The National Registration Authority
for Agricultural and Veterinary Chemicals

THE RESIDUE IMPLICATIONS OF SHEEP ECTOPARASITICIDES

A Report for The Woolmark Company

by

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About This Review

"Nobody eats wool, so why worry about pesticide residues in wool?"

"It's no use growing the stuff if you can't bloody sell it."

Those two direct quotations come from opposite ends of the diverse spectrum of opinions about pesticide residues on wool.

The first one sums up fairly succinctly the widespread lack of understanding about the human health, occupational health and safety, environmental and trade implications of pesticide residues on wool and why they are of concern. The second draws attention to the primary purpose of this project - to maintain the marketability of Australian wool.

This review summarises most of the currently known information about residual pesticide on wool. To facilitate reading, the report has been broken up into discrete sections, some of which are intended to stand alone, but which are also linked together. This approach inevitably leads to some repetition.

The sections cover the issues involved, the residue data that are available and the implications of those residues for human health, occupational health and safety, the environment and trade. Suitable standards have been identified as well as the implications of those standards for the pesticides currently used on sheep. Finally, recommendations are proposed which if implemented, will allow continued use of sheep ectoparasiticides and still allow treated wool to be marketed.

It is important to appreciate that this review is not a formal reconsideration of individual sheep ectoparasiticides. The primary purpose of the review is to identify and recommend residue standards against which individual products can be assessed for registration purposes. Once those standards are in place the NRA will then be in a position to assess new and existing products against them and, if necessary, initiate formal reconsideration of individual products.

There are a couple of conventions adopted in the review that should be mentioned.

(a) The substance that gives unscoured wool its greasy feel is, technically speaking, a wax. For this reason, the terms "wool wax" and "raw wool" have been used rather than "wool grease" and "greasy wool". The only exception is a reference to "raw wool grease" which is the commercial term used to describe unrefined wool wax recovered from the scouring process.

(b) The concentrations of pesticide on wool and in scouring effluent are referred to as residue levels and are expressed respectively as mg/kg wool or mg/L of scouring effluent, unless otherwise indicated.

Terms of Reference and Scope of the Review

This review was undertaken by the NRA in response to a request from the Australian Wool Residues Management Council to:

(a) conduct a review of all currently registered long wool sheep ectoparasiticides with particular priority given to long wool backline products; and

(b) provide clear guidelines for the chemical industry on the type of data required to address emerging trade and marketing needs with respect to residual pesticide on wool.

At the first meeting of the steering committee established to oversee the project, which included representatives from the Wool Residues Management Council, it was decided that the primary purpose of the review was to:

(a) address concerns about pesticide residues on wool arising from use of registered sheep ectoparasiticides, in relation to:

- occupational hazard to shearers and other wool handlers;
- the environmental impact of pesticide residues in scouring effluent;
- trade of Australian wool.

(b) establish acceptable residue limits for pesticides on raw wool and withholding periods (if appropriate), which take into account trade, environmental and occupational safety considerations as well as the animal welfare implications of flystrike and lice.

It was also decided that the review should also consider application techniques and application rates for sheep ectoparasiticides to the extent that they impact on residual pesticide levels.

Executive Summary

Background

The National Registration Authority for Agricultural and Veterinary Chemicals (NRA) has been asked by the Australian Wool Residue Management Council to:

(a) conduct a review of all currently registered long-wool sheep ectoparasiticides with particular priority given to long-wool backline products; and

(b) provide clear guidelines for the chemical industry on the type of data required to address emerging trade and marketing needs with respect to residual pesticide on wool.

The request was made because of wool industry and government concerns about the public health, occupational safety, environmental and trade implications of pesticide residues on Australian raw wool arising from the use of sheep ectoparasiticides.

The Council's concerns have arisen largely from residue monitoring data collected by The Woolmark Company (formerly known as the International Wool Secretariat or IWS) and associated farmer surveys conducted by NSW Agriculture, as well as from recent studies conducted jointly by the Department of Natural Resources and Environment and CSIRO Wool Technology in Victoria.

The Woolmark Company monitoring studies on the Australian wool clip in the 1992/93 season showed that while residue levels were generally quite low, about 20% of sales lots contained more than 13 mg pesticide/kg wool. This was thought, at the time, to be the maximum residue level required to meet proposed Australian standards for the pesticide content of scouring effluent and other trade wastes discharged to sewers. Furthermore, about 50% of the total residue loading came from about 5% of sales lots sampled, which had residues in excess of 50 mg/kg wool.

The Victorian studies showed that it was possible for these high residue levels to arise from the use of certain registered long-wool treatments applied 3 months before shearing, in accordance with label directions. These conclusions were supported by an Avcare report which provided data in response to an earlier concern raised by the National Occupational Health and Safety Commission (NOHSC) about the occupational hazard of pesticide residues on raw wool, as well as by farmer surveys conducted by NSW Agriculture and the Tasmanian Department of Primary Industry and Fisheries.

The farmer surveys indicated that high residue levels were generally associated with the use of long-wool products for both lice and fly control in the 6 months before shearing, use of long-wool backline products, repeated applications, and pesticide applications to young sheep or sheep shorn with less than 12 months wool. On the other hand, correct use of off-shears and short-wool products within the first 6 weeks after shearing generally resulted in low residue levels in sales lots, provided treated sheep were shorn with 12 months wool. Likewise, treatment of individual struck sheep in a flock with wound dressings usually resulted in low residue levels in sales lots, even when these treatments were applied in the last 3 months before shearing.

The Victorian studies also raised concern about the occupational safety of registered long-wool backline products containing synthetic pyrethroids, because of very high residue levels (>5000 mg/kg wool wax) remaining on the tip of the wool staple, along the backline of the sheep, for at least 3 months after treatment. Other concerns have been raised by the Commonwealth Department of Health and Family Services about the human health aspects of residual pesticide in pharmaceutical grades of lanolin, and other pharmaceutical and cosmetic products containing lanolin.

The Wool Industry's marketing concerns are driven mainly by concern both in Australia and overseas about the potential environmental impact of residual pesticides in scouring effluent. Environmental standards presently in place in the UK, and which are expected to be adopted by other European Union (EU) member countries in October 1999, will require even lower levels of residual pesticide in raw wool than are currently considered acceptable. The International Wool Textile Organisation has recently indicated support for routine testing of raw wool for chemical residue levels.

Because of those concerns, the wool industry decided to take a pro-active role in reducing the levels of pesticide residues on Australian raw wool and, in May 1994, introduced a strategy to halve, by mid 1997, the levels of residual pesticide in the clip from what they were in the 1994/95 season. That strategy included monitoring of residue levels in the wool clip, research into the causes of high residues, farmer education to encourage correct use of pesticides and asking the NRA to ensure that correct use of registered ectoparasiticides did not contribute to the problem.

On the basis of this information, the NRA agreed to conduct a review of all the sheep ectoparasiticides to address the wool industry's concerns. It also set up a Steering Committee composed of representatives from The Woolmark Company , the Wool Council of Australia, the veterinary chemical industry, Environment Australia, NOHSC, CSIRO Wool Technology and the NRA to oversee the review process. The terms of reference and scope of that review have been described earlier.

Procedure

A detailed review of occupational health and safety (OH&S) aspects of the issue was carried out by NOHSC. That review indicated that, if the modified OH&S protocol (Appendix I) was to be used for assessing the sheep ectoparasiticides, a 6 month rehandling period would apply for most of the existing organophosphate products and cyromazine. Shorter rehandling periods would apply for the other pesticides used on sheep. However the NRA review has identified deficiencies in the proposed method of estimating the exposure hazard of wool residues to shearers and other wool handlers, and further work will be required to clarify this issue before OH&S standards can be finalised.

After consultation with Environment Australia, CSIRO Wool Technology, and ENco (an environmental consultancy group previously associated with the former International Wool Secretariat in the UK), a decision was made to base Australian environmental requirements on the standards that have to be met at the Black Rock ocean sewage outlet by scouring plants in the Geelong area. UK/EU requirements were based on the standards that have to be met by a ‘worst case scenario’ scour in the UK that discharges effluent to the Aire-Calder River complex in the Leeds-Bradford scouring district in the UK. The protocol described in Appendix IV was then used to determine the maximum residue levels in raw wool that could be tolerated in a scouring lot if those environmental requirements were to be met.

Where possible, market share considerations (ie the percentage of the national flock treated with a particular pesticide), as well as wool blending practices carried out at wool scours were then taken into account in determining the maximum allowable residue levels in individual sales lots, using models proposed by Shaw (ENco) and Russell (CSIRO Wool Technology). Relevant withholding periods were determined, where possible, using residue dissipation models developed by Campbell (Department of Natural Resources and Environment, Victoria) and Horton (Department of Primary Industry and Fisheries, Tasmania).

The review has shown that all existing off-shears and short-wool treatments (ie those applied up to 6 weeks after shearing) would meet proposed Australian environmental requirements if used as directed; however only the organophosphate, dicyclanil, triflumuron and magnesium fluorosilicate/rotenone treatments would meet UK/EU requirements at current use patterns. As far as long-wool products are concerned, all of them, apart from cyromazine and dicyclanil, would need a withholding period of at least 6 months in order to meet Australian environmental requirements. Some (eg diflubenzuron and certain synthetic pyrethroid backline products) would need a withholding period of at least 52 weeks. Apart from cyromazine and dicyclanil, none of the existing long-wool treatments would meet UK/EU requirements if used any closer than 9 months before shearing. Longer withholding periods would be required for the synthetic pyrethroid backliners and diflubenzuron.

Setting registration standards

In setting registration standards for sheep ectoparasiticides, it was noted that the NRA needs to take into account safety to humans (both to users of the products and to people likely to come into contact with treated wool), safety to the environment, and the potential of residual pesticide to adversely impact on trade of Australian raw wool.

The logical and easiest approach is to define acceptable criteria for each of the key areas (public health, occupational health and safety, environment and trade) and then adopt the most critical of these as the standard which products should meet.

A major difficulty with this approach when dealing with sheep ectoparasiticides is that the likely withholding periods (6 months or more in most cases) would impose severe limitations on the use of long-wool products at a time when sheep are most susceptible to flystrike. This could give rise to an animal welfare problem.

Also, most sheep ectoparasiticides need not pose an environmental threat if treated wool is processed in a facility able to handle pesticide contaminated effluent in an environmentally acceptable manner. If treated wool could be identified and scoured in an appropriate facility, there is scope for taking a more relaxed approach to registration standards based on environmental needs.

The NRA already determines for each ectoparasiticide, maximum residue limits (MRLs) for sheep meat and milk and an appropriate meat/milk withholding period. Any further standards imposed would be in addition to those existing standards.

The Australian Wool Residues Management Council has recommended that any environmental standards be based on Australian environmental requirements for the ocean sewage outlet at Black Rock. The Council also recommended that such standards take into account the percentage of the national flock treated with a particular pesticide, as well as a risk analysis based on the 95% probability of a particular residue level being exceeded. The Council indicated that it would be prepared to investigate alternative mechanisms for ensuring that raw wool exported overseas meets relevant standards.

With these difficulties and requirements in mind, the following three options were considered:

Option 1

Do nothing.

Option 2

For each product and approved use pattern, establish a “critical residue level” for harvested raw wool that is based on the most critical of the Australian environmental and occupational health and safety standards referred to above, determine the withholding or rehandling period necessary to meet that standard, and stick fairly rigidly to those standards, withdrawing any product that fails to meet them.

If this option were to be adopted, the wool industry would need to develop mechanisms for ensuring that wool exported overseas meets residue requirements of importing countries.

Such an approach would effectively remove most long wool products from the market.

Option 3

Take a much more difficult but more pragmatic approach to the setting and regulation of standards as follows:

(a) For each product and approved use pattern, determine an occupational health and safety “rehandling period” that must elapse before treated sheep are shorn, that will take precedence over all other standards.

(b) Also establish a “critical environmental residue limit” for harvested wool that is based on Australian environmental requirements at Black Rock ocean outlet, after taking into account the percentage of the national flock likely to be treated, and determine the withholding period necessary to meet that standard (referred to subsequently in this report as the "wool harvesting withholding period").

(c) Where the proposed use is considered essential for animal welfare reasons, and it is possible to scour the wool in certain scouring facilities without posing an environmental threat, consider approving use of the product within the wool harvesting withholding period, providing the following conditions are met:

   (i) any shearing rehandling period must be observed;

   (ii) treated sheep and wool must be suitably identified to intending buyers; and

   (iii) mechanisms must be in place to identify and deal with treated sheep and wool, and to educate wool producers, buyers and processors about their obligations.

   Obviously where the shearing rehandling period is longer, use of the product within the wool harvesting withholding period would not be possible.

(d) If this approach is taken, it is essential that the wool industry, in consultation with the NRA and State departments responsible for agriculture, develop suitable mechanisms for identifying and handling wool that has been treated within the withholding period (eg by requiring a vendor declaration or analytical certificate at sale), ensuring that treated wool is appropriately processed and, if considered necessary, authorising and monitoring such use.

(e) The wool industry will also need to develop a satisfactory mechanism for ensuring that exported wool meets residue requirements of importing countries. Such a mechanism at the very least would require some way of identifying pesticide contaminated wool to intending buyers (eg by requiring a vendor declaration or analytical certificate at sale), as well providing advice to interested parties on overseas trade requirements.

The Steering Committee's preferred option is Option 3. This option also has the support of the Wool Residues Management Council and, with some reservations, the Wool Council of Australia (the peak wool grower body).

It is proposed that the wool harvesting withholding period be shown on the product label in the form of an advisory statement along the following lines:

"***Wool harvesting withholding period***

Use of this product may result in residue levels in harvested wool that are unacceptable to Australian and overseas processors. It is recommended that wool not be harvested for at least 'x' months after treatment. Longer withholding periods may be necessary for wool intend for certain overseas markets. If sheep are treated within this period, treated sheep and wool must be identified to *intending buyers by vendor declaration. For further information, including information on overseas trade requirements, contact 1800 phone number".*

CSIRO Wool Technology has developed an analytical technique that promises to allow screening of wool samples for pesticide content at reasonable cost. If widely adopted commercially, such a technique would provide the wool industry with an acceptable way of assessing the residue status of wool prior to sale. This would allow buyers and processors to identify wool that meets their processing and environmental requirements and help to overcome many of the problems identified in this report.

The NRA will need to develop appropriate guidelines for registrants to help them develop appropriate data for registration and assessment purposes. Those guidelines are currently being prepared.

The wool industry should continue to monitor the residue status of the Australian wool clip and the needs of overseas markets. If Australian wool is not adequately meeting those needs, consideration should be given to incorporating the residue requirements of overseas countries into relevant standards.

Recommendations

1. Option 3 described above should be adopted as the preferred method of assessing sheep ectoparasiticides. This would require the NRA to:

    (a) establish three standards and associated withholding/rehandling periods for each of the sheep ectoparasiticides as follows:

    - meat/milk MRLs and an associated withholding period
    - a shearing rehandling period
    - a standard (critical environmental residue level and an advisory withholding period) for harvested wool that is based on Australian environmental requirements at Black Rock ocean outfall (Table 1).

    (b) allow use of the product within the wool harvesting withholding period where there are valid animal welfare reasons for doing so, provided such use does not contravene any OH&S rehandling period and that treated sheep and wool are identified to intending buyers prior to sale, either by a vendor declaration or by an analytical report.

2. The NRA should adopt the model proposed by Environment Australia for assessing environmental requirements (Appendices III and IV). Where practical, the procedures proposed by Shaw and Russell should be used for determining the critical environmental residue level, and those proposed by Campbell and Horton, for determining appropriate withholding periods. The NRA should also develop guidelines on data requirements for registrants.

3. Current withholding periods for long-wool sheep ectoparasiticides should be phased out as soon as possible and replaced by the wool harvesting withholding periods described in Recommendation 1 above.

4. The wool industry, in consultation with the NRA and State departments responsible for agriculture, should develop suitable mechanisms for identifying sheep and wool that have been treated within the wool harvesting withholding period (eg by requiring a vendor declaration and/or analytical certificate at sale), educating wool producers, buyers and processors about these requirements and, if considered necessary, approving and monitoring use within the withholding period.

5. In order to allow wool buyers to meet customer requirements, the wool industry should make available at the point of sale all known information about the chemical residue status of wool on offer, including any relevant vendor declarations and analytical certificates.

6. The wool industry should develop suitable mechanisms for ensuring that wool exported overseas meets the residue requirements of importing countries and for

making relevant information available on request to the various sectors of the wool industry, the veterinary chemical industry and other interested parties.

7. To assist in this regard, the wool industry, in consultation with CSIRO Wool Technology and appropriate analytical laboratories, should explore options for providing a cost effective method of analysing wool for its pesticide content.

8. A more scientifically based estimate of shearer exposure to wool wax and the pesticide it contains needs to be developed as a matter of priority, preferably within the next 12 months. Once that is done, NOHSC should revise the protocol used for assessing the occupational hazard of residues in harvested wool and determine appropriate rehandling periods for each of the sheep ectoparasiticides.

9. The NRA should formally reconsider the registration status of all the long wool products other than cyromazine and dicyclanil, and the insect growth regulator diflubenzuron, in view of occupational health and safety and environmental concerns raised in this report.

10. The wool industry, in consultation with State departments responsible for agriculture, should develop guidelines on producing low-residue wool and make them available to wool producers. Such guidelines should discourage farmers from using long-wool ectoparasiticides during the wool harvesting withholding period, applying repeat applications of ectoparasiticides to sheep with long wool, or applying ectoparasiticides to lambs likely to be shorn or slaughtered early, unless absolutely necessary. These guidelines should clearly state that if such products have to be used within the withholding period for animal welfare reasons, treated sheep and wool should be identified by a vendor declaration or analytical certificate prior to sale.

11. The wool industry should continue to monitor residue levels in the Australian wool clip and the needs of overseas markets. If Australian wool is not adequately meeting those needs, the NRA, in consultation with the wool industry, should consider incorporating the residue requirements of overseas countries into relevant standards.

The likelihood of currently available sheep ectoparasiticide treatments meeting proposed environmental requirements in Australia and Europe, given 1997/98 use patterns, is summarised in the following table. The estimated wool harvesting withholding periods necessary to meet those requirements are also shown.

Likelihood of currently available sheep ectoparasiticide treatments[§] meeting proposed environmental requirements in Australia and Europe, given 1997/98 use patterns, and the estimated wool harvesting withholding periods (WHP)* necessary to meet those requirements.

Treatment	Australia		EK/EU	
	Likely to meet standards?	Estimated WHP (weeks)	Likely to meet standards?	Estimated WHP (weeks)
Off-shears backline/spray-on				
Organophosphates	Yes	19	Yes	32
Synthetic pyrethroids	Yes	50	No	>52
Dicyclanil	Yes	12	Yes	12
Triflumuron	Yes	9*	Yes	50
Short-wool dipping				
Organophosphates	Yes	12-16	Yes	22-26
Synthetic pyrethroids	Yes	46	No	>52
Diflubenzuron	Yes	46	No	>52
Magnesium fluorosilicate[+]	Yes	<12	Yes	<12
Short-wool backline/spray-on				
Dicyclanil	Yes	12	Yes	12
Long-wool jetting				
Organophosphates	Yes	21-26	No	27-36
Synthetic pyrethroids	Yes	12	No	>52
Cyromazine	Yes	9*	Yes	9*
Diflubenzuron	No	>52	No	>52
Long-wool backline/spray-on				
Synthetic pyrethroids	No	52	No	>52
Diazinon[#]	Yes	12	Yes	22
Cyromazine	Yes	9*	Yes	9*
Dicyclanil	Yes	12	Yes	12

Note:

§ Amitraz has not been included because of inadequate data and ivermectin has been temporarily withdrawn from the market by the registrant.

* All WHPs estimated on the basis of currently available residue data and subject to review. Where critical environmental residue level unlikely to be met in practice, a default withholding period of 9 weeks (2 months) is recommended.

\# Diazinon backline treatment in combination with cypermethrin.

\+ In the case of magnesium fluorosilicate/rotenone, insufficient data available to determine a precise withholding period.

The Residue Implications of Sheep Ectoparasiticides

1. Background

The National Registration Authority for Agricultural and Veterinary Chemicals (NRA) has been asked by the Australian Wool Industry Residue Management Council to:

(a) conduct a review of all currently registered long wool sheep ectoparasiticides with particular priority given to long wool backline products; and

(b) provide clear guidelines for the chemical industry on the type of data required to address emerging trade and marketing needs with respect to residual pesticide on wool.

The request was made because of wool industry and government concerns about the public health, occupational safety, environmental and trade implications of pesticide residues on Australian raw wool arising from the use of sheep ectoparasiticides.

The Council's concerns have arisen from residue monitoring data collected by The Woolmark Company (formerly known as the International Wool Secretariat or IWS) and associated farmer surveys conducted by NSW Agriculture, as well as from recent studies conducted jointly by the former Victorian Department of Agriculture (now the Department of Natural Resources and Environment) and CSIRO Wool Technology in Victoria. All of these studies have reinforced concerns about the future marketability of Australian raw wool because of the presence of pesticide residues.

The Woolmark Company monitoring studies on the Australian wool clip in the 1992/93 season showed that while residue levels were generally quite low (mean organophosphate residue levels in the Australian clip were 10.2 mg/kg raw wool, and mean synthetic pyrethroid residue levels were 5.8 mg/kg), about 20% of sales lots contained more than 13 mg pesticide/kg wool. This was thought, at the time, to be the maximum residue level required to meet proposed Australian guidelines for the pesticide content of scouring effluent and other trade wastes discharged to sewers. Furthermore, about 50% of the total residue loading came from about 5% of sales lots sampled, which had residues in excess of 50 mg/kg wool.

The Victorian studies showed that it was possible for these high residue levels to arise from the use of certain registered long wool treatments applied 3 months before shearing, in accordance with label directions. These conclusions have been supported by an Avcare report which provided data in response to an earlier concern raised by the National Occupational Health and Safety Commission (NOHSC) about the occupational hazard of pesticide residues on raw wool to shearers and other wool handlers, as well as by farmer surveys conducted by NSW Agriculture and the Tasmanian Department of Primary Industry and Fisheries.

The farmer surveys indicated that high residue levels were generally associated with the use of long-wool products for both lice and fly control in the 6 months before shearing, long-wool backline products, repeat applications, and pesticide applications to young sheep or sheep shorn with less than 12 months wool. On the other hand, correct use of off-shears and short wool products within the first 6 weeks after shearing generally resulted in low residue levels in sales lots, provided sheep were shorn with 12 months wool. Likewise, treatment of individual struck sheep in a flock with wound dressings resulted in low residue levels in sales lots even when these treatments were applied in the last 3 months before shearing.

The Victorian studies have also raised concern about the occupational safety of registered backline long-wool products because of very high residue levels remaining on the tip of the wool staple along the backline of the sheep at the time of shearing. Other concerns have been raised by the Commonwealth Department of Health and Family Services about the public health hazard of residual pesticide in pharmaceutical grades of lanolin, and other pharmaceutical and cosmetic products containing lanolin.

The wool industry's marketing concerns are driven mainly by concern both in Australia and overseas about the environmental impact of pesticides in scouring effluent. For example, scouring wool with a residual pesticide concentration of 13 mg/kg raw wool (or 100 mg/kg in wool wax) will produce a scouring effluent containing about 1 mg pesticide/L, which is the maximum pesticide concentration recommended in guidelines for trade wastes discharged to sewers, published jointly by the Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) and the Australian and New Zealand Environment and Conservation Council (ANZECC). Environmental standards currently imposed in the UK, and expected to be adopted by other European Union (EU) member countries in October 1999, will require much lower maximum levels of residual pesticide in raw wool than are currently considered acceptable. The International Wool Textile Organisation (IWTO) has recently indicated support for routine testing of raw wool for chemical residue levels.

Because of those concerns, the wool industry decided to take a pro-active role in reducing the levels of pesticide residues on Australian raw wool, and in May 1994 introduced a strategy to halve, by mid 1997, the levels of residual pesticide in the clip from what they were in the 1994/95 season (Pattinson 1995). That strategy included monitoring of residue levels in the wool clip, research into the causes of high residues, farmer education to encourage correct use of pesticides and asking the NRA to ensure that correct use of registered ectoparasiticides did not contribute to the problem.

On the basis of this information, the NRA in November 1995 agreed to conduct a review of all the sheep ectoparasiticides to address the wool industry's concerns. It also set up a Steering Committee comprised of representatives from The Woolmark Company, the Wool Council of Australia, the veterinary chemical industry, Environment Australia, NOHSC, CSIRO Wool Technology and the NRA to oversee the review process. The Steering Committee will be referred to subsequently in this report as "the Steering Committee".

2. The Issues

2.1 Fate of pesticide residues in wool

Pesticides are applied to sheep to control external parasites (or ectoparasites) such as lice and blowflies, using various techniques, at different times during the wool growing season. The most common application techniques and timing are:

- off-shears backline application (ie within 24 hours after shearing);
- plunge or shower dipping of short-wool sheep (ie up to 6 weeks growth of wool);
- hand jetting of long-wool sheep (ie sheep with more than 6 weeks growth of wool), where a pesticide solution is “raked” into the wool using a jetting wand, along the backline and sometimes into the breech or crutch, as well as the poll;
- automatic jetting race application to long-wool sheep;
- backline application to long-wool sheep;
- treatment of individual fly-struck sheep, by hand, using wound or fly-strike dressings.

