DRAFT SHEEP DIP POLLUTION REDUCTION PROGRAMME

1.Introduction

Sheep are prone to attack by a number of pests such as scab, blowfly, ticks and lice. To safeguard animal welfare such infestations are treated with authorised veterinary medicines. Products are either applied externally, by pour-ons, plunge dipping, shower spraying or high pressure jetting, or internally via injection.

Two active ingredients are authorised for use in 'sheep dip' products which are applied externally: the synthetic pyrethroid, cypermethrin and the organo-phosphate, diazinon. Both chemicals are highly toxic to aquatic life and entry into streams and rivers can occur via:

- use of sheep dip products on farms
- discharge of wool textile effluents via sewage treatment works.

Routine monitoring and targeted investigations by the Environment Agency shows levels of contamination in rivers and streams and impacts on wildlife from these active ingredients are unacceptable.

In 2003 about one third of all Environmental Quality Standard (EQS) failures in freshwaters in England and Wales were due to sheep dip. Between January 2004 and May 2005 thirty four sheep dip incidents causing major or significant ecosystem damage and effects on water quality were investigated in England and Wales. The great majority of serious incidents involved cypermethrin, reflecting its much greater toxicity to many forms of aquatic life. In 2005 eight farmers have been prosecuted by the Environment Agency (EA).

The introduction of the Water Framework Directive means water bodies across Europe will have to meet 'good ecological status' by 2015. Early risk mapping estimates that around half of Welsh water bodies are at risk of failure

because of sheep dip pollution, as well as other locations in the England where sheep farming takes place.

This Pollution Reduction Programme (PRP) has been prepared because the EA and Veterinary Medicines Directorate (VMD) agree that action is urgently needed to tackle the unacceptable impacts sheep dip products containing cypermethrin and diazinon are having on the environment. Whilst focus is presently on England and Wales, it is the intention the PRP could also cover Scotland and Northern Ireland.

Representatives from farming organisations, environmental NGOs with interests in fishing and wildlife, sheep dip manufacturers, the wool textile industry, government and relevant regulatory authorities discussed potential actions which could be taken to tackle sheep dip pollution at a stakeholder meeting on 30th September 2005. The outcomes from this meeting, and views obtained from other groups including the Veterinary Products Committee (VPC) and the EA's regional environment and fisheries committees have been used to develop the PRP Action Plan included in this document.

2. The Action Plan

A phased approach

The Action Plan is phased, identifying short, medium and long term actions. This phased approach is in line with the views of those attending the sheep dip stakeholder meeting help by VMD and the EA on 30th September 2005.

Many of the short term actions are investigational in nature, and their outcomes will inform the shape of the subsequent medium and long term actions. Thus, at this stage, whilst the short term actions can be clearly defined, this level of detail is not possible for the medium and long term actions. In this respect the action plan should be considered a live document,

with medium and long term actions being subject to refinement as and when new information becomes available.

It is proposed all short term actions are implemented over the first 12 month period, with some starting immediately. The majority of these actions are relatively small and discrete and will not require significant resource to deliver. In addition there was clear agreement between the many stakeholders involved in the sheep dip meeting that momentum in tackling the sheep dip issue needs to be maintained and some simple measures should be taken swiftly to try to halt the rise in environmental impacts.

Medium and long term actions are proposed to run from Year 1 to Year 4, and from Year 5 onwards respectively. Compared with short term actions, medium and long term ones may be more onerous with respect to resource requirements and impact on present practice. As such they will be subject to a cost effectiveness study. This will involve reviewing all potential actions so that those which are most effective in reducing environmental impacts, which ensure 'good ecological status' in our rivers, and which are least costly (for farmers, regulators, industry) to deliver can be identified.

Groups of Actions

Within the plan 5 groups of actions have been identified. These span across the short, medium and long term periods of the plan. They are:

(i) **Raising user awareness**. There are a range of actions that can be taken associated with generation of better guidance for users, and better delivery of that guidance.

(ii) **Understanding impacts**. Some information gaps exist, such as the extent of sheep dip impacts across the UK, and the relative importance of different exposure routes to the aquatic environment. Science and field investigations are needed to fill these gaps, so that risks are better understood and action can be better targeted.

(iii) **Using existing initiatives and tools**. There are a wide range of agri-environment and rural initiatives, and food assurance schemes already in place in the UK funded by Government, Europe and industry, as

well as over arching Government strategies on agriculture and rural development. It may be sheep dip management could be more prominent within these initiatives and opportunities are not being maximised. Several agricultural risk management tools also exist with the possibility for wide application to sheep dip. Review work to ascertain whether existing initiatives and tools could be used to better effect should be undertaken. Significant new initiatives for sheep dip should only be set up where gaps are identified.

(iv) **Product reviews.** Sheep dip products are presently subject to a marketing authorisation renewal process. More information is needed from manufacturers on how to safely use existing products. Less toxic alternatives to cypermethrin and diazinon are needed.

(v) **Regulatory action.** Some existing regulatory mechanisms (e.g. Certificate of Competence) need strengthening. In addition the scope of regulatory options (e.g. products bans) available needs to be reviewed, such that the right options are in place and ready to use should non-regulatory action fail to bring about the necessary environmental improvements.

