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The Use of Diazinon as a Veterinary Medicine in New Zealand
A Report to ERMA New Zealand

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This report has been prepared as guidance to assist ERMA with its reassessment of the organophosphate diazinon and its formulations under the Hazardous Substances and New Organisms Act 1996. This report on the uses of diazinon as a veterinary medicine in New Zealand is intended to form part of the information ERMA will consider in the course of its reassessment. It is not, and nor should it be used or relied on as, a substitute for professional advice or veterinary services. AgResearch expressly disclaims all or any liability or responsibility to any person in respect of this report (as it may be amended from time to time) and in respect of anything done or omitted to be done by any person in reliance on all or any part of the contents of this report.

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Executive Summary

In December 2009, ERMA (The Environmental Risk Management Authority New Zealand) established that grounds existed for the reassessment of the organophosphate diazinon and its formulations under the Hazardous Substances and New Organisms Act 1996. This report on the uses of diazinon as a veterinary medicine in New Zealand is intended to form part of the information ERMA will consider in the course of its reassessment.

The uses of diazinon as a veterinary medicine have been under review in a number of countries including important export markets for New Zealand's agricultural products. Reasons for the reviews have included the potential for highly toxic degradation products of diazinon to accumulate in some formulations, particularly in non-aqueous hydrocarbon based formulations; concerns for the safety of people and animals exposed to diazinon, and the potential for adverse environmental effects. An area of particular focus has been the safety of farmers using diazinon for dipping and jetting sheep.

Diazinon has been used for the broad spectrum control of insect and some arachnid ectoparasites of a variety of animals for more than 40 years in New Zealand. The products containing diazinon currently registered for use as veterinary medicines in this country are a sheep dip, a powder for treating sheep, horses and dogs, and collars for the control of fleas on dogs and cats.

Alternative organophosphates and numerous alternative classes of actives are available for ectoparasite control of sheep, dogs and cats in New Zealand. The range of registered products is more limited for horses. Further restriction or withdrawal of diazinon for use in New Zealand would increase use of alternative organophosphates and/or increase costs of the control of ectoparasites to dog, cat and horse owners and sheep farmers. In the longer term, unavailability of diazinon, and possibly all organophosphates, may increase pressure for the development of resistance to alternative actives in ectoparasites, potentially reducing profitability in the sheep industry.

No adverse events related to the use of any of the currently registered diazinon-containing products have been officially recorded in New Zealand. However, dipping of sheep appears to be a high risk area and there is a view that not all farmers follow manufacturer's safety instructions. While this lack of care may have health consequences for farmers, no data on this issue in New Zealand is available.

Environmental effects of the use of diazinon-containing veterinary medicines appear to be negligible in New Zealand. Residues of diazinon in food derived from animals are low to undetectable and are not a concern. However, wool residues of diazinon, and of many of the other pesticides used for the control of ectoparasites of sheep, require further attention so that requirements of ecolabels and regulations in overseas markets are met by greater quantities of New Zealand wool products.

1. Introduction

ERMA New Zealand established in December 2009 that grounds exist for the reassessment of diazinon and its formulations under the Hazardous Substances and New Organisms Act 1996. The uses of diazinon in veterinary medicine and in other areas of application; for example, horticulture, have been under review in a number of countries including important export markets for New Zealand's agricultural products. The reviews of diazinon in Australia are particularly relevant to New Zealand given the similarities of cultures and because, in both countries, many of the same ectoparasites of animals occur, the sheep industries remain important economically, and we are amongst few countries free of the serious disease 'sheep scab', due to the mite, *Psoroptes ovis*, having been eradicated. Reasons for the reviews have included concerns for the safety of people and animals exposed to diazinon, and the potential for adverse environmental effects. This report on the uses of diazinon in veterinary medicine in New Zealand is intended to form part of the information ERMA will consider in the course of its reassessment.

Diazinon is a broad spectrum organophosphate and has been used for the control of insect (flies, lice, fleas) and some acarine (mite and tick) pests of a variety of animals for more than 40 years in New Zealand. Its mode of action, in common with other organophosphate pesticides, is inhibition of the enzyme acetylcholinesterase which hydrolyzes the neurotransmitter acetylcholine in cholinergic synapses and neuromuscular junctions. The resultant disruption to neurotransmission leads to rapid paralysis and death of susceptible organisms. The products containing diazinon currently registered for use as veterinary medicines in New Zealand are a sheep dip, a powder for treating sheep, horses and dogs, and a range of collars for the control of fleas on dogs and cats. These products do not require veterinary prescription, that is, they are available over the counter (OTC).

2. Size and value of animal industries where diazinon is used.

Currently, diazinon-containing products are registered for use on sheep, dogs and cats, and horses in New Zealand (Tables 1 and 2).

2.1. The Sheep Industry

Sheep and beef cattle are commonly farmed together in New Zealand and the most recent data (2007) show 46 % (29,135) of all farms are of this type (Compendium of New Zealand Farm Facts, 33rd Edition, March 2009. Meat & Wool New Zealand Economic Service, Wellington). In 2008, the total number of sheep wintered in New Zealand was 38.5 million and 27.1 million lambs and 6.6 million older sheep were slaughtered to 30 September in that year Meat exports were valued at $2,638 million while further income was generated from edible offal, skins (pelts, leather and dressed skins), and other carcase products (Table 3). Wool and products derived from wool contributed export earnings in excess of $873 million (Table 3). Thus, total export income from the sheep industry was in excess of $3,511 million. Apart from export returns, the sheep industry generates additional value in the domestic market through sale of meat, milk, wool and other products and supports a range of service industries. The size of the pesticide market for the control of ectoparasites of sheep, principally strike flies (blowflies that lay eggs or maggots on livestock) and the sheep biting louse, in New Zealand is estimated at $13 to 15 million p. a (pers. com., industry sources).

2.2. Dogs and cats

The companion animal industry in New Zealand is principally focused on pet dogs and cats. At January 2010, 475,072 dogs were registered on the National Dog Database (Department of Internal Affairs, www.dogsafety.gov.nz) and it is recognised that a considerable number of dogs are not registered, perhaps in the order of 5% to 10%. There are an estimated 900,000 to 1,500,000 pet cats in New Zealand not including stray or feral cats. [Animal Welfare (Companion Cats) Code of Welfare 2007 Report, Biosecurity NZ]. High value domestic industries cater to these companion animals and are centred on provision of pet food, veterinary medicines and care, and pet accessories. However, the export income from the export of dogs and cats is likely small. The market for ectoparasiticides, principally for control of fleas, of these pets in New Zealand has been estimated at $13 to $14 million p. a. (pers. com., industry sources).

2.3. The horse industry

The horse industry has a relatively high profile in New Zealand and the number of horses in this country was estimated at 66,215 in 2007 (www.maf.govt.nz/statistics/pastoral/livestock-numbers). The racing industry in New Zealand (including thoroughbred (73%) and harness (22%) horse racing and greyhound (5%) racing) has an estimated direct domestic economic impact of $445 million p.a., with the industry itself sustaining over 9,000 fulltime jobs ("Size and Scope of New Zealand Racing Industry" a report to the New Zealand Racing Board, 2004). When the flow-on economic impacts are included, the contribution of the industry was estimated to increase to $1.4 billion p.a. Additionally, the sports horse sector contributes substantially to the national economy however quantification of this is not readily available. The value of exports of horses is estimated at $159 million p. a. (Table 3). The market for products providing control of ectoparasites of horses; principally nuisance flies, lice and ticks, in New Zealand is relatively small compared to the sheep and companion animal markets.

3. Potential impacts on industries and the New Zealand economy if uses of diazinon were further restricted.

3.1. The sheep industry

The potential for substantial industry costs if diazinon was not available are greatest for the sheep industry. This is well illustrated by the Australian situation where resistance to many families of actives for the control of fly strike and biting louse control has become apparent and, in the case of lice, the removal of diazinon for dipping of sheep has further reduced options (Levot and Sales, 2004; Levot 2008). Dipping with diazinon was popular in Australia for the control of the biting louse on sheep and disquiet continues even though an alternative organophosphate is available for dipping (Temephos- Coopers Assassin Sheep Dip) and diazinon can be applied by back spray (Eureka Gold, Coopers; however this does not provide rapid knockdown of lice over the whole sheep). Demand has lead one contractor to provide caged plunge dipping with diazinon under permit from the Australian Pesticides and Veterinary Medicines Authority (APVMA) (The Weekly Times. 2010). In New Zealand, numerous farmers dip sheep in diazinon for the control of lice and for rapid knockdown of larvae (maggots) in fly strikes, in the latter case often in combination with Insect Growth Regulator (IGR) products which are slower acting but provide more prolonged protection (Tables 2 and 5). The unavailability of diazinon will likely increase costs if farmers move to

alternative non-organophosphate products to which lice and strike flies are susceptible. It is additionally possible, as farmers come to rely more on IGRs rather than broad spectrum pesticides for dipping, that economic losses due to some of the presently less important ectoparasites such as sucking lice and mange mites may become more prevalent. However, it should be noted that 2 other organophosphates, chlorpyrifos and propetamphos, which are economically priced remain available for dipping sheep in New Zealand. A further diazinon-containing product, Strike Powder, used as a dressing to treat fly strike on individual sheep, would be missed by many farmers as the powder formulation is economical and more convenient to use than liquid formulations. Further, many of the currently-available fly strike preventives are not suitable as a dressing for an active strike as they do not have immediate 'knock-down' effects leaving the fly larvae to continue their damage. In a worst case, but unlikely, scenario where effective ectoparasite control was not available, animal welfare would be compromised and substantial losses would occur from increased labour costs, damage to wool and pelts, reduced condition of sheep and deaths. Conversely, it may be argued that unavailability of diazinon may increase revenues in the sheep industry as this may improve pesticide residue profiles of our wool products in terms of access to higher value overseas markets (Tectra Report, 2004) however scrutiny of many of the alternative actives is increasing because of the risks they pose to freshwater ecosystems.