The method and timing of application can have a bearing on the amount of pesticide applied to the sheep and the amount left in the wool by the time sheep are shorn. So can the duration of the application (eg the time sheep spend in the dip), and the location of the pesticide in the fleece. These issues are all discussed later in this report.

The pesticides used generally fall into three main groups - organophosphates (such as diazinon, chlorfenvinphos, propetamphos, and temephos), synthetic pyrethroids (such as alphacypermethrin, cypermethrin, cyhalothrin, lamda-cyhalothrin and deltamethrin), and insect growth regulators (such as cyromazine, dicyclanil, diflubenzuron and triflumuron). A fourth group, the macrocyclic lactones, is represented by ivermectin. Two other ungrouped pesticides used on sheep are amitraz and a magnesium fluorosilicate/rotenone mixture.

Most ectoparasiticides are lipophilic (ie fat soluble) and are mostly absorbed by the wax component of the wool. Cyromazine, dicyclanil and the magnesium fluorosilicate/rotenone combination are the only registered ectoparasiticides with appreciable water solubility.

Pesticides applied to the fleece of a sheep dissipate over time, due to volatilisation, the action of sunlight, the oxidising effects of the atmosphere and in some cases, microbial degradation. Higher rates of dissipation are experienced in those parts of Australia which experience higher temperatures and more sunlight. The location of the pesticide in the wool, and hence exposure to the sun and atmosphere, are thought to strongly influence the rate of degradation (Rammell and Bentley, 1989, 1990). Thus pesticides remaining on the tip of the staple tend to break down more quickly than those located in the body of the fleece. Dissipation rates are generally higher on coarse wool sheep with open fleeces such as the carpet wool breeds than they are on finer wool breeds such as the Merino (Robinson *et al*, 1998).

The rate of dissipation is also influenced by the type of pesticide, with organophosphates breaking down relatively quickly (eg half life of 4-5 weeks under Australian conditions) compared with the synthetic pyrethroids (half life of 14-15 weeks). The insect growth regulators are also very persistent and exhibit half lives of similar magnitude to the synthetic pyrethroids (14-18 weeks).

Very little dissipation occurs in baled wool.

Regardless of the type of pesticide, residue levels on raw wool at shearing are generally related to the amount of active constituent applied and the length of time between application and shearing. The higher the application rate of pesticide, the more frequently it is applied and the closer it is applied prior to shearing, the higher will be the level of residual pesticide on harvested wool.

When raw wool is scoured, most of the residual pesticide is removed from the fibre, along with the wool wax, suint, dirt and other contaminants. About 4-5% of the pesticide may stay on the fibre after scouring, associated with residual wool wax and lipids. Most of this is removed during subsequent wet processing of the wool, particularly during late-stage processing such as dyeing. Thus dye-house effluent can also be a source of environmental contamination.

Residues of lipophilic pesticides remain associated with the wax when it is removed from the wool during the scouring process. Wool scours recover about 30% of the wax (and any lipophilic pesticide residues it contains), and this is usually sold as “raw wool grease” for further refining into lanolin products. Modified forms of lanolin are used as a base for a wide variety of industrial products as well as for human pharmaceuticals and cosmetics.

The remaining wool wax (and hence about 65% of the lipophilic pesticide residues) leaves the scouring line as scouring effluent, which may be treated by additional on-site effluent treatment systems or centralised sewage treatment plants before being discharged to the environment as a liquid effluent.

On-site treatments are mainly designed to reduce the high organic loadings from wool scours. They vary in complexity, cost and effectiveness. The simplest, and cheapest to install and run, are based on chemical coagulation and flocculation. Others include more expensive biological and evaporative treatments. These treatments do not destroy the pesticides, but simply transfer them to another medium which may be easier to handle and process. They all discharge a liquid effluent that may contain some residual pesticide. Recovered materials are usually collected on-site as a sludge, and can be used for a wide variety of beneficial purposes such as composting material and potassium fertiliser (Russell, 1996). Alternative methods of disposal include landfilling or incineration.

The simpler flocculation treatments vary widely in efficiency but, on average, they allow scouring plants to remove about 80% of the remaining lipophilic pesticide from effluent before it is discharged off-site (Shaw, personal communication). Thus it is possible to reduce the lipophilic pesticide content of the final effluent down to about

10% of the original pesticide content of the wool, although Shaw's data suggests that an average figure of about 20% is more likely under commercial scouring conditions.

Water soluble pesticides (such as cyromazine) do not associate with wool wax and other lipid materials, and they may not be removed from effluent effectively by simple on-site treatments designed to remove wool wax. They are mostly discharged to the environment in liquid effluent unless total containment systems such as evaporation or incineration are used.

Scourers in overseas countries are under increasing pressure from environmental authorities to install some form of on-site treatment of scour liquors before discharge. That pressure does not exist in Australia at present and to date, few Australian scouring plants have adopted these processes.

2.2 Public health

Processed wool contains very little, if any, residual pesticide and consequently, contact with woollen garments and other woollen products is unlikely to pose any kind of health risk.

However, residues in wool may become a public health issue if they end up in lanolin-based pharmaceuticals and cosmetics which are applied to human skin. A significant proportion of residual pesticide in the recovered wool wax may remain associated with the wax component of the lanolin during normal refining techniques. It can only be removed by more sophisticated and hence expensive refining techniques. These techniques are now widely available and most major lanolin refiners now produce low pesticide grades.

Residual pesticide in lanolin is of particular concern if that lanolin is used as a nipple emollient by nursing mothers. In those circumstances the risk of the pesticide being orally ingested by the suckling infant is very real. A small amount of pesticide which poses little risk to an adult weighing 60-70 kg poses a much greater risk to an infant weighing 3-5 kg, particularly when it is orally ingested. Concern was first raised about this issue in the mid 1980s, and the current standard for lanolin intended for human use in Australia was set at a maximum level of 40 mg/kg for diazinon, the most common but by no means the only pesticide applied to sheep.

The risk of dermal exposure to residual pesticide in lanolin-based products may also be significant, particularly if such products are applied to abraded or broken skin, such as cuts and rashes. A high risk of dermal exposure occurs if a lanolin-based lotion, contaminated with pesticide, is applied to an infant's groin affected by nappy rash. Dermal transfer would be enhanced if the rash is then covered with a nappy which subsequently gets wet.

In view of these concerns, the Advisory Committee on Pesticides and Health (ACPH) of the Commonwealth Department of Health and Family Services has recommended to the National Health and Medical Research Council (NHMRC) that the Australian standard for pesticide residues in lanolin used for human use be brought into line with the comparable US Food and Drug Administration (FDA) standard for modified lanolin, ie no more than 1 mg/kg for any one pesticide and no more than 3 mg/kg total pesticide. The ACPH also recommended that the use of raw wool grease as a nipple emollient or for other topical application in humans be actively discouraged. However, the NHMRC has yet to amend Australian standards for the pesticide content of lanolin intended for human use.

It should be noted that the FDA monograph refers to “specified residues”, rather than “pesticides”. The list of “specified residues” includes the organochlorine and organophosphate pesticides commonly used on sheep, but does not include the synthetic pyrethroids, the insect growth regulators or other sheep ectoparasiticides considered less toxic to humans.

Low pesticide grades of lanolin, which meet the US standard, are now commercially available from most of the major lanolin suppliers and these pesticide-reduced grades should now be used for all applications where human contact is involved.

2.3 Occupational Health and Safety

2.3.1 Dermal absorption hazard

Shearers are exposed to significant quantities of wool wax when shearing sheep, as are other workers who handle raw wool and sheep. Concern has been raised that residual pesticide in that wool wax might pose an occupational hazard to such workers through dermal absorption.

NOHSC (then Worksafe Australia) investigated this possible occupational hazard in the late 1980s. It was thought at the time that wool wax might actually enhance dermal absorption of pesticides. However subsequent research by Russell and Nunn (1991) and Wester *et al* (1992) showed that lanolin actually depressed dermal absorption of pesticides, although this effect was reduced by the presence of moisture.

In 1989, all the then registered sheep ectoparasiticides were reviewed for their potential hazard to shearers by a Department of Primary Industries and Energy (DPIE) working party, which included representatives from NOHSC, CSIRO and the veterinary chemical industry. That review raised concern about a number of products (mostly organophosphates) and the registrants of those products were asked to provide additional residue dissipation and dermal absorption data so that the occupational hazard of the products to shearers and other wool handlers could be more accurately assessed. That gave rise to the Avcare data described later in this report. NOHSC’s evaluation of these data has been considered as part of this review.

In assessing the potential exposure of a shearer to residual pesticide, the DPIE working party developed a protocol based on a “worst case scenario” (Appendix I), which assumes among other things that a 70 kilogram shearer accumulates a heavy coating of wool wax (2-3 mg/cm^2) on the entire front half of his body (approximately 9000 cm^2) in the course of a day’s shearing. This amounts to a total of 23 gram of wool wax a day. The protocol, which is currently used by NOHSC to assess the occupational hazard of sheep ectoparasiticides, was designed as a trigger mechanism to request more detailed residue and dissipation data when the estimated exposure was considered to pose an occupational hazard.

There are no data to support the assumption that a shearer is exposed to 23 gram wool wax a day and it has been challenged by this review’s Steering Committee. NOHSC has agreed that this aspect of the protocol does need to be reviewed, although it is difficult to do that until a more scientific estimate is made of shearer exposure to wool wax. That estimate needs to take into account the distribution of wax over the shearer’s body, especially under clothing. The veterinary chemical industry is presently exploring options for undertaking such a study.

The protocol also assumes that a product can be considered safe if the estimated internal dose experienced by a worker is less than one-tenth of the “no observable effect level” (NOEL) for the active constituent. This amounts to a safety factor, or a “margin of exposure” (MOE), of 10. However NOHSC has pointed out that a safety factor of 10 is usually only acceptable when the NOEL is derived from good quality human data, and that it is current international practice to use a safety factor of 100, particularly where the NOEL is derived from animal data. Consequently the Steering Committee agreed that for future assessments a safety factor of 100 should be used unless the NOEL was based on good human data.

This decision has been challenged by Strong (personal communication), who argues that in the UK consideration is being given to the use of the “no observable adverse effect level” (NOAEL) for occupational hazard assessment rather than the more conservative NOEL. He noted that in Europe a lower safety factor of 25 has been used for selected well-defined groups of workers, and that shearers would fall into these categories. Strong also feels that dermal toxicity data would be more relevant in an assessment of occupational hazard to shearers and wool handlers than oral toxicity data. NOHSC noted in its draft report that no suitable dermal NOELs were available.

It is possible to use the protocol and residue dissipation data to estimate the time that should elapse between treatment and handling of treated wool (the rehandling time) in order to be sure that residual pesticide does not pose an occupational hazard through dermal absorption. However the assumptions used in the protocol (NOEL, dermal absorption factor, margin of exposure, amount of wool wax a worker is exposed to in a day) all have a significant effect on the estimated rehandling time.

Given the uncertainty about some of these assumptions, and in particular the estimate of worker exposure to wool grease, the Steering Committee felt that the protocol should be revised and that further consideration of rehandling times should be deferred until a more realistic estimate of shearer exposure to wool wax was available.

2.3.2 Dermal irritation hazard

It has been recognised for some time that dermal exposure to synthetic pyrethroids can give rise to a temporary but still rather painful dermal erythema, not unlike sunburn. A number of shearers have reported such dermal irritation when shearing sheep treated with certain synthetic pyrethroid pesticides.

Herbst *et al* (1993) reported that dermal irritation from alphacypermethrin can occur at concentrations of 5000-12,000 mg/kg in wool wax. Russell *et al* (1995) have shown that concentrations of this magnitude can be present on the tip of the wool staple along the backline for at least 3 months following application of backline pyrethroid products to long-wool sheep (see Section 3.4.5).

NOHSC used a threshold concentration of 5000 mg/kg wool wax for their assessment of long-wool backline products containing synthetic pyrethroids.

2.3.3 Breakdown products of diazinon

Another issue that needs to be addressed is the possibility of workers being exposed to toxic breakdown products of diazinon once the product has been applied to sheep. Older formulations of diazinon were known to decompose to more toxic compounds such as sulfotep in the presence of certain metals and small amounts of moisture, which can occur in unsuitable or improperly sealed containers. More recent formulations of diazinon have been stabilised to prevent this happening.

In general, these toxic compounds degrade to harmless breakdown products faster than diazinon itself when there is excess water available. Strong and Russell (personal communication) feel that sulfotep toxicity following the application of diazinon to sheep is not an issue as there would be sufficient moisture in the fleece to rapidly hydrolyse any sulfotep that might form. Russell did find trace amounts of sulfotep in some diazinon treated fleeces but there was no accumulation.

2.4 Environment

As mentioned earlier, almost all of the water soluble and about 65% of the lipophilic pesticide residues in harvested wool are discharged from the scouring line in some form of scouring effluent. In Australia, discharge of untreated scouring effluent to surface waters is specifically prevented (*National Water Quality Management Strategy, Effluent Management Guidelines for Aqueous Wool Scouring and Carbonising, 1997*), and all effluent receives some treatment before discharge to the environment. In fact in developed countries, there are few wool scours discharging untreated effluent directly to the environment.

The type of effluent and the method of disposal varies depending on the location of the scouring plant and the nature of the scouring process. For example, scouring works located in major cities are most likely to discharge effluent into an urban sewer for further processing before it is finally discharged into the environment, and in many parts of the world, regulations require some sort of pre-treatment before discharge to sewer. On the other hand, scouring plants located in rural areas are more likely to discharge their effluent onto land, typically spraying treated effluent onto pastures.

As environmental requirements in developed countries grow tighter, there is increasing pressure on the scouring plants to clean up their effluent before it is discharged to the environment. Japan was the first of the major wool processing countries to make treatment of scouring effluent to high standards compulsory. Many evaporation plants installed in the 1970s were relatively inefficient and Japanese scourers eventually “exported” the problem by carrying out scouring in grower countries. There is now very little wool scoured in Japan.

In the UK and Europe where the tightest environmental regulations apply, additional on-site effluent treatment is being increasingly required, particularly for city-based scours discharging to a sewer. As mentioned earlier, modern scouring and effluent treatment processes (such as evaporation and chemical coagulation/flocculation processes) remove much of the solid material and wool wax (and hence residual lipophilic pesticide) from the effluent before it is finally discharged as an aqueous solution.

The environmental requirements for a land-based disposal system are quite different from those for ocean or river disposal and are generally less stringent. In most cases, effluent is passed through anaerobic and aerobic treatment lagoons and storage dams before being sprayed onto pasture. The main restrictions are that effluent must not drain directly into a stream or contaminate ground water. Modern ectoparasiticides degrade readily in soil and most exhibit low mobility, and in this situation residual pesticide poses less of an environmental risk. Care may be needed to ensure that residues do not contaminate meat if livestock graze pasture that has been recently sprayed with scouring effluent.

2.4.1 Assessing the environmental hazard of pesticide in scouring effluent

When assessing the environmental hazard of pesticide residues in scouring effluent, a number of factors need to be kept in mind:

(a) A significant proportion of the national fleece contains little or no pesticide. Considerable blending of sales lots occurs at the start of the scouring process, which means that there is significant potential for dilution of residues arising from a high residue lot. Conversely, a high residue sales lot may contaminate lower residue wools. Shaw (personal communication) has also found that high residue scouring lots can cause significant contamination of subsequent lots processed with the same scouring liquors.

(b) Modern scouring and on-site effluent treatment processes remove a significant proportion of lipophilic residues in wool wax, dirt and other sediments. As these processes become more widely adopted, the amount of pesticide discharged in the final liquid effluent will be reduced.

(c) The capacity of the sewerage processing plant to remove residual pesticide needs to be taken into account. While the Werribee treatment plant in Victoria has the capacity to virtually remove all pesticide residue from its effluent, the nearby Geelong treatment plant has limited capacity to do so. It may be argued that there are circumstances where centralised effluent treatment is more efficient and more cost-effective than separate on-site treatments.

(d) Likewise, the capacity of the environment into which the effluent is discharged needs to be considered. In Australia, treated sewage effluent containing scouring effluent is often discharged to the ocean, where residual pesticide is likely to be rapidly dispersed and diluted to below toxic levels (provided the pesticide is degraded). Under those circumstances, target concentrations at point of discharge can usually be based on less conservative acute toxicity data such as LC_{50} values. On the other hand, scouring effluent in the UK and Europe is mostly discharged into a riverine environment where residual pesticide is not rapidly dispersed and diluted once it moves out of the mixing zone. Under these circumstances, target Environmental Quality Standards (EQSs) at the discharge point tend to be based on chronic toxicity data (whole of life studies).

(v) Finally, the persistence of the pesticide needs to be considered. Scours discharge on a constant basis and for pesticides that persist in the environment (eg half life greater than 6 weeks), the use of chronic end points may be indicated, even in ocean discharge situations.

2.4.2 ARMCANZ/ANZECC Guidelines for Trade Wastes Discharged to Sewers

Recently in Australia (1994), the Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) and the Australian and New Zealand Environment and Conservation Council (ANZECC) jointly issued a number of recommended acceptance levels for pesticides in trade wastes discharged to sewers. While these recommended acceptance levels are not binding on local water authorities, most authorities are expected to adopt them and this may have implications for wool scours discharging to an urban-based sewerage system.

The maximum pesticide level recommended by the Councils for the sheep ectoparasiticides currently marketed is 1 mg/L. In order to meet this standard, it has been estimated that for lipophilic pesticides, the mean residue level on wool going into an Australian scour at any one time must not exceed 13 mg/kg raw wool. Note that this estimate assumes that scouring plants use at least 10 litres of water per kilogram of raw wool containing 13% wax on average, that 30% of the wool wax is recovered from the scour, and that the scour does not have additional on-site effluent treatment facilities. The corresponding residue level for water soluble pesticides, which do not associate with recovered wool wax, is 10 mg/kg wool.

It should be kept in mind that the residue levels recommended jointly by ARMCANZ and ANZECC are guidelines only. They are not based on rational risk assessment and local sewage authorities may set alternative values where they have “an appropriate basis to nominate alternative criteria”. There is scope for an authority to set “site specific” pesticide limits that take into account:

- toxicity of the pesticide;
- potential for biodegradation within the treatment plant;
- retention times within the treatment system;
- bioaccumulation; and

- persistence (duration in the environment).

It is important to appreciate that different water treatment plants and water receiving systems have differing capacities to adequately deal with pesticide contaminated effluent. For example, several scours in the major scouring centre of south western Melbourne discharge to the Werribee sewage farm. It has land disposal and ponding systems that readily accommodate the discharges, and in fact, the sensitive invertebrate *Daphnia* is commercially harvested from the ponds, indicating that residual pesticide concentrations are below the ‘no-effect’ levels at current discharge rates. The nearby Barwon Water treatment plant at Geelong does not have such facilities, and so is less able to degrade residual pesticide before discharge to the environment.

It was originally thought in 1994 that the ARMCANZ/ANZECC guidelines would impact on urban-based scours discharging to urban sewerage systems. However the mean residue levels on Australian wool are now much lower than 13 mg/kg wool (Table 5) and it is unlikely that the 1 mg/L discharge limit will be exceeded. This was demonstrated in a recent CSIRO study (Russell, personal communication) which monitored effluent from an Australian scouring plant at 4 hourly intervals over a four week period. While pesticide concentrations in the effluent varied considerably, the 1 mg/L limit was not exceeded, and the mean residue concentration in effluent corresponded with the mean residue level in Australian wool. Thus the ARMCANZ/ANZECC guidelines now have little relevance to wool scouring effluent.

In any case, the rational risk assessment, carried out by Environment Australia (Appendices III and IV), shows that the guidelines would allow discharges of organophosphate and synthetic pyrethroid ectoparasiticides that are unacceptably high from an environmental point of view. Concentration-based regulations are an inappropriate way of encouraging pollution control in the scouring industry as they favour the greatest water use and potentially penalise the more efficient scour operators. On the other hand, risk-based assessments, such as that proposed by Environment Australia, are more consistent with international systems and have greater credibility.

Because wool scours generate large amounts of organic materials that place a significant load on sewage treatment systems, urban scouring plants in Australia are under increasing pressure to install on-site effluent treatment processes which remove higher proportions of the dirt and wool wax (and hence lipophilic pesticide residues) from the effluent before it is finally discharged to the sewer. There is little economic incentive for them to do so at present, as discharge to sewer is still relatively cheap, and very few Australian urban scouring plants have installed such systems. Once they do however, the likelihood of exceeding ARMCANZ/ANZECC guidelines for trade wastes discharged to sewers will be even less than it is at present.

2.4.3 Environment Australia’s approach

(a) Australian requirements for effluent discharged to ocean outfall

Environment Australia, in consultation with Wool Development International (trading as ENco) in the UK, CSIRO Wool Technology and the veterinary chemical industry, has developed a model for assessing the environmental impact of pesticide residues in scouring effluent. That model, which is described in Appendix III, uses the Geelong sewage treatment plant as a worst case scenario in Australia and takes most of the factors described in Section 2.4.1 into account. Some of the assumptions and calculations used in the model have subsequently been modified by Russell (personal communication) to more accurately reflect commercial scouring practice (see Appendix IV).

The Geelong (Barwon Water) sewage treatment plant discharges into the ocean at Black Rock and because of the prevailing environmental circumstances (ie discharge into ocean, followed by rapid and considerable dilution and dispersion), assessment of environmental hazard at Black Rock is based on acute (LC_{50}) toxicity data. Default data for scour performance, for the efficiency of sewage treatment plants and for aquatic toxicity to sensitive species have been used, and there is opportunity to use better data if they are available. Diazinon has been used as the typical organophosphate, and cypermethrin as the typical synthetic pyrethroid.

Using that model, Environment Australia has estimated the maximum residue levels of various pesticides in wool that would allow sewage effluent to meet environmental requirements at Black Rock. These are shown in Table 1. Appendix IV shows the calculations involved in arriving at those figures.

Note that Table 1 shows the maximum residue level that can be tolerated on a scouring (or processing) lot in order to meet environmental requirements. Individual scouring lots are made up of wool drawn from different sales lots, and consequently the residue level of a scouring lot will be governed by the number of contaminated sales lots (which is a reflection of the percentage of the national flock treated with the pesticide in question) as well as their residue content. If, for example, a scouring lot was made up of 10 evenly weighted sales lots, each containing 3 mg/kg diazinon, the mean residue level in the scouring lot would be 3 mg/kg (the maximum residue level shown in Table 1). If one of the sales lots were to contain diazinon at 30 mg/kg and the other nine contained none, the mean residue level in the scouring lot would again be 3 mg/kg. If 25% of the sales lots were contaminated, and the mean residue level in a scouring lot could be no higher than 3 mg/kg, the maximum residue level that could be tolerated in an individual sales lot would be 12 mg/kg.

This is a fairly simplistic approach to factoring in the percentage of the national flock treated and the outcomes are shown in Table 1. A more rigorous statistical approach is described later in this report (Section 4.3.4).

Table 1: Maximum levels of residual pesticide in raw wool (mg/kg) required to meet environmental requirements (acute environmental toxicity to sensitive species) at ocean outfall at Black Rock.

Pesticide	Required environmental concentration (ng/L)	Maximum residue level in scouring lots (mg/kg wool) required to meet environmental standards	Maximum acceptable residue level (mg/kg wool) in individual sale lots at different levels of use	
			50% of national flock treated	25% of national flock treated
Organophosphates	1000	3	6	12
Synthetic pyrethroids	50	1.5	3	6
Cyromazine	93×10^6	97000	na	na
Dicyclanil	1.1×10^6	1146	na	na
Diflubenzuron	1000	7.4	14	28
Triflumuron	3500	70	140	280

Note:

na Not applicable. Maximum acceptable level unlikely to be reached in practice

Note that the values shown in Table 1 assume that the scouring plant does not have an on-site effluent treatment facility (which is the usual situation in Australia), and that in the case of most lipophilic pesticides, 4% of residual pesticide is retained on wool, 30% is retained on-site in recovered wool wax and that the remaining 66% is discharged from the plant in aqueous effluent. In the case of triflumuron, it is assumed that only 25% of residual pesticide is discharged in liquid effluent. Recent laboratory and pilot scale scouring studies have shown that triflumuron associates partly with the dirt component of the fleece and partly with the wax (Cranna 1998, and Russell, personal communication), and that consequently, a higher proportion of the residue is likely to be retained on site. In the case of water soluble pesticides such as cyromazine and dicyclanil, 96% of residual pesticide is assumed to be discharged in liquid effluent.

It is important to appreciate that these assessments are made using generic assumptions and that they may be revised should better data become available.

(b) Australian requirements for effluent discharged to land-based disposal systems

Environment Australia has also assessed the likely environmental hazard of residual pesticide in scouring effluent released to the environment through a land-based effluent disposal system. The rationale for that assessment is shown in Appendix V.

Environment Australia noted that, in a worst case scenario based on mean residue levels detected by The Woolmark Company's monitoring program in 1996/97, the annual application rates of residual pesticide released to pasture by such disposal systems were "at worst comparable with, and in some cases considerably below, application rates used for crop protection".

Consequently, it was concluded that pesticide residues in scouring effluent were unlikely to pose an environmental hazard when discharged through land-based disposal systems.

The Department of Primary Industry and Fisheries in Tasmania expressed concern that continual application of effluent containing the pesticide concentrations shown in Appendix V might result in build up of residual pesticide in treated soil. However all currently registered sheep ectoparasiticides degrade in soil and Russell (personal communication) has data that confirm that the residual pesticide concentrations in soils irrigated with effluent from commercial scouring operations are well below those estimated by Environment Australia and are unlikely to pose any environmental threat.