Management of the Plan

It is proposed the Action Plan should be managed by a steering group of stakeholders. It is not the intention of Government or the regulatory authorities to take on full responsibility for delivery of the action plan. This should be considered a joint responsibility to be shared by those who benefit from the marketing and use of sheep dip, by government and regulators, and by non-governmental bodies with concerns about the environmental impacts of sheep dip (e.g. angling and wildlife groups). The steering group will oversee all aspects of delivery including further development of the plan as time goes on, and measuring and reporting on progress.

It is intended the plan will identify an organisation or group responsible for taking the lead on each action, and that where necessary (likely to be most instances) they will co-ordinate with existing stakeholders and others to ensure its delivery.

Objectives, targets, and reporting progress

The objectives of the Action Plan have been set out in terms of a significant reduction in environmental contamination and damage, and a need to meet the Water Framework Directive objective of ‘good ecological status’. However, it is considered that beneath these broad objectives more definitive, time limited targets should be set (e.g. using environmental data and indicators) and that these should be routinely used to assess progress, at least on an annual basis. The development of these targets should be one of the first jobs of the working group.

ACTION PLAN

Objectives

- To significantly reduce the environmental contamination and damage caused by sheep dip
  - On farms (from what to what…stakeholder group to identify some targets and indicators)
  - From the sewage works receiving wool textile effluent (from what to what… stakeholder group to identify some targets and indicators)
- To ensure sheep dip is not responsible for river catchments failing to meet 'good ecological status' under the Water Framework Directive

Within the plan, actions are grouped into those of a short, medium and long term nature. Within each of these groups there is further categorisation of actions, signalling the type of activity (e.g. raising user awareness, product review, regulatory action etc.). The order in which the individual actions are listed within the short, medium and long term groups should not be taken to reflect their relative priority within that group, or the order in which they should be implemented.

	Description of Action	**Category of action**	**Who leads?**	**Comments**
SHORT TERM ACTIONS – over the next 12 months				
1	Publish poster on sheep dip for distribution to sheep dip merchants.	Raising user awareness	VMD	To have in place for main purchasing of dip next taking place early Spring 2006.
2	Publish and circulate A4 laminated guidance sheets to farmers, contractors and relevant regulatory staff.	Raising user awareness	EA	To have in place for early Spring 2006.
3	Produce interim guidance for contractors and farmers on the use of showers and jetters.	Raising user awareness	NAAC	Interim guidance is possible but NAAC indicate further work is needed to provide definitive guidance (also see Action 25 and 37).
4	Ensure 'suitably qualified persons (SQPs) at	Raising user	AMTRA	This programme of training will take

	merchant outlets are trained (via existing routes) on the environmental toxicity of sheep dip.	awareness		place over the next 3 years, and thus spans the short and medium term periods of this plan
5	Update HSE's leaflet on how to dip sheep safely, enhancing environmental messages consistent with Defra CoP on Sheep Dipping.	Raising user awareness	HSE	
6	Conduct targeted environmental monitoring outside of Wales to better identify scope and magnitude of sheep dip impacts elsewhere in the UK.	Understanding impacts	UK env regulators	This data should also be used for WFD risk mapping for sheep dip.
7	Establish a network of UK monitoring sites that can be used to provide base line chemical and biological data on sheep dip impacts, and track trends over time (i.e. a sheep dip indicator).	Understanding impacts	UK env regulators	This data should also be used for WFD risk mapping for sheep dip.
8	Identify whether monitoring data collected by the wool textile industry can be used as an additional sheep dip indicator.	Understanding impacts	CBWT	
9	Review EQSs for cypermethrin and diazinon in light of new information on ecotoxicity.	Understanding impacts	UK env regulators	
10	Identify additional scientific research (beyond Action 9 and 26) needed to better understand impacts of sheep dip on the environment, such that risk management actions are correctly targeted.	Understanding Impacts	Stakeholder sub group?	Discussion and agreement on the need for any further scientific research, its nature, funding etc. could be taken forward by a stakeholder sub group.
11	Review existing flock management and biosecurity initiatives and how these might be expanded to all sheep farming areas in the UK.	Using existing initiatives	Government / UK Regulators	Such initiatives should reduce sheep scab. Review: • Scottish initiative • Existing sheep flock management

				tool
12	Scope out existing environmental risk management tools used by farmers and identify which could be usefully extended to sheep dipping.	Using existing initiatives	UK Regulators	• LERAPs • ? others
13	Scope out existing agri-environment initiatives and identify which could offer scope for provision of education / assistance on sheep dipping, and how this could be implemented.	Using existing initiatives	EA	Initiatives include: • Farming Connect (Wales) • Tir Cynnal, Tir Gofal • Environmental Stewardship • Small scale 'catchment adviser' initiatives (e.g. with FWAG, Rivers Trust) • Multi-agency catchment sensitive farming project • EA catchment co-ordinators • Catchment Sensitive Farming Initiative (Defra & WAG)
14	Review how existing farm assurance schemes for lamb are managed and the scope for strengthening environmental criteria relating to sheep dip.	Using existing initiatives	EA	Need to liaise with: • Assured British Meat • Farm Assured Welsh Livestock • Meat and Livestock Commission
15	Review the scope of Government rural strategies / plans and identify potential to build in initiatives on sheep dip.	Using existing initiatives	Defra	Initiatives include: • Wales Rural Development Plan • England Rural Development Plan • The Rural Strategy (Defra) • Regional Rural Development Frameworks • Government strategy for