3.2. Dogs, cats and horses

In the case of the companion animal industry (dogs and cats), unavailability of diazinon-containing products will not make a substantial impact as numerous alternative actives are available for the control of the targeted ectoparasites (Table 2 and 7). However, diazinon-containing flea collars are very convenient and economical products with extended periods of activity (typically 5 months). Their unavailability may lead some households to provide less or no flea control for their pets and thus compromise animal welfare and potentially human health, for example, due to flea bites, tapeworm infection; and zoonotic diseases spread by fleas (Kelly et al., 2005). In the case of humans, flea bites and tapeworm infections are unpleasant, however, while uncommon, several diseases spread by fleas can be serious and life threatening. In contrast, diazinon-containing flea collars are considered not to pose an undue hazard to human health [Australian Pesticides & Veterinary Medicines Authority (APVMA), 2006). A single diazinon-containing product is presently available for use on horses in New Zealand and the range of alternative registered ectoparasiticide products is relatively limited (Tables 2 and 8). Nonetheless, it appears unlikely that removal of diazinon would have any substantial impact on the horse industry.

3.3. Summary

The impacts on these industries and on the New Zealand economy if diazinon was no longer available is likely to be limited in the short term as control of ectoparasites of the various animal species would not be compromised because of the availability of efficacious alternative pesticides including alternative organophosphates (Tables 5, 7, and 8). In general, the immediate impact would be increased costs of ectoparasite control for a proportion of users because diazinon-containing products are usually cheaper than alternative effective products. In the longer term, the unavailability of diazinon, and potentially all

organophosphates, may increase pressure for the development of resistance to the remaining actives in target organisms. However, whether this would translate into substantial problems in ectoparasite control and economic losses for the various animal industries is difficult to predict. Potentially, some economic impacts may be felt in the sheep industry longer term depending on the development of pesticide resistance to newer actives and issues around pesticide residues and market access.

4. Quantity of diazinon used as a veterinary medicine in New Zealand

This information has been communicated separately to ERMA as manufacturer's regard it as commercially confidential. The manufacturers report that sales of Strike Powder and flea collars have been consistent in recent years. On the other hand, sales of Top Clip have declined in line with the continuing reduction in the number of sheep being farmed in New Zealand.

5. Use patterns of diazinon-containing veterinary medicines in New Zealand.

Products containing diazinon as the active ingredient are registered for use on sheep, horses, dogs and cats. Application methodology, rates, frequency and indications of the diazinon-containing veterinary medicines for these species are shown in Table 2. In general, ectoparasiticides may be applied on a seasonal basis, anticipating the emergence of ectoparasites in the warmer months of the year, or in response to clinical signs suggestive of infestation or actual identification of the presence of ectoparasites on animals. Application is prompted either through concern for animal welfare or for economic reasons, or both. In the sheep industry the principal value of long-acting insecticides, especially for fly strike prophylaxis, is that farmers are given peace of mind at a busy time of the year knowing that all their sheep are protected, when they would otherwise have to maintain intensive surveillance in order to treat each new fly strike as it arose; a very labour-intensive practice (see section 10.3. Alternatives to chemical pesticides). To a similar, although lesser, extent the same reasoning applies to the treatment of companion animals with relatively long-lasting insecticides.

5.1. Sheep.

The principle ectoparasites causing economic loss to the sheep industry are the biting louse and blowflies (Heath, 1994). The biting louse (*Bovicola ovis*) spends its entire lifecycle on the skin and in the wool of sheep causing irritation and damage to the fleece and skin leading to reduced value from the sale of wool and pelts. Blowfly strike of sheep results from adult flies depositing eggs or maggots in the fleece or on wounds. The developing maggots feed on the skin or exposed tissues of the sheep and predispose the sites to secondary bacterial infection and further strikes by adult flies. Fly strike is an agonising, debilitating infestation leading to skin damage, wool loss, loss of body condition and ultimately death if untreated. A number of fly species may be involved with the recently introduced *Lucilia cuprina* now dominant in strikes and *L. sericata, Calliphora stygia and Chrysomya rufifacies* also commonly seen. Fly strike occurs throughout New Zealand but is more prevalent in the North Island and upper South Island usually from late spring to

autumn (Heath and Bishop 2006). Other ectoparasites infest sheep in New Zealand but are of lesser importance nationally. The sheep ked (*Melophagus ovinus*), a wingless fly with all lifecycle stages spent on the sheep, causes similar types of damage and losses to the biting louse however this parasite is now rare in New Zealand. Sheep may also be infested by a tick (*Haemophysalis longicornis*), the nasal bot fly (*Oestrus ovis*), and a mange mite (*Chorioptes bovis*), while the sucking lice (*Linognathus pedalis, L. ovillus*) and the itch mite (*Psorergates ovis*) are rarely encountered these days.

Two products with diazinon as the active ingredient are registered as ectoparasiticides for use on sheep, Top Clip and Strike Powder. Top Clip is registered for the control of lice, fly strike and keds on sheep. It is an emulsifiable concentrate containing 400 g/L of diazinon which, when diluted and applied correctly, gives immediate and residual control of lice, blowfly strike and keds. The manufacturer claims that, in the case of fly strike, residual diazinon in the fleece provides 4 weeks of protection. For application by plunge or standard replenishment shower dipping it is diluted to 200g diazinon/1000L in water and is reinforced (more concentrate added) or replenished (fresh diluted formulation added) during the course of treatment of a mob of sheep. For constant replenishment shower dips the product is used at 400g diazinon/1000 L. For plunge dipping the sheep swim through a bath of diluted diazinon and the head is manually submerged so the entire body is wetted whereas for shower dipping the sheep are contained in a specifically designed enclosure with spray nozzles located so the entire body is wetted. Manual jetting to prevent blowfly strike of the breech area of lambs is also described. The product is diluted to 500g diazinon/1000L and 0.5 to 1 L applied at high pressure through a manual spray wand to each lamb. The diluted product may also be used as a dressing treatment for active fly strike of affected individuals. According to the manufacturer, application is predominantly by shower dipping (90%) and Top Clip is commonly used with IGR ectoparasiticides to provide rapid knockdown when sheep may already be affected by strikes. When used alone, Top Clip is most probably used more for louse control than for fly control as the period of residual activity against strike is relatively short compared to some more recent actives. Thus, as fly strike is less of a problem in the southern regions of New Zealand, Top Clip's market share of the sheep ectoparasite market is higher in these regions. The quantities of diazinon used for dipping of sheep in New Zealand, and probably of the other 2 organophosphates available, are declining in line with the decline in numbers of sheep in this country and potentially in response also to recent publicity about these chemicals and regulatory actions overseas.

Dipping with Top Clip for the control of fly strike is usually seasonal and often based on the historical prevalence of fly activity in a region and, in some cases, also accounting for the prevailing weather pattern which can determine fly activity. As the residual activity claim is for 4 weeks only, Top Clip may be applied more than once during the fly strike season. Alternatively, Top Clip is applied together with an IGR (persistent activity up to 18 weeks) so that rapid knockdown of existing strikes is achieved along with a longer period of protection. Top Clip may be applied at any time of the year for treatment of lice, either on an annual basis or in response to clinical signs suggesting infestation or identification of a louse problem.

Strike Powder is registered, in the case of sheep, for localised site applications for the treatment of active fly strikes and prevention of re-strike of the affected area. This product is the only powder composition available to sheep farmers, contains 20g diazinon/kg, and is provided with a puffer pack to facilitate application by dusting. As a preventative, Strike Powder is dusted onto wounds such as shearing cuts and onto docking sites of lambs (where the tails and the testes of males are removed 'surgically') to prevent strikes by blowflies attracted to the areas. In the treatment of active blowfly strike, wool is trimmed from the affected area and the powder is dusted onto the struck and surrounding areas killing maggots almost immediately. Use of Strike Powder on sheep would be restricted to when flies are active.

5.2. Dogs and cats.

Flea infestation of dogs and cats is common throughout New Zealand with the cat flea, *Ctenocephalides felis felis*, mostly responsible for infestations of both dogs and cats while other species are seen less often. Fleas cause skin irritation and their faeces soil the coat of the animal. Further, it is relatively common that some dogs and cats develop flea allergy in which itchy lesions with consequent self-trauma occur in response to fleas feeding on the skin. To ameliorate flea allergy, very effective flea control on the pet and its environment is required. A further consequence of infestation of pets is contamination of the house and outside environment via eggs shed from the pet leading to teneral fleas (recently emerged from pupae) infesting human beings and other animals. Infestation of the home and occupants has psychological and social consequences. In New Zealand, fleas are the intermediate host of the tapeworm *Dipylidium caninum* of dogs and cats and the filarial worm of dogs *Dipetalonema reconditum*, and transmit micro-organisms (*Bartonella* spp. and *Rickettsia* spp.) responsible for serious diseases of man such as murine typhus and cat-scratch fever (Kelly et al., 2005). Flea control is important in the prevention of transmission of these agents to human beings and other hosts. Clinically obvious infestations with lice on dogs (*Trichodectes canis*, *Linognahus setosus*) and cats (*Felicola subrostrata*) are uncommon in New Zealand and occur largely on aged or immuno-compromised animals. Infestation with lice can lead to skin irritation and inflammation and coat derangement. Mange mites also occasionally occur on dogs and cats, requiring acaricidal treatment. The multi-host tick *Haemaphysalis longicornis* present in the North Island and northern parts of the South island infests dogs on occasion; however while of concern to owners, the tick appears to have little clinical significance unless infestation is heavy.