2.4.4 UK/EU requirements

Tighter environmental standards are about to be introduced overseas.

Shaw (personal communication) has advised that the EU Integrated Pollution Prevention and Control Directive was passed into law in October 1996. It was developed from UK Integrated Pollution Control legislation and the requirements are similar but not identical. The EU Directive must be transposed into national legislation in member states by October 1999 and fully implemented, with all listed industries fully compliant, by 2007. The long implementation period recognises that capital investment will be required by many companies in order to comply.

The legislation requires that controlled installations (such as wool scours) use the best available technology that is economically feasible to reduce emissions to the environment. Operators of controlled installations must also demonstrate that their emissions cause no environmental harm. Shaw takes this last requirement to mean that the equivalent of UK EQS values will be applied throughout the EU because the EQSs are intended to ensure no environmental harm. Among the priority substances listed for emissions control in the Directive are "organophosphorus compounds" and "biocides".

The situation in the UK is quite different from that in Australia. Most wool scours are concentrated in the Leeds-Bradford area and discharge into sewerage systems which in turn discharge into two rivers - the Aire and the Calder. The UK Environmental Agency regularly monitors pesticide levels in those rivers and has mechanisms in place which allow it to trace the source of contamination back to the discharge point.

There is one scouring plant located at Spenborough on Spen Beck which is a small tributary of the Calder. This plant mainly scours Australian wool and is thought to be representative of other overseas scours, particularly in Europe, where a single scouring line is located on a small river system. For that reason it is used as a generic "worst case scenario" for assessment purposes.

UK scours presently have to meet two quite different environmental standards:

(a) annual average Environmental Quality Standards (EQS) which are published by the UK Environmental Agency for specified pesticides. These are based on annual average emissions from scouring plants under average river flows and take into account the chronic exposure hazard of the pesticide to aquatic organisms (Table 2);

(b) a maximum allowable concentration (MAC), which is allowable for short periods of time only and which is based on acute toxicity hazard (short term exposure) under conditions of low river flow (Table 3). These MAC concentrations are estimates of acute no-effect concentrations (LC_0) and this is a more severe requirement than that suggested for Australia, which is based on LC_{50} data.

Tables 2 and 3 show "worst case scenario" EQSs and MACs based on the Spenborough scour, as well as estimates of the maximum residue levels in scouring lots required to meet UK/EU environmental standards at different levels of pesticide use. The assumptions and calculations used to arrive at those figures are detailed in Appendix IV.

The EQS and MAC concentrations used are a combination of the proposed UK Environment Agency figures where these are available (diazinon and cypermethrin), assessments conducted by Shaw (cyromazine, diflubenzuron and triflumuron) and Environment Australia (dicyclanil). Note that the official UK EQS figures for diazinon and cypermethrin are subject to review at this stage, although they seem almost certain to be adopted.

Shaw has advised that the UK Environmental Agency has an official "draft" EQS for diflubenzuron of 1 ng/L as well as a draft MAC of 15 ng/L which are also subject to review at this stage. Shaw's less conservative figure of 6 ng/L for the EQS and Russell's estimate of 100 ng/L for the MAC have been used, but these values may need to be revised if the draft UK standards are adopted. There are no official EQS or MAC figures for cyromazine, dicyclanil and triflumuron, and estimated values for these pesticides have no official standing. In the case of dicyclanil, a decision was made to use the more conservative of the two EQS values (0.2 µg/L) considered by Environment Australia in their evaluation of the product (NRA 1998).

Table 2: Annual average levels of residual pesticide in raw wool scouring lots and individual sales lots (mg/kg wool) required to meet average annual environmental requirements at discharge point in the UK.

Pesticide	Environmental standard (EQS) ng/L	Mean residue level in scouring lots (mg/kg wool) required to meet environmental standard	Maximum acceptable residue level (mg/kg wool) in individual sale lots at different levels of use	
			50% of national flock treated	25% of national flock treated
Organophosphates	10*	0.56	1.12	2.24
Synthetic pyrethroids	0.1*	0.06	0.12	0.24
Cyromazine	5000**	28	56	112
Dicyclanil	200**	1.12	2.24	4.48
Diflubenzuron	6**	0.84	1.68	3.36
Triflumuron	18**	4.9	9.8	19.6

Notes:

* EQS figures for organophosphates and synthetic pyrethroids are UK 'draft operational standards' and are subject to review.

** EQS figures for cyromazine, dicyclanil, triflumuron and diflubenzuron are either Shaw's or Environment Australia's estimates and have no official standing.

Table 3. Maximum levels of residual pesticide in scouring lots and individual sales lots (mg/kg wool) required to meet Maximum Allowable Concentrations (MACs) in the UK at different levels of pesticide use.

Pesticide	Maximum Allowable Concentration (MAC) ng/L	Maximum residue level in scouring lots (mg/kg wool) required to meet environmental standard	Maximum acceptable residue level (mg/kg wool) in individual sale lots at different levels of use	
			50% of national flock treated	25% of national flock treated
Organophosphates	100*	2.7	5.4	10.8
Synthetic pyrethroids	2.0*	0.54	1.1	2.2
Cyromazine	930,000**	2492	na	na
Dicyclanil	11,000**	29.5	na	na
Diflubenzuron	100**	2.7	5.4	10.8
Triflumuron	350**	45	90	180

Notes:

* MAC figures for organophosphates and synthetic pyrethroids are UK 'draft operational standards' and are subject to review.

** MAC figures for cyromazine, dicyclanil, triflumuron and diflubenzuron are Russell's estimates based on LC_0 acute toxicity figures and have no official standing.

na Not applicable. Maximum acceptable residue level unlikely to be reached in practice.

Note that UK scouring plants are required to have on-site effluent treatment facilities and a number of them are installing, or have installed, coagulation/flocculation processes described earlier in Section 2.1. The data in Tables 2 and 3 were derived on the assumption that these plants operate at 80% efficiency.

This assumption is based on Shaw's observations (personal communication) that scouring plants fitted with such facilities retained, on average, about 80% of the initial lipophilic pesticide loading on site. The 80% figure includes residual pesticide in recovered wool wax. Under laboratory conditions, flocculation processes can achieve higher retention rates (up to 99%) for lipophilic pesticides (Russell, personal communication). However, both Russell and Shaw believe that such recovery rates are unlikely to be achieved in a commercial scour.

Shaw's observations were confined to organochlorine, organophosphate and synthetic pyrethroid pesticides only and it has been assumed in Appendix IV that similar retention rates apply to other lipophilic pesticides such as diflubenzuron. In the case of triflumuron, a retention figure of 90% has been used, as recent studies referred to earlier have confirmed that a higher level of on-site retention can be expected (Cranna and Russell, personal communication). Again, where more detailed site or chemical-specific data are available, they can be used to provide a more specific assessment.

Comparison of Tables 2 and 3 with residue data in Section 4 shows that the MAC requirements for organophosphates and synthetic pyrethroids, and to a lesser extent diflubenzuron, would be exceeded by some of the residue levels detected. However, compliance with the annual average EQS requirements will be even more difficult to achieve.

Shaw argues that while the UK standards for organophosphates and synthetic pyrethroids are based on rational risk assessments, they are unnecessarily strict particularly in the case of the organophosphates. He has proposed more liberal values for both diazinon and cypermethrin, and also for diflubenzuron. The difference in opinion is related to the bioavailability of pesticides once they are absorbed on river sediments and the scientific community is still debating this. Nevertheless, if the UK Environmental Agency's proposed EQS values come into effect, the wool industry will have no alternative but to meet them, while at the same time encouraging the relevant authorities to take a more pragmatic scientific approach to setting standards for the pesticide content of scouring effluent.

2.4.5 Future environmental issues

Scouring plants in developed countries are progressively being required to treat their effluent prior to discharge, in order to reduce the amount of wool wax and organic contaminants discharged to the environment. Consequently a high level of on-site treatment may be required to meet environmental standards unless residual pesticide levels on raw wool can be reduced. One would expect the considerable cost involved sooner or later to be passed on to the producer or late stage processor and ultimately the consumer, although that hasn't happened in Europe according to Shaw. In any case, modern principles of waste minimisation suggest that the current reliance on ‘end of pipe’ effluent treatment is inappropriate, and that a much more preferable approach is to minimise the level of residual pesticide on wool at shearing.

Future EU standards will demand that industry adopts ‘best practice’. Shaw has suggested that a part of ‘best practice’ in wool scouring will be for scours to select low residue wools for processing, in the same way that wool buyers currently select wools on the basis of micron, length and yield. Under the present wool marketing system, it is almost impossible to identify such wool. However the wool industry is exploring options for developing a low cost system that would allow buyers to differentiate between low and high residue wool and hence source wool that meets their customers’ requirements.

If this happens, not only will pesticide releases from subsequent down-stream processing be reduced, but growers will be under considerable pressure to reduce pesticide residues in their wool. This in turn will provide a strong incentive for research organisations and the veterinary chemical industry to identify innovative ways of controlling external parasites that do not leave high levels of pesticide residues on harvested wool.

2.5 Trade and other wool industry issues

The wool industry is very conscious of the fact that wool’s image and hence its marketability might be damaged by adverse publicity about residual pesticide on wool, even though the residue is largely confined to the wax component of the wool and is removed during processing. In addition, given that 70% of Australian raw wool is scoured overseas, the industry is keen to ensure that overseas buyers don’t reject Australian wool because of possible pesticide contamination. Australia is particularly vulnerable because of the large percentage of wool exported in an unprocessed state. Most of the other Southern Hemisphere wool growing countries (New Zealand, South Africa, Uruguay) scour at least 80% of their wool on-shore.

In a trade environment of increasing demand for “eco-wool”, that is wool guaranteed to have a low residual pesticide content and produced in an “environmentally friendly” manner, there are market advantages in being able to produce low residue wool. Australian raw wool has a relatively low residual pesticide content when compared with that from some competing overseas countries. The Australian wool industry is keen to take advantage of that and intends to capitalise on and protect the current image of Australian wool as a pure natural fibre that is produced in an environmentally friendly way.

Shaw has commented that Interlaine, the European wool textile industry trade association, has developed criteria for wool eco-products which are presently being considered by the European Commission for adoption into official eco-labelling criteria for a wide range of textile products. The Interlaine criteria for pesticides in raw wool are intended to ensure absence of organochlorines and allow for off-shears treatment only with organophosphates or synthetic pyrethroids. The insect growth regulators were not considered at the time the criteria were drawn up.

There is increasing pressure on overseas wool scours to meet even more stringent environmental standards. Proposals by the EU to adopt tougher standards have already been referred to. The Woolmark Company anticipates that other wool processing countries such as Korea and China will eventually adopt similar risk-based environmental standards, and is conscious of the potential market advantage for Australian raw wool if its residual pesticide levels are low.

Increased processing costs overseas may encourage the trend for Australia to process more of its wool onshore, especially if land-based and other ‘zero-waste’ treatment systems can be developed to convert wool processing wastes into beneficial by-products.

In recent years, at least one US buyer has notified Australian suppliers that they will not accept any raw wool grease with diazinon levels in excess of 15 mg/kg in order to meet US standards for pesticide residues in lanolin. Sales of raw wool grease remain important to the wool industry and this is another marketing signal that high levels of residual pesticide in harvested wool are no longer acceptable.

It was for these reasons that the wool industry decided in May 1994 to implement a strategy to reduce residual pesticide levels in raw wool, and mounted an industry wide extension and education program to help it achieve that goal. That strategy appears to have been moderately successful. Mean levels of organophosphate and synthetic pyrethroid residues in the wool clip have progressively fallen since then (Table 5). However, in recent years there appears to have been some product substitution of the organophosphates and synthetic pyrethroids by insect growth regulators such as cyromazine, diflubenzuron and triflumuron, and residue levels of these pesticides are increasing. Also more recent years have been relatively free of bad fly waves and average residue levels of organophosphates and cyromazine could rise should a bad fly season occur. This is a concern from a marketing point of view.

The Woolmark Company’s residue monitoring survey suggests that at present there is sufficient low residue wool in Australia to meet European demand. The problem, as mentioned earlier, is to identify such wool.

2.6 Animal welfare and productivity

There is a growing body of opinion that the use of long wool ectoparasiticides should be phased out in the 3 months prior to shearing and discouraged in the 3 months prior to that. Such restrictions are likely to give rise to animal welfare problems in some circumstances, as well as having an adverse impact on animal productivity and wool quality.

Lice can be controlled, and even eradicated, by correct use of pesticides in the 6 weeks after shearing and subsequent management to prevent reinfestation. Nevertheless there will always be situations where pesticides are the most appropriate treatment to control severe lice infestations in long wool in the months prior to shearing. Such treatments are likely to give rise to high residues.

Fly strike, the other insect problem growers have to contend with in Australia, most commonly occurs during summer months when many sheep are carrying long wool. Again, while fly strike in long wool can be minimised by good management and by timely preventative treatment with persistent pesticides such as cyromazine, there will always be situations where sheep need to be treated with “knock-down” pesticides in the months close to shearing. Treatment of individual sheep with flystrike preparations is one approach that appears not to pose a residue problem, but that approach is not always practical when large numbers of sheep are affected.

For this reason, mechanisms need to be in place to allow sheep to be treated with appropriate ectoparasiticides in the months immediately prior to shearing, even though such treatment may fall inside recommended “environmental” withholding periods and result in high residues.

Residual pesticide on wool treated at this late stage will not cause environmental problems if the wool is processed in plants with appropriate effluent treatment facilities. The key is to identify high residue wools (eg by vendor declaration combined with chemical testing) and ensure that they are scoured by a suitable facility. Most of the scours located in NSW, for example, should meet this criterion.

Occupational health and safety implications of such residues for shearers and other wool handlers would also need to be considered.

2.7 Treatment of lambs

Ectoparasiticide treatments applied to lambs are of particular concern for several reasons:

- lambs are usually shorn with less than 12 months wool and a significant number are slaughtered with as little as 6 months wool;
- a significant proportion of that wool is recovered by fellmongers for further processing;
- wool yield is generally much lower than for an adult sheep, eg at 6 months wool yield is likely to be about 1.6 kg/lamb;
- the amount of pesticide (active ingredient) retained by lambs following treatment is thought to be in the order of half to three-quarters the amount retained by an adult sheep (Hanrahan and Plant, personal communication).

Consequently the concentration of residual pesticide in lambs wool may be at least as high if not higher than that in wool from an adult sheep. This may have implications for the use of ectoparasiticides on lambs.

Much depends on what happens to the wool. Lambs wool represents a relatively small proportion of the total wool clip and is often mixed with other lines of similar length to form a composite sales lot. Thus high-residue lambs wool may well be diluted by other wool with a low residue content. Of course the contrary also applies -

high residue lambs wool will contaminate low residue wool if the two are mixed. Composite sales lots tend to have higher than average residue levels.

Good quality lambs wool is sometimes baled and sold as such. If it comes from lambs treated with ectoparasiticides, which have been shorn or slaughtered early, such wool is likely to have a high residue content.

2.8 Repeat applications

Numerous farmer surveys (see Section 3.2) have confirmed that significant numbers of farmers apply more than one application of ectoparasiticide in any one season. The repeat application may be of the same chemical, although in many cases, different chemicals are used.

For example, Horton *et al* (1994) found that 37% of Tasmanian wool producers had applied two or more pesticide treatments in the previous season. Plant (1996) in a survey of 735 wool producers throughout Australia found that about 47% of growers had applied more than one ectoparasiticide treatment for lice or flies or both. Similarly, a survey of 340 producers in Queensland (Armstrong and Ward, personal communication), found that 27% of producers had used two or three lice treatments in the 1996/97 season, while 10% had applied two or three fly treatments.

Obviously, repeated applications of the same chemical are likely to result in higher residue levels than would occur following a single application and this was confirmed by the surveys of Plant (1996) who found that the higher the number of applications the higher the residue level (Table 4). Likewise Horton *et al* (1994) found that residue levels following two applications were generally double those following a single application.

Table 4. Effect of repeated lice treatments (irrespective of fly treatments) on the residue level of organophosphate and synthetic pyrethroid insecticides in wool at shearing (after Plant 1996).

No of treatments applied	No. of clips sampled	Organophosphate residue level (mg/kg wool)	Synthetic pyrethroid residue level (mg/kg wool)
1	186	5.2	4.5
2	44	14.6	15.4
3	3	76.4	2.3
4	1	235.6	None recorded

3. Summary of available data

3.1 The Woolmark Company's monitoring program

The Woolmark Company has been monitoring residual pesticide levels in the Australian wool clip since the mid 1980s. The initial emphasis was on arsenic and organochlorines which were the main pesticides of concern at the time. By the early 1990s, residual levels of those pesticides had fallen to background levels and the focus then turned to the organophosphates and synthetic pyrethroids.

Since the start of the 1992/93 wool growing season, samples have been collected from a total of 600 sale lots each year from wool stores around the country and analysed for residues of these pesticides. Cyromazine was included in the 1994/95 season and in the following year, two other insect growth regulators (diflubenzuron and triflumuron) were included to reflect increasing use of such products. Because of budget constraints, only 325 lots were tested for cyromazine in 1995/96, while only 50 lots were tested for diflubenzuron and triflumuron. All 600 sale lots were tested for cyromazine, diflubenzuron and triflumuron in subsequent years. Data from 1992 to 1998 are shown in Table 5.

Table 5: Mean residual pesticide levels (mg/kg raw wool) detected in The Woolmark Company's monitoring program from 1992-98.

Pesticide group	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98
Organophosphates	10.2	9.0	4.3	4.4	4.5	5.8
Synthetic pyrethroids	5.8	6.6	5.7	5.5	3.8	3.3
Cyromazine*	-	-	5.2	6.3	8.7	5.8
Diflubenzuron**	-	-	-	4.9	1.2	3.6
Triflumuron**	-	-	-	2.9	3.5	6.1

Notes:

* Only 325 lots were tested for cyromazine in 1995/96; fewer were tested in 1994/95.

** Only 50 lots were tested for diflubenzuron and triflumuron in 1995/96. All 600 lots were tested for cyromazine, diflubenzuron and triflumuron in subsequent years.

The table shows that mean residual levels of pesticide in the Australian wool clip are generally quite low. It also shows that mean residue levels for organophosphates have fallen over the study period, while the level of synthetic pyrethroid residues has remained relatively constant until the 1997/98 season when there was a noticeable fall, possibly a reflection of reduced use. There was a marked reduction in residual organophosphate during the 1994/95 season and it has remained fairly steady since then. This is thought to be due to a combination of factors, including

Table 6: Range of residue levels detected, the percentage of samples in which they were detected and the contribution that each residue level made to the overall residue loading in the wool clip during the 1997/98 season (The Woolmark Company residue monitoring program).

Residue level (mg/kg wool)	Organophosphates		Synthetic pyrethroids		Cyromazine*		Diflubenzuron		Triflumuron	
	Detected in % samples	Contribut'n to residue load (%)	Detected in % samples	Contribut'n to residue load (%)	Detected in % samples	Contribut'n to residue load (%)	Detected in % samples	Contribut'n to residue load (%)	Detected in % samples	Contribut'n to residue load (%)
0.0 – 0.9	64	3	84	4	75	0	89	0	80	0
1.0 – 9.9	26	15	12	11	11	10	4	5	3	3
10.0 - 24.9	6	16	2	8	8	24	3	15	5	16
25.0 - 49.9	3	17	1	11	4	25	3	24	8	44
50 or more	2	50	2	67	3	42	2	56	4	38
Mean (mg/kg)	5.8		3.3		5.8		3.6		6.1	
Range (mg/kg)	0-598		0-338		0-160		0-280		0-140	

favourable weather patterns in recent years (thus minimising flystrike), increased popularity of cyromazine as a treatment for flies, as well as increased grower awareness of the chemical residue issue and more careful use of pesticides. As mentioned above, The Woolmark Company anticipates that mean residue levels of organophosphates and cyromazine might increase should weather patterns more conducive to flies occur, leading to an increase in the use of long-wool treatments. Mean residue levels of the insect growth regulators diflubenzuron and triflumuron have risen with increased use, and early 1998/99 data indicates that this trend is likely to continue.

Table 6 shows the range of residue levels detected and the contribution that each residue level made to the overall residue loading during the 1997/98 season, which is fairly typical of recent years.

The table illustrates, once again, that residual pesticide levels in most Australian sales lots are generally very low. About 30% of the clip contained either no residues or total pesticide levels of less than 1 mg/kg (a number of sales lots contained residues of more than one pesticide). On the other hand, a very small proportion of the lots tested made a significant contribution to the total residue loading, eg 11% of lots tested contributed 83% of the total organophosphate residue load, and 5% of lots contributed 86% of the total synthetic pyrethroid residue load.

3.2 On-farm surveys

Farmers whose wool was sampled as part of The Woolmark Company monitoring program were surveyed by an experienced sheep husbandry officer of NSW Agriculture to ascertain chemical use patterns and to see if any particular practices could be linked to high residue levels (Plant, 1995 and 1996). Questionnaires were sent to 985 growers and returns were received from 735 (a response rate of 74.6%).

The survey showed, among other things that high organophosphate and synthetic pyrethroid residues in wool at shearing were associated with:

- repeat applications (about 47% of growers reported applying more than one application for lice or flies or both, and the higher the number of applications the higher the residue level - see Table 4);
- use of long-wool treatments, for both lice and fly control, and as a general rule the closer to shearing the higher the residue level;
- use of long-wool synthetic pyrethroid backline treatments; and
- pesticide applications to young sheep or sheep shorn with less than 12 months wool.

The survey also showed that the use of short-wool products, including backliners, in the first 6 weeks after shearing, was not likely to result in high residue levels and neither was the practice of treating individual struck sheep.

On the other hand, Plant reported mean synthetic pyrethroid residue levels of 2 mg/kg wool in a few sales lots following off-shears treatment 12 months earlier. He also found mean residue levels of 2.6 mg synthetic pyrethroids/kg wool and 3.8 mg organophosphates/kg wool in a small number of flocks dipped during the first 6 weeks after the previous shearing. While these residue levels are not high in the normally accepted sense of the word, they do exceed levels required to meet UK standards as shown in Table 2.

These conclusions have generally been supported by other farmer surveys conducted by State departments responsible for agriculture in Tasmania (Horton *et al*, 1994; Horton and Best, 1995), Victoria (Hanrahan, personal communication) and Queensland (Armstrong and Ward, 1998). For example, Horton and Best and Armstrong and Ward reported similar findings about repeat applications, while Horton *et al* (1994) reported an average residue level of 2 mg/kg wool in sales lots following off-shears treatment with synthetic pyrethroids.

3.3 Avcare Task Force

In response to earlier concerns about the dermal absorption hazard of residues in raw wool to shearers and other wool handlers, the then Australian Agricultural and Veterinary Chemicals Council (AAVCC) in 1991 requested registrants of nominated products to provide 'additional residue dissipation data' to address those concerns.

In response to that request, Avcare established an industry task force comprising members of affected manufacturers, which commissioned an independent research organisation (NSW Agriculture's Elizabeth Macarthur Agricultural Institute) to:

(a) determine the concentration of pesticide in raw wool and wool wax expressed as a function of time after treatment; and

(b) define the proportion of the concentration changes from the pesticide in the fleece that is the result of dilution on the growing wool and that which results from the actual degradation of the compounds.

Products used in the trial included:

Active constituent	Representative product	Treatment regimes
Diazinon	TopClip Blue Shield	Dip and jet
Amitraz (and diazinon)	Amidaz	Dip
Propetamphos	Seraphos 360 and Ectomort	Dip and jet
Chlorfenvinphos	Supona	Jet
Cyromazine	Vetrazin	Jet
Diazinon and cypermethrin	Blitz	Pour-on

All treatments were applied in November 1992 by experienced operators at the highest rate applicable for each particular treatment/product combination (as per label directions), as follows:

- dipping - sheep with 6 weeks wool plunge-dipped;
- jetting – sheep with 9 months wool hand-jetted using a Dutjet handpiece;
- pour-on - applied to sheep with 9 months wool, using the recommended applicator.

Measurement was taken of the amount of chemical solution retained by the sheep following application. Wool was sampled, weighed and residual pesticide measured 1, 6, and 12 weeks (shearing) after treatment for the jetting and pour-on treatments; and 1, 6, 12 weeks, 6 months and 10.5 months (shearing) after dipping.

Measurements were taken of wool growth and estimates made of the occupational hazard to shearers and other wool handlers from residues in the wool at shearing.

Residue depletion data from the trial are shown in Table 7.

The data show that pesticides applied to sheep 6 weeks after shearing left quite low residue levels in wool shorn 46 weeks after treatment (all less than 6 mg/kg wool). On the other hand, all long wool jetting treatments applied to sheep with 9 months wool, 3 months before shearing, left residues in the range of 44-138 mg/kg wool. The pour-on application of cypermethrin/diazinon 3 months before shearing left cypermethrin residues within the same range as the other long wool treatments, although diazinon residues were substantially lower (ie 6 mg/kg wool).

Estimates were made by the Avcare researchers of degradation rates (half-life) for the various active constituents, based on the mass of active constituent retained on the fleece after making corrections for the diluting effects of wool growth, and these are also shown in Table 7.

Table 7: Residue levels detected in wool (mg/kg raw wool) at different sampling dates following treatment with a range of chemical products (Avcare study).