				Sustainable Farming and Food Need to consult with Rural Development Agency
16	Review the role Cross Compliance can play in the management of sheep dip pollution.	Using existing initiatives	UK Regulators	
17	Consider whether setting up a Voluntary Initiative for sheep dip would be worthwhile and how this would work.	Using existing initiatives	Farming Unions, NSA	
18	Confirm through exposure modelling / risk assessment techniques, the amount of time sheep should be kept away from water post dipping.	Product review	Sheep dip manufacturers	Can be progressed as part of present marketing authorisation renewal process for sheep dip products overseen by VMD
19	Review present labelling on sheep dip products and strengthen messages about (i) environmental toxicity and (ii) amount of time sheep must be kept away from water post dipping.	Product review	Sheep dip manufacturers	Can be progressed as part of present marketing authorisation renewal process for sheep dip products overseen by VMD
20	Continue investigations into alternative sheep dipping products.	Product review	Defra	3 projects are currently underway. The projects are complex and likely to span the short, medium and long term periods of this action plan.
21	Conduct literature review to identify world wide research on alternatives to diazinon and cypermethrin.	Product review	Sheep dip manufacturers?	
22	To review to use of sheep dip treatment / neutralising agents and whether they should be promoted.	Product review	VMD	
23	Confirm the changes needed in the Certificate of Competence and how to deliver these.	Regulatory action	VMD	• Must include purchasers and users

				• Strengthen environmental training • Time limit • Reinforce its need via regulatory and non regulatory routes.
MEDIUM TERM ACTIONS Year 1 – Year 4 (actions subject to cost effectiveness study prior to implementation)				
24	Update the existing UK Codes of Practice (e.g. Groundwater Protection Code: Use and disposal of sheep dip compounds) and consider whether to strengthen their statutory status.	Raising awareness	EA	
25	Produce definitive environmental guidance on the use of showers and jetters.	Raising awareness	EA	Follows on from Action 3. The use of sheep dip products in showers and jetters needs to come under label approval (see Action 37. Action 25 and 37 should be addressed together.
26	Conduct research and field studies to clarify what the specific causes of most sheep dip incidents are.	Understanding impacts	VMD/EA	Should include: • Role of sheep entering watercourses, • Risks from jetters and showers
27	Conduct further scientific research identified under Action 10	Understanding impacts	Defra/VMD/EA	
28	Implement any actions relating to flock management and biosecurity, as a result of review carried out under Action 11	Using existing initiatives	Government/UK Regulators	
29	Implement any actions relating to use of existing farm risk management tools, result of review carried out under Action 12	Using existing initiatives	UK Regulators	
30	Implement any actions relating to use of agri-	Using existing	EA	

	environment initiatives, as a result of review carried out under Action 13	initiatives		
31	Implement any actions relating to Farm Assurance schemes, as a result of review carried out under Action 14	Using existing initiatives	EA	
32	Implement any actions relating to Government rural strategies, as a result of review carried out under Action 15	Using existing initiatives	Defra	
33	Implement any actions relating to Cross Compliance as a result of review carried out under Action 16	Using existing initiatives	UK Regulators	
34	Implement a voluntary initiative for sheep dip should the review carried out under Action 17 conclude this is worthwhile.	Using existing initiatives	Stakeholders	
35	If gaps in how to effectively reach users of sheep dip still exist after implementation of Actions 28 – 34 instigate further measures.	Raising awareness	Stakeholders	May include: • Targeting high priority catchments • Undertaking training days
36	Subject to the outcomes of Action 22 consider the feasibility of selling sheep dip treatments / neutralisers as an integral part of the sheep dip product.	Product reviews	VMD	
37	Encourage dip manufacturers to gain label approval for use of dip in showers and jetters, and provide label information on products.	Product reviews	VMD	Also see Action 25
38	Review the feasibility and costs / benefits of phasing out cypermethrin.	Product review	VMD	
39	Identify and cost out the range of regulatory measures that could be imposed if non-regulatory actions fail to achieve sufficient	Regulatory action	Government, UK regulatory authorities	Will be informed in part from findings from Action 36, since one potential regulatory action is the phase out of

	progress towards action plan objectives.			cypermethrin
40	Amend the CoC in light of findings from Action 23.	Regulatory action	VMD	
LONG TERM ACTIONS Year 5 onwards (actions subject to cost effectiveness study prior to implementation)				
41	Implement regulatory controls, if necessary, as identified under Action 37.		UK Regulators	E.g. phase out of cypermethrin

3. ANNEX

This Annex contains background information on sheep dip, split into the following sections:

3.1 The chemicals used
3.2 Entry routes in the environment
3.3 Evidence of environmental impacts
3.4 Codes of Practice and other guidance

3.1 The chemicals used

In the UK, sheep dip products must be approved for use by the Veterinary Medicines Directorate (VMD). These products are effective by virtue of the insecticides they contain, notably the organophosphate (OP) diazinon and the synthetic pyrethroid (SP) cypermethrin.

