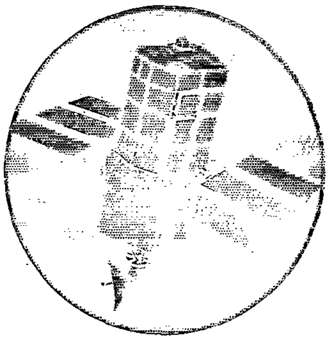
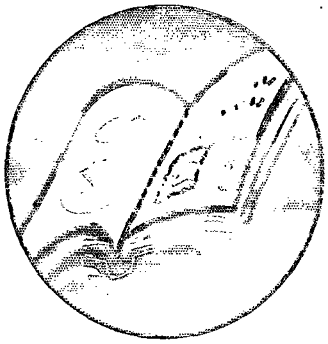
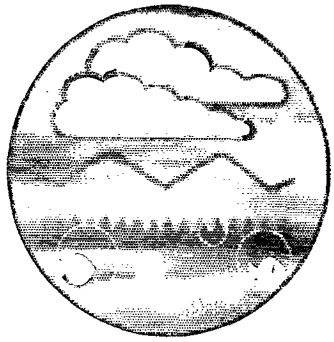
A Strategic Review of Sheep Dipping

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Technical Report
P170

ENVIRONMENT AGENCY

A Stategic Review of Sheep Dipping

R&D Technical Report P170

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Research Contractor:
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FOREWORD

The Environment Agency is concerned with the current situation regarding sheep dipping, especially the high level of pollution reported in some regions, and the seemingly widespread poor practices, together with the absence of effective legislation and controls to tackle such practices.

Agency actions to date have been mainly to respond to widespread threats or cases of water pollution, many of which have arisen from the recent changes in use of sheep dip compounds or changing sheep dipping practices. The Agency wishes to take a strategic view of these problems, exploring all available options for reducing impact and threat to the environment from sheep dipping. Whilst this is coincidental with Government proposals to implement regulations under the EC Groundwater Directive, it reinforces the need for such an approach, to help ensure effective consideration and implementation of such regulations.

This document was written by Adrian Armstrong and Kate Phillips with contributions from ADAS specialist colleagues: Stephen Bailey, Paula Child, Peter Hancocks, Robin Hodgkinson, Ross Mitchell, Fiona Nicholson, Nick Nicholson and Lynn Powell. In addition, the authors of the report consulted many people, both formally and informally, whose views and ideas are reflected in the content of this report. We are grateful to them for their responses. Those who responded formally included many people, our colleagues, our friends, and representatives of many organisations who made the time to comment on the issues covered by this report. These include:

- R.Anderson, Veterinary Medicines Directorate
- A.Brewer, FRCA;
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- R Nowell-Phillips, Farmers' Union of Wales.
- M.Payne, National Farmer's Union
- L.Stubbings, Sheep Consultancy, Kettering;
- J.Thorley, National Sheep Association;

The views that are expressed in this review remain the authors' own, and are in no way an expression of the official viewpoint of those who advised us.

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EXECUTIVE SUMMARY

Control of ectoparasites is necessary for the continuing health of the UK sheep flock. Sheep Scab is a particular problem, traditionally controlled by dipping sheep in a bath containing a diluted solution of a powerful insecticide. Recent surveys have shown that pollution of surface waters by sheep dip is widespread, and that action needs to be taken to reduce this pollution. This review examines the background and options to reduce the environmental impact of sheep dipping.

1. Traditional methods of controlling ectoparasites have involved dipping sheep in organophosphate (OP), or more recently synthetic pyrethroid (SP) chemicals. Alternative pour-ons and injectables have recently become available, although some of these are less effective for the treatment of some diseases, notably scab. The usual means of disposal of spent sheep dip is by spreading on the land, where it is sorbed to organic material and subject to microbial and chemical breakdown. Where it by-passes this organic material, or is applied at excessive rates, it moves to surface or ground waters, and presents a direct environmental hazard.

2. Although only few reported pollution incidents each year are attributable directly to sheep dip, this conceals widespread background pollution. In 1995 only 4 of the 55 substantiated pesticide pollution incidents reported involved sheep dip, although in the same year 5% of all samples analysed for sheep dip chemicals had these chemicals present above the limit of detection. In response to this concern and to assess the possible impact of such pollution. a survey in Wales conducted by the Agency in 1997 showed a widespread pollution problem. A recent increase in reported incidents in 1997 may be due both to a greater awareness of the problem, and the greater use and toxicity of SP (as opposed to OP) dips.

3. Sheep dip, as waste from agricultural premises is not a controlled waste. Pollution of water courses by dip is covered by the Water Resources Act 1991, and criteria for the safe disposal of spent dip to land are contained in the MAFF/WOAD Code of Good Agricultural Practice for the Protection of Water (1991). Regulations proposed by DETR to protect groundwaters (and currently under discussion) will require Agency authorisation of sheep dip disposal sites. It is considered that the effect of this proposed regulation will be to reduce the frequency of sheep dipping, with an increase in the use of non-dipping alternatives. This report argues that the current legislative framework is too limited, and that more positive control is needed, based on the requirement for agreed dip management plans, the licensing of dip facilities as well as dip disposal sites, and the notification of dipping operations.