Treatment	Residue levels (mg/kg wool) at various times after treatment					Estimated half life (days)**	
	1 week	6 wks	12 wks	26 wks	46 wks	Avcare	Russell
Dipping (6 wks post-shearing)							
Diazinon	801	78	26	1.3	**5.5**	47	25
Propetamphos	58	50	7.4	0.38	**0.29**	31	29
Amitraz	46	0.5	nd*	nd*	**nd***	5	5
Cyromazine	886	103	64	9.9	**1.0**	51	47
Jetting (9 mths post-shearing)							
Diazinon	380	92	**48**			26	26
Propetamphos	413	169	**44**			24	26
Chlorfenvinphos	297	345	**120**			57	74
Cyromazine	431	198	**138**			70	59
Pour-on (9 mths post shearing)							
Diazinon	99	49	**6**			19	20
Cypermethrin	261	527	**81**			44	52

Notes:
Values in bold - residues at shearing (composite of side and backline patch sample data)
* Not detected
** Half life of active constituent estimated by registrants from the mass of active constituent on the wool after taking wool growth into account. Russell's estimates derived after applying Horton's models to the data. See comments below and in Section 3.4.2.

Russell (personal communication) reworked the Avcare half-life data using Horton's models as described in Section 4.3.5. He noted difficulty in calculating a single half life figure for the whole season in the case of the diazinon and propetamphos dipping treatments, as the half life slowed as wool length increased. The reported half lives of 25 days and 29 days for diazinon and propetamphos respectively were obtained when estimates were based on the first four data points (r^2=0.965 and 0.94 respectively based on log pesticide mass). When all data points were used, the corresponding half lives were 69 and 51 days respectively, but r^2 values were only 0.46 and 0.80. Russell's estimated half lives for the short wool dipping treatments of diazinon and propetamphos were similar to those for the corresponding jetting treatments.

Russell's estimates show that amitraz degrades rapidly, while degradation rates for diazinon and propetamphos were shorter than for chlorfenvinphos, cyromazine and cypermethrin.

3.4 CSIRO/Victorian Department of Agriculture project

3.4.1 Residue studies

The Victorian studies, which were conducted co-operatively by CSIRO Wool Technology and the then Victorian Department of Agriculture (now Natural Resources and Environment) focused initially on long-wool synthetic pyrethroid products, including two jetting and two backline products, although it also included two organophosphate jetting fluids. Jetting treatments with insect growth regulators and ivermectin were included in a second study.

In the first experiment all treatments were applied in August 1992 to sheep with 9 months wool, approximately 3 months before shearing, by experienced operators, in accordance with label directions. All jetting treatments were applied by hand jetting, using a Dutjet wand. Backline treatments were applied using the manufacturers' applicators.

Measurements were taken of the quantities of product applied to each sheep at time of treatment, and wool growth and residual pesticide levels in raw wool at 2, 4, 8 and 12 weeks after treatment. Wool was sampled by taking a 7.6 cm wide band from around the girth of the sheep on each sampling occasion, which was broken up into four sections - backline treatment area, each side and the belly.

For each of the long-wool backline treatments, the staples from half the harvested wool in each section, from one of the treated sheep, were divided along their length into tip (top 10-15 mm), base (bottom 10-15 mm) and middle (remainder of the staple) and analysed separately to determine migration of pesticide from the weathered tip down into the base of the staple and around the body of the sheep.

Sheep were shorn at the end of the experiment (12 weeks after treatment) and the entire fleece was sampled on the classing table in two different ways - firstly by placing a 'weldmesh' grid (20 cm squares) and taking a single staple from each square to give a combined sample of about 70 staples, and secondly by taking the equivalent of a band sample from around the middle of the body of the sheep. These were analysed, without further sub-sampling, for residual pesticide.

The remaining wool from all sheep in each treatment mob was baled and core-sampled using the standard hand-coring technique used by the Australian Wool Testing Authority, and analysed for pesticide content. The reason for the different sampling regimes was to see if sampling method had any effect on the residue level detected and to determine the variability of different sampling regimes.

Pesticide treatments applied in the first experiment included:

Product	**Active constituent**	**Type of treatment**
Vanquish	Alpha cypermethrin	Backline
Blitz	Cypermethrin/diazinon	Backline
Grenade	Cyhalothrin	Hand jetting
Robust	Cypermethrin	hand-jetting
TopClip blue	Diazinon	Hand jetting
Ectomort	Propetamphos	Hand jetting

The experiment was repeated the following season, except that this time, treatments were applied to sheep with 6 months wool, 6 months prior to shearing, and the treatment range was extended to also include:

Product	**Active constituent**	**Type of treatment**
Vetrazin	Cyromazine	Hand-jetting
Fleececare	Diflubenzuron	Hand-jetting
Jetamec	Ivermectin	Hand-jetting

Wool was sampled as in the previous experiment, and analysed for residual pesticide at 4, 9, 17 and 26 weeks after treatment. Sheep were shorn 26 weeks after shearing and wool was again sampled as in the previous season, although a less detailed analytical protocol was used.

Residual pesticide levels at various times after treatment in the first and second years of the experiment are shown in Tables 8 and 9 respectively.

The data from the first experiment (Table 8) show that mean residues in shorn wool from synthetic pyrethroid backline treatments applied 3 months before shearing ranged from about 120-216 mg/kg wool. Those from organophosphate jetting treatments applied at the same time left residues ranging from 73-112 mg/kg wool. Residues from synthetic pyrethroid jetting treatments were in the range of 7-9 mg/kg wool.

When organophosphate or synthetic pyrethroid treatments were applied 6 months before shearing, the residue levels at shearing were much lower (4-23 mg/kg wool), apart from the cypermethrin backline treatment which still had residues of 134 mg/kg wool (Table 9). The cyromazine treatment left residues of 24 mg/kg while ivermectin left residues of 1 mg/kg wool. Diflubenzuron, on the other hand, still had high residue levels (>100 mg/kg wool) 6 months after application.

Table 8: Residual pesticide levels (mg/kg raw wool) determined by band sampling at various times after treatment in the first year of the Victorian experiment.

Treatment	Mass ac* applied (g/sheep)	Residue level (mg/kg raw wool) Weeks after treatment				Half-life** (days)
		2	4	8	12	
Alpha cypermethrin b/line	1	549	409	160	117	34
Cypermethrin/ diazinon b/line	1.5 1	1227 522	706 230	316 55	216 14	32 14
Cyhalothrin h/jetting	0.08	14	13	11	9	198#
Cypermethrin h/jetting	0.07	15	11	11	7	105
Diazinon h/jetting	1.3	251	162	148	112	96
Propetamphos H/jetting	1.5	209	77	97	73	87

Notes:

* ac - active constituent

** Half life of active constituent estimated from the mass of active constituent on the wool after allowance made for wool growth. See discussion on half-life data in Section 3.4.2.

\# Estimated half life of cyhalothrin is higher than expected and may be due to experimental variability.

Table 9: Residual pesticide levels at various times after treatment in the second year of the Victorian experiment using the band sampling technique.

Treatment	Mass ac* applied (g/sheep)	Residue level (mg/kg raw wool) Weeks after treatment				Half-life** (days)
		4	9	17	26	
Alpha cypermethrin b/line	1	440	142	57	23	45
Cypermethrin/ diazinon b/line	1.5 1	915 105	636 24	378 2	134 0.2	76 18
Cyhalothrin h/jetting	0.08	15	13	8	4	124
Cypermethrin h/jetting	0.07	12	15	12	7	>400[#]
Diazinon h/jetting	1.3	181	95	53	8	42
Propetamphos h/jetting	1.5	138	90	24	4	34
Cyromazine h/jetting	1.1	80	67	40	24	143
Diflubenzuron h/jetting	0.7	302	210	124	144	400[#]
Ivermectin h/jetting	0.06	5	5	3	1	92

Notes:

* ac - active constituent

** Half life of active constituent estimated from the mass of active constituent on the wool after allowance made for wool growth. See discussion on half-life data in Section 3.4.2.

Estimated half lives for cypermethrin and diflubenzuron were higher than expected possibly due to experimental variability. When degradation rates are low, errors in estimated half lives increase significantly, and are increasingly affected by experimental variability.

3.4.2 Half-life data

Care is needed in interpreting half-life figures and some of the difficulties have already been mentioned in Section 3.3.

The concentration of residual pesticide on wool will be reduced by wool growth as well as by degradation of the active constituent. Consequently the apparent degradation rate, particularly if it is based on residue concentration (mg/kg wool), will be faster in short wool than in long wool for two reasons – firstly, the residual pesticide is more exposed to sunlight and secondly, the growth rate of the wool relative to the mass of pesticide is higher.

This was confirmed by both the Avcare studies and the Victorian studies - the breakdown rate of many of the products used in the trials was much higher during the first few weeks after treatment than it was in later weeks, and this differential was more obvious with the short wool dipping treatments. This leads to difficulties when using data from short-term experiments to estimate longer term withholding periods.

The half-life figures quoted for most of the products in Tables 7-9 are average figures applying over the whole experimental period; however, as noted previously, over a full year period, the degradation rate may change with time.

It is possible to separate the effects of degradation and wool growth on pesticide dilution by allowing for the growth of wool. For simplicity, wool growth is usually assumed to be linear throughout the growing season. Estimation of the amount of pesticide actually applied at the time of treatment is difficult (except where the pesticide is applied by fixed volume applicators). However pesticide concentrations (mg/kg wool) measured at various times can be converted to pesticide mass after estimating the weight of the fleece present at the time. The regression equation can then be based on pesticide mass. The pesticide concentration at any time can then be derived by estimating the mass of residual pesticide from the regression equation and dividing that by the estimated fleece weight.

Long half lives are very sensitive to experimental variability and a small change in a measured variable can make a significant difference to the slope of the regression line. This is reflected in the unexpectedly high half-life values for cyhalothrin, cypermethrin and diflubenzuron shown in Tables 8 and 9, and adds to the difficulty of estimating half-lives for the more persistent pesticides.

Campbell and Horton (personal communication) have used computer modelling techniques (described in Campbell *et al*, 1998) to develop residue depletion curves for each of the products used and method of application. These models draw all the available data together (including data from farmer surveys and some experimental data not covered by this review) and take into account the differing rates of degradation in short and long wool. They have been used to develop most of the withholding periods proposed in Section 4.3.5.

3.4.3 Sampling methods

The effect of the different sampling methods used in the Victorian study on mean residue levels in the fleece is shown in Table 10.

Russell (personal communication) is of the view that while ‘band’ samples give good results for estimation of degradation rates, they tend to over-estimate the overall residue level in the fleece, particularly with backline and jetting treatments where the application is more localised. He believes that movement of pesticides on sheep away from the treatment area is poor and consequently parts of the fleece may be untreated. Band samples are taken through the treated parts of the fleece and untreated parts may not be represented. Core samples on the other hand include all parts of the fleece including those areas not treated. Consequently Russell is of the view that blended core samples provide the best estimates of residues in the total fleece shorn from the sheep.

Table 10. Effect of different sampling methods on residue levels measured at shearing in the fleece of sheep treated with ectoparasiticides 3 months earlier.

Treatment	Residue level (mg/kg raw wool) Measured by different sampling methods		
	Grid sample	Band sample	Core sample
Alphacypermethrin (backline)	100	120	64
Cypermethrin Diazinon (backline)	330 29	540 40	57 8

A subsequent statistical review of the core sampling technique (Campbell *et al*, 1996) confirmed that it did provide a statistically reliable estimate of wool residue levels. It is essential however that core samples are very well blended to obtain homogenous sub-samples for analysis.

The residue data quoted in Tables 8 and 9 have resulted from band samples which, as mentioned above, tend to overestimate the mean residue level in the whole fleece. The Avcare data (Table 7) were derived from patch samples taken from the backline and sides of sheep near to the treated area, and again, estimated residue levels may not accurately represent the mean residue levels on whole sheep. On the other hand The Woolmark Company's residue monitoring data is based on core samples taken from sales lots, as would be most regulatory testing. This needs to be taken into account when deriving regulatory standards from experimental data.

3.4.4 Backline treatments

Data from the first year of the Victorian study also showed that pesticides applied to sheep as backline treatments remained at very high concentrations on the tip of the staple where they were placed and that there was very little movement of the pesticide down the staple and around the body of the sheep (Tables 11-12).

The data from these studies are of questionable statistical significance (in both cases, studies were done on one sheep) and further properly replicated studies may be necessary before any firm conclusions can be drawn from them. Nevertheless they do show a pattern consistent with whole staple measurements that show there is very little movement of the active constituent from where it has been placed, either around the body of the sheep or down the staple.

Table 11: Distribution of alphacypermethrin residues in the fleece of a single sheep following treatment with a backline product 9 months after shearing.

		Alphacypermethrin level in wool wax (mg/kg wax) Weeks after backline treatment.			
		2	4	8	12
Back	Tip	30400	50200	27800	7210
	Middle	2030	5380	2090	735
	Base	145	2530	840	50
Left side	Tip	3750	4020	560	915
	Middle	660	520	35	90
	Base	60	40	10	20
Right side	Tip	675	750	1975	220
	Middle	35	30	40	20
	Base	50	25	10	10

Table 12: Distribution of cypermethrin and diazinon residues in the fleece of a single sheep following treatment with a backline product 9 months after shearing.

		Residue levels in wool wax (mg/kg wax) Weeks after backline treatment			
		2	4	8	12
Cypermethrin					
Back	Tip	130000	111000	21500	25000
	Middle	1300	2950	1210	70
	Base	350	390	370	85
Left side	Tip	360	470	400	65
	Middle	50	370	30	15
	Base	130	40	40	30
Right side	Tip	250	240	90	260
	Middle	180	200	40	120
	Base	300	25	30	15
Diazinon					
Back	Tip	75400	29000	4530	1140
	Middle	30	200	370	70
	Base	830	360	35	10
Left side	Tip	120	380	170	30
	Middle	70	180	35	20
	Base	50	50	30	20
Right side	Tip	460	320	190	30
	Middle	360	280	40	15
	Base	35	100	20	10

The concentrations of residual synthetic pyrethroid in the wool wax on the tip of the staple were within the range likely to cause dermal irritation (5000-12000 mg/kg wool wax), as proposed by Herbst *et al* (1993), for at least 3 months after treatment. This may help to explain why shearers sometimes experience dermal erythema after shearing sheep treated with synthetic pyrethroid backline products.

3.4.5 Efficiency of backline products

These data also raise questions about the efficiency of the backline products studied, particularly given that in most cases approximately 10 times the amount of active constituent has to be applied per sheep to achieve the same effect as a jetting treatment (eg 1.5 gram cypermethrin applied per sheep as a backline treatment compared with a maximum of 0.15 g/sheep applied as a jetting treatment). As Tables 8 and 9 show, the residues from backline treatments are correspondingly higher.

Another area of concern is the potential of such products to contribute to the development of resistance to synthetic pyrethroids in lice and flies, given that lice and flies are probably exposed to sub-lethal doses in many parts of the fleece.

In view of the residue and resistance implications, there is a high price to pay for the convenience of a backline treatment and it is recommended that the efficacy of the backline products be reviewed, particularly with respect to their potential to enhance the development of resistance.

3.5 CSIRO trials with short wool products

Earlier CSIRO on-farm studies in eastern Australia (using a cocktail of active ingredients in non-standard formulations) showed that residues at shearing (10 months after treatment) following early application of organophosphate and synthetic pyrethroid pesticides (short wool treatments) were generally very low (Table 13), although the alphacypermethrin treatment at Werribee left residues of about 9.3 mg/kg wool. Note that these residues were obtained by analysis of 'worst case' backline patch samples.

3.6 Other recent Australian wool residue trials.

3.6.1 Off-shears and short wool treatments

Campbell (personal communication) has reported another series of residue depletion trials that were recently conducted in Queensland, Victoria, Tasmania and Western Australia. The studies included a wide range of off-shears and short wool treatments, with wool sampled at least three times between treatment and shearing. A summary of the work, which is being co-ordinated by Campbell, is shown in Table 14.

Table 13: Calculated residual pesticide levels in wool (mg/kg) approximately 10 months after treatment from sheep hand-jetted 4 days after shearing, or backlined 56 days after shearing, at three different locations in eastern Australia.

Treatment type and time	Active constituent	Residue level approx 10 months after shearing (mg/kg wool*)		
		Werribee	Trangie	Charleville
Jetting 4 days after shearing	Propetamphos	<0.01	<0.01	<0.01
	Diazinon	0.1	0.05	0.02
	Cyhalothrin	0.2	0.06	1.2
	Cypermethrin	0.5	0.06	0.54
Backline, 8 weeks after shearing	Cypermethrin	1.4		0.3
	Alphacypermethrin	9.3		0.8
	Deltamethrin	0.4		0.3

***Note:** These data were originally expressed in mg/kg wool wax. They have been converted to mg/kg wool, assuming the wool had 13% wool wax.

Table 14: Details of application methods, chemicals used, location of trials and times of application (weeks after shearing) in recent residue depletion studies carried out on off-shears and short wool products (Campbell, personal communication).

Application method	Chemical group	Active constituent	Location and time of application (weeks after shearing)			
			WA	Qld	Vic	Tas
Off-shears backline	OP	Diazinon	✓	✓	✓	✓
	SP	Alphacypermethrin	✓	-	✓	-
	SP	Cypermethrin	✓	-	✓	-
	SP	Deltamethrin	✓	✓	✓	✓
	IGR	Triflumuron	✓	✓	✓	✓
Shower dip	OP	Diazinon	0, 6 & 12	0	6	6
	OP	Propetamphos	-	-	6	-
	OP	Temephos	-	0	6	6
	SP	Cyhalothrin	0, 6 & 12	-	-	-
	IGR	Diflubenzuron	0, 6 & 12	0	6	6
	Other	MgFSi & rotenone	0, 6 & 12	-	-	-
	Other	Zinc Sulphate	0, 6 & 12	-	-	-

Notes:

OP	organophosphate	IGR	insect growth regulator
SP	synthetic pyrethroid	MgFSi	magnesium fluorosilicate

Most of these trials commenced in the latter half of 1996 and field work has now been completed. Residue data were not available for this review. However as data become available, they are being incorporated into the residue depletion models being developed by Campbell and Horton, and will eventually be used to develop suitable withholding periods for the various treatments.

3.6.2 Automatic jetting race studies

Levot and Sales (1997) have compared residue levels in wool of sheep with 8 months wool, treated with either diazinon or cyromazine, by hand jetting, jetting with a standard Harrington automatic jetting race or a Harrington jetting race modified as recommended by NSW Agriculture (Lund and Kelly, 1994).

They found that residue levels at shearing, 16 weeks after treatment, ranged from less than 10 to about 125 mg/kg wool in the case of diazinon, and from about 50 to about 150 mg/kg wool in the case of cyromazine. Residue levels were lowest from standard automatic jetting race application and highest from hand jetting. The modified jetting race left residues of about 20 mg diazinon/kg wool and about 75 mg cyromazine/kg wool.

Estimated half lives for hand-jetted propetamphos and diazinon on sheep were about 26 days, while that for hand-jetted cyromazine was about 75 days. These values are consistent with the previous Avcare and Victorian studies. Insecticide half lives were much lower on sheep treated with the standard jetting race, presumably because much of the applied chemical remained on the outside of the fleece where it would have been exposed to sunlight.

Sampling studies confirmed the Victorian observations that residue levels in core samples taken from baled wool were generally much lower than those in band samples taken from sheep. Residue levels in a single core sample taken from a bale of wool varied widely and the researchers concluded that multiple core sampling techniques would be required to accurately reflect mean residue levels in baled wool.

Levot and Sales also compared residue levels resulting from hand jetting at low concentrations (50 mg/L) with hand jetting at normal concentrations (360-400 mg/L of propetamphos or diazinon respectively). As might be expected, the low concentration treatments left significantly lower residue levels at shearing 4 months after treatment than the high concentration treatments (for example, 21 mg/kg wool compared with 125 mg/kg wool in the case of diazinon). Further studies are being carried out to assess the efficacy of low concentration jetting treatments on lice control.

3.7 New Zealand data

Two New Zealand papers (Rammell and Bentley, 1989 and 1990) have examined breakdown rates of a number of organophosphate pesticides in sheep over an 18 week period, following dipping in either May or December, at Upper Hutt. The study confirmed that breakdown rates were much higher on the back of the sheep than on the sides (similar findings have been noted in the two Australian projects referred to earlier) and that degradation rates were higher in summer months (half-lives ranging from 14-36 days) than in winter (half-lives ranging from 37-67 days). Degradation rates in New Zealand were generally much higher than those estimated for Australian conditions (eg estimated half lives for diazinon were 15 days under New Zealand summer conditions, compared with 25 days or more under Australian conditions). This difference is possibly due to the more open wool type sheep used in the New Zealand experiments, although application time and hence sunlight intensity may have been a factor - the New Zealand treatments were applied in December, whereas the Australian treatments were applied in August.

Residue levels 13 weeks after summer dipping with diazinon, coumaphos and propetamphos were in the order of 5 mg/kg wool. On the other hand they ranged from 15-50 mg/kg wool approximately during winter months.

3.8 Other Company data/individual product data

Individual product data with respect to more recently registered products such as dicyclanil, diflubenzuron, triflumuron and temephos have been examined and taken into account. Limited residue data for a combined magnesium fluorosilicate and rotenone product were also examined. However in view of their confidential nature, these data are not reproduced in this document.

4. Relevance of data

4.1 Public health issues

As mentioned in Section 2.2, the current Australian standard for pesticide residues in lanolin allows residue levels of up to 40 mg diazinon/kg. The average concentration of organophosphates in raw wool in the 1997/98 season was 5.8 mg/kg (The Woolmark Company residue monitoring program), which equates to about 45 mg/kg wool wax. This residue level would probably allow Australian lanolin manufacturers to meet the current standard of 40 mg/kg on average, given that there is some removal of pesticide in the lanolin purification process. Sighted Certificates of Analysis for commercial batches of raw wool grease confirm that diazinon residue concentrations are commonly in the 35-40 mg/kg range. Substantial refining would be required to meet new standards proposed by the Advisory Committee on Pesticides and Health (ie no more than 3 mg/kg total pesticide and no more than 1 mg/kg for any one pesticide).

Residue levels detected in wool wax 3 months following hand jetting (369-923 mg/kg for organophosphates and 50-70 mg/kg wool wax for synthetic pyrethroids) are greatly in excess of both the current and proposed standards for lanolin intended for human use. However, The Woolmark Company's data (1997/98 season) indicate that residues of this magnitude occur in less than 2% of the clip. Because of the amount of blending of wool in the commercial scouring process, and blending of raw wool grease from different sources into sales lots of lanolin, these residue levels are unlikely to be encountered in commercial lanolins.

Given that low pesticide grades of lanolin are now commercially available for use in pharmaceutical and cosmetic products, the public health aspects of pesticide residues on wool are of less concern than they were a few years ago. Nevertheless, relevant health authorities should still consider the need to revise the present Australian standard for residual pesticide in lanolin intended for human use.

If the residue status of wool was known at the time of scouring, this would assist wool scourers to meet customer requirements for raw woolgrease and facilitate the preparation of low pesticide grades of lanolin.

4.2 Occupational Health and Safety

4.2.1 Dermal exposure hazard

The main exposure hazard of residues in wool to shearers and other wool handlers is through dermal absorption. Using the proposed NOHSC protocol which assumes a shearer being exposed to 23 g wool wax per day and a safety margin of 100, it is possible to calculate the threshold residue levels that could be considered safe to shearers and other workers handling raw wool on a regular basis. The basis for these calculations is shown in Appendix II, as are the calculated threshold levels for a number of pesticides commonly used on sheep. The calculations suggest that residues in excess of 1.2 mg chlorfenvinphos, 3.9 mg propetamphos and 9.8 mg diazinon/kg wool pose a potential risk to humans through dermal absorption. Much higher thresholds apply to the other pesticides commonly used on sheep such as the synthetic pyrethroids and the insect growth regulators.

Obviously, care is needed in interpreting these threshold levels, given the limitations of the protocol used to derive them. Those limitations are highlighted by the relatively low threshold level of 28.3 mg/kg wool for cyromazine, given that cyromazine is generally regarded as having low mammalian toxicity (eg no poison schedule classification).

Residues of chlorfenvinphos (120 mg/kg wool), propetamphos (44-73 mg/kg wool) and diazinon (48-112 mg/kg wool) were detected 3 months following hand jetting, and these are well above the relevant threshold levels mentioned above. Cyromazine residues of between 67-138 mg/kg are also well above the calculated threshold level. In most cases it took about 6 months for residue levels from the organophosphate and cyromazine treatments to fall below estimated "safe" threshold levels.

On the other hand, mean residue levels for other types of pesticides used on sheep (eg synthetic pyrethroids and diflubenzuron) were generally well below relevant threshold levels for dermal exposure, although in the case of one of the synthetic pyrethroid backline treatments (a cypermethrin/diazinon combination), residue levels of both cypermethrin and diazinon along the backline were well above the threshold level for dermal absorption 3 months following treatment.

NOHSC have used the residue data provided by both the Victorian and Avcare studies, as well as individual product data, to estimate "rehandling" times for the various pesticides currently used on sheep, where the rehandling time is defined as the time that should elapse before sheep can be shorn safely without the need for protective clothing. These rehandling times take into account both systemic and topical toxicity, and relate to day-long, close handling of sheep over many days as would occur with shearing.

