl	1
Dicofol	100	Pirimiphos-methyl	60
Dieldrin	1	Profenofos	0.6
Difenzoquat	200	Promecarb	60
Dimethoate	100	Propanil	1000
Diquat	10	Propargite	1000
Disulfoton	6	Propoxur	1000
Diuron	40	Pyrazophos	6
DPA	500	Quintozene	40
Endosulfan	40	Sulprofos	20
Endothal	600	2,4,5-T	2
Endrin	1	Temephos	30
EPTC	60	Thiobencarb	40
Ethion	6	Thiometon	20
Ethoprophos	1	Thiophanate	100
Fenchlorphos	60	Thiram	30
Fenitrothion	20	Trichlorfon	10
Fenoprop	20	Triclopyr	20
Fensulfothion	20	Trifluralin	500

* *Source:* Standard for Maximum Residue Limits of Pesticides, Agricultural Chemicals, Feed Additives, Veterinary Medicines and Noxious Substances in Food (1987). National Health and Medical Research Council.

** One microgram per litre is equal to one part per 1000 million.

MARINE AND ESTUARINE WATER QUALITY CRITERIA FOR MAINTENANCE AND PRESERVATION OF AQUATIC ECOSYSTEMS. (the "EPA CRITERIA")

Pesticide	Criteria µg/L
aldrin	0.003
azinphos-methyl	0.01
camphechlor	0.005
chlordane	0.004
2,4-D	4
DDT	0.001
dieldrin	0.003
endosulphan	0.001
endrin	0.004
heptachlor	0.001
lindane	0.004
maldison	0.1
methoxychlor	0.03
parathion	0.04
other pesticides	not to exceed 0.01 of the 96-hour LC_{50} value for the selected test species.

Definition of "used pesticide container"

21A. (1) Subject to subregulation (2) for the purposes of regulations 21B, 21C, 21D and 21E—

"used pesticide container "means a container—

(a) which has contained pesticide; or

(b) in which pesticide is contained.

(2) Subregulation (1) does not apply to a container designed to contain less than—

(a) 2 L of liquid pesticide; or

(b) 2 kg of solid pesticide,

when used for domestic or home garden purposes.

[*Regulation 21A inserted in Gazette 9 December 1988 p. 4823.*]

Disposal of used pesticide containers

21B. Unless the Executive Director, Public Health in any particular case otherwise directs, a person shall, after disposing of the contents (if any) in accordance with regulation 21F and washing out the used pesticide container; dispose of a used pesticide container by one of the following methods—

(a) by arrangement with a local rubbish collection agency;

(b) at a local shire rubbish tip after the owner of the container, by puncturing, breaking or flattening it, has rendered the container unusable; or

(c) subject to regulation 21C by burying on the property of the owner of the used pesticide container.

[*Regulation 21B inserted in Gazette 9 December 1988 p. 4823.*]

Disposal of private property

21C. Where a used pesticide container is disposed of by the method referred to in regulation 21B (c) the owner shall ensure that the used pesticide container—

(a) is rendered unusable by puncturing, breaking or flattening it; and

(b) is buried at least 0.5 m below natural ground level in a place which is situated at least 30 m from any water course and a minimum of 3 m above the water table.

[*Regulation 21C inserted in Gazette 9 December 1988 p. 4823.*]

Cleansing, reuse and labelling of a used pesticide container

21D. (1) Subject to subregulation (2), a used pesticide container may be reused after it has been—

(a) cleansed in a manner approved by the Executive Director, Public Health; and

(b) subject to subregulation (3) clearly labelled "USED PESTICIDE CONTAINER".

(2) A container referred to in subregulation (1) shall be—

(a) use to contain substances or foodstuffs for human or animal consumption; or

(b) reused as a pesticide container.

(3) A person who reuses a used pesticide container on the property of the owner of the used pesticide container is not required to comply with subregulation (1) (b).

[*Regulation 21D inserted in Gazette 9 December 1988 p. 4824.*]

Authority required for disposal etc., of used pesticide containers

21E. (1) A person shall not undertake to collect and dispose of used pesticide containers for reward unless the person holds a written authority from the Executive Director, Public Health approving the person's methods of collection and disposal.

(2) The Executive Director, Public Health may—

(a) impose any conditions on an authority referred to in subregulation (1); or

(b) at any time cancel or revoke any such authority.

[*Regulation 21E inserted in Gazette 9 December 1988 p. 4824.*]

Disposal of pesticides

21F. (1) Pesticides may be disposed of—

(a) by using in accordance with the label registered in respect of the pesticide;

(b) by destroying by chemical means approved by the Executive Director, Public Health;

(c) by incinerating at high temperature in an incinerator approved by the Executive Director, Public Health;

(d) in a manner approved by the Executive Director, Public Health in a gazetted land-fill site;

(e) where the pesticide contains less than 500 mL or 500 g of active constituent and the material does not contain a prescribed organochlorine or a substance specified in the Seventh Schedule in Appendix A to the *Poisons Act 1964*, by burying at least 0.5 m below natural ground level in a pit lined with an equal volume or weight of lime situated at least 30 m from any water course and a minimum of 3 m above the water table;

(f) where the pesticide contains a prescribed organochlorine or a substance specified in the Seventh Schedule in Appendix A to the *Poisons Act 1964*, by burying the pesticide in accordance with paragraph (e) after obtaining the permission of and subject to any conditions imposed by the Executive Director, Public Health; or

(g) by any other method approved in writing by the Executive Director, Public Health.

(2) For the purposes of subregulation (1) "prescribed organochlorine" shall have the same meaning as in regulation 54.

[*Regulation 21F inserted in Gazette 9 December 1988 p. 4824.*]