Diazinon-impregnated collars (or bands) produced by a number of companies are registered for use on dogs and cats for the control of fleas and, in the case of one product, as an aid in the control of ticks (Table 2). The collars contain 150g diazinon/kg as the only active or may also contain pyriproxyfen (2.5g/kg), an insect growth inhibitor. The collars are made of plastic which is impregnated with the actives. Collars for cats are in the order of 14 g while those for dogs are 24g to 30g. The manufacturers' directions are to fit the collars closely around the neck of the animals and cut off any excess collar. These directions provide that the amount of collar placed on an animal is roughly proportional to its size.

Once placed around the neck of the animal, the diazinon is slowly released and enters the sebum (fatty layer) overlying the skin and diffuses in this layer to cover the body. Manufacturers claim the diazinon delivered kills all fleas on the animal within 24 hours of placement of the collars. Claims also include efficacy for up to 5 months on the animal irrespective of environmental factors such as wetting. The application of flea collars to dogs and cats will show seasonality in line with the activity of fleas. For dogs living outside of the home the majority of treatments occur in the warmer months from spring to autumn when fleas are active. However, in homes which are heated fleas remain active and reproduce for longer periods and thus treatments of pets occur over longer periods of the year. Some pet owners will apply collars in anticipation of the active period of the fleas, especially if the pet is affected by flea allergy, while others will wait until clinical signs or the presence of fleas becomes obvious.

Strike Powder is registered for the control of fleas and lice on dogs. The directions for use are to thoroughly dust the animal, work the powder well into the fur, repeat as necessary at 2 weekly intervals, and dust kennels and bedding. In the case of fleas, applications of Strike Powder to the dog are intended to treat infestations rather than be used as a preventative and will show seasonality as above. However, the environmental treatments are preventative for fleas, reducing re-infestation, but would not contribute to the control of lice which spend their whole life cycle on the dog. Obvious infestations with lice, although uncommon, can occur throughout the year so that treatments of this ectoparasite would show less seasonality.

5.3. Horses.

Strike Powder is the only diazinon-containing product registered for use in horses and is recommended by the manufacturer for the control of both fleas and lice. The lice affecting horses in New Zealand are a sucking louse (*Haematopinus asini*) and a biting louse, (*Werneckiella equi*), and, while fleas have not been recorded from horses in this country, it is possible that various fleas of mammals may attack horses. Mange mite (*C, bovis, Ps. cuniculi*) infestations of horses may be infrequently observed. Lice, mange mites and fleas on horses may cause irritation and lead to derangement of the fur and hair and inflammation of the skin. Compared to problems due to the foregoing ectoparasites, horses are more often afflicted with bot flies (*Gasterophilus* spp.) and a biting fly (*Stomoxys calcitrans*) although prevention and treatment of these do not rely on diazinon-based products but either pyrethroids used as repellents of adult flies or oral medications to control the larvae of bot flies. The manufacturer's directions for Strike Powder in the treatment of lice and fleas are to dust the horse thoroughly and work the powder well into the fur and hair. It is further recommended that the treatment be repeated at 2 weekly intervals if required and that 'infected areas' such as stables are dusted. As with dogs, the application of Strike Powder to horses is largely in response to signs of infestations with fleas and lice. Application to the surroundings is only useful in the case of flea infestation. The treatment of fleas will occur in the warmer months from spring to autumn when the parasite is active. Fluctuations in louse infestation levels can occur at any time of the year so that treatments of this ectoparasite would show less seasonality.

5.4. Off-label use.

No information was received that off-label use of diazinon-containing veterinary products occurrs in New Zealand. Top Clip and Strike Powder may occasionally be used to treat ectoparasites or nuisance insects on species for which they are not registered however this is thought to be rare. It is also possible that these products may be used for horticultural application, but there were no data to support this view and there are more suitable formulations available. In the case of Strike Powder, the Safety Data Sheet has under recommended uses: 'For the control of fleas, lice and the treatment of flystrike on sheep, cattle and other animals' and on the label under withholding periods, the company states 'Do not use on lactating dairy cows'. These statements could lead users to believe the product is registered for a range of animals other than sheep, dogs and horses. Fil NZ report 2 cases in the last 15 years where off-label use of Strike Powder on poultry led to mortalities. Their product label now warns against this use. It is unlikely that flea collars are used on large production animals due to the impracticability of attaching them and no information was obtained indicating they were used on animals of similar size to dogs and cats.

6. Formulation of diazinon-containing veterinary medicines in New Zealand

Products containing diazinon registered in New Zealand are formulated as a hydrocarbon-based emulsifiable concentrate (Top Clip), a powder (Strike Powder) and flea collars (slow release impregnated plastic). Concerns about diazinon have been greatest with regard to hydrocarbon-based formulations (non-aqueous liquid) because unsuitable storage conditions and trace amounts of water in the absence of sufficient stabilizer can lead to the build-up of highly toxic degradation products (APVMA Report, 2003). The degradation products of most concern are monotepp (O,O-TEPP and O,S-TEPP) and sulfotepp (S,S-TEPP) which are up to 2500 and 300 times respectively more toxic than the parent compound. Excessive quantities of these degradation products can pose risks to both target animals and users. The stabilizer most commonly used is epoxidised soybean oil. Registration of such commercial products found to have inadequate levels of stabilizer was cancelled in Australia in 2003. In New Zealand, the NZFSA have updated requirements for emulsifiable concentrates containing diazinon (NZFSA, 2006). The requirements imposed include specifications covering maximum content of O,S-TEPP, S,S-TEPP and water, the need for stabilizer and non-permeable packaging, and inclusion of expiry date and additional warning statements on labels. Top Clip appears to comply with these requirements. Powder and flea collar formulations of diazinon have been assessed by the APVMA as not posing undue hazards (see section 7.1.) and as long as they are stored in packs with unbroken seals (as purchased) should remain stable until used.

7. Operator, bystander and public exposure to diazinon

7.1. Operator exposure

For the treatment of sheep, authorities in Australia determined that they could not be satisfied that diazinon-containing products used for hand and auto race jetting (the latter where jetting is automatically activated as the sheep rapidly passes through the race), and plunge and shower dipping could be applied safely [with adequate margins of exposure (MOE) for the user] and that there was no evidence that amendments to the use practises would provide adequate MOE (APVMA Report, 2006, Part 2, Volume 1). These findings were based on a study 'Worker exposure to Diazinon in Australian Sheep Industries (Wood 2004, unpublished) and assessment of this study by the Australian Office of Chemical Safety (described in AVPMA Report 2006, Part 2, Volume 2). Contamination was determined where label instructions for personal protective equipment were used (cotton overalls, PVC gloves and water resistant boots). Operator exposure was found to be via the dermal route while inhalation was negligible. Consequentially, in Australia, registration of diazinon-containing products for hand and auto race jetting, and plunge and shower dipping were revoked in 2007, while existing stocks of product could be used by these methods until expiry (2009). However one diazinon formulation (Eureka Gold, Coopers) which is applied by back spray remains registered as it was found to have adequate MOE provided recommended personal protective equipment was used. Further, caged dipping with diazinon has been allowed under permit and is being assessed for safety by the APVMA (The Weekly Times. 2010). Similar data are not available on the uses of diazinon for dipping sheep in New Zealand and dipping methods will be similar to those no longer permitted in Australia. We are not aware that cage dipping is being examined here.

The APVMA found that powders containing diazinon (up to 20g/Kg) for treatment of docking sites, wounds or fly strike on individual sheep did not pose an undue hazard for the safety of users provided appropriate personal protective measures were taken. Factors contributing to this assessment included the relatively low concentration of active, the low numbers of sheep that would be treated per day (with the exception of docking) and the lower likelihood that powders, relative to liquid formulations, would penetrate clothing. These findings are directly applicable to the use of Strike Powder on sheep in New Zealand. However, the recommendations for use of Strike Powder on dogs and horses, "dust animals thoroughly, working the powder well into the hair or fur', suggests the possibility that user exposure may be greater than during use on sheep. This is because the whole animal is being treated, the user rubs the powder into the pelage, and there is greater potential for powder particles to be suspended in the air and/or be blown over the user. Mitigating factors relevant to exposure while treating dogs and horses include the application to single or few animals at any one time and the infrequency of use (2 weekly cycles).

Flea collars are made of plastic impregnated with diazinon which is slowly released over a period of months. These products are not considered to represent an undue hazard to the safety of people exposed to them in normal use (APVMA, 2006). Risks associated with inhalation, oral and dermal toxicity are considered low. Highest exposures to the active may

occur when the collar is being fitted to the pet or if a child played with or sucked the product. Label instructions indicated the product must be kept out of reach of children and, on some product labels, that hands should be washed after handling the product when fitting to the animal.