NOHSC concluded that rehandling times of about 6 months may be needed for all the organophosphate jetting products (apart from chlorfenvinphos and temephos) as well as cyromazine. A rehandling time for chlorfenvinphos was not determined because of insufficient data, although the limited data in Table 7 and those reported by Rammell and Bentley (1989) suggest that it is likely to be much longer. Much shorter rehandling times would apply to the other pesticides commonly used on sheep. Temephos, diflubenzuron and triflumuron were assessed separately and temephos was given a 6 week rehandling period following dipping. No specific rehandling times have been proposed for diflubenzuron or triflumuron.

These estimated rehandling times are based on mean residue levels on the fleece and assume that shearers come into contact with all parts of the fleece during the course of a days work, and not just the parts of the fleece that have been treated. The residual pesticide on the fleece at shearing is anything but uniformly distributed. In the case of the long-wool backline treatments, as Tables 11 and 12 show, most of the residue, three months after treatment, will be found along the backline (up to 97% in the case of the cypermethrin treatment, 85% with alphacypermethrin, and 62% in the case of diazinon). The NOHSC assessment of the long-wool backline treatments has taken this extreme uneven distribution into account.

As mentioned previously, the protocol used by NOHSC to estimate rehandling times has a number of limitations, including the questionable assumption that a shearer is exposed to 23 g wool wax/day. If this exposure factor is varied, the rehandling time will vary accordingly. The same comments apply to the dermal absorption factor used. The need for a more precise estimate of shearer exposure to wool grease and the dermal absorption factors for the various pesticides cannot be over-emphasised.

Furthermore, the present method of assessing rehandling times is based on band sampling data which over-estimate mean residue levels on the fleece. Blended core samples from baled wool, although more difficult to obtain under experimental conditions, give a lower, more realistic and less variable estimate of mean residue level on the fleece. The variability of band sampling data limits the extent to which estimated half-lives can be used to calculate rehandling times, although as more data become available, modelling techniques proposed by Campbell and Horton should prove useful in calculating rehandling intervals.

In view of these limitations, it is recommended that steps be taken to determine a more scientifically-based estimate of shearer exposure to wool wax and that the protocol presently used by NOHSC to assess the occupational hazard of residual pesticide in wool to shearers and other wool handlers be revised as a matter of priority.

It is also recommended that further consideration of the occupational hazard of residual pesticide in harvested wool to shearers and other wool handlers be deferred until a more realistic estimate of worker exposure to wool wax is available.

Rehandling times for the other activities associated with shearing such as gathering up wool and throwing it into bales have yet to be estimated, although they are likely to be similar to those indicated for shearing. Similar comments apply to contract crutching which is often done on a regular basis by shearers. Short-term wool-handling activities, such as drenching, occasional crutching, routine examination for flystrike, etc, may also need to be considered in order to determine whether rehandling times are required for these activities.

Registrants wanting a more realistic estimate of rehandling time are advised to address all of the issues referred to above, and guidance notes are being prepared to assist in the gathering of the most appropriate data.

4.2.2 Dermal irritation hazard

As mentioned in Section 2.3.2, Herbst et al (1993) reported that dermal irritation from synthetic pyrethroids can occur in humans at concentrations between 5000-12000 mg/kg wool wax. Tables 11 and 12 show that residue levels of cypermethrin and alphacypermethrin on the tip of the fleece along the backline exceeded those threshold levels three months after treatment with backline products. While the acceptable daily intake (ADI) for the synthetic pyrethroids is unlikely to be exceeded at these concentrations, the fact that the residues may cause a temporary dermal erythema is an occupational health and safety concern.

The study referred to in Section 3.3.2 did not progress beyond 3 months after treatment. It is likely that alphacypermethrin residues would fall below threshold levels by 6 months after application, but it is doubtful if cypermethrin levels would.

Because of these concerns, it is recommended that the NRA reconsider the present registration status of long-wool backline products containing synthetic pyrethroids.

4.3 Environment

Table 15 summarises the maximum allowable residue levels for a range of pesticides that can be tolerated in a scouring lot in order to meet the various environmental standards described in Section 2.4, and compares them with the current mean residue levels in the Australian wool clip (The Woolmark Company data, 1997/98 wool growing season). Products not included in this table (such as amitraz, dicyclanil, ivermectin and magnesium fluorosilicate/rotenone) were omitted because they were not included in The Woolmark Company monitoring program.

4.3.1 ARMCANZ/ANZECC Guidelines for Trade Wastes Discharged to Sewers

Mean residue levels of all pesticides measured in the Australian clip during 1996/97 wool growing season were well below the 13 mg/kg residue level required to meet ARMCANZ/ANZECC guidelines for the pesticide content of trade wastes discharged to urban sewerage systems.

Experimental data (Tables 7-9 and 13) suggest that most of the off-shears and short wool treatments, if used as directed, are unlikely to cause a problem for scourers if the ARMCANZ/ANZECC guidelines for trade wastes have to be met. It is residues from the long wool treatments that are likely to exceed those guidelines, as almost all of these treatments left residues in excess of 13 mg/kg wool when applied less than 6 months before shearing.

Table 15: Maximum residue levels (mg/kg wool) required in a scouring lot to meet various environmental requirements compared with mean residue levels in the Australian wool clip in 1997/98.

Active constituent*	Mean residue level in Australian wool during 1997/98 (mg/kg wool)	Maximum allowable residue level in a scouring lot (mg/kg wool)		
		ARMCANZ guidelines for trade wastes	Australian requirements at Black Rock ocean outfall	UK average annual EQS requirements at Spenborough
Chlorfenvinphos	0.22	13	3	0.56
Diazinon	5.0	13	3	0.56
Propetamphos	0.16	13	3	0.56
Alphacypermethrin**	3.2	13	1.5	0.06
Cypermethrin**	3.2	13	1.5	0.06
Cyhalothrin	0.01	13	1.5	0.06
Deltamethrin	0.06	13	1.5	0.06
Cyromazine	5.7	13	97000	28
Diflubenzuron	3.6	13	7.4	0.84
Triflumuron	6.1	13	70	4.9

Note:
* Only products included in The Woolmark Company residue monitoring program are included in this table.
** In most cases the analytical laboratory does not report cypermethrin isomer ratios to allow discrimination of these products.

However, as mentioned previously in Section 2.4.2, scouring studies in a modern Australian facility using efficient effluent recycling and recovery loops, have confirmed that it is most unlikely that residues of any lipophilic pesticide would ever exceed 1 mg/L in urban scouring effluent under Australian conditions, particularly when predicted use patterns and the blending of sales lots that occurs prior to scouring are taken into account (Russell, see previously).

The pesticide most likely to cause concern is cyromazine as it is not removed in wool wax recovery systems. However, a discharge of 1 mg/L would only be exceeded if a significant quantity of wool containing a high level of cyromazine were to be scoured at any one time. Even then, the environmental consequences are of little significance as cyromazine has low aquatic toxicity.

Again, as mentioned previously, the ARMCANZ/ANZECC guidelines for trade wastes discharged to sewers are of questionable relevance to wool scours. Apart from the fact that they are most unlikely to be breached, Table 15 shows that they would allow pesticide residue levels that are environmentally unacceptable. Consequently the Steering Committee has decided that environmental standards for sheep ectoparasiticides should be based on the approach taken by Environment Australia and not on the ARMCANZ/ANZECC guidelines for trade wastes discharged to sewers.

4.3.2 Proposed Environment Australia standards for Australia

The model proposed by Environment Australia is a much more rational approach to assessing the environmental hazard of residual pesticide in scouring effluent and is preferred by the Steering Committee and the Wool Residues Management Council. However, the estimated standards derived from that model (Table 1) are much tougher than the ARMCANZ/ANZECC guidelines for the organophosphates, the synthetic pyrethroids and some insect growth regulators such as diflubenzuron, as they take into account the high aquatic toxicity of these pesticides.

Experimental data (Tables 7-9) suggest that all of the short wool organophosphate treatments would meet Environment Australia's proposed Australian standards provided sheep were shorn later than 6 months after treatment. Likewise Cranna's data (1998) indicate that off-shears use of triflumuron would meet Australian environmental requirements if used as directed, as would the magnesium fluorosilicate/rotenone treatment. There is very little residue data on the off-shears and short-wool synthetic pryethroid treatments. However, some registration data held by the NRA, as well as limited CSIRO data for off-shears jetting application of the synthetic pyrethroids (Table 13), suggest that residue levels at shearing would meet Australian environmental environmental requirements. There are insufficient residue data to allow firm comment on the short-wool diflubenzuron treatment.

As far as the long wool treatments go, the available residue data suggest that none of them, apart from cyromazine or dicyclanil, would meet Australian environmental requirements if applied less than 6 months before shearing. The Victorian studies indicate that long-wool treatment with diflubenzuron would require a withholding period much longer than 6 months.

It should be kept in mind that the above comments apply only when all of the wool going into a scouring lot is contaminated with that particular level of pesticide. That rarely occurs in practice. Section 4.3.4 explores further the implications of proposed Australian environmental requirements for continued use of existing products when pesticide use patterns and wool blending practices are taken into account.

4.3.3 UK/EU requirements

As mentioned in Section 2.4, UK/EU scourers will have two environmental standards to meet in future - an average annual Environmental Quality Standard (EQS) and a Maximum Allowable Concentration (MAC) which is allowable for short periods of time. Of these, the average annual EQS requirements (Table 2) are likely to be the more critical for scourers of Australian wool.

Data in Table 7 suggest that all of the short wool dipping treatments examined (amitraz, diazinon and propetamphos) would be able to meet those standards, provided sheep were shorn at least 6 months after treatment (or 3 months in the case of amitraz). As far as the off-shears synthetic pyrethroid backline treatments are concerned, there is very little data available. Limited registration data held by the NRA suggest that some products leave residues at shearing that would exceed UK requirements. Likewise limited data for off-shears jetting application of these products (Table 13) suggest that residue levels at shearing (estimated to be in the range 0.2-0.5 mg/kg wool) may exceed UK/EU environmental requirements. Further doubt has been raised about these treatments by Plant (1995 and 1996) and Horton *et al* (1994). In the case of triflumuron, mean residue levels of 25-30 mg/kg in wool 12 months after treatment, as reported by Cranna (1998), are well above the maximum residue level proposed in Table 2.

The data in Tables 7, 8 and 9 suggest that, apart from cyromazine, all of the long wool treatments would have difficulty in meeting average annual EQS requirements 6 months after treatment.

Again, these comments apply only when all of the wool going into a scouring lot is contaminated with that particular level of pesticide.

Because the EQS requirements are based on annual average figures, comparison with the average residue levels detected in the Australian wool clip provides a better indication of the probability of meeting those standards. Table 16 shows how mean residue levels for the major pesticide groups detected in the Australian clip (The Woolmark Company, 1997/98 data) compare with the mean residue levels required in scouring lots to meet EQS requirements. Such a comparison takes into account the percentage of the national flock treated with each pesticide.

Table 16 indicates that in 1997/98, mean residue levels for all pesticides in the Australian clip except cyromazine would have exceeded proposed UK environmental requirements. Mean residue levels of diflubenzuron have risen from 1.2 to 3.6 mg/kg wool in the past 12 months while those of triflumuron have almost doubled. They are likely to increase still further if use of those products increases. If that happens, the chances of wool treated with those pesticides failing to meet UK environmental requirements is also likely to increase.

Because the Australian clip contains sales lots that have both high and low residue levels, it is possible that scouring effluent might occasionally exceed short-term MAC standards. Shaw and Russell have both used computer spreadsheet programs to estimate the probability of this happening, using hypothetical scour lots made up by randomly selecting 10 sales lots from The Woolmark Company residue monitoring program. Given that the average sales lot in Australia is around 1500 kg, this corresponds with a scouring lot of 15 tonnes that would be processed in about 10 hours. While this may underestimate the size of scouring lots, it does reflect the blending procedures used in most mills. This method takes into account the proportion of the flock currently treated with a particular pesticide, and the range and distribution pattern of residue levels currently present.

Table 16: Mean levels of residual pesticide in raw wool (mg/kg) required to meet annual average environmental requirements (EQSs) in the UK compared with mean residue levels in the Australian clip in 1997/98.

Pesticide	Mean residue level in scouring lots (mg/kg wool) required to meet UK/EU EQS standards*	Australian wool clip (1996/97)	
		Mean residue levels (mg/kg wool)	% national flock treated**
Organophosphates	0.56	5.8	76
Synthetic pyrethroids	0.06	3.3	36
Cyromazine	28	5.8	26
Diflubenzuron	0.84	3.6	11
Triflumuron	4.9	6.1	20

Notes:

* Organophosphate (OP) and synthetic pyrethroid (SP) values are based on UK EQS figures; others are based on Shaw's assessment.

** % flock treated figures for OPs and SPs are based on diazinon and cypermethrin figures respectively. Several flocks are treated with more than one pesticide.

Table 17: Estimate of the percentage of scouring lots in 1997/98 that would have exceeded pesticide residue levels necessary to meet Australian and UK environmental standards.

Pesticide	Percentage of scouring lots likely to exceed relevant environmental standards for:		
	Australia (Black Rock)	UK MAC	UK EQS
Diazinon	52	46	92
Cypermethrin	50	53	89
Cyromazine	0	0	0
Diflubenzuron	15	17	60
Triflumuron	0	0	51

Table 17 shows the proportion of scouring lots that would have failed to meet Australian and UK environmental requirements in 1997/98 and it is clear that MAC requirements for organophosphates and synthetic pyrethroids would have been frequently exceeded. However the table also shows that the average annual EQS requirements would have been more frequently exceeded by a wider range of pesticides and hence confirms that they are the more critical of the UK standards.

Section 4.3.4 explores further the implications of existing UK and proposed EU environmental requirements for continued use of existing products when current and predicted use patterns, and wool blending practices are taken into account.

4.3.4 Impact of pesticide use patterns and risk analysis on standards

Because wool from different sales lots is blended into processing lots at the scouring plant, it is important to take the percentage of the national flock treated with particular pesticides into account when setting standards for the residual pesticide content of harvested wool. The effect of doing so on the maximum acceptable residue level required in an individual sales lot to meet environmental standards is shown in Tables 1 to 3.

The wool blending models proposed by Shaw and Russell can be used to provide a more statistically sound estimate of the maximum residue levels that can be tolerated in an individual sales lot in order to be confident that scouring effluent will meet environmental requirements, say 95% of the time. Using The Woolmark Company survey data to represent the national clip, higher residue lots can be progressively removed from the clip (as would happen if a strict withholding period was to be imposed), until a residue level is reached at which 95% of remaining scouring lots meet environmental requirements. That residue level can then be used as the maximum acceptable residue level for an individual sales lot and an appropriate withholding period determined from residue depletion data. The Wool Residues Management Council has decided to accept a 95% level of confidence, although this can be varied to suit the level of risk the user is prepared to take.

Shaw and Russell’s models can also be used to estimate the likely impact of changing market share of a particular pesticide on mean residue levels, and on the relevant maximum allowable residue level and withholding period. These estimates assume that the residue distribution pattern remains the same when the use pattern changes. This was supported by the roughly proportional increase in average residues of triflumuron and diflubenzuron as their market share increased between 1996/97 and 1997/98.

The model can be varied to reflect local conditions. For example, when considering the Geelong scouring district, Russell assumes that two scouring lines are operating in parallel, and estimates are based on 20 sales lots being processed simultaneously, whereas for the UK situation, the model is based on a single processing line.

It must be appreciated that the model does have some limitations. It is based on the most recent Woolmark Company survey data and as such reflects pesticide use patterns (percentage of the national flock treated) in the previous wool growing season. This information can be up to 18 months out of date. Also, the survey does not include bulk sales lots, which tend to be composites of wool from a number of properties, or non-fleece wool such as crutchings. Horton (personal communication) has found that the mean residue level in bulk sales lots is usually about twice the mean residue level in other sales lots. Thus The Woolmark Company survey may under-estimate true residue levels in the clip. Nevertheless, the model and the results it produces can be modified as more recent data become available.

The way in which the model can be applied to both proposed Australian and UK/EU environmental requirements is shown in the following sections.

(a) Australia

Table 18 shows the current residue status of Australian wool and how it compares with proposed Australian environmental requirements. The proportion of scour lots likely to exceed those requirements, based on the 1997/98 use pattern, is also shown.

Table 18: Residue status of Australian wool in 1997/98 compared with proposed Australian environmental requirements, and the percentage of scouring lots that would have exceeded those requirements.

Pesticide	1997/98 use pattern (% national flock treated)	Maximum acceptable residue level in scouring lot (mg/kg wool)	Mean residue level in national clip (mg/kg wool)	Percentage of scouring lots likely to exceed requirements
Diazinon	76	3	5.4	52
Cypermethrin	36	1.5	3.2	50
Cyromazine	26	97000	5.8	0
Diflubenzuron	11	7.4	3.6	15
Triflumuron	20	70	6.1	0

The table shows that the level of compliance with the proposed environmental guidelines for organophosphates and synthetic pyrethroids (using diazinon and cypermethrin respectively as indicators) was poor in 1997/98. This was to be expected as the average concentration of organophosphate and synthetic pyrethroid residues in the clip is around twice the concentration allowed in any processing lot. Clearly, if the organophosphates and synthetic pyrethroids continue to be used at the same levels, there is a need to reduce the number of high residue sales lots in order to meet environmental requirements.

Diflubenzuron, although present in only 11% of the clip, would have caused 15% of processing lots to exceed the estimated maximum allowable residue level. This is in marked contrast to the 1996/97 situation, when only 2% of scouring lots would have exceeded them. Diflubenzuron tends to leave relatively high residue levels (the mean residue level in treated wools was 33 mg/kg) and this, coupled with an increase in the number of treated clips, increased the chances of a scouring lot exceeding environmental standards. Obviously if the use of diflubenzuron increases still further, the risk of exceeding environmental standards will also increase.

Triflumuron residues did not exceed environmental requirements in 1997/98, and the table suggests that the percentage of the national flock treated with triflumuron could increase substantially without adverse environmental impact.

Cyromazine has a low acute toxicity and proposed environmental limits will never be approached, even if its usage was to increase significantly.

Organophosphates and synthetic pyrethroids

Table 19 shows how Russell's model can be used to predict what will happen to residue levels of diazinon and cypermethrin in scouring lots when a maximum acceptable residue level is imposed on individual sales lots.

In the case of diazinon for example, the model shows that had a maximum residue level of 10 mg/kg wool been established for sales lots in 1997/98, 94% of scouring lots would have met Australian environmental standards for scouring effluent. This compares with only 48% of scouring lots meeting environmental requirements in the absence of any standard. A similar maximum residue level for cypermethrin in sales lots (ie 10 mg/kg wool) would have seen 87% of scouring lots comply. Russell has estimated that the maximum residue level required to achieve 95% compliance for diazinon was 9 mg/kg, and for cypermethrin, 7 mg/kg.

Had those target maximum residue levels been applied to sales lots, the mean concentration of diazinon in the national clip would have been 1.8 mg/kg wool (compared with the recorded mean of 5.8 mg/kg), and for cypermethrin, 0.72 mg/kg wool (recorded mean of 3.3 mg/kg). About 15% of sales lots would have exceeded the proposed maximum residue levels.

Insect Growth Regulators

Russell's model has also been used to predict what might happen if the use of the insect growth regulators, cyromazine, diflubenzuron and triflumuron was to increase from what it was in 1997/98 (Table 20).

Diflubenzuron was used on only 5% of the flock in 1996/97 and this increased to 11% in 1997/98. The mean residue level in the clip increased from 1.2 mg/kg to 3.6 mg/kg wool.. There were six samples in the 600 sales lots tested with residues above 75 mg/kg wool, and these probably resulted from long wool treatments. Had a scouring lot included one of those contaminated lots, the mean residue concentration in the lot would have been above the Australian environmental standard of 7.4 mg/kg (for a single scouring line) and this would have occurred about 1% of the time. In fact, in Geelong, with two scouring lines operating and with other wool containing diflubenzuron residues present, the chances of exceeding the environmental limit in 1996/97 were around 2%, but in 1997/98, the probability increased to 15% (Table 20). Obviously if use of diflubenzuron increases, the chances of exceeding environmental standards will increase still further.

Table 19: Effect of imposing a maximum acceptable residue level for organophosphates and synthetic pyrethroids in individual sales lots on residue levels in scouring lots and their ability to meet Australian environmental requirements.

Pesticide	Maximum acceptable residue level in scouring lot (mg/kg wool)	1997/98 situation		Prediction if maximum residue level in sales lots is 10 mg/kg wool*		Prediction if maximum residue level in sales lots is 5 mg/kg wool**	
		Mean residue level in national clip (mg/kg wool)	% scouring lots above maximum residue level	Mean residue level in national clip (mg/kg wool)	% scouring lots above maximum residue level	Mean residue level in national clip (mg/kg wool)	% scouring lots above maximum residue level
Diazinon	3	5.8	52	1.9	6	1.3	0
Cypermethrin	1.5	3.3	50	0.87	13	0.59	1

Notes: ** 9% of survey samples exceeded 10 mg/kg diazinon and 5% exceeded 10 mg cypermethrin.*
*** 14% of survey samples exceeded 5 mg/kg diazinon and 7% exceeded 5 mg cypermethrin.*

Table 20: Estimate of the percentage of scouring lots likely to exceed Australian environmental standards if market share of insect growth regulators increases.

Pesticide	Maximum acceptable residue level in scouring lot (mg/kg wool)	1997/98 situation			Prediction if use doubles		Prediction if use triples	
		Current use pattern (% flock treated)	Mean residue level in national clip (mg/kg wool)	% scouring lots exceeding target	Mean residue level in national clip (mg/kg wool)	% scouring lots exceeding target	Mean residue level in national clip (mg/kg)	% scouring lots exceeding target
Cyromazine	97000	26	5.8	0	17.3	0	26	0
Diflubenzuron	7.4	11	3.6	15	7.3	39	10.9	70
Triflumuron	70	20	6.1	0	12.2	0	18.3	0

If a maximum residue level (and an appropriate withholding period) were introduced to limit the high residue treatments of diflubenzuron, a higher level of use could be tolerated. In fact, had the maximum residue level been set at 65 mg/kg wool in the 1997/98 season, 95% compliance with the proposed environmental standards would have been obtained. If the number of flocks treated was to double, the maximum residue level would need to come down to 25 mg/kg in order to achieve 95% compliance with environmental requirements.

Triflumuron was found on only 118 of the 600 sales lots sampled in 1997/98 (20%), an increase from 14% in 1996/97. The mean residue level in the national clip was 6.1 mg/kg wool (compared with 3.5 mg/kg the previous year), while the mean residue level in treated wools was 31 mg/kg. The maximum level detected was 140 mg/kg wool (on one sample) and about 2% of lots had more than 60 mg/kg. Russell's model shows that the target environmental standard of 70 mg/kg in a scouring lot would only be exceeded if all of the sales lots going into that scouring lot were highly contaminated. This is most unlikely when only 20% of the national flock is treated with the product. Using the model, it is possible to show that the use of triflumuron could increase to three times its 97/98 level (ie close to 60% of the national flock treated) before scouring lots would exceed proposed environmental standards for Australia.

At present triflumuron is used as an off shears pour-on product. Higher residue levels would be expected in the clip if the product was to be used later in the growing season, or if it was to be used extensively on early shorn lambs.

As mentioned previously, the proposed environmental standards for cyromazine will never be exceeded, even if the level of use were to treble.

It is important to appreciate that this initial analysis of the insect growth regulators is based on a fairly relaxed consideration of the acute toxicity of individual chemicals at ocean outfall, under conditions of rapid dispersion and disposal. It does not consider the possible additive effects of diflubenzuron and triflumuron (both have similar modes of action), or the possibility of long-term accumulation in the environment. Environmental authorities may at some stage in the future take these issues into account when revising standards for the insect growth regulators.

(b) UK/EU

The most critical environmental conditions in the UK are based on the requirement to meet average EQS target concentrations in Spen Beck. Calculations based on MAC environmental requirements (Appendices III and IV) show that short term toxicity figures are unlikely to be exceeded if the more critical average annual EQS requirements are met.

Table 21: Status of the Australian wool clip in 1997/98 with respect to UK EQS environmental requirements, and the estimated maximum residue levels required in individual sales lots to meet those standards.

Pesticide	Annual average residue level required in scouring lots to meet UK EQS (mg/kg wool)	1997/98 status of the clip and scouring lots with respect to UK EQS		Estimated maximum residue levels in sales lots required to meet EQS standards in 97/98	
		Mean residue in national clip (mg/kg wool)	% scouring lots exceeding required average residue level	Maximum acceptable residue level in sales lots (mg/kg wool)	% sales lots exceeding that max residue level
Diazinon	0.56	5.8	94	1.25	30
Cypermethrin	0.06	3.3	89	0.2	24
Cyromazine	28	5.8	1	nd*	nd*
Diflubenzuron	0.84	3.6	60	9	7
Triflumuron	4.9	6.1	51	37	6

Notes:
nd* Not determined as cyromazine never likely to exceed standards

Table 21 compares the 1997/98 residue status of the Australian clip with the UK's EQS requirements. Russell's model has again been applied to estimate the maximum acceptable residue level required in individual sale lots to meet those standards. Because the EQS is based on annual average values, the mean residue levels in the Australian clip were used as a basis for estimating the probability of meeting target EQS values and for determining the maximum residue levels required. Again, using The Woolmark Company residue data, higher residue sales lots were progressively removed from the clip (as would happen if a withholding period was to be imposed) until the mean residue level of remaining sales lots reached the target environmental requirement for scouring lots.