In recent years, products based on the synthetic pyrethroids have assumed greater importance because (a) these active ingredients are less toxic to operators and by-standers who may come into accidental contact with the product, and (b) there is no longer a legal requirement to treat for scab, a condition that is more effectively controlled by OP insecticides. The synthetic pyrethroids are less persistent in the environment than many of the organophosphate and carabamate insecticides but, as we explain later, are highly toxic at low concentrations to many aquatic fauna.

The environmental fate of these insecticides is determined by their physico-chemical properties. Diazinon is more water soluble and, by virtue of its lower octanol:water partition coefficient, is less likely to bioaccumulate or to sorb to biota and sediments. Indeed, cypermethrin is rapidly lost from the water column by a process of sorption in this way. Both substances are liable to biotic and abiotic degradation in the environment with typical half-lives in water of a few weeks. Whereas cypermethrin is stable under acidic conditions, diazinon hydrolysis is increased under both acidic and alkaline conditions compared to that at neutral pH. Analysis of cypermethrin is complicated by the

existence of three asymmetric carbon atoms in the molecule giving rise to 2 x 2 x 2 = 8 different isomers, four adopting a *trans* conformation and four a *cis* conformation. Routine analysis of cypermethrin underestimates the true concentration present in a sample because the reference standard used is a mixture of *cis* isomers that can fail to quantify the *trans* isomers present.

Table 1 summarises the products currently available and the active ingredients they contain and Table 2 summarises trends in the use of OP and SP sheep dips, based on total UK sales.

Table 1 Sheep Dip products used in the UK

Product	Active ingredient
Coopers Ectoforce	Diazinon
Osmonds Gold Fleece	Diazinon
Paracide Plus	Diazinon
Auriplak Fly and Scab	High-cis Cypermethrin
Ecofleece	High-cis Cypermethrin
Robust	High-cis Cypermethrin

Table 2 Sales (tonnes p.a.) of sheep dip products 2000-2004 (VPC Annual Report 2004 – Appraisal Panel for Human Suspected Adverse Reactions to Veterinary Medicines)

Year	2000	2001	2002	2003	2004
OP[1]	10	48	13	54	20.5
Non-OP[2]	9	1.7	4.5	8	5.5

Clearly, annual sales of sheep dips fluctuate markedly. The drop in sales of non-OP dips in 2001 coincided with the return to the market of OP dips, whilst a general decrease in sales of both OP and non-OP dips in 2004 may be linked to a shift toward the use of pour-ons and injectables rather than dips.

Defra has funded four research & development projects on the development of non-chemical alternatives for the control of sheep scab. All four of these projects have been completed and three continuation projects are currently being funded to develop further the advances made on immunological (vaccine) and biological (entomopathogenic fungi) control methods. Details of this research can be found on the Defra (www.defra.gov.uk) and VMD (www.vmd.gov.uk) websites. These are complex long-term projects and if they

[1] From 2001-4, OP refers to diazinon only but in earlier years also includes propetamphos
[2] Non-OP refers mostly to cypermethrin. The only other SP approved for use in sheep dip (flumethrin) was withdrawn in 2003

do lead to the development of viable alternative products it is unlikely that such products will be available for at least 5 and probably 10 years.

3.2 Entry routes into the environment

Following treatment, residues of sheep dip remain in the sheep's fleece and may be lost to the environment through dripping onto impermeable surfaces, dripping from treated fleeces, loss of wool, product misuse, sheep walking through watercourses, and in processing of fleeces. A further potential source arises from the disposal of spent sheep dip. Disposal to land is the normal method but requires Environment Agency authorisation under the 1998 Groundwater Regulations. Incorrect disposal can lead to contamination of groundwater. Groundwater can feed surface water, and vice versa.

The different sources that may contribute to levels of sheep dip found in rivers is illustrated in Figure 1. The relative importance of these are not well understood but it is reasonable to conclude that industrial sources (fleece processing) are a more important cause of EQS exceedances in Northern England whilst dipping-related sources are more important in upland Wales and other areas of sheep farming.