7.2. Public and bystander exposure to diazinon

It is unlikely that significant exposure of bystanders or the public would occur from uses of the diazinon-containing veterinary products registered in New Zealand. In the case of Top Clip, dipping of sheep is usually undertaken remote from the public and bystanders typically would be few and infrequent. Additionally, a bystander is unlikely to spend prolonged periods of time close to the sheep being treated and thus would not be contaminated to the same degree, for example, by splashing, as would the operator who typically would spend numbers of hours treating sheep. This appears likely to hold even though the bystander may not wear personal protective equipment. Ideally, disposal of dip is by spreading it on soil on the farm in an area away from waterways and that is not susceptible to runoff (Levot, 2007). Diazinon is relatively rapidly degraded in soil (for example, half life range from 4 to 27 days, APVMA 2003) and under the disposal method above will not lead to environmental contamination. Explicit label instructions on disposal of containers is provided with Top Clip.

The circumstances of the application of Strike Powder to sheep is similar to the above so that the presence of bystanders or the public during use of this product is unlikely to be more than occasional. The presence of bystanders (including family members) is more likely during treatments of dogs and horses and, given that the whole animal is dusted, it is conceivable that a person 'downwind' or handling the animal after treatment may be excessively exposed to the product. Data to evaluate these risks are not readily available. The risks are mitigated by the relatively low concentration of diazinon in Strike Powder (20g/kg) and the fact that the rural community is the target market and the product is used predominantly on sheep.

The use of flea collars is unlikely to pose any risk to bystanders or the public provided label instructions are followed as the active is only slowly released and is absorbed into the fatty sebum of the host.

7.3. Adverse events involving diazinon

The NZFSA has no adverse event reports filed against any currently registered diazinon-containing product. The manufacturers of the products also reported no adverse events related to the diazinon other than 2 instances of deaths in poultry due to the off-label use of Strike Powder. The manufacturers of flea collars report no adverse reactions to these products other than skin reactions on the neck due to hypersensitivity or because the collars were applied too tightly. We have received no other information on adverse events related to the use of these products. It is plausible that some people using these products do not take appropriate precautions however there are no data on this. The Tectra Report (2004) contains the following comments "... there are numerous anecdotal reports of the adverse effects of OP use in the farming community. ... the chemicals are often used with little regard to the

potential dangers associated with their use". It would be useful if quantitative data were available on these issues.

8. Diazinon residues

8.1. Residue levels in foods of animal origin.

For the New Zealand domestic market, all imported and domestically-produced food sold (except for food imported from Australia) must comply with the New Zealand (Maximum Residue Limits of Agricultural Compounds) Food Standards (the MRL Standards) and amendments. The MRL listed for diazinon is shown in Table 4. The MRL listed is for fat as diazinon preferentially accumulates in fat. For other foods, under the New Zealand MRL Standards, where no specific MRL is listed, the "default" MRL of 0.1 mg/kg applies. Under the Trans Tasman Mutual Recognition Arrangement (TTMRA), food imported from Australia may be legally sold in New Zealand, as long as it complies with Australian residue requirements. The converse is also true, so that food imported from New Zealand into Australia is legal, so long as it complies with New Zealand requirements (the MRL Standards). The Australian MRLs for diazinon are set out in Standard 1.4.2, Schedule 1, of the Australia New Zealand Food Standards Code (Table 4). Under the Australian standard if a MRL for an agricultural or veterinary chemical in a food is not listed in Schedule 1 there must be no detectable residues of that agricultural or veterinary chemical in the food.

Residue levels are further controlled in New Zealand under the Animal Products Act 1999, with maximum permissible levels (MPL) of contaminants for animal products intended for human consumption set in the Animal Products (Contaminant Specifications) Notice 2008 (Table 4). Note that the MPLs for diazinon in mammalian fat are ambiguous, indicating 2 different levels, probably as a result of a transcription error. MPLs are primarily aimed at protecting trade with countries that have lower MRLs than New Zealand. MPLs apply to specified animal products at the point of harvest and take precedence over the MRL if that food is intended for export. Further, product processed with the intention of export, other than to Australia, must comply with the 'Codex' (Codex Alimentarius (2005) List of Codex Maximum Residue Limits for Veterinary Drug Residues in Food; and Codex Alimentarius (2006) List of Codex Pesticide Residues in Food: Extraneous Maximum Residue Limits), and country specific requirements.

The NZFSA administers residue monitoring programmes for dietary exposure in New Zealand and for dairy and meat products produced in New Zealand. The NZFSA periodically undertakes a Total Diet Survey (NZTDS) which assesses exposure to chemical residues across locally produced and imported foods representative of the diet of different age-sex groups within the New Zealand. Unlike other residue assessments by the NZFSA, foods are prepared as for eating before testing. The 2003/04 NZTDS showed estimated daily dietary exposures to diazinon were very low in the foods tested, for example, 0.0 to 0.07% of acceptable daily intake (NFSA. 2003/04 New Zealand Total Diet Survey: Agricultural Compound Residues, Selected Contaminants and Nutrients). The dairy National Chemical

Contaminants Programme (NCCP) monitors compliance to an extensive list of compounds, including diazinon, and the most relevant New Zealand, Codex and international maximum residue limits applicable. Action limits are set which, while not applying for a specific market, serve to prompt an "action" that will include, as a minimum, confirmation of the applicable MRLs for that market (that is; for exported products, MRLs specified in the Codex or by the importing country) and determination of product conformance status. The Action Limit for Diazinon in raw milk and colostrums is 0.02 mg/L. The National Residues Programme (NRP) tests other animal products (meat from animals, birds and salmon, as well as honey) for registered veterinary medicines and other classes of substances. If the marker tissue residues exceed food standards, the carcass is subjected to further testing to ensure the levels of residues in the edible tissues comply. Diazinon residues are low or undetectable in animal products from New Zealand and are not a concern (pers. com. Mike Clear, NZFSA).

The ACVM group set withholding periods for registered veterinary medicines that ensure that residues of these medicines do not exceed food standards for animal products. Withholding periods for Top Clip and Strike Powder are 21 and 28 days respectively for sheep producing meat or offal for human consumption and, for both formulations, are 35 days for sheep producing milk for human consumption. The withholding period for Strike Powder in horses producing meat or offal for human consumption is 63 days.

8.2. Residue levels in wool and environmental contamination.

There has been concern within the New Zealand wool industry over access to higher value international markets as eco-brands and government regulations increase restrictions on pesticide residues in woollen products and in regard to environmental contamination (Edwards 1997; Tectra 2004, New Zealand Ecolabelling Trust Proposal EC-47-10). The Tectra report concluded that there was little risk of environmental harm arising from scouring activities within New Zealand where over 80% of our crossbred wool is scoured. However, the report indicated that residues of diazinon, together with those of cypermethrin and diflubenzuron, in scoured wool while low could be problematic for some European processors. Further, to qualify for the EU commission's Ecolabel required that the total concentrations of organophosphates do not exceed 2 mg/kg in greasy wool, while limits are also set for organochlorines (0.5 mg/kg; not now used in NZ), synthetic pyrethroids (0.5 mg/kg) and IGRs (2 mg/kg, then including only diflubenzuron and triflumuron). The Tectra (2004) proposal that pesticide treatments of sheep could be focused on cyromazine and dicyclanil to sidestep residue issues ignored pressures on pesticide resistance development and the need for other actives to control louse infestations. Subsequent to this report, the EU has added dicyclanil to the set of IGRs and the NZ Ecolabelling Trust has proposed to include dicyclanil and cyromazine in the set of IGRs for which residues will be restricted (EU Ecolabel User Manual 2010; New Zealand Ecolabelling Trust Proposal EC-47-10). So far, spinosad has not been included in any residue requirements to our knowledge. EU Ecolabel criteria do not apply if documentary evidence can be presented that establishes the identity of the farmers producing at least 75% of the wool or keratin fibres in question, together with a declaration from these farmers that the pesticides listed have not been applied to the fields or animals concerned.

For Top Clip, to minimize wool residues, label recommendations are that the time between treatments and shearing is at least 2 months, although spot treatments (dressing of a small area) are exempted from this recommendation.

9. Biosecurity

Ectoparasiticides are used when animals are imported or exported to exclude specified ectoparasites that are not wanted in New Zealand or importing countries. MAF Biosecurity have indicated that they have no concerns over possible changes in the conditions of use or availability of diazinon as there is a broad range of ectoparasiticides available in New Zealand.

10. Alternatives to diazinon for the control of ectoparasites on animals in New Zealand

10.1. Alternative veterinary medicines (ectoparasiticides)

10.1.1. Sheep.

There are three other organophosphate actives (chlorpyrifos, propetamphos and chlorfenvinphos) and six other classes of actives registered in New Zealand for the treatment of ectoparasites of sheep (Table 5). Applied correctly and in the absence of resistance to the pesticide in the targeted ectoparasites, all products are efficacious in respect of their registered uses.