The table shows that, with the exception of cyromazine, mean residue levels of all pesticides in Australian wool in 1997/98 exceeded the residue levels required to meet UK annual average EQS requirements. In principle, cyromazine could be used on 90% of the flock and still meet UK standards. The other products would only meet UK requirements if either their usage was reduced or if maximum residue levels and appropriate withholding periods were applied to ensure that the mean residue levels in Australian wool did not exceed the target environmental requirements for scouring lots.

In the case of diazinon, while there is a large quantity of wool with low residues (which has probably resulted from short wool treatment), there is nevertheless a significant number of sales lots with residue levels higher than the annual average residue level acceptable in a scouring lot. To allow UK scourers to meet the annual average EQS requirements, it would have been necessary in 1997/98 to set a maximum residue level of 1.25 mg/kg wool in a sales lot to ensure that the national clip had an average diazinon residue level of 0.56 mg/kg or lower. Thirty percent (30%) of sales lots would have exceeded this residue level (Table 21). Experimental data (Table 7) suggest that this mean value can be achieved by restricting use of diazinon and the other organophosphate products to early in the wool growing season.

The proposed environmental standard for cypermethrin would be almost impossible to reach at 1997/98 use patterns (about 36% of flock treated). It would be necessary to set a maximum acceptable residue level of 0.2 mg/kg wool and the limited data available suggest that even off-shears and short-wool dipping treatments would have difficulty in meeting this standard.

Diflubenzuron had a small market share in 1996/97 (about 5% of the national flock treated) and at that level of use, a maximum residue level of 60 mg/kg wool would have been required to ensure EQS requirements were met. In 1997/98, a maximum residue level of 9 mg/kg wool would have been required, because of the higher level of use (11% of the flock treated).

In the case of triflumuron, at the 1996/97 usage level (14%), the average level of triflumuron in the clip was 3.5 mg/kg and lower than that required to meet EQS requirements. However at the 97/98 treatment level (20%), a maximum residue level of 37 mg/kg wool would have been needed to ensure that EQS requirements were met.

When these proposed maximum residue levels were applied to The Woolmark Company data and the scouring model run on the remaining sales lots, the UK MAC requirements were exceeded less than 1% of the time. This confirms that the annual average EQS requirement is the more difficult target to meet, and that if environmental standards are based on EQS values, the MAC requirements will also be met.

It has to be appreciated that the above estimates are very dependant on the basic assumptions in the models used to derive the data. Any change in those assumptions (such as a revised estimate of the amount of pesticide discharged in scouring effluent, or the effectiveness of sewage treatment in removing residual pesticide) will change the outcome.

4.3.5 Estimation of withholding periods

Campbell and Horton (personal communication) have combined the residue data from the various controlled experiments and the on-farm surveys described in Section 3, as well as data from more recent unpublished experimental data, and used it to produce residue depletion models for the various pesticide treatments used on sheep. Similar models can be produced using experimental data only. The models, which are described in Campbell *et al* (1998), are updated as data from more recent experiments and surveys become available.

Examination of their models (Horton, Russell, personal communication) shows that there is good agreement between experimental data and farmer survey data in the case of controlled dose treatments such as pour-on products, but not in the case of treatments such as dipping and jetting where the application rate is less controlled. For example, growers appear to generate higher than expected residues from dipping treatments, and lower than expected residues from hand jetting. The difference is greatest for late-season hand-jetting, where experience suggests that growers may apply less than recommended quantities, or treat only specific parts of the sheep such as the breech. Levot and Sales (1997) also showed differences in residue levels resulting from different jetting treatments using different equipment.

Russell has used these depletion models to estimate the withholding periods required to ensure that scourers are able to meet both Australian and UK/EU environmental requirements (Table 22). Where possible, he has used depletion models based on data from controlled experiments in which treatments were applied according to label directions. Where experimental data were limited, as was the case with off-shears and short wool treatments, models based on both experimental and farmer survey data were used.

In the case of persistent pesticides which are thought to have minimal environmental impact at this stage, eg cyromazine, a default withholding period of 2 months (or 60 days) has been recommended.

Table 22: Estimated maximum acceptable residue levels (mg/kg wool) in sales lots and withholding periods (weeks after treatment) required for the common ectoparasiticide treatments§ to ensure that scouring lots meet proposed Australian and UK environmental standards.

Treatment/ chemical	Australia		EK/EU	
	Maximum acceptable residue level (mg/kg wool)	Withholding period (weeks)	Maximum acceptable residue level (mg/kg wool)	Withholding period (weeks)
Off-shears backline/spray-on				
Organophosphates	9	19	1.25	30
Synthetic pyrethroids	7	50	0.2	>52
Triflumuron*	See notes	9	37	**50**
Dicyclanil**	See notes	12	7.5	12
Short wool dipping (plunge or shower)				
Diazinon	9	**16**	1.25	**26**
Propetamphos	9	**12**	1.25	**22**
Temephos	9	12	1.25	24
Synthetic pyrethroids	7	46	0.2	>52
Diflubenzuron	65	46	9	>52
Mg fluorosilicate/rotenone+	See notes	<12	See notes	<12
Short-wool backline/spray-on				
Dicyclanil*	See notes	12	7.5	12
Jetting				
Diazinon	9	**26**	1.25	**36**
Propetamphos	9	**22**	1.25	**29**
Temephos	9	21	1.25	27
Synthetic pyrethroids	7	12	0.2	>52
Cyromazine#	See notes	9	See notes	9
Diflubenzuron	65	**>52**	9	**>52**
Long wool backline/spray-on				
Synthetic pyrethroids	7	**52**	0.2	**>52**
Diazinon	9	**12**	1.25	**22**
Cyromazine#	See notes	9	See notes	9
Dicyclanil**	See notes	12	7.5	12

Notes:
All WHPs estimated on the basis of currently available residue data and subject to review. Figures in bold are those derived from experimental data only as proposed by Russell. Most other figures derived from both experimental and farmer survey data as proposed by Campbell and Horton except where indicated below.

§ Amitraz has not been included because of inadequate data and ivermectin has been temporarily withdrawn from the market by the registrant.

* Maximum acceptable residue level for triflumuron in Australia (estimated to be about 150 mg/kg) unlikely to be met in practice. Default withholding period of 9 weeks (2 months) recommended.

** Maximum acceptable residue level for dicyclanil in Australia (>1000 mg/kg) unlikely to be met in practice. The withholding period has been left at 12 weeks as proposed by Environment Australia.

Maximum acceptable residue levels for cyromazine (>1000 mg/kg) unlikely to be met in practice Default withholding period of 9 weeks (2 months) recommended.

\+ Insufficient data to determine precise withholding period for magnesium fluorosilicate/rotenone.

The withholding periods in Table 22 should be used as a guide only, as there are large gaps and some inconsistencies in the original data. For example, residues from jetting or dipping treatments should increase as wool length at treatment time increases (more fluid is retained), but there are few data to support this. The Woolmark Company is currently sponsoring a study that should improve the quality of available data. Preliminary observations indicate that this study may also show differences in pesticide degradation rates between Queensland and Tasmania (Campbell, personal communication) and even between different parts of Queensland (Armstrong, personal communication). When these data are available (early in 1999), Table 22 may need to be revised.

Note that the withholding periods shown in Table 22 relate to treatments applied to adult sheep and to whole fleeces. As discussed in Section 4.5, treatment of lambs, particularly those likely to be slaughtered or shorn early, requires further examination. Likewise the issue of crutchings requires further examination.

(a) Australian withholding periods

Table 22 reinforces earlier conclusions that currently registered off-shears backline treatments and short wool dipping treatments (both plunge and shower dipping up to 6 weeks after shearing) are unlikely to cause environmental problems in Australia, provide they are used according to label and wool is not harvested within the proposed withholding period.

Apart from cyromazine and dicyclanil, long-wool products should not be used in the 6 months prior to shearing in order to meet Australian environmental requirements. Cyromazine is a product with low aquatic toxicity, that appears acceptable from an environmental point of view and it is questionable whether a wool harvesting withholding period is really necessary. A default withholding period of 9 weeks (2 months) has been proposed to discourage use close to shearing. Dicyclanil, a recently registered product, has a 3 month withholding period based on overseas requirements which would allow it to meet Australian environmental requirements.

It is interesting to note that Wools of New Zealand originally recommended a 2 month withholding period for sheep ectoparasiticides and the New Zealand Animal Remedies Board made it mandatory to show a 60 day wool harvesting withholding period on all sheep ectoparasiticide labels. This was loosely based on the data of Rammell and Bentley (1989 and 1990), which apply to coarse wool sheep. Their data are not applicable to Australian sheep types which generally have a denser fleece structure. The New Zealanders have recognised this and a 4 month withholding period is now recommended when products are used on Merino types. New Zealand scours most of its wool on-shore, and so their withholding periods are comparable with Australia's internal ones.

(b) UK/EU withholding periods

As far as short wool treatments are concerned, a 6 month withholding period would be required for most organophosphate products in order to allow UK and EU scours to meet environmental requirements. There are insufficient data to determine a precise withholding period for the off-shears and short-wool synthetic pyrethroids but some limited data suggest that it is possible for residues at shearing to exceed 0.5-1 mg/kg. This means that current use patterns may cause problems. Campbell and Horton have proposed a withholding period of more than 12 months for these products. It is possible that residue concentrations in areas where sheep are exposed to high levels of sunlight might be lower than those from southern Australia.

Off-shears use of triflumuron, at 1997/98 use levels, is likely to be just acceptable in terms of meeting overseas environmental requirements, but if its market share increases, average residues in Australian wool are likely to exceed those requirements, even with a 12 month withholding period. The short-wool dipping treatment with diflubenzuron would not meet UK environmental requirements, at present market share.

On the other hand, off-shears and short wool treatment with dicyclanil (3 months withholding period) would meet proposed UK environmental requirements, as would treatment with the magnesium fluorosilicate/rotenone combination. The present withholding period for dicyclanil (12 weeks) may need to be revised, if use exceeds the anticipated level.

There are not likely to be any limitations on the use of cyromazine.

Clearly the use of any long-wool product containing organophosphates or synthetic pyrethroids is likely to result in residues that exceed UK/EU environmental requirements. A withholding period of at least 6 months would be required for most organophosphate products, with some products (eg diazinon) needing up to 9 months. The withholding period for synthetic pyrethroid products is likely to be more than 12 months. Diflubenzuron would need a withholding period of more than 12 months in order to meet overseas environmental requirements, even at the currently low levels of use. Dicyclanil, on the other hand, could be used with a 12 week withholding period, although that withholding period may need to be revised if use in long wool exceeds the anticipated level.

(c) Assessing the impact of use pattern on withholding periods

The approach described above takes into account the percentage of the flock treated, as well as the environmental toxicology of the various compounds and the efficiency with which they can be handled in common effluent treatment systems. The difficulty from a regulatory point of view is that the percentage of the flock treated may vary from year to year and the data on which it is based are at least 12 months out of date. This means that if the proposed approach is taken, legal standards such as maximum acceptable residue levels and withholding periods (and hence labels) may need to be reviewed on a regular basis.

It is recommended that the wool industry continue to monitor product use, as is currently done by The Woolmark Company, and that for regulatory purposes the use pattern of each product (ie percentage of the national flock treated) be considered in discrete bands, for example, 0-15%, 16-30%, 31-50% and >50%. The withholding periods can then be reviewed when use of a particular product moves from one band to another. This should provide sufficient allowance for changing use patterns without the need to review all withholding periods (and change labels) on an annual basis. It means that if a company sets out to increase its market share for a particular product, it would need to trade that off against a decreased maximum residue level and a longer withholding period (and a need to amend labels).

Despite the difficulties it poses for regulators and the veterinary chemical industry, this overall approach is more rational than has been used in the past.

(d) Other regulatory aspects of proposed withholding periods

Clearly the current withholding period of 2 months that applies to all long wool lousicides and all blowfly treatments (unless an alternative withholding period can be supported by data) is inappropriate. In view of this it is recommended that where necessary, current withholding periods for sheep ectoparasiticides be phased out as soon as possible and replaced by more appropriate ones. It is also recommended that the NRA consider adopting the procedure proposed by Shaw and Russell to develop critical environmental residue levels, and the models being developed by Campbell and Horton for determining appropriate withholding periods. In addition, the NRA should develop suitable guidelines on data requirements for registrants.

Any proposal to set withholding periods will need to take into account any rehandling periods proposed by NOHSC.

4.4 Trade

In most cases, trade issues are likely to be governed by environmental issues and the only real information we have at present is that provided by Shaw (personal communication) on proposed UK/EU environment standards which are likely to impact on trade to the UK and other European Union countries. Estimates of the maximum residue levels necessary to meet those proposed standards and the withholding periods needed to meet those requirements are shown in Table 22.

As pointed out above, of the short wool treatments, only the organophosphates, dicyclanil, triflumuron and magnesium fluorosilicate/rotenone would have a chance of meeting overseas requirements. These treatments should be applied as early as possible in the growing season while the wool is short to give best control of pests, to reduce the amount of chemical retained, to allow greatest actinic degradation, and to allow longest time for degradation.

Available data suggests that all of the long wool treatments, apart from cyromazine and dicyclanil, would have difficulty in meeting proposed UK/EU environmental requirements if used less than 6 months before shearing. In the case of the organophosphates, an estimated withholding period of 6-9 months would be required, while the synthetic pyrethroid treatments and diflubenzuron would need a withholding period of at least 12 months.

Cyromazine and dicyclanil are the only long-wool products that can safely be used at this stage if wool is likely to go to Europe. Use of dicyclanil will need to be closely monitored.

Clearly, if the wool industry wishes to maintain its trading position, it does need to address the residue issue. There are several options open to the industry - minimising residues in wool at the farm gate, minimising residues in effluent discharged from scouring plants, scouring more wool on-shore, and identifying pesticide treated wool so that buyers and exporters can make an informed choice.

As mentioned earlier, The Woolmark Company data indicate that there is sufficient low residue wool available to meet European market requirements. The key is to develop a system of identifying the pesticide-contaminated wool.

To assist in this regard, it is recommended that the wool industry makes available, at the point of sale, all known information about the chemical residue status of wool on offer, including any relevant vendor declarations and analytical certificates. The wool industry should also develop suitable mechanisms for ensuring that wool exported overseas meets the residue requirements of importing countries and make relevant information available on request to the various sectors of the wool industry, the veterinary chemical industry and other interested parties.

The Woolmark Company has supported research at CSIRO Wool Technology to develop low-cost residue analysis technology (Russell, personal communication) for confirming the residue status of sales lots. It is recommended that the Wool Industry, in consultation with the CSIRO Wool Technology and appropriate analytical laboratories, further explore this and other options for providing cost-effective residue testing to the wool industry.

4.5 Treatment of lambs

As far as is known, there are very limited data available on the residual pesticide levels likely to be found in lambs wool.

Hanrahan (personal communication) and Plant (personal communication) are of the view that the amount of active constituent applied to lambs is commonly in the order of half to three-quarters that applied to an adult sheep. In some cases, application rates for lambs are clearly shown on the container label, but that is not always the case.

Lambs have a lower body mass (and wool mass) than adult sheep, and they are often shorn early (a few months after treatment), either for slaughter or to synchronise them with the rest of the flock. In Victoria and other parts of Australia (Hanrahan, personal communication), a significant proportion of lambs are shorn at about 6 months of age, and this is supported by Australian Bureau of Statistics data which show that the mean harvested fleece weight for lambs in 1996/97 was 1.62 kg.

The Avcare data for diazinon showed that the fleece of an adult sheep, hand jetted at nine months of age, contained 164 mg diazinon in 3.4 kg wool three months later, ie a residue concentration of about 48 mg/kg wool. If a lamb was hand jetted at three months of age and retained half the adult amount of pesticide, and then shorn three months later, it would be reasonable to assume that the fleece would weigh about 1.6 kg and contain about 80 mg diazinon. This equates to a residue concentration of 50 mg/kg which is about the same concentration as that found on an adult sheep. However if the lamb retained three-quarters the adult amount of pesticide, the residue level would be about 77 mg/kg wool.

Thus residue levels in lambs wool could be as high as, and possibly higher than those arising from late season treatment of adult sheep.

It can be argued that the fleece of a lamb is more open than an that of an adult sheep and that residual pesticide will dissipate more quickly. However this has yet to be supported by experimental data.

Again, as mentioned in Section 2.7, much will depend on what happens to the harvested wool. Short lambs wool is often mixed in with other short-fibre wool to make a composite bulk sales lot. Such lots usually have a higher than average residue level.

Further data are required to determine the full residue implications of both short and long-wool lamb treatments. Meanwhile it is recommended that growers be discouraged from applying ectoparasiticides to lambs likely to be shorn or slaughtered early unless absolutely necessary, and that any treated lambs or wool be identified to intending buyers.

4.6 Repeat applications

All of the data shown in Section 3 above relate to a single application. As far as is known there are no data to show the effect on residues of repeat applications, other than survey data reported by Plant in 1996 (Table 4) and that reported by Horton *et al* (1994) who found that residue levels in Tasmanian flocks were related to the number of treatments.

As was shown by the Victorian experiments, residual pesticide level is related to the mass of pesticide applied, especially if the treatment is close to harvesting. If multiple treatments are used, it is likely that at least one has been applied late in the season, and this is likely to contribute most to the final residue level. Consequently, it is reasonable to expect that repeat applications will leave higher residue levels on the fleece at shearing than a single application.

Further data are required to determine the full residue implications of repeat applications. Meanwhile, it is recommended that growers be discouraged from applying repeat applications of pesticide to sheep in the same season unless absolutely necessary. Again, any treated sheep or wool should be identified to intending buyers.

4.7 Short wool treatments

The limited residue data available (Tables 7 and 13) suggest that off-shears backline and short wool products are not likely to cause environmental problems in Australia, provided they are applied no later than 6 weeks after shearing and the withholding periods shown in Table 22 are observed.

However most of these treatments would have difficulty in meeting overseas environmental requirements. Short wool organophosphate treatments may meet overseas requirements provided wool is shorn at least 9-10 months after treatment. The synthetic pyrethroids are likely to cause problems for overseas scourers, even with a 12 month withholding period. Likewise the insect growth regulator, diflubenzuron, needs a withholding period of more than 12 months in order to meet overseas requirements. Based on the 1997/98 residue survey figures provided by The Woolmark Company, triflumuron appears acceptable at the present level of use. However, if use increases, as recent survey data suggests, residue levels are likely to exceed overseas requirements.

It follows therefore that early shearing is likely to exacerbate any potential residues problem and for that reason, proposed withholding periods for wool harvesting should be observed. Any rehandling times proposed by NOHCS also need to be taken into account. If treated sheep are shorn or slaughtered early, intending buyers should be notified.

4.8 Wound/blowfly strike dressings

Wound and blowfly strike dressings, which are mostly based on organophosphate pesticides such as diazinon, chlorfenvinphos and propetamphos, are normally applied at higher concentrations than those used for dipping or jetting. Although they are often applied relatively close to shearing (ie within 2-3 months before shearing), these treatments are usually applied only to a relatively small number of fly-blown sheep in a mob, and consequently are not likely to have much impact on mean residue levels in the flock.

A lot will depend on the number of sheep treated, the way the treatment is applied and what happens to the wool afterwards. Some farmers apply the treatment only to fly-blown areas of skin after clipping away all affected wool. Others clip very little wool off and simply apply dressing to the affected area. Regardless of clipping practice, most farmers apply a liberal amount of the dressing. Consequently the surrounding wool is likely to have quite high residue levels. Some growers sell affected fleeces as a separate line and these often end up in composite bulk lots with other high residue wool.

The survey data referred to in Section 3.2 of this report indicated that use of these treatments on individual struck sheep is unlikely to result in unacceptable residue levels on a whole flock basis. However, the residue levels on the wool of treated sheep may be high enough to pose an occupational hazard to workers shearing large numbers of those sheep.

Further data are required to determine the full residue implications of such treatments, although they are not considered a high priority at this stage.

5. Proposed standards

In setting registration standards against which to assess the residue implications arising from the use of sheep ectoparasiticides, the NRA needs to take into account:

- safety to humans (both to users of the products and to people likely to come into contact with treated wool);
- safety to the environment; and
- the potential of residual pesticide to adversely impact on trade of Australian raw wool.

The logical and easiest approach is to define acceptable criteria for each of the key areas (public health, OH&S, environment and trade) and then adopt the most critical of these as the standard which products should meet. In keeping with normal NRA practice, registrants would still have the option of providing satisfactory data or argument to justify a particular use pattern that resulted in residue levels outside those standards. In such cases, the registrant would reasonably be expected to propose a mechanism for dealing with any unacceptable residues.

This approach has a number of difficulties when dealing with sheep ectoparasiticides:

(a) Standards tend to be based on “worst case scenario” situations, even though these may not reflect many “real life” situations; eg environmental standards based on Black Rock requirements may not reflect environmental requirements elsewhere in Australia.

(b) Lengthy occupational health and safety rehandling periods may be required for some products and these will need to take priority over other requirements. Likewise, in order to meet proposed environmental and trade requirements, withholding periods of 6 months or more will be required for most long-wool products. Such rehandling and withholding periods will restrict use of long-wool products considered essential for animal welfare reasons in the months close to shearing.

(c) Most sheep ectoparasiticides need not pose an environmental threat if treated wool is scoured in a facility able to dispose of effluent in an environmentally acceptable manner.

(d) The insect growth regulators have significant benefits in terms of human safety compared with the other sheep ectoparasiticides, yet if proposed environmental and trade standards take precedence, the necessary withholding period may be impractical and effectively deprive farmers of valuable products.

(e) In some cases, environmental (and trade) standards are likely to be based on those imposed by other agencies (eg the ARMCANZ/ANZECC acceptance guidelines for the pesticide content of trade wastes discharged to sewers), which are not always based on scientific principles.

(f) In spite of the experimental data which suggest that correct use of long wool products is likely to result in high residue levels in sales lots, in practice these high residue levels are being detected in less than 5% of lots tested by The Woolmark Company.

(g) Experimental data on which standards tend to be based are usually derived from band or spot sampling techniques which are known to over-estimate average residue levels in treated wool. On the other hand, The Woolmark Company samples, and most regulatory samples for that matter, are based on core sampling techniques which more closely reflect mean residue levels in wool.

The NRA already determines for each ectoparasiticide maximum residue limits (MRLs) for sheep meat and milk and an appropriate meat/milk withholding period. Any further standards imposed would be in addition to those existing standards.

The Australian Wool Residues Management Council has recommended (9 December 1997 meeting) that any processing or environmental standards be based on Australian environmental requirements at ocean outfall at Black Rock, and that they incorporate market share factors as well as a risk analysis. The Council has indicated that it would be prepared to investigate alternative mechanisms for ensuring that raw wool exported overseas meets relevant standards.

With these difficulties and requirements in mind, the Steering Committee has considered three options:

Option 1

Do nothing. This option amounts to burying our head in the sand and hoping that the problem will go away. It won’t and so this option is unacceptable.

Option 2

For each product and approved use pattern, establish a “maximum acceptable residue limit” for harvested raw wool that is based on the most critical of the Australian environmental and OH&S “standards” referred to above, determine the withholding or rehandling period necessary to meet that standard, and stick fairly rigidly to those standards, withdrawing any product that fails to meet them.

If this approach were to be adopted, the wool industry would need to develop mechanisms for ensuring that wool exported overseas meets residue requirements of importing countries.

This option would effectively remove most if not all existing long wool products from the market. If the revised NOHSC protocol were to be applied (ie the one based on a safety factor of 100 and a shearer exposure of 23 g wool wax/day), most of the organophosphate products and even cyromazine could end up with a 6 month rehandling period. For other products the most critical standards would be the environmental requirements proposed by Environment Australia, which would require the “maximum acceptable residue limits” shown in Table 2 and the withholding periods shown in Table 22. In either case, Option 2 would effectively impose a withholding/rehandling period of 6 months or more on most existing long wool products. This would impose severe limitations on their usefulness.

Such an approach fails to address the animal welfare problem. It also fails to recognise that different scouring plants and water treatment facilities have differing capacity to deal with pesticide residues, and makes no allowance for the fact that the standards on which it is based might be very conservative or lacking in scientific rigour. Nor does it take into account the fact that the level of contamination in the Australian wool clip is generally lower than experimental data would suggest.

Option 3

A third option is to take a much more difficult but more pragmatic approach:

(a) For each product and approved use pattern, determine a “rehandling period” that must elapse before treated sheep are shorn or otherwise handled in large numbers, that will take precedence over all other standards.

(b) Also, establish a “critical environmental residue limit” for harvested raw wool that is based on the environmental standards proposed by Environment Australia for the ocean outfall at Black Rock, and determine the withholding period necessary to meet that standard (referred to subsequently in this report as the “wool harvesting withholding period”).

(c) Relevant standards would be based on the model proposed by Environment Australia for assessing environmental requirements, and where possible, the procedure developed by Shaw and Russell for determining critical environmental residue levels, and the models developed by Campbell and Horton for estimating wool harvesting withholding periods.

(d) Where the proposed use is considered essential for animal welfare reasons, and it is possible to scour the wool in certain scouring facilities without posing an environmental threat, consider approving use of the product within the wool harvesting withholding period, providing the following conditions are met:

   (i) any shearing rehandling period must be observed;

   (ii) treated sheep and wool must be suitably identified to buyers; and

   (iii) mechanisms must be in place to identify and deal with treated sheep and wool, and to educate wool producers, buyers and processors about their obligations.