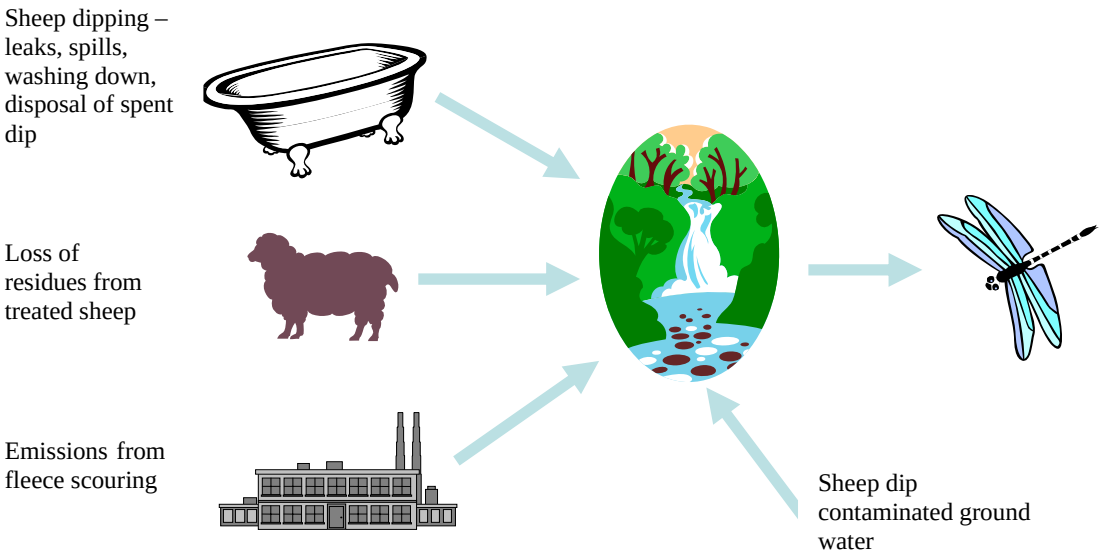

Figure 1. Possible sources of sheep dip and pathways to the aquatic environment

The Environment Agency has recently carried out research on the fate and redistribution of spent sheep dip following disposal. Measures to promote degradation of spent pyrethroid-based products (mixing with lime to raise pH, thereby promoting hydrolysis) have been identified but a survey of farms ('Characterisation and Field Evaluation of Sheep Dip Chemical Disposal: Phase 1', Environment Agency, 2004, R&D Technical Report P2-250/TR) showed that, even with approved methods of disposal, there was clearly potential for migration of sheep dip chemicals into groundwater by leaching or run-off to surface waters.

3.3 Evidence of environmental impacts

Evidence for potential and actual impacts of the two main active ingredients used in Sheep Dip, cypermethrin and diazinon, is available from a variety of sources:

a) Ecotoxicity studies
b) Environmental Quality Standards
c) Environment Agency Pesticide Monitoring
d) Environment Agency Pollution Incident Reports (NIRS)
e) Operational Investigations

<u>a) Ecotoxicity studies</u>

A substantial body of experimental ecotoxicity data is available for both diazinon and cypermethrin. Most of the data have been generated under laboratory conditions and are based on observations made after 24 -96 hours. Such exposure periods are relevant to incidents resulting in exposure for short periods, such as might occur in a spillage. The toxicity data from these experiments are usually expressed as LC_{50} values (the concentration killing 50% of a test population). Some chronic (long-term) studies are also available, in which toxicity is more usually expressed as the highest test concentration at which no adverse effect could be seen (the 'no-effect concentration', NOEC).

Diazinon

Like other OP insecticides, diazinon acts by inhibiting the enzyme acetyl cholinesterase which is involved in the transfer of nerve impulses. When inhibited, the neurotransmitter acetylcholine is no longer broken down and a continuous, uncontrolled firing of nerve impulses results.

Diazinon exhibits high acute toxicity to invertebrates, with acute LC_{50} values between 0.2 and 800 μgl^{-1}. Among the most sensitive species are the crustaceans of the genus *Gammarus* and water fleas e.g. *Daphnia* spp. Insect larvae are also highly sensitive with acute toxicities at only slightly higher concentrations (e.g. 48h LC_{50} to the mayfly, *Cloeon dipterum* of 7.8 $\mu g/l$). Chronic no-effect concentrations below 1 μgl^{-1} are also reported.

Fish, planarians, molluscs and annelids are less sensitive but a 96h LC_{50} to rainbow trout of 90 μgl^{-1} is reported and lower LC_{50} values are reported for some warm water fish species such as bluegill sunfish (*Lepomis macrochirus*).

Studies on freshwater communities carried out under simulated field conditions confirm the high sensitivity of insect larvae and crustaceans with an estimated population-level NOEC for chironomids and cladocerans of <2.4 μgl^{-1} (Giddings *et al*, 1996, Environmental Toxicology and Chemistry, 15, 618-629) and significant drift of *Hyalella* even at concentrations of 0.3 $\mu g/l$ (Arthur *et al*, 1983, Aquatic Toxicology, 4, 283-301).

Cypermethrin

Cypermethrin acts by altering ion permeability of nerve membranes, causing trains of nerve impulses that ultimately immobilise sensitive organisms. It has also been shown to inhibit ATPase enzymes involved in movement of ions against a concentration gradient; this action is critical to fish and aquatic insects because these processes are used to regulate oxygen exchange (Siegried, 1993, Environmental Toxicology and Chemistry, 12, 1683-1689).

Fish and invertebrates are particularly sensitive and a substantial body of experimental evidence has been gathered to quantify its toxicity. Much of these data refer to 'target' species such as midge and mosquito larvae but data for 'non-target' species have also been generated. Acute LC_{50} values for most crustaceans and insects lie in a range between 0.03 and 5 μgl-1. However, some species are much more sensitive, including some commonly encountered freshwater invertebrates (Table 3). On a simple concentration basis, cypermethrin is more toxic to aquatic invertebrates than diazinon.

Table 3 Acute toxicity of cypermethrin to some indigenous freshwater invertebrate species

Species	Exposure duration (h)	LC_{50}(μgl^{-1})
Freshwater shrimp, *Gammarus pulex*	96	0.009
Mayfly, *Cloeon dipterum*	96	0.02
Mayfly, *Baetis rhodani*	96	0.012
Water hog louse, *Asellus aquaticus*	24	0.2
Water boatman, *Corixa punctata*	96	5.0
Water flea, *Daphnia magna*	24	2.0
Whirligig beetle, *Gyrinus gyrator*	24	>5.0 (unable to swim and dive when exposed to 0.07μgl^{-1})

In a comprehensive analysis of pyrethroid toxicity data, Solomon *et al* (2001, Environmental Toxicology and Chemistry, 20, 652-659) estimated that a cypermethrin concentration of 0.006 μgl^{-1}represented the lower 10th percentile of the distribution of arthropod sensitivities. In other words, at this concentration, we would expect to see significant mortalities in no more than 10% of the species present. Broadly similar conclusions were drawn by Friberg-Jensen *et al* (2003a and b, Aquatic Toxicology, 63, 357-371 and 373-389) from experiments on freshwater communities under field conditions, in which they showed that, over a period of 11 days, the no-effect concentration for sensitive taxa was 0.01μgl^{-1}.