The pesticides used for flock treatments can be divided into those that have rapid knockdown (paralyse and/or kill the ectoparasites) like diazinon or the insect growth regulators (IGRs) that lead to a gradual decline in ectoparasite populations. The alternative organophosphate actives provide rapid knockdown as do alpha-cypermethrin, ivermectin used as a jetting treatment, and spinosad in the control of both flystrike and louse infestations and potentially other less important ectoparasites of sheep in New Zealand. The orally delivered and injectible macrocyclic lactones do not have claims for the control of sheep lice and only indirectly reduce flystrike by controling diarrhoea and breech soiling as a consequence of the treatment of parasitic gastrointestinal nematodes. The benzoyl urea, triazine and pyrimidine carbonitrile IGRs are effective for the prevention of fly strike but are not acceptable alone for the treatment of established fly strike due to lack of rapid knock down. The benzyl urea actives are also effective for the treatment of lice where the farmer accepts a delay in the control of the infestation. Persistence of activity is particularly important in providing useful periods of prevention of fly strike. In this respect the alternative organophosphates and cypermethrin show similar periods of activity to diazinon (4 - 6 weeks), the ivermectin jetting product, benzoyl urea derivatives and cyromazine generally protect for longer (6 to 12 weeks), while dicyclanil claims protection of up to 18 weeks. Spinosad provides the shortest

period of protection against fly strike (2 - 4 weeks). Diazinon is often used in combination with IGRs to provide both rapid knockdown and persistence. Potentially, for such combinations, diazinon could be replaced by the alternative dips containing the other organophosphates or spinosad. One product (Cyrex Liquid) combining the IGR cyromazine with spinosad has been registered but has not been launched on the market at the present time. For the treatment of established fly strike on individual sheep, where the treatment is applied as a dressing, actives must have rapid knockdown effects. Products containing the organophosphates chlorfenvinphos or propetamphos, or spinosad or ivermectin are registered for this purpose and are alternatives to diazinon (Table 5). Several of the products registered for use on sheep also have claims for the control of keds, as does the diazinon-containing Top Clip, and Seraphos (propetamphos) also has a claim for the control of ticks (Table 5).

Compared to the meat withholding period for diazinon (21 days) following dipping or jetting, the meat withholding periods are similar for chlorpyrifos and propetamphos (21 and 14 days), are shorter for cypermethrin, ivermectin jetting liquid and cyromazine (all 7 days) while no meat withholding is required for diflubenzuron or spinosad. Meat withholding periods are longer for products containing triflumuron (49 to 56 days) and dicyclanil (35 - 56 d). Generally, all products have milk withholding periods of 35 days and wool withholding of 2 months is recommended for all except spinosad for which a wool withholding period is not required.

The best method of comparing relative costs of available pesticide formulations is to use per sheep (dose) cost. However, as definitive comparisons are difficult due to variations in costs of products within classes of actives and the effects of sales, promotions, outlet and quantities purchased, the retail costs shown in Table 6 should be considered as representative of the current market place. The cost of diazinon active for plunge or shower dipping is comparable to the other organophosphates, chlorpyrifos and propetamphos, available for these uses and usually cheaper than alternatives actives irrespective of application method. However, if diazinon needs to be applied twice in a season for fly strike, its cost then becomes comparable to the lower cost non-organophosphate alternatives. Jetting formulations tend to occupy the medium cost range while the more expensive products are found amongst those applied as pour-ons or by applicators.

10.1.2. Dogs and cats.

Diazinon-containing collars are registered in New Zealand for the control of fleas only with the exception of one brand which has an additional claim as an aid in the control of ticks (Table 2). It is likely that diazinon-containing flea collars also provide some control of lice and ticks on dogs and cats. Strike Powder is also registered for the control of fleas and lice on dogs. This product is normally marketed at farmers and it is likely that its use on dogs is largely confined to this sector. Numerous alternative insecticide treatments are available in New Zealand for the control of fleas on dogs and cats including 9 different classes of pesticide with a range of methods of application (Table 7). Three alternative

organophosphates, maldison (applied by dusting), coumaphos (spray or bath) and fenthion (spot-on) are registered. The majority of alternative actives have knock down effects, like diazinon, while the IGRs available are often combined with a knock-down active to give more rapid relief from fleas. Caution is required in the application of permethrin to cats due to toxicity problems in this species. While fleas are the major ectoparasite causing problem in dogs and cats, a number of the alternative products have wider claims including control of lice and ticks and, less frequently, nuisance flies and mosquitoes. The macrocyclic lactones have claims for the control mites and internal parasites. Diazinon-containing collars are efficacious and provide protection against fleas for 5 months however they may not be as effective as some newer actives in the control of flea allergy. Flea collars sell in supermarkets for $6.00 to $7.00 and this relatively low cost, convenience, and their prolonged activity make them very cost effective. Alternative products containing rotenone, pyrethroids and organophosphates applied by dusting, shampooing, spray etc can also be cost effective but are not as convenient (especially for cats) and do not have the same persistent activity. The fenthion spot-on and products containing newer actives in supermarkets, cost $20 to $25 to provide convenient treatments for similar periods of protection while the cost of products sold only through veterinary practices can be expected to be similar or greater.

10.1.3. Horses.

Strike Powder, which contains diazinon, is the only powder formulation registered for use on horses (Tables 2 and 8). Alternative actives for the control of ectoparasites of horses include one organophosphate (coumaphos) and pyrethroids, which are applied as sprays or wiped on, and an IGR which is applied as a pour-on (Table 8). Strike Powder and the coumaphos-containing product both have claims for control of fleas and lice which can be problems on horses and both actives may help control ticks. The IGR, triflumuron, is registered for control of lice only. It is likely that the organophosphate- and pyrethroid-based products are similarly cost effective while the IGR benefits from being formulated as a pour-on (low volume dose) and thus is the easiest to apply. Applying powder to all surfaces of a large animal such as a horse is difficult and time-consuming and it is likely Strike Powder is less often used than the alternatives that can be applied more conveniently. Nuisance flies, including stable flies, sandflies (blackflies) and bot flies (whose larvae live in the horse's gastrointestinal tract), are also problems for horses and only the pyrethroid-containing products address this need.

10.2. Resistance management issues relating to ectoparasiticides registered as veterinary medicines

10.2.1. Sheep industry

Comprehensive investigations of pesticide resistance in ectoparasites of sheep in New Zealand have not been undertaken recently however organophosphate and pyrethroid resistance in the dominant strike fly, *L. cuprina*, and biting louse populations respectively were identified in the 1990s (Gleeson et al., 1994; Wilson et al., 1997). There was also some evidence of diflubenzuron resistance in *L. cuprina* (Haack et al.

1999). The situation in the New Zealand sheep industry may mirror to an extent that in Australia where widespread resistance to pyrethroids and benzoyl urea IGRs in both louse populations and *L. cuprina* and oganophosphate resistance in *L. cuprina* are apparent (Levot and Sales, 2004; Levot 2008).

With respect to treatment for the biting louse, the decision to cease dipping sheep with diazinon and resistance problems in Australia has restricted available options there with the trend likely to be that farmers will rely more on products containing spinosad and a permitted backline diazinon spray-on (Levot 2008). A further option is treatment using ivermectin. In New Zealand, spinosad, ivermectin and diflubenzuron products are available and efficacious for the treatment of lice together with 2 alternative organophosphates, chlorpyrifos and propetamphos (Table 5). Industry sources indicate that spinosad has achieved substantial market share in New Zealand.

For the prevention of fly strike in Australia, the IGRs cyromazine and dicyclanil are effective dipping options for sheep farmers with spinosad available for knock-down effects (Levot and Sales 2004). In New Zealand, despite laboratory evidence of resistance to organophosphates in *L. cuprina* and anecdotal concerns regarding reduced protection periods, dipping with diazinon (Top Clip) mixed with IGRs to provide immediate control of existing strikes is economical and popular with many sheep farmers as is the use of Strike powder for individual treatments because of the convenience of the powder formulation. Should diazinon become unavailable for use on sheep, cyromazine and dicyclanil will provide persistent and effective control of fly strike while chlorpyrifos and propetamphos and spinosad may be used for rapid knock down applications (Table 5). A disadvantage of using cyromazine and dicyclanil alone is that an additional product, with associated costs, needs to be applied for louse control. This further supports the practice of combining a knock-down product with these IGRs. Alternatively, the benzoyl urea IGRs, when knock-down is not required, and ivermectin remain options both for control of lice and medium term prevention of fly strike in New Zealand.

Alternative actives would provide effective control of ectoparasites of sheep in New Zealand in the face of further restrictions on the use of diazinon. However such restrictions will increases the pressure for the development of resistance to the remaining actives in the target insects. In the case of spinosad this is mitigated to an extent by its short residual activity while field resistance to dicyclanil and cyromazine in *L. cuprina* was not apparent in Australia up to 2004 despite 10 and 20 years of use respectively ((Levot and Sales 2004).

10.2.2. Dogs and cats

The cat flea, the most common species infesting both dogs and cats, has shown resistance to a range of pesticides including cyclodienes, carbamates, organophosphates

(including diazinon) and pyrethroids in overseas countries (Bossard et al., 1998; Rust, 2005). However, the degree of resistance generally has been low, e.g., resistance ratios for diazinon ranging from 1.3 to 15 where a value of 1 equates to baseline susceptibility (Bossard et al., 1998). Evidence of resistance to newer actives is limited although there are concerns that the effectiveness of these actives is maintained. The prevalence of pesticide-resistance in fleas of pets is not well studied and we are not aware of any information on this subject in New Zealand. With the introduction of a number of alternative families of actives and alternative organophosphates presently available in New Zealand (Table 7) it is unlikely that restrictions on the use of diazinon-containing collars would compromise the ability to control ectoparasite on cats or dogs in New Zealand. However, costs and inconvenience of flea control for many households would increase and some pet owners may choose to provide less or no control.

10.2.3. Horses

Products for control of ectoparasites of horses rely largely on pyrethroid and organophosphate actives with the newer active, triflumuron, confined to the control of lice (Table 8). Coumaphos, an alternative organophosphate to diazinon, is presently available. Information on the resistance of equine ectoparasites to pesticides in New Zealand is not available to our knowledge however it seems unlikely that restrictions on the use of diazinon would substantially impact present control options. A range of the newer actives could be registered for horses should present products become ineffective.