   Obviously where the shearing rehandling period is longer, use of the product within the wool harvesting withholding period would not be possible.

(e) If this approach is taken, it is essential that the wool industry, in consultation with the NRA and State agencies responsible for agriculture, develop a suitable mechanism for identifying and handling wool that has been treated within the withholding period (eg by requiring a vendor declaration or analytical certificate at sale), ensuring that treated wool is appropriately processed, and if considered necessary, authorising and monitoring such use.

(f) Registrants would still have the option of providing satisfactory data or argument to justify a particular use pattern that resulted in residue levels higher than proposed standards. In such cases, the registrant would reasonably be expected to address the possible impact of residues on trade and on the local scouring industry, propose a mechanism for dealing with any unacceptable residues and obtain wool industry support for the proposed treatment.

While this approach does create problems for regulators, the veterinary chemical industry and growers, it does allow continued but controlled use of such products, while at the same time sending strong signals to wool growers and the chemical industry that the use of products which leave unacceptable residues is undesirable. It may in fact encourage the development of more suitable alternatives.

A precedent has been set with the vendor declaration system used in the cattle industry to cover likely causes of chemical contamination. Although it is a voluntary system, a number of markets insist on a vendor declaration and in that sense it is market driven. Producers who make false declarations can be penalised under State Fair Trading legislation.

The Steering Committee’s preferred option is Option 3. This option also has the support of the Australian Wool Residues Management Council and, with some reservations, the Wool Council of Australia (the peak wool grower organisation).

This option would require sheep ectoparasiticide labels to show three withholding/rehandling periods:

- a meat/milk withholding period
- a shearing rehandling period
- a wool harvesting withholding period for harvested wool based on Australian environmental requirements.

Existing procedures for assessing the occupational hazard of sheep ectoparasiticides and for determining rehandling periods must be revised before heading down this path. There is an urgent need to obtain a more realistic estimate of the amount of wool wax a shearer is exposed to in a days shearing to allow a more scientifically-based and credible assessment of occupational hazard.

It is proposed that the wool harvesting withholding period would be shown on the product label in the form of an advisory statement along the following lines:

*“**Wool harvesting withholding period***

Use of this product may result in residue levels in harvested wool that are unacceptable to Australian and overseas processors. It is recommended that wool not be harvested for at least ‘x’ months after treatment. Longer withholding *periods may be necessary for wool intended for certain overseas markets. If sheep are sold or wool is harvested within this period, intending buyers must be notified by vendor declaration. For further information, including information on overseas trade requirements, contact 1800 phone number".*

It is also essential that both OH&S and environmental standards be reviewed at regular intervals and amended as new information comes to hand or as circumstances change in the wool industry. If critical environmental residue levels are to be based on product use patterns (ie percentage of the national flock treated), product use will need to be monitored on a regular basis, preferably by a reasonably independent agency. The present Woolmark Company residue monitoring program appears to be the most effective way of doing this.

The wool industry needs to keep in mind that proposed EU environmental standards will be adopted by member countries in October 1999 and will be fully implemented by October 2007. Once that happens, UK and other EU processors are likely to only buy low-residue raw wool which will allow them to meet those standards. The long lead time between treatment and scouring (usually at least 18 months) needs to be kept in mind.

For that reason, it is essential that the wool industry develop a suitable mechanism for ensuring that wool exported overseas meets the residue requirements of importing countries. At the very least, this would require some method of identifying pesticide contaminated wool to buyers, as well as the provision of advice on overseas trade requirements. Mechanisms proposed for identifying contaminated wool include a suitably worded vendor declaration and/or a certificate of analysis, which would be made available to intending buyers at the point of sale.

As mentioned earlier, CSIRO Wool Technology (Russell, personal communication) has developed an analytical technique which is expected allow screening of wool samples for pesticide content at a reasonable cost. If widely adopted commercially, such a technique would provide the wool industry with an acceptable way of assessing the residue status of wool prior to sale. This would allow processors to select wool that meets their processing and environmental requirements, and help to overcome many of the problems identified earlier in this report.

The NRA, in consultation with the veterinary chemical industry, will need to develop appropriate guidelines for registrants to help them develop appropriate data for assessment purposes. Those guidelines are currently being prepared.

The wool industry should continue to monitor the residue status of the Australian wool clip and the needs of overseas markets. If Australian wool is not adequately meeting those needs, consideration should be given to incorporating the residue requirements of overseas countries into relevant standards.

6. Recommendations

1. Option 3 described above should be adopted as the preferred method of assessing sheep ectoparasiticides. This would require the NRA to:

   (a) establish three standards and associated withholding/rehandling periods for each of the sheep ectoparasiticides as follows:

   - meat/milk MRLs and an associated withholding period
   - a shearing rehandling period
   - a standard (critical environmental residue level and an advisory withholding period) for harvested wool that is based on Australian environmental requirements for Black Rock ocean outfall (Table 1).

   (b) allow use of the product within the wool harvesting withholding period where there are valid animal welfare reasons for doing so, provided such use does not contravene any OH&S rehandling period and that treated sheep or wool are identified to intending buyers prior to sale, either by a vendor declaration or by an analytical report.

2. The NRA should adopt the model proposed by Environment Australia for assessing environmental requirements (Appendices III and IV). Where practical, the procedures proposed by Shaw and Russell should be used for determining critical environmental residue levels, and those proposed by Horton and Campbell for determining appropriate withholding periods. The NRA should also develop guidelines on data requirements for registrants.

3. Current withholding periods for long-wool sheep ectoparasiticides should be phased out as soon as possible and replaced by the wool harvesting withholding periods described in Recommendation 1 above.

4. The wool industry, in consultation with the NRA and State departments responsible for agriculture, should develop suitable mechanisms for identifying sheep and wool that have been treated within the wool harvesting withholding period (eg by requiring a vendor declaration and/or analytical certificate at sale), educating wool producers, buyers and processors about these requirements and, if considered necessary, approving and monitoring use within the withholding period.

5. In order to allow wool buyers to meet customer requirements, the wool industry should make available at the point of sale all known information about the chemical residue status of wool on offer, including any relevant vendor declarations and analytical certificates.

6. The wool industry should develop suitable mechanisms for ensuring that wool exported overseas meets the residue requirements of importing countries and for making relevant information available on request to the various sectors of the wool industry, the veterinary chemical industry and other interested parties.

7. To assist in this regard, the wool industry, in consultation with the CSIRO Wool Technology and appropriate analytical laboratories, should explore options for providing a cost effective method of analysing wool for its pesticide content.

8. A more scientifically based estimate of shearer exposure to wool wax and the pesticide it contains needs to be developed as a matter of priority, preferably within the next 12 months. Once that is done, NOHSC should revise the protocol used for assessing the occupational hazard of residues in harvested wool and determine appropriate rehandling periods for each of the sheep ectoparasiticides.

9. The NRA should formally reconsider the registration status of all the long wool products other than cyromazine and dicyclanil, and the insect growth regulator diflubenzuron, in view of occupational health and safety and environmental concerns raised in this report.

10. The wool industry, in consultation with State departments responsible for agriculture, should develop guidelines on producing low-residue wool and make them available to wool producers. Such guidelines should discourage farmers from using long-wool ectoparasiticides during the wool harvesting withholding period, applying repeat applications of ectoparasiticides to sheep with long wool, or applying ectoparasiticides to lambs likely to be shorn or slaughtered early, unless absolutely necessary. These guidelines should clearly state that if such products have to be used within the withholding period for animal welfare reasons, treated sheep and wool should be identified by a vendor declaration or analytical certificate prior to sale.

11. The wool industry should continue to monitor residue levels in the Australian wool clip and the needs of overseas markets. If Australian wool is not adequately meeting those needs, the NRA, in consultation with the wool industry, should consider incorporating the residue requirements of overseas countries into relevant standards.

The likelihood of currently available sheep ectoparasiticide treatments meeting proposed environmental requirements in Australia and Europe, given 1997/98 use patterns, is summarised in Table 23. The estimated wool harvesting withholding periods necessary to meet those requirements are also shown.

Table 23: Likelihood of currently available sheep ectoparasiticide treatments[§] meeting proposed environmental requirements in Australia and Europe, given 1997/98 use patterns, and the estimated wool harvesting withholding periods (WHP)* necessary to meet those requirements.

Treatment	Australia		EK/EU	
	Likely to meet standards?	**Estimated WHP (weeks)***	**Likely to meet standards?**	**Estimated WHP (weeks)***
Off-shears backline/spray-on				
Organophosphates	Yes	19	Yes	32
Synthetic pyrethroids	Yes	50	No	>52
Dicyclanil	Yes	12	Yes	12
Triflumuron	Yes	9*	Yes	50
Short-wool dipping				
Organophosphates	Yes	12-16	Yes	22-26
Synthetic pyrethroids	Yes	46	No	>52
Diflubenzuron	Yes	46	No	>52
Mg fluorosilicate/rotenone[+]	Yes	<12	Yes	<12
Short-wool backline/spray-on				
Dicyclanil	Yes	12	Yes	12
Long-wool jetting				
Organophosphates	Yes	21-26	No	27-36
Synthetic pyrethroids	Yes	12	No	>52
Cyromazine	Yes	9*	Yes	9*
Diflubenzuron	No	>52	No	>52
Long-wool backline/spray-on				
Synthetic pyrethroids	No	52	No	>52
Diazinon[#]	Yes	12	Yes	22
Cyromazine	Yes	9*	Yes	9*
Dicyclanil	Yes	12	Yes	12

Notes:

§ Amitraz has not been included because of inadequate data and ivermectin has been temporarily withdrawn from the market by the registrant.

* All WHPs estimated on the basis of currently available residue data and subject to review. Where critical environmental residue level unlikely to be met in practice, a default withholding period of 9 weeks (2 months) is recommended.

Diazinon backline treatment in combination with cypermethrin.

+ In the case of magnesium fluorosilicate/rotenone, insufficient data available to determine a precise withholding period.

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Bob Armstrong, Queensland Department of Primary Industries, Indooroopilly, Queensland.

Noel Campbell, Victorian Animal Research Institute, Department of Natural Resources and Environment, Attwood, Victoria.

Bob Cranna, Bayer Australia Limited, Pymble, New South Wales.

Peter Hanrahan, Department of Natural Resources and Environment, Seymour, Victoria.

Brian Horton, Department of Primary Industry and Fisheries, Kings Meadow, Tasmania.

John Plant, Elizabeth Macarthur Agricultural Institute, NSW Agriculture, Menangle, New South Wales.

Ian Russell, CSIRO Wool Technology, Belmont, Victoria.

Trevor Shaw, ENco, Ilkley, West Yorkshire, England.

Michael Strong, Novartis Animal Health Australasia Pty Limited, Pendle Hill, New South Wales.

APPENDIX I

NOHSC PROTOCOL FOR ASSESSING OCCUPATIONAL HAZARD OF SHEEP ECTOPARASITICIDES

(Modified Extract from Part 6, Occupational Health and Safety, of the NRA's Guidelines for Registering Veterinary Chemicals, November 1997)

REQUIREMENTS FOR SHEEP ECTOPARASITICIDE PRODUCTS

Applications for clearance of sheep ectoparasiticides should be accompanied by an occupational health and safety hazard evaluation. This should take into account information on the estimated level of pesticide residues in wool at shearing, and the potential for occupational exposure to these residues. The implications of the estimated extent of exposure should then be drawn, taking into account the inherent toxicity of the compound.

Overview of hazard evaluation

The initial evaluation involves estimation of the concentration and distribution of residues in the fleece, and the extent of potential worker exposure.

Factors which influence the amount of pesticide retained in the fleece include:

the initial deposit of pesticide left on the sheep after treatment;
- the treatment regime;
- subsequent distribution and dissipation of the pesticide.

Factors which influence the extent of worker exposure include:

- amount and distribution of pesticide residues in the fleece;
- area of skin exposed; and
- the rate of percutaneous absorption.

The potential exposure is then considered in the light of information on concentrations resulting in toxicity. Both topical and systemic toxicity should be considered. Toxicity indices which may be useful for assessing the toxic concentrations include acute toxicity, the no-observable-effect level (NOEL) and the acceptable daily intake (ADI).

Recommendations for controls

Where an evaluation indicates concern for OHS, relevant control methods must be proposed. In particular, the need for a withholding period should be addressed. Note that in accordance with the *Code of Practice for Labelling Veterinary Chemical Products*:

- label statements are required indicating the withholding period, including where the withholding period is nil.

- the withholding period statement, **NOT TO BE USED ON ANIMALS PRODUCING WOOL/FIBRE WITHIN 2 MONTHS OF SHEARING**, must be used for long wool products where a specific withholding period has not been established.

Protocol for hazard evaluation

A protocol to evaluate occupational hazard to shearers and other wool handlers was developed jointly by industry and Government, taking into account current knowledge. Stage 1 of the protocol, which is detailed below, enables use of assumptions where specific data are not available.

1. Perform an initial hazard evaluation using the following steps (a-d).

(a) From the recommended application rate, calculate the amount of pesticide deposited on the sheep.

Assumptions:
- sheep weigh 50 kg; weight of fleece at shearing is 5 kg
- a maximum of 3 litres of pesticide is retained by the fleece, (although if the amount applied is less than 3 litres/sheep, the calculation should be based on the actual amount applied).

(b) Calculate the amount of pesticide in the wool grease at shearing (assuming wool contains on average 13% wool grease, ie 0.65 kg wool grease per animal)[1].

(c) Calculate the amount of pesticide picked up by the shearer.

Assumptions:
- 23 gram of wool grease is adsorbed by the shearer
- pesticide is transferred with the wool grease

(d) Calculate the amount of pesticide absorbed.

Assumptions:
- 100% absorption rate
- shearer weighs 70 kg

The following is a hypothetical example of Stage 1 of the evaluation, with calculations based on conservative assumptions (steps a - d):

PRODUCT NAME: JETFLU JETTING FLUID

Active constituent	X 100 mg/ml
Minimum dilution rate	100 ml/100 L of water
Maximum application rate	5 litre/sheep
Lowest NOEL	0.5 mg/kg/day

(a) Amount of X deposited on the sheep will be 300 mg
(b) Amount of X in 1 kg wool grease will be 462 mg
(c) Amount of X in 23 gm of wool grease will be 10.6 mg
(d) Amount of X absorbed by the shearer will be 0.15 mg/kg.

2. If on the basis of the hazard evaluation (stage 1), the calculated amount of pesticide is greater than $^{1}/_{100}$ of the NOEL*[2], specific dissipation data will be required.

***Note**: Where the NOEL has been derived from animal studies a safety factor of 100 is used. If derived from good quality human data a safety factor of 10 will be considered.

In assessing any specific dissipation studies, information on any backline concentration of residue must be taken into account.

In the example given above, the amount absorbed by the shearer (0.15 mg/kg) is greater than NOEL/100 (0.005 mg/kg), and specific dissipation data for the residues will be required to prove that the amount of residue in the fleece, to which the shearer is exposed, is less than the amount calculated, using conservative assumptions.

3. If after considering the dissipation data, concerns still exist (ie amount absorbed by the shearer more than NOEL/100) then specific percutaneous absorption data for the residues will be required.

NOHSC can be contacted if assistance is required in applying this protocol.

NOTES:

This protocol has been modified from the original, by the reviewer, in the following two areas:

1 the assumed percentage of wool grease in raw wool (13% rather than 20%); and

2 a safety factor of 100 has been used when comparing shearer exposure to NOEL rather than a safety factor of 10 which only applies if good human data are available.

APPENDIX II

REVIEWER'S ESTIMATES OF OH&S THRESHOLD VALUES FOR VARIOUS SHEEP ECTOPARASITICIDES

Calculation for diazinon

Relevant NOEL applying is 0.1 mg/kg/day.
Maximum amount that can safely be absorbed/day = NOEL/100 = 0.001 mg/kg bw
ie 70 kg shearer should absorb no more than 0.001x70 = 0.07 mg pesticide/day

Assume 23 g wool grease absorbed by shearer and pesticide in it absorbed by shearer
If residue level is Y mg/kg then the amount of residual pesticide is Y x 23/1000 = 0.023Y mg

So where 0.023Y mg pesticide is the maximum that can be absorbed by the shearer, then:

0.023Y = 0.07
Therefore, Y = 0.07/0.023 = 3.04 mg/kg wool wax.

If the actual dermal absorption figure is 4%, then maximum residue level acceptable would be 3.04/0.04 = 750 mg/kg wool wax,
or 750 x 0.13 = 9.75 mg/kg wool (assuming wool contains 13% wax).

On this basis, it is possible to estimate the threshold residue level for a number of pesticides (active constituents) that is likely to pose a dermal absorption hazard, assuming the NOEL and dermal absorption factors in Table 1.

Table 1 Threshold residue level (mg/kg wool grease and mg/kg raw wool) for a number of pesticides that is likely to pose a dermal absorption hazard to a shearer exposed to contaminated wool containing an average of 13% wool wax.

Pesticide	NOEL (mg/kg bw/day)	Dermal absorption factor*	Assume 100% absorption (mg/kg w/wax)	Apply known dermal absorption factor	
				mg/kg w/wax	mg/kg wool
Diazinon	0.1	4%	3.01	75.25	9.8
Chlorfenvinphos	0.15	50%	4.57	9.14	1.2
Propetamphos	0.1	10%	3.01	30.1	3.9
Amitraz	0.25	10%	7.61	76.1	9.9
Alpha cypermethrin	5.0	2%	152.17	7609	989
Cypermethrin	5.0	3%	152.17	5072	659
Cyhalothrin	1.5	10%	45.65	456.5	59.3
Cyromazine	1.0	14%	30.43	217.4	28.3
Diflubenzuron	2.0	0.2%	60.87	30435	3957
Ivermectin	0.1	1%	3.01	301	39.1

***Note** dermal absorption factors provided by NOHSC, based on the best available information.

APPENDIX III

ENVIRONMENT AUSTRALIA MODEL FOR ASSESSING THE ENVIRONMENTAL IMPACT OF SHEEP ECTOPARASITICIDES

Model and Assumptions

The environmental impact of sheep ectoparasiticides depends on the environmental concentration and toxicity. The following model is used to predict impact in Australia, based on the listed assumptions.

STAGE	PROCESS	ASSUMPTIONS	DATA NEEDED
Sheep treatment.			
↓	Dissipation in fleece.	Applicant provides data on residues at shearing and degradation kinetics in fleece.	Residues at shearing and degradation kinetics in fleece.
Shearing/ scouring.			
↓	Grease/dirt removal.	Lipophilic pesticides follow the wool grease (30% removal). On-site treatment (eg Sirolan CF) can remove more pesticides.	
Sewage treatment.			
↓	Dilution and removal through sorption to sludge and degradation.	Geelong is the worst case situation. Barwon Water receives effluent from 50 tonnes raw wool in a daily flow of 50 ML. The following removals are assumed: 80% DFB, TFM; 95% SPs; 0% cyromazine; 50% OPs (Villarosa, 1994).	Specific studies of removal during sewage treatment are an option if applicants wish to refine assumptions.
Ocean outfall.			
↓	Comparison of concentration at outfall with toxicity to sensitive organisms.	Applicant provides acute toxicity data, and fate data to demonstrate that pesticide will not persist in environment. Laboratory tests are accurate predictors of toxicity in the environment.	Environmental fate and acute toxicity data according to standard protocols. Studies under more realistic conditions (eg simulated outfall) are an option.
	Dilution in receiving waters	150-fold dilution assumed based on work by Sydney Water (1996).	
Environment			
	Comparison of chronic exposure concentration with chronic endpoints	If applicant can not demonstrate low persistence in environment, chronic toxicity data will be provided.	Chronic toxicity data according to standard protocols. Again, tests under simulated environmental conditions are an option

Previous environmental assessments of sheep ectoparasiticides have only considered acute toxicity. Analysis based on chronic endpoints is indicated for ectoparasiticides that persist in the environment (half-life greater than 6 weeks). Ectoparasiticides that exhibit a morphological rather than toxic mode of action [eg triflumuron (TFM), diflubenzuron (DFB), cyromazine (Cryom)] also merit special consideration. Testing of such substances must include at least one moult of the test organisms.

If environmental safety is not confirmed by the above model, registrants have the opportunity to generate data or argument to challenge the assumptions made. For example:

- greater removal may be assumed at the scour if the registrant can guarantee that wool will be scoured in a facility equipped with on-site treatment;

- greater removal may be assumed during sewage treatment if the applicant can provide data to substantiate such a claim (this would be particularly relevant to temephos, for example); and

- robust field data, or laboratory test data simulating environmental conditions, may provide a more realistic measure of toxicity in receiving waters.

The above model may also be used for the UK situation, but with the omission of the penultimate stage involving comparison of outfall concentration with acute endpoints. In the UK, environmental exposure must be compared with environment quality standards (EQSs) because of the chronic exposure situation in receiving waters (rivers). EQSs are commonly derived from toxicity data by applying assessment factors of 100 to acute LC50s, 10 to chronic LC50s, or 1 to chronic NOELs (see, for example, Robinson and Scott, 1995). An additional factor of 10 may be applied to data poor chemicals.

Target Concentrations Based on Acute Toxicity.

Acute endpoints for the Australian situation are taken from the following sources.

For triflumuron, the most sensitive organism based on unpublished data from Bayer is a marine crustacean, mysid shrimp.

For diflubenzuron, the most sensitive organism is the pre-moult stage of the grass shrimp (Fisher and Hall, 1992).

According to the US EPA's AQUIRE database (cited in Giddings *et al*, 1996) the mean acute EC50 of diazinon to *Daphnia magna* is 1.1 $\mu g.L^{-1}$ from 8 values. A target of 1 µg/L is adopted for organophosphates (OPs).

The target of 50 ng/L for synthetic pyrethroids (SPs) is based on data compiled for cypermethrin by the IPCS (1989).

The lowest acute endpoint for cyromazine is 93 mg/L, for *Daphnia magna* (Robinson and Scott, 1995).

Residue Requirements for Australian Scours

The model can be used to estimate maximum mean residues across the Australian clip that would generate a non-toxic effluent at the outfall. Acute LC50s are used as target concentrations as considerable dilution occurs in receiving waters. For simplicity, the calculation begins with a fleece residue of 1 mg/kg raw wool. As 50 tonnes wool contains 50 g pesticide, 35 g pesticide is discharged to sewer after scouring (50 g for cyromazine). The following table lists concentrations at the outfall, target concentrations, and maximum wool residues. Target concentrations are in agreement with those suggested for use in the UK (Shaw, 1997).

Pesticide:	TFM	DFB	OPs	SPs	Cyrom
Removal:	80%	80%	50%	95%	0%
Amount discharged (g)	7	7	17.5	1.75	50
Concentration (ng/L):	140	140	350	35	1000
Target (ng/L):	3500	1000	1000	50	93×10^6
Max residue (mg/kg):	24	7	3	1.5	93000

For analysis based on chronic exposure, an additional dilution factor of 150 is assumed. As an indicative example, and without inferring environmental persistence, cyromazine could be evaluated against the chronic NOEL of 10 µg/L for *Chironomus zealandicus* (Robinson and Scott, 1995). Note that this example is artificial in that cyromazine is specific to Diptera, an order not found in marine waters. The estimated environmental concentration for cyromazine based on a level of 1 mg/kg in raw wool would be 6.7 ng/L. For a target of 10 µg/L, the maximum concentration that may be tolerated across the clip would be 1490 mg/kg. The example indicates evaluation against chronic rather than acute data to be more demanding, an outcome likely to prevail for most ectoparasiticides.

Knowledge of market share and degradation kinetics on the fleece allows estimation of a shearing withholding period to meet the above residue requirements.

Residue Requirements for UK Scours

A similar exercise can be conducted for the UK situation, where the Aire and Calder Rivers receive effluent from daily scouring of 500 tonnes raw wool containing 1 mg/kg pesticide (total 500 g). Daily flow is 600 ML during summer low-flow conditions. An additional assumption for the UK situation is that all scours are equipped with on-site treatment that removes 95% of lipophilic pesticides remaining after an initial 30% is removed with wool grease. Therefore, the daily amounts discharged to sewer are 17.5 g, except for cyromazine where the discharge is 500 g.

Pesticide:	TFM	DFB	OPs	SPs	Cyrom
Removal at STP:	80%	80%	50%	95%	0%
Amount discharged (g)	3.5	3.5	8.8	0.88	500
Concentration (ng/L):	5.8	5.8	14.6	1.46	830
EQS (ng/L):	18	6	100	0.5	5000
Max residue (mg/kg):	3.1	1.0	6.8	0.3	6

Note that the above outcome differs from that reached by Shaw (1997) who estimated residue requirements of 8.4, 2.8, 47, 0.47 and 28 mg/kg, respectively. However, results are in the same order. Different outcomes indicate different assumptions. For example, Shaw may have included market share considerations. The basis for derivation of the EQSs is also unclear. Clarification will need to be sought regarding the assumptions used in estimating maximum residues on fleece to meet EQSs, and the data and methods used to derive the EQSs.

Acknowledgments

The above model was developed, and residue limits determined, at a meeting on 26 August 1997 between Ian Russell (CSIRO Wool Technology), Ian Pitt (Environment Australia), Stephen Page (Pfizer/Avcare) and Michael Strong (Novartis/Avcare).