Finally, much of the cypermethrin entering a watercourse will quickly sorb to bed and suspended sediments. Recent studies show that such residues are

bioavailable, causing toxicity to benthic species at concentrations that can be explained by uptake from the sediment pore water (Maund *et al*, 2002, Environmental Toxicology and Chemistry, 21, 9-15). The significance of this observation is that sorption to bed sediments does not necessarily render residues of cypermethrin unavailable to exert biological imapcts.

Other taxa, such as molluscs, algae, amphibians and fish are less sensitive to cypermethrin, as shown by the appreciably higher LC_{50} values for these taxonomic groups, although acute LC_{50} values as low as 0.5 $\mu gl^{-1}$are reported for some fish species (particularly salmonids).

Effects of cypermethrin and diazinon on the Atlantic salmon

A research programme undertaken by CEFAS between 1990-2002 has highlighted sublethal effects of sheep dip chemicals on salmonids at concentrations close to the EQS concentrations.

Moore and his co-workers (Moore and Waring, 1995, Journal of Fish Biology, 48, 758-775; Moore and Waring, 2001, Aquatic Toxicology, 52, 1-12) found that both diazinon and cypermethrin affected the olfactory system of the salmon, reducing the ability of the male fish to detect and respond to the female priming pheromone. This is important because it plays a key role in synchronising reproductive physiology and behaviour. In laboratory experiments, the olfactory system of the male fish was significantly affected by exposure to 0.4 μgl^{-1}diazinon and <0.004 μgl^{-1}cypermethrin. This resulted in a significant reduction in the sperm produced by the spawning male salmon exposed to cypermethrin. Moreover, endocrine responses of the male to the female priming pheromone was reduced after exposure to 0.06 μgl^{-1}diazinon. These concentrations are within the range measured in surface waters and are close to the EQS values for these substances (see later).

Other effects on salmon reproduction were also seen, but at higher concentrations. These included effects on sperm motility, egg development and survival of the embryos. Sub-lethal effects on the surviving embryos

(increased steroid and cortisol levels, decreased levels of thyroid hormones) were also evident following exposure to 5-10 μgl^{-1}diazinon. These effects are summarised in Table 4; they are significant because they point to possible impacts on reproduction at levels of diazinon and cypermethrin that can occur in the environment.

Table 4 Sublethal effects of sheep dip insecticides on Atlantic salmon, in relation to concentrations detected in surface waters. (Potter & Dare Science Series Technical Report 119, CEFAS 2003)

Endpoint	Diazinon (μgl^{-1})	Cypermethrin (μgl^{-1})
Threshold levels for harmful effects		
Olfactory disruption (males)	0.4	>0.001
Endocrine response (males)	0.06	-
Sperm reduction/mortality	-	>0.001-0.5
Embryo mortality/impairment	5-10	0.03
Environmental levels		
Max levels measured (EA Pesticide Monitoring Report, 2003)	0.1-5.2	0.002- 0.027
Max levels recorded in salmon rivers (CEFAS)	18.5-35	0.85

b) Environmental Quality Standards

Environmental Quality Standards (EQSs) for diazinon and cypermethrin have been developed (Environment Agency (2002) *Proposed Environmental Quality Standards for cypermethrin and flumethrin in water*. R&D Technical report P2-115/TR5). These are threshold concentrations derived from existing ecotoxicity data to which a safety factor has been applied, and below which no adverse effects are expected to occur. They are not statutory standards but were developed for operational purposes, as benchmarks for water quality monitoring and for permitting discharges.

The EQSs are expressed as a Maximum Allowable Concentration (MAC) and a lower Annual Average (AA) concentration (Table 5). While the former is based on acute toxicity data, the latter uses chronic data, the lower value for the AA reflecting the greater toxicity following prolonged exposure to these insecticides. Both are used in the assessment of compliance with EQSs (see following Section) but whereas compliance with the MAC may be based on a single sample, compliance assessment against the AA requires several samples to be taken over a 12-month period.

Table 5 Operational EQSs for cypermethrin and diazinon

	Annual Average (μgl^{-1})	**Maximum Allowable Concentration (μgl^{-1})**
Diazinon	0.03	0.1
Cypermethrin	0.0002	0.002

c) Environment Agency Pesticide Monitoring Surveys

Pesticide Monitoring Report 2003 (EQS failures)

About one third of all EQS failures in freshwaters monitored in 2003 were caused by sheep dip chemicals. There are two main sources: sheep-dipping, especially in Wales and the north of England, and discharges from the wool processing industries centred on Yorkshire. In 2003, 44 sites failed EQS standards for cypermethrin and diazinon in England and Wales, compared with 50 sites in 2002, 39 sites in 2001 and 70 sites in 2000 (Table 6).