10.3. Alternatives to chemical pesticides

10.3.1. Sheep industry

A range of actions other than pesticide application can be undertaken to reduce fly strike of sheep and many of these are practised by farmers (Cole and Heath, 1999). If sheep can be kept free of breech soiling (faeces and urine), foot-rot, wounds and microbial conditions of the skin and fleece (fleece rot, mycotic dermatitis) then many of the chemical signals that attract blowflies to sheep can be mitigated. Farmers use ‘surgical’ procedures to achieve some of these desirable conditions, docking (removing tails) and mulesing of merinos (removing skin folds at the breech), and wool removal including crutching (removing wool from the breech) and shearing to lessen risk during the active fly period. Ensuring that sheep are not left too long in paddocks so that the extent of faecal contamination and resultant odour plumes to attract flies are limited reduces risk, and grazing sheep on areas that are exposed to high air flow can also helps because fly activity is reduced at air speeds above 3m/sec. Further, reducing fly numbers in the environment by trapping or by providing odour sources that distract flies from sheep have some promise, as do ‘targets’ with an odour and colour combination that attract flies to an insecticide-treated surface. A clean farm policy with respect to fly breeding resources, especially carrion, is mandatory for limiting blowfly pressure. Parasitoid wasps (which develop in fly larvae and pupae) occur naturally that can reduce fly populations, but their numbers need to be artificially enhanced and they only affect a small proportion of available hosts principally in carrion. Other natural population

controls exist in the form of bacteria and fungi but technologies for their useful deployment have not been developed. Such organisms include *Bacillus thuringiensis* (Bt) and a soil fungal organism, *Tolypocladium cylindrosporum*, isolated in New Zealand (Heath et al. 2004a; Wright et al. 2009). As animal welfare concerns lead to more scrutiny of docking and mulesing and the industry seeks to reduce pesticide residues, there is increasing interest in selecting sheep that are less predisposed to fly strike. Sheep bred for reduced wool around the breech, or without a conformation of the shoulder that leads to water retention in the fleece will reduce the risk of strike. Further, sheep that do not scour readily in response to internal parasites are less susceptible to fly strike and this can be enhanced by feeding pasture plants containing abundant tannins. In most regions of New Zealand where fly strike occurs, none of the forgoing measures can provide confidence that fly strike will be prevented. However, on some farms, the prevalence of strike may be reduced to a level where it is possible to control the problem by individually treating only those sheep that are affected. Ethically, this requires frequent surveillance of sheep flocks so that strikes are identified early and acceptance of some costs including the increased labour, wool losses and skin damage, and loss of condition of some affected sheep.

Shearing of sheep physically removes a substantial quantity of biting lice (35-66%) and their eggs and exposes the remaining population to detrimental environmental conditions including solar radiation, excessive temperature, reduced humidity and conversely excessive wetting so that populations over time can show declines of 95-98% (see Kettle, 1990 for a summary; Heath et al. 1995). Dipping twice in water with or without detergent achieved a short lived reduction (27-35%) in louse numbers on unshorn sheep and when combined with shearing generally improved the reduction of lice compared to shearing alone (Heath et al. 1995). Such treatments need to be repeated about 7 days later because there is no residual activity to kill lice that hatch from eggs that remain on the sheep. It is also important that ewes should be treated before lambing, and their lambs are also treated as soon as practical so that lice transferred from the ewes are also killed. In addition, dipping with neem oil was shown to be as effective against lice as pyrethroids applied as a dip or pour-on over a period of 48 days after treatment (Heath et al., 1995). Careful application of these approaches to louse control may break the cycle of infestations or limit levels of infestation to acceptable levels but require more effort compared to the application of conventional pesticide formulations. Other potential approaches to the control of the biting louse identified have included proteins produced by the bacterium, Bt and entomopathogenic nematodes but these have not yet progressed to commercial availability (Hill and Pinnock, 1998; P. James, pers com.). Further, susceptibility to louse infestation in sheep is heritable and selective breeding could be used to limit the degree of infestation as could weight selection at weaning (Heath et al. 2004b;
Pfeffer et al., 2007).

10.3.2. Dogs, cats and horses

Populations of fleas, lice, ticks and mites on dogs and cats can be reduced by grooming and regular shampooing of dogs may keep flea and louse numbers down. In the case of fleas, attention also has to be paid to the environment so that re-infestation of the animals is reduced using measures such as washing of bedding and vacuuming to remove eggs, larvae, pupae and teneral fleas. Natural chemical options for flea control contain substances such as citronella, garlic, tea tree oil and neem oil and may have a repellent action against fleas but are usually not very effective or long-lasting adulticides. On horses, similar measures to those used in dogs and cats would also be expected to reduce populations of lice and fleas. Biting flies annoying horses are less easy to manage however, in the case of stable flies, their numbers can be reduced by eliminating their breeding places and trapping adult flies on white, sticky 'targets' set up in direct sunlight (Heath 2002). Options for biological control are sparse for these species and no commercial products are available.

10.3.3. Summary

Overall, presently available non-chemical options for the control of ectoparasites on sheep, dogs, cats and horses in New Zealand can reduce pest populations, and potentially reduce the need to use pesticides. However, overall they are usually more expensive because they require greater effort and do not offer control comparable to that able to be provided by currently available pesticide formulations.

11. Conclusions

Diazinon has been a popular and efficacious treatment for the control of the major ectoparasites of sheep, dogs and cats. It remains an economical and valued active for the control of the biting louse and knock-down of active fly strikes of sheep and the control of fleas on dogs and cats. Use of diazinon on horses is likely quite limited.

It is possible that uses of diazinon (Top Clip) in the sheep industry for plunge and shower dipping and hand and auto race jetting pose similar risks to those identified in Australia where unacceptable dermal exposure was identified in the course of these uses. However, data on the New Zealand circumstances are lacking. It is also possible that use of Strike Powder on dogs and horses poses risks to operators and bystanders by dermal and inhalation routes. On the other hand, flea collars containing diazinon appear to pose no undue risk provided reasonable precautions are taken.

Further restrictions on the use of diazinon in the sheep industry may increase pressure for resistance to the alternative families of actives in the targeted ectoparasites. If the two other organophosphates for dipping sheep continue to be available, this pressure may be minimal and it would be reassuring that this class of active would remain an option for the future. If restrictions on use for plunge and shower dipping and jetting were applied to all organophosphates, pressures for development of

resistance to alternative actives would be greater and this may have potential to reduce economic returns in the sheep industry.

Restrictions on the use of Strike powder for treating fly strike would be unpopular with many sheep farmers because of the convenience of this powder formulation. However, little impact on dog and horse owners is expected because of limited use on these species.

Unavailability of diazinon for use in collars for dogs and cats would be of concern because this may lead to less control of fleas in many households. This would compromise animal welfare and increase the risk of the spread of zoonotic diseases to human beings, some of which can have serious consequences.

No concerns over contamination of animal-derived foods or the environmental with diazinon in New Zealand were identified however diazinon residues, together with those of other pesticides, in wool pose a risk in international markets.

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13. References

APVMA. 2003. The reconsideration of registrations of products containing diazinon and their labels. Part 1: Product cancellations. Review Reports, Review Series 1, April 2003.

APVMA. 2006. The reconsideration of approvals of the active constituent diazinon, registrations of products containing diazinon and approval of their associated labels. Part 2: Preliminary Review Findings, Volume 1 and 2, June 2006.

Bossard, R. L., Hinkle, N. C., Rust, M. K. 1998. Review of insecticide resistance in cat fleas (*Siphonaptera: Pulicidae*). Journal of Medical Entomology 35:415-22.

Cole, D. J. W., Heath, A. C. G. 1999. Progress towards development and adoption of integrated management systems against flystrike and lice in sheep. Proceedings of the New Zealand Grassland Association 61:37-42.

Edwards, S. 1997. Operation Cleanfleece. Vetscript, November 1997:16-17.

EU Ecolabel. 2010. Textile floor coverings EU ecolabel award scheme: User manual. http://ec.europa.eu/environment/ecolabel/ecolabelled_products/categories/pdf/textiles/User_manual.pdf.

Gleeson, D. M, Barry, S. C., Heath, A. C. G. 1994. Insecticide resistance status of *Lucilia cuprina* in New Zealand using biochemical and toxicological techniques. Veterinary Parasitology 53:301-308.

Haack, N. A., Heath, A. C. G., McArthur, M. J. 1999. A preliminary survey of tolerance to diflubenzuron in the blowflies *Lucilia cuprina* and *L. sericata* in New Zealand. New Zealand Journal of Zoology 26:81. (Abstract).

Heath, A. C. G. 1994. Ectoparasites of livestock in New Zealand. New Zealand Journal of Zoology. 21:23-38.

Heath, A. C. G. 2002. Distribution, seasonality and relative abundance of *Stomoxys calcitrans* (stablefly) (Diptera: Muscidae) in New Zealand. New Zealand Veterinary Journal 50:93-98.

Heath, A. C. G., Bishop, D. M. 2006. Flystrike in New Zealand: an overview based on a 16-year study, following the introduction and dispersal of the Australian sheep blowfly, *Lucilia cuprina* Wiedemann (Diptera: Calliphoridae). Veterinary Parasitology 137: 333-344.

Heath, A. C. G., Broadwell, A. H., Chilcott, C. N., Wigley, P. J., Shoemaker, C. B. 2004a. Efficacy of native and recombinant Cry1B protein against experimentally induced and naturally acquired ovine myiasis (fly strike) in sheep. Journal of Economic Entomology 97:1797-1804.

Heath, A. C. G., Lampkin, N., Jowett, J. H. 1995. Evaluation of non-conventional treatments for control of the biting louse (*Bovicola ovis*) on sheep. Medical and Veterinary Entomology 9:407-412.