Note

This model was subsequently amended by Russell to more accurately reflect commercial scouring practice in both Australia and the UK. The amendments include:

- Allowance was made for the fact that approximately 4% of residual pesticide remains on the wool after scouring.

- UK scours equipped with on-site effluent treatment processes retain a total of about 80% of the initial lipophilic pesticide load on site. This includes pesticide in recovered raw wool grease. For triflumuron, it has been assumed that 90% of residue is retained on site (including that left on wool fibres and in recovered wax).

Revised calculations are shown in Appendix IV.

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APPENDIX IV

REVISED ESTIMATES OF ENVIRONMENTAL STANDARDS FOR SHEEP ECTOPARASITICIDES

1. Australian - Ocean outfall at Black Rock (Geelong)

Assumptions:

- Scouring wool initially with 1 mg pesticide/kg wool.
- Scouring lot of 50 tonnes.
- Scouring process removes 96% residue from wool (ie 4% remains on scoured wool).
- A further 30% of lipophilic residues removed in recovered wool grease by scouring process.
- In case of triflumuron, assume 75% of residue stays on site (including that on wool fibre and in recovered wool wax).
- In the case of water soluble pesticides (eg cyromazine and dicyclanil), no residue removed in recovered wool grease.
- No further removal of residue on site.
- Percentage of received residue removed by sewerage treatment process at Black Rock (Villarosa 1994):

Organophosphates	50%
Synthetic pyrethroids	95%
Cyromazine	nil
Dicyclanil	nil
Triflumuron	80%
Diflubenzuron	80%

- Sewerage discharge rate at Black Rock - 50 ML/day.
- Environmental requirements at ocean outfall (ng/L). Environment Australia estimates based on acute toxicity figures (LC_{50} at 96 hours).

Organophosphates	1000
Synthetic pyrethroids	50
Cyromazine	$93x10^6$
Dicyclanil	$1.1x10^6$
Triflumuron	3500
Diflubenzuron	1000

Calculation for organophosphates

Assume 50 tonnes wool scoured per day containing 1 mg OP/kg wool.
50 tonnes wool contain 50 gram OP residue.
Assume 96% of residue removed from wool.
Assume a further 70% of that residue discharged in effluent after recovery of raw wool grease (30% recovered).
Therefore amount of residue discharged in effluent is:
50 x 0.96 x 0.70 = 33.6g.
In case of OPs, 50% of residue removed by sewerage treatment plant.
Therefore amount of residue discharged to ocean outfall is: 33.6g x 0.5 = 16.8g
Volume of sewerage discharged to ocean outfall is 50ML/day.
Therefore residue concentration in discharge is 16.8g/50ML
ie 16.8 x 10^6 µg/50 x 10^6 L.
ie 0.336 µg/L, or 336 ng/L.

Target concentration is 1000 ng/L
Therefore maximum residue level acceptable is 1000/336
ie 2.98 mg/kg wool

Calculation for cyromazine

Assume 50 tonnes wool scoured per day containing 1 mg cyromazine/kg wool
50 tonnes wool contain 50 gram cyromazine residue.
Assume 96% of residue removed from wool.
Assume 100% of that remaining residue discharged in effluent.
Therefore amount of residue discharged in effluent is 50x0.96 = 48g
In case of cyromazine 0% of residue removed by sewerage treatment plant
Therefore amount of residue discharged to ocean outfall is 48g.
Volume of sewerage discharged to ocean outfall is 50ML/day
Therefore residue concentration in discharge is 48g/50ML or 16.8 x 10^6 µg/50 x 10^6 L
ie 0.96µg/L, or 960ng/L

Target concentration is 93,000,000 ng/L
Therefore maximum residue level acceptable is 93,000,000/960
ie 96875 mg/kg wool

Summary of calculations for all major ectoparasiticides

Step	OPs	SPs	Cyrom	Dicyclan	Triflum	Diflubenz
Initial amount pesticide/50 tonne scouring lot (g)	50	50	50	50	50	50
Residue left after scouring (g)	33.6	33.6	48	48	12.5	33.6
Proportion of residue left after sewerage treatment	0.5	0.05	1	1	0.2	0.2
Residue discharged to ocean (g)	16.8	1.68	48	48	2.5	6.72
Concentration in 50 ML discharge/day (ng/L)	336	33.6	960	960	50	134.4
Target concentration (ng/L)	1000	50	$93x10^6$	$1.1x10^6$	3500	1000
Maximum residue in scouring lot (mg/kg wool)	2.98	1.49	97000	1146	70	7.44

2. UK/EU EQS requirements - discharge to Spen Beck riverine environment below Spenborough, UK

Assumptions:

- Scouring wool initially with 1 mg pesticide/kg wool.
- Spenborough scours an average of 27.6 tonne raw wool /day.
- Scouring process removes 96% residue from wool (ie 4% remains on scoured wool) except for triflumuron.
- Of this a further 80% of lipophilic residues removed by the scouring plant as recovered wool grease and by associated on site effluent treatment processes.
- In the case of triflumuron, assume 90% retention of residues on site (including those retained on wool fibre and in recovered wool wax).
- In the case of water soluble pesticides (eg cyromazine and dicyclanil), no further residue removed by wool grease recovery or on site effluent treatment
- Percentage of received residue removed by sewerage treatment process at Spenborough (after Villarosa 1994)

Organophosphates	50%
Synthetic pyrethroids	95%
Cyromazine	nil
Dicyclanil	nil
Triflumuron	80%
Diflubenzuron	80%

- Mean daily river flow in Spen Beck is 149 ML/day.
- Environmental requirements in river (ng/L) - based on chronic (whole of life) toxicity figures. OP and SP figures are UK operational standards. Others are Shaw's estimates and have no official standing.

Organophosphates	10 9
Synthetic pyrethroids	0.1
Cyromazine	5000
Dicyclanil	200
Triflumuron	18
Diflubenzuron	6*

*Note that UK water authorities have issued a draft EQS for diflubenzuron of 1 ng/L. Estimates for diflubenzuron will need to be revised if the draft UK standard is adopted.

Calculation for organophosphates

Assume 27.6 tonnes wool scoured per day containing 1 mg OP/kg wool.
27.6 tonnes wool contain 27.6 gram OP residue.
Assume 96% of residue removed from wool.
Assume 20% of remaining residue discharged into sewer after on-site effluent treatment (80% residue removed).
Therefore amount of residue discharged in effluent to Spenborough sewerage plant is:
27.6 x 0.96 x 0.20 = 5.30g
In case of OPs, 50% of residue removed by sewerage treatment plant.
Therefore amount of residue discharged to river is: 5.3gx0.5 = 2.65g.
Mean daily river flow is 149 ML/day.
Therefore residue concentration in river is 2.65 g/149ML, or 2.65 x 10^6 µg/149 x 10^6 L
ie 0.0178 µg/L, or 17.8 ng/L.

Target concentration is 10 ng/L
Therefore maximum residue level acceptable is 10/17.8
ie 0.56 mg/kg wool.

Calculation for cyromazine

Assume 27.6 tonnes wool scoured per day containing 1 mg cyromazine/kg wool.
27.6 tonnes wool contain 27.6 gram cyromazine residue
Assume 96% of residue removed from wool.
Assume none of remaining residue discharged into sewer after on-site effluent treatment
Therefore amount of residue discharged in effluent to Spenborough sewerage plant is:
27.6 x 0.96 = 26.5g
In case of cyromazine 0% of residue removed by sewerage treatment plant.
Therefore amount of residue discharged to river is 26.5g.
Mean daily river flow is 149 ML/day.
Therefore residue concentration in river is 26.5g/149ML or 26.5 x 10^6 µg/149 x 10^6 L
ie 0.178 µg/L
or 178 ng/L

Target concentration is 5000 ng/L
Therefore maximum residue level acceptable is 5000/178
ie 28.12 mg/kg wool

Summary of calculations for all major ectoparasiticides

Step	OPs	SPs	Cyrom	Dicyclan	Triflum	Diflubenz
Initial amount pesticide per 27.6 tonne scouring lot (g)	27.6	27.6	27.6	27.6	27.6	27.6
Residue left after scouring and on-site effluent processing (g)	5.3	5.3	26.5	26.5	2.76	5.3
Proportion of residue left after sewerage treatment	0.5	0.05	1	1	0.2	0.2
Residue discharged to river (g)	2.6	0.26	26.5	26.5	0.55	1.1
Concentration in 149 ML river flow/day (ng/L)	17.8	1.8	177.8	177.8	3.7	7.1
Target concentration (ng/L)	10	0.1	5000	200	18	6
Maximum residue in scouring lot (mg/kg wool)	0.56	0.06	28	1.12	4.9	0.84

3. UK/EU - MAC requirements for discharge to Spen Beck riverine environment below Spenborough, UK

Assumptions:

- Scouring wool initially with 1 mg pesticide/kg wool.
- Spenborough scours an average of 27.6 tonne raw wool /day.
- Scouring process removes 96% residue from wool (ie 4% remains on scoured wool), except for triflumuron.
- Of this a further 80% of lipophilic residues removed by the scouring plant as recovered wool grease and by associated on site effluent treatment processes.
- In the case of triflumuron, assume 90% retention of residues on site (including those retained on wool fibre and in recovered wool wax).
- In the case of water soluble pesticides (eg cyromazine and dicyclanil), no further residue removed by wool grease recovery or on-site effluent treatment.
- Percentage of received residue removed by sewerage treatment process at Spenborough (after Villarosa 1994):

Organophosphates	50%
Synthetic pyrethroids	95%
Cyromazine	nil
Dicyclanil	nil
Triflumuron	80%
Diflubenzuron	80%

- Low river flow in Spen Beck is 71 ML/day
- MAC environmental requirements in river (ng/L) - based on estimates of acute toxicity figures (LC_0 at 96 hours). OP and SP figures are UK operational standards. Others are Shaw's or Environment Australia's estimates and have no official standing. Where data are unavailable, LC_0 is estimated as $LC_{50}/10$ (diflubenzuron or triflumuron) or $LC_{50}/100$ (cyromazine and dicyclanil).

Organophosphates	100
Synthetic pyrethroids	2
Cyromazine	93×10^4
Dicyclanil	1.1×10^4
Triflumuron	350
Diflubenzuron	100

Calculation for organophosphates

Assume 27.6 tonnes wool scoured per day containing 1 mg OP/kg wool.
27.6 tonnes wool contain 27.6 gram OP residue.
Assume 96% of residue removed from wool.
Assume 20% of remaining residue discharged into sewer after on-site effluent treatment (80% residue removed).
Therefore amount of residue discharged in effluent to Spenborough sewerage plant is:
$27.6 \times 0.96 \times 0.20 = 5.30$g
In case of OPs 50% of residue removed by sewerage treatment plant.
Therefore amount of residue discharged to river is: 5.3g x 0.5 = 2.65 g
Low daily river flow is 71 ML/day.
Therefore residue concentration in river is 2.65 g/71 ML or 2.65×10^6 µg/71×10^6 L
ie 0.037 µg/L, or 37 ng/L.

Target concentration is 100 ng/L
Therefore maximum residue level acceptable is 100/37
ie 2.68 mg/kg wool

Calculation for cyromazine

Assume 27.6 tonnes wool scoured per day containing 1 mg cyromazine/kg wool.
27.6 tonnes wool contain 27.6 gram cyromazine residue.
Assume 96% of residue removed from wool into scour effluent.
Assume none of remaining residue discharged into sewer after on-site effluent treatment.
Therefore amount of residue discharged in effluent to Spenborough sewerage plant is:
27.6 x 0.96 = 26.5g
In case of cyromazine 0% of residue removed by sewerage treatment plant.
Therefore amount of residue discharged to river is 26.5 g
Low daily river flow is 71 ML/day.
Therefore residue concentration in river is 26.5 g/71 ML or 26.5 x 10^6 µg/71 x 10^6 L
ie 0.373 µg/L
or 373 ng/L.

Target concentration is 930,000 ng/L.
Therefore maximum residue level acceptable is 930,000/373
ie 2492 mg/kg wool

Summary of calculations for all major ectoparasiticides

Step	OPs	SPs	Cyrom	Dicyclan	Triflum	Diflubenz
Initial amount pesticide per 27.6 tonne scouring lot (g)	27.6	27.6	27.6	27.6	27.6	27.6
Residue left after scouring and on-site effluent processing (g)	5.3	5.3	26.5	26.5	2.76	5.3
Proportion of residue left after sewerage treatment plant	0.5	0.05	1	1	0.2	0.2
Residue discharged to river (g)	2.6	0.26	26.5	26.5	0.55	1.06
Concentration in 71 ML river flow/day (ng/L)	37.3	3.7	373.2	373.2	7.8	14.9
Target concentration (ng/L)	100	2	93×10^4	1.1×10^4	350	100
Maximum residue in scouring lot (mg/kg wool)	2.7	0.5	2492	29.5	45	2.7

APPENDIX V

FATE OF WOOL RESIDUES IN INLAND SCOURS

A typical line scours 150 tonnes wool per week. At 10 L/kg, effluent production is 1.5 ML/week. This volume of effluent would typically be used to irrigate 100 ha (rate is 15 kL/ha/week, ignoring possible evaporation losses during ponding).

As a first approximation, the pesticide concentration in effluent is 10% of the residue in raw wool. Residual pesticides will be applied to land at the following estimated rates, based on current residue levels in the Australian clip. Note that these are unrealistic worst case estimates that take no account of grease recovery. Further, raw effluent is not irrigated directly, but retained in settling ponds for grease/dirt separation, which will also remove lipophilic pesticides. Dissipation during ponding may also occur through other processes, such as biodegradation, volatilisation or photolysis.

Pesticide	**Wool residue (mg/kg)**	**Raw effluent concentration (mg/L)**	**Weekly application rate (g/ha)**	**Annual application rate (g/ha)**
Organophosphates	4.5	0.45	6.75	350
Pyrethroids	3.8	0.38	5.7	300
Cyromazine	8.7	0.87	13.0	680
Diflubenzuron	1.2	0.12	1.8	95
Triflumuron	3.5	0.35	3.5	180

Even under these unrealistic worst case assumptions, annual application rates are at worst comparable with, and in some cases considerably below, application rates used for crop protection. It can therefore be argued that environmental risks should be minimal, particularly as application is spread through the year and pesticide residues would be largely removed before irrigation.

Aquatic risk assessment can be carried out using procedures developed for crop protection. The US EPA's standard runoff model assumes 1.5% loss from a 10 ha catchment into a 1 ha pond, depth 2 m (Urban and Cook, 1986). Where the predicted environmental concentration using this approach is less than 10% of the lowest LC50, minimal risk is assumed.

Maximum permissible concentrations in effluent may be estimated by dividing the target concentration in the pond by the concentration of runoff (112.5 ppm) delivered to the pond from a week of irrigation. Assuming no losses of residues prior to irrigation, maximum permissible concentrations in greasy wool may also be estimated as tabulated below. More realistic estimates for lipophilic pesticides would be an order of magnitude higher, reflecting the minimum 90% removal to sludge that would be expected to occur prior to irrigation.

Pesticide	Maximum acceptable concentration		
	Pond	**Effluent**	**Wool**
Organophosphates	0.1 µg/L	0.89 mg/L	8.9 mg/kg
Pyrethroids	0.005 µg/L	0.044 mg/L	0.44 mg/kg
Cyromazine	9 300 µg/L	83 000 mg/L	830 000 mg/kg
Diflubenzuron	0.1 µg/L	0.89 mg/L	8.9 mg/kg
Triflumuron	0.35 µg/L	3.1 mg/L	31 mg/kg

Reference:

Urban DJ & Cook NJ (1986): Hazard Evaluation Division, Standard Evaluation Procedure, Ecological Risk Assessment. United States Environmental Protection Agency, June 1986 (EPA 540/9-85-001).

APPENDIX VI

Registered Sheep Ectoparasiticides - October 1998

ORGANOPHOSPHATES (OPs)

Diazinon (24 products)

Ausgen Diazinon Sheep Dip Jetting Fluid and Blowfly Dressing	Artfern Pty Ltd
Ciba-Geigy TopClip Purple Shield Sheep Dip	Novartis Animal Health Australasia Limited
Ciba-Geigy TopClip Blue Shield Sheep Dip Jetting Fluid and Blowfly Dressing	Novartis Animal Health Australasia Limited
Cooper's 4 in 1 Dip	Schering Plough Animal Health Ltd
Cooper's Amidaz 4-in-1 Liquid Dip - Part A + Part B *(diazinon/amitraz))*	Schering Plough Animal Health Ltd
Cooper's Blaze Long Wool Sheep Lice Treatment *(combn. product with cypermethrin)*	Schering Plough Animal Health Ltd
Cooper's Blaze Long Wool Sheep Lice Treatment and Sheep Blowfly Suppressant *(combn. product with cypermethrin)*	Schering Plough Animal Health Ltd
Coopers Blitz Sheep Blowfly Suppressant *(combn. product with cypermethrin)*	Schering Plough Animal Health Ltd
Cooper's Di-Jet Sheep Dip/Jetting Fluid, Cattle and Pig Spray	Schering Plough Animal Health Ltd
Cooper's Fly Strike Powder Insecticide	Schering Plough Animal Health Ltd
Cooper's Mulesing Powder Insecticide	Schering Plough Animal Health Ltd
David Gray's Diazinon Sheep Dip Jetting Fluid and Blowfly Dressing	David Gray and Co Pty Ltd
Di-Shield Sheep Dip and Jetting Fluid, Cattle, Goat and Pig Spray	Dover Laboratories Pty Ltd
Diazol Sheep Dip, Jetting Fluid and Blowfly Dressing	Makhteshim-Agan (Aust) Pty Ltd
KFM Blowfly Dressing	Nufarm Ltd (Laverton)
TopClip Blue Shield Sheep Dip Jetting Fluid and Blowfly Dressing	Novartis Animal Health Australasia Limited
Virbac Jetdip 4-in-1 Sheep Dip	Virbac (Australia) Ltd
Virbac Jetdip Sheep Jetting Fluid & Blowfly Dressing	Virbac (Australia) Ltd
Virbac Kleen-Dok with Diazinon	Virbac (Australia) Ltd
Virbac Mulesing and Flystrike Powder	Virbac (Australia) Ltd
WSD Diazinon for Sheep, Cattle, Goats and Pigs	Western Stock Distributors
WSD Fly Strike Powder	Western Stock Distributors
WSD Mulesing Powder Wound Dressing	Western Stock Distributors
Young's Eureka Gold OP Sprayon Off- Shears Sheep Lice Treatment	Novartis Animal Health Australasia Limited

Chlorfenvinphos (5 products)

Cooper's Suprex 100 Jetting Fluid	Schering Plough Animal Health Ltd
David Gray's Aerosol Sheep Dressing	David Gray and Co Pty Ltd
Defiance 'S' Insecticidal Flystrike, Mules and Wound Dressing	Fort Dodge Australia Pty Limited
WSD Aerosol Sheep Dressing	Western Stock Distributors
WSD Jetting Fluid 100 – for Control of Flystrike	Western Stock Distributors

Organophosphates (Cont).

Propetamphos (5 products)

Nufarm Seraphos 360 Dip and Jetting Fluid for Sheep	Nufarm Animal Health
Nufarm Mules 'N Mark II Blowfly Dressing	Nufarm Ltd (Laverton)
Young's Deadmag Blowfly Strike Dressing Fluid	Novartis Animal Health Australasia Limited
Young's Ectomort Plus Lanolin Sheep Dip	Novartis Animal Health Australasia Limited
Young's Magget Mulesing Fluid	Novartis Animal Health Australasia Limited

Temephos (1 product)

Cooper's Assassin Sheep Dip	Schering Plough Animal Health Ltd

SYNTHETIC PYRETHROIDS (SPs)

Cypermethrin (12 products)

Banish Off-Shears Sheep Lice Treatment	BOC Gases Australia Ltd
Barricade S Cattle Dip and Spray*	Fort Dodge Australia Pty Limited
Coopers Blockade S Cattle Dip and Spray*	Schering Plough Animal Health Ltd
Coopers Blaze Long Woolled Sheep Lice Treatment *(combn. Product with diazinon)*	Schering Plough Animal Health Ltd
Coopers Blaze Long Woolled Sheep Lice Treatment and Sheep Blowfly Suppressant *(combn. product with diazinon)*	Schering Plough Animal Health Ltd
Coopers Blitz Sheep Blowfly Suppressant *(combn. product with diazinon)*	Schering Plough Animal Health Ltd
Cypercare Off-Shears Pour-on Sheep Body Lice treatment	Virbac (Australia) Ltd
Kleenklip Off-shears High Volume Backline Treatment for Sheep	Virbac (Australia) Ltd
Outflank Off-Shears Pour-on Sheep Lice Treatment	Fort Dodge Australia Pty Limited
WSD Spurt Off-Shears Pour-on Sheep Lice Control	Western Stock Distributors
Youngs Cypon Off-Shears Backline Sheep Lice Treatment	Novartis Animal Health Australasia Limited
Youngs Robust SP Plunge and Shower Sheep Dip	Novartis Animal Health Australasia Limited
Youngs Supreme Sheep Dip	Novartis Animal Health Australasia Limited

***Note These cattle and pig sprays are also used on sheep for tick control**

Alpha-cypermethrin (2 products)

Vanquish Long Wool Spray-on Lice Treatment and Blowfly Strike Preventative for Long Woolled Sheep and Unshorn Lambs	Pfizer Animal Health
Duracide Sustained action Spray on Lice Treatment for Shorn Sheep	Pfizer Animal Health

Deltamethrin (3 products)

Coopers Clout Off-the-Board Backline Sheep Lice Treatment	Schering Plough Animal Health Ltd
Coopers Clout-S Backline Treatment	Schering Plough Animal Health Ltd
Butoflin Off-the-Board Backline Sheep Lice Treatment	Hoechst Roussel Vet

Synthetic Pyrethroids (cont)

Cyhalothrin (2 products)

Coopers Grenade Sheep Dip	Schering Plough Animal Health Ltd
Coopers Grenade Plus Rotenone Sheep Dip	Schering Plough Animal Health Ltd

Lamda-cyhalothrin (1 product)

Outlaw Off-Shears High Volume Backline Pour On Treatment for Sheep Body lice	Virbac (Australia) Pty Limited

INSECT GROWTH REGULATORS (IGRs)

Cyromazine (5 products)

Ciba Geigy Vetrazin Liquid Australian Sheep Blowfly Treatment	Novartis Animal Health Australasia Limited
Ciba-Geigy Vetrazin Sheep Blowfly Treatment	Novartis Animal Health Australasia Limited
Vetrazin Liquid Sheep Blowfly Treatment	Novartis Animal Health Australasia Limited
Vetrazin Spray-on Sheep Blowfly Treatment	Novartis Animal Health Australasia Limited
Nufarm Jetcon Australian Sheep Blowfly treatment	Nufarm Ltd (Laverton)

Dicyclanil (1 product)

Clik Spray-on Sheep Blowfly Treatment	Novartis Animal Health Australasia Limited

Diflubenzuron (2 products)

Coopers Strike Insect Growth Regulator for Sheep Jetting and Dipping	Schering Plough Animal Health Ltd
Fleececare Insect Growth Regulator for Sheep Dipping and Jetting	Hoechst Roussel Vet Australia Ltd

Triflumuron (1 product)

Zapp Pour-on Lousicide for Sheep	Bayer Australia Ltd (Animal Health)

OTHERS

Ivermectin (1 product)

Jetamec Jetting Fluid Concentrate *Temporarily withdrawn from market by Registrant*	Merial Australia Pty Ltd

Magnesium Fluorosilicate/Rotenone (2 products)

Flockmaster Instant Wetting Powder Sheep Dip	Western Stock Distributors
WSD Flockmaster Mk II Instant Wetting Powder Sheep Dip	Western Stock Distributors

OTHERS (cont)

Amitraz (5 products)

Cooper’s Amidaz 4-in-1 Liquid Dip - Part A + Part B *(diazinon/amitraz))*	Schering Plough Animal Health Ltd
Coopers Amitik EC Cattle & Pig Spray	Schering Plough Animal Health Ltd
Coopers Amitik Cattle Dip & Spray	Schering Plough Animal Health Ltd
Taktic EC Acaricidal Spray for Cattle & Pigs	Hoechst Roussel Vet Australia Ltd
Taktic WP Cattle Dip & Spray	Hoechst Roussel Vet Australia Ltd

***Note These cattle and pig sprays are also used on sheep for tick control**

<u>Total:</u>

16 active constituents
68 products (including 4 combination products).

Four of these products (amitraz) are essentially cattle products which are used on sheep for tick control

APPENDIX VII

STEERING COMMITTEE MEMBERS

Name	Organisation represented
Mr Graham Savage	NRA (Convener)
Dr Peter Holdsworth	NRA
Mr Peter Hanrahan	Dept Natural Resources and Environment, Victoria/ International Wool Secretariat
Mr Peter Walsh	Wool Council of Australia
Dr Ian Russell	CSIRO Divn Wool Technology
Mr Ian Pitt	Environment Australia
Ms Carolyn Vickers/ Ms Megan Smith	National Occupational Health and Safety Commission
Dr Steve Burman	Avcare/Schering Plough Animal Health
Dr Stephen Page	Veterinary Manufacturers and Distributors Association/ Pfizer Animal Health
Dr Michael Strong	Novartis Animal Health
Dr Valerie Villiere	Avcare
Dr John Plant	Animal Health Committee/NSW Agriculture
Dr Nick Whelan	NZ Ministry of Agriculture