Table 6 EQS failures for diazinon and cypermethrin in 2003 (EA Pesticide Database 2003)

Chemical	Region	EQS exceedances (number of sites)	Concentrations (gl-1)
Diazinon		*AA*	
	Midlands	2	74.4 - 95.2
	NorthEast	9	32.2 – 98.5
	Wales	2	56.3 – 877.8

	Midlands NorthEast NorthWest Wales	*MAC* 3 16 failures from 9 sites 2 4	159 - 818 110 - 341 106 – 295 104 - 5244
Cypermethrin	NorthEast Southern Wales	*AA* 1 6 6	1.7 0.2 – 0.7 0.2 – 6.8
	NorthEast Southern Wales	*MAC* 1 7 7	20 2.4 – 8.3 2 -27

Although there appears to be a decline in the incidence of EQS exceedances since 2000, changes in sampling locations and the number of samples collected in a year (particularly to assess compliance with the AA) may mask underlying changes in occurrence. Interpretation is further complicated by improvements in analytical sensitivity for diazinon, so that samples previously declared to be free of diazinon might be shown to contain the insecticide. Furthermore, in routine analysis, only *cis*-isomers of cypermethrin are available in a sufficiently pure form to be used as a reference substance. This has an important consequence when reporting measured concentrations of cypermethrin. Instead of reporting the sum of <u>all</u> the peaks (including both *cis* and *trans* isomers), the contribution made by the *trans* isomers is effectively lost because only the *cis* isomers can be quantified. As a result, the reported concentrations systematically underestimate the actual concentration of cypermethrin present, by approximately 25-50%.

Despite these uncertainties, it is clear that routine monitoring shows that both cypermethrin and diazinon can occur in surface waters at concentrations that may pose a risk to aquatic biota.

<u>d) Pollution Incidents</u>

Details of pollution incidents due to sheep dip chemicals are reported by various agencies, including the EA, SEPA, and WIIS, to the Ecopharmacovigilance group headed by the Veterinary Medicines Directorate

(VMD). Numbers of confirmed incidents are subsequently described in VPC SARSS reports and in the VPC Annual Report.

Sheep dip incidents reported in the VPC's 2004 Annual Report are shown in Table 7. These appear to show no particular trend in the number of environmental incidents due to sheep dip insecticides (aquatic pollution) in Scotland, England and Wales.

Environment Agency incident data (covering England and Wales) is now available for 2004, and for 2005 up until May. In 2004 thirty seven incidents concerning sheep dip were investigated, representing a large increase compared with previous years. This increase reflects in part, targeted investigations into sheep dip pollution by Environment Agency field staff, especially in Wales. Twenty two of the incidents reported in 2004 were Category 1 (major) or 2 (significant), and for several prosecution files have been prepared. Up until the end of May 2005, 8 Category 1 incidents 4 Category 2 incidents have been reported. Again, this is in part due to continuing targeted investigations in the Wales. The identification of high levels of environmental impact in Wales through the use of targeted investigations raises the question as to whether similar levels of impact would be identified in other sheep farming regions were EA investigations to be extended.

Table 7 Summary of environmental incidents 2000-2004 (Source: VPC Annual Report 2004)

Year	Aquatic incidents due to dip occurring in	
	England and Wales	Scotland
2000	8	17
2001	5	8
2002	12	4
2003	7	3
2004	to be reported	0

e) Operational Investigations

Reflecting concern about the occurrence and impacts of sheep dip in watercourses, a number of operational investigations have been mounted in Welsh Region in recent years. These have focussed on:

- emissions from sewage treatment works (STWs) receiving inputs from livestock markets or fellmongers/pelt processors and, more recently,
- investigations of watercourses in rural areas

Sewage treatment works

In 1997 and 1998, surveys of the discharges from 12 STWs found detectable concentrations of sheep dip chemicals in 11 of them. In the following year the study was extended to 28 STWs (Welsh Sheep Dip Monitoring Programme: Sewage Treatment Works Report, 1999-2000). Sheep dip chemicals (diazinon, propetamphos and cypermethrin) were found in the final effluent from all but one 'control' works (a works that did not receive any fleece-related inputs). Although MAC exceedances in the final effluent were commonplace, none were found in the receiving waters downstream of the STW outfall. Nevertheless, detectable residues were again found in the watercourse downstream of the STW outfall at 12 sites.

Watercourse investigations

Chemical monitoring was extended in 2000 in a joint programme between the Environment Agency Wales and Midlands Regions (Welsh Sheep Dip Monitoring Programme, 2000 and 2001). Monthly sampling at 50 sites in 2000 revealed detectable residues of OP and pyrethroid insecticides in 86% of sites, rising to 92% of sites in 2001. EQS (MAC) exceedances were frequent and most of these were attributed to cypermethrin (28% of EQS exceedances in 2000 and 20% in 2001). Improvements in the analytical limit of detection for diazinon around this time led to MAC exceedances that might previously have gone unnoticed. In contrast, a relaxation of the MAC for cypermethrin (from 0.001 to 0.002 ugl-1) meant that samples, which previously would have failed the MAC for cypermethrin, were now reported as non-exceedances.