Heath, A.C.G., Pfeffer, A.T., Morrison, L. 2004b. Association of sheep body louse (*Bovicola ovis*) infestation with weaning weight, birth rank and cockle in lambs. Wool Technology and Sheep Breeding 52: 8-18.

Hill, C. A., Pinnock, D. E. 1998. Histopathological Effects of *Bacillus thuringiensis* on the Alimentary Canal of the Sheep Louse, *Bovicola ovis*. Journal of Invertebrate Pathology 72:9-20.

Kettle, D. S. 1990. Medical and Veterinary Entomology, Walingford, CAB International, 658pp.

Kelly, P., Roberts, S., Fournier, P-E. 2005. A review of emerging flea-borne bacterial pathogens in New Zealand. The New Zealand Medical Journal 118:1-9.

Levot, G. W. 2007. Effective remediation of diazinon from spent sheep dip wash by disposal on land. Australian Journal of Experimental Agriculture 47:13-16.

Levot, G. 2008. Speed of action and *in vitro* efficacy of spinosad against sheep body lice, *Bovicola ovis* (Schrank) (Phthiraptera: Trichodectidae), resistant to pyrethroid, organophosphate or insect growth regulator insecticides. Australian Journal of Entomology. 47:251-255.

Levot, G., Sales, N. 2004. Insect growth regulator cross-resistance studies in field- and laboratory-selected strains of the Australian sheep blowfly, *Lucilia cuprina* (Wiedemann) (Diptera: Calliphoridae). Australian Journal of Entomology 43:374-377.

NZFSA. 2003/04 New Zealand Total Diet Survey: Agricultural Compound Residues, Selected Contaminants and Nutrients. http://www.nzfsa.govt.nz/science/research-projects/total-diet-survey/reports/full-final-report/nzfsa-total-diet.pdf

NZFSA. 2006. Review: Diazinon Products. AgVet Link No. 55, www.nzfsa.govt.nz/acvm/publications/agvetlink/issue.../page-12.htm).

Pfeffer, A., Morris, C. A., Green, R. S., Wheeler, M., Shu, D., Bisset, S. A., Vlassoff, A. 2007. Heritability of resistance to infestation with the body louse, *Bovicola ovis*, in Romney sheep bred for differences in resistance or resilience to gastro-intestinal nematode parasites. International Journal for Parasitology 37:1589-1597.

Rust, M. K. 2005. Advances in the control of *Ctenocephalides felis* (cat flea) on cats and dogs. Trends in Parasitology 21:232-236.

Tectra Ltd. 2004. Impact of greasy wool pesticide residues on scour effluent discharge eco-toxicity and scoured wool exports. SFF Project: 03/102; Meat and Wool Project: 03TT/63. http://www.maf.govt.nz/sff/about-projects/search/03-102/03-102-final-report.pdf

The New Zealand Ecolabelling Trust. 2010. Proposed licence criteria for scoured wool. EC-47-10. http://www.enviro-choice.org.nz/specifications/EC-47-10ScouredWoolDraft.pdf

The Weekly Times. Fight against sheep lice. May 17, 2010. Australia. http://www.weeklytimesnow.com.au/article/2010/05/17/186371_sheep.html

Town Centre Development Group, Sandringham. 2005, The Equine Industries in Counties Region: A Study to Determine Their Current Position. www.towncentredevelopment.c.nz

Wilson, J. A., Heath, A. C. G., Quilter, S., McKay, C., Litchfield, D., Nottingham, R. 1997. A preliminary investigation into resistance to synthetic pyrethroids by the sheep biting louse (*Bovicol;a ovis*) in New Zealand. New Zealand Veterinary Journal 45:8-10.

Wright, D. A., Cummings, N. J., Haack, N. A., Jackson, T. A. 2009. *Tolypocladium cylindrosporum,* a novel pathogen for sheep blowflies. New Zealand Journal of Agricultural Research 52:315-321.

Table 1. Veterinary medicines containing diazinon registered under the ACVM Act 1997 in New Zealand

Registration number	Trade Name	Date of Registration	Registrant	Concentration of diazinon (and other actives)
A003292	TOP CLIP 40	14-01-1977	Orion Crop Protection Ltd	400g/L
A000223	STRIKE POWDER	10-09-1968	FiL New Zealand	20g/kg
A005172	PetGard 5 Month Flea Band for Cats	23-10-1985	Virbac New Zealand Ltd	150g/kg
A006013	PetGard 5 Month Flea Band for Dogs	06-11-1989	Virbac New Zealand Ltd	150g/kg
A006369	Billy Peach 5 month Stardust Flea Collar for Cats	10-09-1991	Virbac New Zealand Ltd	150g/kg
A006370	Billy Peach 5 month Stardust Flea Collar for Dogs	10-09-1991	Virbac New Zealand Ltd	150g/kg
A009023	Vitapet Triple Active 5 Month Flea Collar (dogs and cats)	27-11-2001	Virbac New Zealand Ltd	150g/kg (pyriproxyfen, 2.5g/kg)
A007692	TripleGard Triple Active Flea Band for Cats	27-10-1998	Virbac New Zealand Ltd	150g/kg (pyriproxyfen, 2.5g/kg)
A007693	TripleGard Triple Active Flea Band for Dogs	27-10-1998	Virbac New Zealand Ltd	150g/kg (pyriproxyfen, 2.5g/kg)
A005442	Vitapet 5 Month Flea Collar For Cats	25-03-1987	Vitapet Corporation Ltd	150g/kg
A005441	Vitapet 5 Month / Water Resistant Flea Collar For Dogs	20-03-1987	Vitapet Corporation Ltd	150g/kg

A005443	Masterpet 5 Month Flea Collar for Cats	06-01-1987	Masterpet Corporation Ltd NZ	150g/kg
A005444	Masterpet 5 Month / Water Resistant Flea Collar For Dogs	25-03-1987	Masterpet Corporation Ltd NZ	150g/kg
A009825	Pet Team 5 Month Flea Collar For Cats	29-01-2007	Pet Team Company (A division of Masterpet Corporation Ltd)	150g/kg
A009827	Pet Team 5 Month / Water Resistant Flea Collar For Dogs	29-01-2007	Pet Team Company (A division of Masterpet Corporation Ltd)	150g/kg

Table 2. Summary of Uses of Diazinon and its formulations in the control of ectoparasites and their associated diseases in New Zealand.

Product	Host species	Ectoparasites	Associated disease	Application method	Application rates[1]	Frequency/ duration of application	Efficacy
Top Clip	sheep	biting louse	fleece damage/skin irritation and damage (cockle)	plunge dip, shower dip, jetting	200g/1000L 400g/1000L 500g/1000L	usually once a year	good
		blowflies	Fleece stain/skin damage and infection/wasting/ death	plunge dip, shower dip, jetting	200g/1000L 400g/1000L 500g/1000L	as required, usually x2 p.a./4 weeks residual activity against fly strike	good
		ked	skin irritation/cockle/ fleece damage	plunge dip, shower dip, jetting	200g/1000L 400g/1000L 500g/1000L	usually once a year	good
Strike Powder	sheep	blowflies	skin damage and 2º infection/wasting/ death	dusting	cover affected areas	as required for wounds and active strike, once at docking of lambs	good
	horses	lice/fleas	skin irritation/wound dressing	dusting on animal and stables	cover whole body surface	as required/repeat at 2 weekly intervals if necessary	good
	dogs	lice/fleas	skin irritation/flea allergy/transmission of tapeworms	dusting on animal and kennel/ bedding	cover whole body surface	as required/repeat at 2 weekly intervals if necessary	good
Flea collars	dogs and cats	fleas (ticks[2])	skin irritation/flea allergy	continuous wearing of collar for 5 months	150g/kg of collar	as required/up to 5 months	good

[1] see text.

[2] The manufacturer of one product claims “aid in the control of ticks”.

Table 3. Export values of the sheep and horse industries.

Sheep industry [1]		$ millions p. a.	
Meat	Lamb	2,247	
	Mutton	391	
Total from meat			> $2638
Wool	Fibre	613	
	Wool carpet and rugs	76.1	
	intermediate products; tops, yarns, sliver, etc.	184	
Total from wool			> 873
Total from sheep			**> 3,511**
Horse industry			
Thoroughbred horse exports [2]		130	
Harness horse exports [3]		10	
Sport horse exports [3]		19	
Total from horses			**159**

[1] Compendium of New Zealand Farm Facts, 33rd Edition, March 2009. Meat & Wool New Zealand Economic Service, Wellington

[2] www.nzthoroughbred.co.nz

[3] Town Centre Development Group, Sandringham. 2005

Table 4. Maximum Residue Levels (MRL) and Maximum Permissible Levels (MPL) of diazinon in New Zealand and Australia.

New Zealand MRLs[1]	mg/kg	**Australian MRLs[2]**	mg/kg	**New Zealand MPLs[3]**	mg/kg
Fats (except milk fats)	0.7	Meat (mammalian) (in the fat)	0.7	Mammalian fat	0.7
		Edible offal (mammalian)	0.7	Meat, fat and offal of any mammal	0.1
				Meat, fat and offal of any other animal	0.01
		Milks (in the fat)	0.5		
Default for other foods	0.1	Default for other foods	0.0		

[1]New Zealand (Maximum Residue Limits of Agricultural Compounds) Food Standards (the MRL Standards)
[2]Standard 1.4.2, Schedule 1, of the Australia New Zealand Food Standards Code
[3]Animal Products (Contaminant Specifications) Notice 2008.