Biological surveys in the same region (although separated from the chemical sampling programme) indicated reduced biodiversities on some sub-catchments of the Severn and Wye (a total 60km of watercourse). Whilst some could be traced back to contamination by sheep dip, conclusive evidence linking these impacts to sheep dip chemicals was lacking.

Between 2002 and 2003, Rutt (2004, Environment Agency Technical Memo TMW04_10) carried out an extensive survey of invertebrate biology and the occurrence of sheep dip chemicals in the Teifi catchment, South-West Wales, with a clearer attempt to assess the link between these chemicals and changes in biological quality. The survey was prompted by reports of reduced abundance in fly life in the upper Teifi that could be linked with a decline in invertebrate fauna over several decades, but especially since the early 1980s (Thomas, 2002). Subsequent surveys by Operations staff in 2001 and 2002 confirmed impacts to the invertebrate fauna in at least 30km of the upper Teifi catchment.

Rutt was able to exclude acidification, metal, nutrient and organic pollution as possible causes of this decline in invertebrate abundance. However, several strands of evidence pointed toward a link between the observed declines in invertebrate abundance and diversity and the presence of sheep dip chemicals. These were:

- Changes in species abundance that are characteristic of pyrethroid exposure, notably declines in certain species of mayfly (*Centroptilum* spp., *Procloeon bifidum*, and several *Baetis* spp.) and the stonefly (*Taenipterix nebulosa*). In contrast, other caddisfly families and some water bugs (Hemiptera) appeared to be relatively unaffected by the presence of pyrethroids.

- Occasional presence in water samples of cypermethrin at concentrations in excess of those causing toxicity in laboratory tests.

- Presence of cypermethrin residues in sediment samples from the impacted area.

- Investigations at specific locations invariably revealed a link with some aspect of sheep treatment (eight such incidents were reported on NIRS in 2003).

- Evidence of poor practice (sheep treatment and flock management) from a farm visits campaign.

In the uplands of Wales in particular, the only plausible source of pyrethroids is sheep dip chemicals. Although the *cis: trans* ratio found in sediments or biota is sometimes indicative of arable cypermethrin (characterised by a ratio of *cis*:*trans* isomers of approximately 60%:40% instead of the 80%:20% *cis:trans* isomer ratio of approved sheep dip products), this simply reflects the illegal use of the (cheaper) arable formulation of cypermethrin for treating sheep.

Indirect impacts on populations of brown trout as a result of declining prey species have been suggested but are difficult to verify. Rutt (2004) suggests that low food abundance might encourage a more migratory life strategy rather than a predominantly residential one, with consequent falls in catch numbers of adult brown trout.

Although diazinon was encountered in water samples more frequently (9/15 locations) than cypermethrin (5/15 locations), this probably reflects the marked difference in water solubility and partitioning behaviour of the two pesticides. The higher log Kow of cypermethrin will favour sorption to biota and sediments, at the expense of residues in the water column, to a greater extent than for the more polar diazinon.

Finally, Rutt was able to confirm that sheep dip chemicals do not occur only in the Teifi catchment. Routine water chemistry sampling in other catchments in

South Wales revealed residues of cypermethrin in water and also in samples of aquatic moss. Sampling of mosses is now practiced widely to monitor for the presence of cypermethrin in particular. This is because its low water solubility and high log Kow mean that any residues are more likely to be associated with biota, such as aquatic moss, especially when organic-rich sediments are sparse, than with the water column. Measured residues of cypermethrin in moss tissue effectively integrate the occurrence of cypermethrin in the stream over time; it is not possible to say whether the residues found in the moss have arisen due to a short exposure to a high concentration of cypermethrin, or to exposure to lower concentrations over a longer period of time.

Investigations in North Wales in 2004 have revealed a similar pattern of contamination by diazinon and cypermethrin. Routine water monitoring (Clay, pers. comm.) detected both chemicals at 15/16 sites on eleven catchments; the MAC for diazinon was exceeded on two occasions and the cypermethrin MAC on seven occasions. Biological investigations at some of these sites also revealed impacts on invertebrate communities with declines in abundance and species diversity that were regarded as indicative of sheep dip pollution.

Finally, it is also significant to note that, in Wales, contamination by sheep dip chemicals has been identified as the major risk to attaining good ecological status under the Water Framework Directive in 2010.

3.4 Codes of Practice and other guidance

Codes of practice have been developed for the use and disposal of sheep dip in response to continuing concerns about the number of pollution incidents arising from the use of sheep dip chemicals. These are:

(i) MAFF Code of Good Agricultural Practice for the Protection of Water (1998)

(ii) (ii) Defra Groundwater protection Code: use and Disposal of Sheep dip Compounds (2001).

In 2001 the Environment Agency published ‘Best Practice Guidelines for the Management of Sheep Flocks’ (Environment Agency, 2001, R&D Technical

Report P396). This was followed by the production of a risk assessment strategy for sheep farmers so that unnecessary chemical usage could be minimised ('Flock Management and Ectoparasite Control in sheep: development of an Ectoparasite Risk assessment Strategy for Sheep Farmers' Environment Agency, 2003, R&D Technical Report P2-167/TR). The strategy helps farmers identify the risk factors associated with scab and lice infestation, and to select products and treatment periods that would be most effective under different circumstances.

The Health and Safety Executive also published a leaflet called 'Sheep Dipping' which advises operators health and safety issues and to avoid harm to humans and the environment.