Table 5. Alternatives to diazinon for the control of ectoparasites on sheep.

Pesticide class	Pesticide active and (product) names	Method of application	Principal target organism and (others)
Pyrethroid	alpha-cypermethrin (Vanquish)	applicator[1]	biting louse (fly strike)
	deltamethrin (Wipeout, Lice-enz)	applicator	biting louse and keds
Organophosphate	chlorpyrifos (Xterminate 10, Xterminate 40)	plunge, shower, jetting	biting louse, keds (fly strike)
	propetamphos (Seraphos 1250)	plunge, shower, jetting	biting louse, keds (fly strike, ticks)
	chlorfenvinphos (FIL Flystrike Aerosol)	dressing	fly strike
Macrocyclic lactone (avermectin/milbemycin)	ivermectin (Erase Jetting Liquid)	spray race and jetting, dressing	fly strike (biting louse)
	ivermectin (Ivomec Maximizer CR Capsule for adult sheep, Ivomec Maximizer CR Capsule for lambs)	ruminal constant release capsule	gastrointestinal nematodes, itch mite, nasal bot, ked (fly strike)
	doramectin (Dectomax Injectable)	injection	gastrointestinal nematodes, lungworm, itch mites, nasal bot (fly strike)
Spinosyn	spinosad (Extinosad)	plunge, shower, jetting, dressing	biting louse, fly strike
	(Expo Extinosad)	pour - on	biting louse
	(Extinosad Aerosol)	dressing	fly strike
IGR[2], chitin synthesis inhibitor (Benzoyl urea)	diflubenzuron (Blitz, DuoDip IGR Jet and Dip for sheep, Ectogard Fleecemaster, Magnum, Zenith, Zenith Spray On)	plunge, shower, jetting, spray-on, applicator	fly strike, biting louse
	triflumuron (Clipguard Pour-on for sheep, Epic Ezy Pour-on for sheep, Exilice, Exit, , Zapp Pour-on, Zapp Jetting Liquid)	applicator, spray-on, jetting	fly strike (biting louse)
IGR, chitin synthesis inhibitor	cyromazine[3] (Cyrazin Liquid, Cyrazin Spray-on, Lucifly	plunge, shower, jetting, spray-	fly strike

(Triazine)	liquid, Lucifly Spray-on, Luzine Liquid, Luzine Spray-on, Swat Liquid, Swat Spray-on, Vetrazin Liquid, Vetrazin Spray-on)	on, applicator	
IGR, chitin metabolism disruption (Pyrimidine carbonitrile)	dicyclanil (Clik,Clikzin)	spray-on	fly strike
Organophosphate/ fumigant	propetamphos/ 1,4-dichlorobenzene (Maggo)	dressing	fly strike.
Organophosphate/ pyrethroid	chlorpyrifos/ cypermethrin (Flypel)	applicator	fly strike (biting louse and ked)
IGR, chitin synthesis inhibitor (Benzoyl urea)/ nicotinoid	triflumuron / imidacloprid (Zapp Encore)	pour-on	fly strike, biting louse
Spinosyn/ IGR, chitin synthesis inhibitor (Triazine)	spinosad/cyromazine/ (Cyrex Liquid[4])	shower/jetting, dressing	biting louse, fly strike

(Sources: IVS Catalogue 2010; New Zealand Food Safety Authority website: https://eatsafe.nzfsa.govt.nz/web/public/acvm-register and FIL New Zealand Ltd website: http://www.fil.co.nz/newsite/Online/sector_results.html?sector=Animal%20Health)

[1]Applicators are hand-operated devices delivering product through single or multiple nozzles to the backline and/or breech at low pressure.

[2]IGR, insect growth regulator

[3]There are 25 products containing this active ingredient registered; only a representative selection is shown here.

[4]Registered but not yet launched on the New Zealand market.

Table 6. Representative retail costs of products containing the range of actives available for controlling the biting louse and fly strike of sheep.

Active	Plunge or shower dipping Adult	Jetting Adult	Jetting Lamb	Pour-on or applicator Adult	Pour-on or applicator Lamb
Diazinon	5 – 6 [1]	na	2 - 4	na	na
Chlorpyrifos	5 - 9	na	na	na	na
Propetamphos	5 – 6	na	na	na	na
Pyrethroids	na	na	na	21 - 86	15 - 58
Spinosad	15 - 30	40	16	*	*
Ivermectin	na	61	*	na	na
Diflubenzuron	24	40	*	65 - 194	32 -65
Triflumuron	na	*	*	46 - 58	22 - 28
Cyromazine	24 - 57	32	*	105 - 140	34 -50
Dicyclanil	na	na	na	151	*

[1] Cents per sheep

na = not applicable

* data not obtained

Table 7. Alternatives to diazinon for the control of ectoparasites on dogs and cats.

Pesticide class	Pesticide active and (product) names	Method of application	Host and target organisms
Botanical	Rotenone (Pestene Insect Powder)	dusting	dogs, cats - lice, fleas, mites
Pyrethroid	permethrin (Billy Peach Flea Shampoo, Masterpet 3 in 1 Flea Shampoo, Vitapet Flea Shampoo, Pet Team Flea Shampoo)	shampoo	dogs, cats - fleas
	(Bugg-off, Buzz-off II)	spray, wipe	dogs - flies, mosquitoes, fleas, environment
	(Vitapet Flea Powder, Masterpet Flea Powder, Pet Team Flea Powder)	dusting	dogs, cats - fleas, environment
	(Permoxin™ Concentrate)	rinse, **s**pray	dogs - fleas, flies, ticks, environment
Pyrethroid /synergist	pyrethrins/piperonyl butoxide (Fido's Flea Shampoo, Naturalgard Shampoo)	shampoo	dogs, cats - fleas, lice
	pyrethrins/dicarboximide/piperonyl butoxide (Fido's Flea Rinse)	bath, spray, swab	dogs, cats - fleas, lice, ticks, environment
Organophosphate	maldison (Flea Di Powder)	dusting	dogs, cats - fleas, lice, environment
	coumaphos (Asuntol)	spray, bath	dogs - fleas, ticks, lice, environment
	fenthion (Spotton)	spot on	dogs, cats - fleas
Pyrazole	pyriprole (Prac-tic)	spot on	dogs - fleas, ticks
	fipronil (Frontline Top Spot, PetScience Fipronil Easi Spot, Frontline Spray)	spot on, spray	dogs, cats - fleas, lice, ticks
Nicotinoid	imidacloprid (Advantage)	spot on	dogs, cats - fleas
	nitenpyram (Capstar tablets)	oral	dogs, cats - fleas
Spinosyn	spinosad (Comfortis tablets)	oral	dogs - fleas
Macrocyclic lactone	selamectin (Revolution)	spot on	dogs, cats - fleas, sarcoptic and ear mites, round worms
IGR[1], juvenile hormone mimic	pyriproxyfen (Cyclio Spot-On Flea Control)	spot on	dogs, cats - fleas
IGR, chitin	lufenuron (Program 80, Program	injection	cats - fleas

synthesis inhibitor (Benzoyl urea)	40) (Program Tablets) (Program Oral Suspension)	 oral oral	 dogs - fleas cats - fleas
Pyrazole/IGR, juvenile hormone mimic	fipronil/s-methoprene (Frontline Plus)	spot on	cats and dogs - fleas, tick, lice
Pyrethroid/ IGR, juvenile hormone mimic	Permethrin/pyriproxyfen (Vitapet Ezi-Squeeze Triple Active Flea and Tick Control, Pet Team Multicare Flea-Off Flea Treatment, PetScription TripleGard Anti-Itch Flea Shampoo etofenprox/pyriproxyfen (Multicare Flea-off, Vitapet Triple Active Ezi-Squeeze Flea Control, Bodygard Plus**)**	spot-on, backline, bath spot-on	dogs - fleas, ticks cats - fleas
Pyrethroid/ synergist/IGR, juvenile hormone mimic	pyrethrins/permethrin/ dicarboximide/ pyriproxyfen (Vitapet Triple Active Flea Spray, PetScription TripleGard 3 Flea Spray)	spray	dogs, cats - fleas
Macrocyclic lactone/ nicotinoid	moxidectin/ imidacloprid (Advocate)	spot on	dogs - fleas, lice, mites, roundworms, hookworms, whipworms cats - fleas, ear mites, roundworms, hookworms

(Sources: IVS Catalogue 2010; New Zealand Food Safety Authority website: https://eatsafe.nzfsa.govt.nz/web/public/acvm-register)

[1]IGR, insect growth regulator

Table 8. Alternatives to diazinon for the control of ectoparasites on horses

Pesticide class	Pesticide active and (product) names	Method of application	Target organisms
Pyrethroid	permethrin (Bugg-Off, Buzz-off II, Permoxin™ Concentrate) cypermethrin (Ripcord)	spray, wipe spray, shower	flies, fleas, ticks, mosquitoes; environment flies
Organophosphate	coumaphos (Asuntol)	spray	fleas, ticks, lice; environment
IGR[1], chitin synthesis inhibitor (Benzyl urea)	triflumuron (Lice 'n' Simple Pour-On Equine Lousicide)	pour on	lice
Pyrethroid/synergist/ repellents	permethrin/piperonyl butoxide/dicarboximide/ dibutyl phthalate/deet (Flyaway)	spray	flies

(Sources: IVS Catalogue 2010; New Zealand Food Safety Authority website: https://eatsafe.nzfsa.govt.nz/web/public/acvm-register)

[1]IGR, insect growth regulator