4. Poor dip installation design and siting has been identified as a major problem that needs to be addressed. Other poor practices result from a lack of care, and a lack of awareness of pollution risks. There is a need for the development of a code of good practice for ectoparasite control in sheep that embraces the whole of the dipping operation, from the management of the flock, the dip installation, the management of the dipping operation, and the disposal of the spent dip. This code could be the focus of a programme of farmer education. The role of the mobile dipping contractor has been identified as being particularly crucial in this respect.

5. Positive flock management techniques present the possibility of managing sheep flocks without the use of dips. Alternative methods of disease control can be used in collaboration with the rigorous use of internal quarantine controls, to create and maintain scab free flocks. Such flocks may require no dipping for scab, although dipping for control of other parasites may be required. Such techniques are not, however, likely to be applicable to those flocks grazing common land unless supported by a legislation.

6. Current guidance excludes disposal of spent dip to any area likely to generate direct runoff to water courses. At application rates of up to 5 m^3/ha, spent dip presents little risk to groundwater, or to surface water or if it does not run off or enter groundwaters. Normally the active ingredients in sheep dip remain bound to the soil organic matter and degrade. However, the impact of dip disposal on terrestrial fauna is poorly documented and needs investigation.

7. On-farm treatment of sheep dip offers the prospect of some detoxification before disposal. Addition of high alkali solutions may lead to chemical decomposition of SPs and some OPs. However, the resultant product may have some residual toxicity, and so present a risk to the environment, and therefore still needs careful disposal to land. Addition of spent dip to organic materials (particularly manures) where high rates of biological activity could potentially lead to the rapid degradation of the active ingredients on dip, appears to offer the potential for the safe treatment of used dip, but is untested. Much further work to evaluate these techniques is needed before they can be advocated.

8. Off-site disposal of spent dip to currently licensed premises is not a practicable option. being prohibitively expensive. Few sites in the UK are able to offer disposal facilities, and the prospect of transporting large quantities of dip by road to these sites presents another environmental hazard.

9. The textile industry can also represent a localised source of sheep dip chemicals. Discharges from wool washing and processing plants may lead to exceedence of Environmental Quality Standards, even after treatment. Because much wool is imported, not all the chemicals found have marketing authorisation as a sheep dip product in the UK. A three stage solution to reduce pollution from this source has been suggested: reducing the amount of pesticide in wool; developing a market for pesticide free wool; and the adoption of better effluent treatment.

10. The indicative annual costs associated with the introduction of site authorisation for sheep dip disposal under proposed groundwater regulations are roughly equivalent to the annual costs of dipping a 500-ewe flock using OP chemical (£280/annum). The cost of using non-dipping alternatives (pour-ons and injectables) is much higher, at up to £1100/annum. However, these costs need to be put in the context of the suggested potential loss of income of £2000 per annum from a 500-ewe flock, if ectoparasitic diseases are not controlled.

11. This review has identified a number of significant weaknesses in current knowledge. There is still much that we do not know about the effects of sheep dip, and in particular research is needed to identify the possible effects of the disposed sheep dip on terrestrial ecosystems. Equally, further research is needed to assess the efficacy of methods of treating spent dip, to render it less harmful to the environment.

Recommendation: A national strategy for sheep dip.

A national strategy for sheep dip must achieve a balance between the requirements of the agricultural industry and the need to protect the environment. Sheep dipping should remain a component of good flock management, ensuring animal welfare at both the individual and national flock levels. Consequently there is a need to develop strategies to achieve two parallel aims: the safe use of dipping where it is carried out; and the reduction in the overall need to dip by the use of alternative flock management strategies. These can perhaps be best achieved by the following action points which present a pattern of education and development, in which the farming industry and the Environment Agency can work in collaboration, to address the very real risks to the environment posed by the necessary continued use of sheep dip.

1. Developing and promoting positive flock management methods to reduce the need to dip, including the use of alternatives to dipping (pour-ons and injectables) for disease control where practical.
2. Increasing of farmer awareness and education by the production and dissemination of a code of good practice for disease control in sheep, to include all aspects of the siting, construction, and use of dipping facilities, the correct storage and disposal of spent dip; the management of sheep to reduce the need for dipping; and the codes should be promoted though a positive campaign of farmer education.
3. Requiring the certificate of competence for all (both farmers and contractors) who purchase, use and dispose of sheep dip chemicals;
4. Extending the ban on the movement of animals infected with sheep scab to the transport of all animals, even to slaughter.
5. Strengthening the legislative framework for the control of dipping, for example by requiring the collaboration between farmer and the agency in the preparation of a dip management plans for each farm involved in dipping sheep.
6. Developing a national register and licensing of mobile dip contractors; an increased dialogue with the dipping contractors, including both a clarification of responsibilities regarding spent dip disposal and the adoption of acceptable dipping practices.
7. Developing methods to reduce dip chemicals in effluent from the wool treatment industry.
8. Research into the effects and methods of disposal of spent dip. The main areas where research are needed include:

   A. Examination of the impact of spent dip on terrestrial ecosystems
   B. A scientific review of the current recommendations dip dilution before spreading.
   C. Examination of the effectiveness of on-farm treatments for detoxification of spent dip.
   D. Risk evaluation of the movement of spent dip to surface and ground waters..
   E. Evaluation of biobeds and reed-beds as means of disposal of spent dip.
   F. Investigation of the environmental hazards of dipping of sheep prior to market.
   G. Examination of the role of stream chemistry in buffering of toxicity effects.
   H. Investigation of the extent to which dip components wash off sheep.

KEY WORDS:

Sheep dipping fluid; agriculture; groundwater pollution; freshwater pollution; organophosphate pesticide; synthetic pyrethroid; agricultural waste management; textile industry.

INTRODUCTION

Sheep are an essential component of the British rural landscape and the rural economy. However, sheep need care. In particular pests and diseases need to be controlled to maintain good standards of animal welfare and production. Control of ectoparasites has traditionally been achieved by dipping sheep in a solution of insecticide. Sheep farmers have dipped sheep for at least 100 years. Dipping is now an established, efficient means of controlling mites, lice, keds and ticks. However, the use of potent insecticides to kill parasites also has the potential to damage the environment should those same chemicals come into contact with non-target organisms. The disposal of waste dip is a particular problem, which has the potential to be a major source of pollution. This review considers the dipping operation, the role of dipping in the agricultural industry, animal health, cost, and the environmental effects of using dips and their alternative.

The aim of this review is to consider the options available, both to the Environment Agency and to the agricultural industry. It places these options in the context of the ongoing need to protect both the health of the UK sheep flock and shepherds; and the need to maintain or improve environmental standards, and to prevent pollution caused by agricultural activities.

The review has been conducted in consultation with many interested bodies. A list of some of those consulted is included in appendix A. The report thus includes many opinions which are based on individuals' and organisations' assessments of the state of the agricultural (particularly the sheep) industry. These are reported without attribution in the review. The authors of the report are grateful for all the various contributions.

1.1 Sheep Farming in UK over the Last 50 Years

Total sheep numbers (Table 1) in the UK doubled between 1950 and 1996 (20.4M to 41.5M), Figure 1. The British sheep meat industry expanded with the introduction of the sheep meat regime in 1981. Breeding ewe numbers increased from 15.4 million in 1981 to a peak of 20.6 million in 1992. The UK flock is the largest in the EU (representing almost a third of the estimated 67 million in the EU breeding flock) and by far the greatest producer of sheep meat in the Community (MLC, 1997). More recently, changes to the detailed rules of the subsidy system, together with structural changes in the agricultural sector have caused reductions in sheep numbers from the peak in 1992. The variation in sheep numbers thus generally reflects the profitability of sheep as an agricultural enterprise.

Despite the increase in total sheep numbers, the number of holdings with sheep has declined considerably and even between 1986 and 1996, 500 fewer farms in Wales kept breeding sheep (16508 to 16002). Consequently, average flock size has increased over the last 50 years and the increase has been particularly noteworthy since 1980. In 1994, average flock size was 466 with the figures for both Scotland and Wales exceeding 600. The importance of sheep farming in Scotland and Wales is further demonstrated by the fact that 50 and 60%, respectively, of holdings carry sheep. Sheep farming represents 7.6% of the total value of agricultural output in the UK.

The higher sheep numbers have been largely accounted for by the increase in breeding females. June census figures for 1959 and 1996 also show that the lambs to ewes ratio has risen from 0.97:1 to 1.14:1 (Pollot, 1998), reflecting the advances in breeding and management practices; and progress in veterinary medicine. Significant changes in management practices over the last 50 years include:

- An increased number of ewes are housed in the final 8 weeks of pregnancy.
- The replacement of hay by silage as the most commonly fed conserved forage.
- Traditional British breeds such as the Ryeland, Clun and Hampshire Down have become comparatively rare while breeds such as Texel and Charollais have been introduced from the Continent for their superior fleshing characteristics.

Increased sheep numbers lead to greater pressure on handling and dipping facilities with greater potential for treatments to be unsatisfactorily applied. High stocking rates at grass also lead to a greater build up of parasites and hence an increased need for veterinary treatments. There has also been a significant increase in the number of sheep that each shepherd is expected to manage. The larger average flock size should lead, in theory, to greater investment in handling facilities, but this is not always the case. Nevertheless, there are still a large number of small flocks and in England. For example, 30% of the holdings with sheep have fewer than 50. Many of these smaller flocks are unlikely to have sufficient handling facilities for effective use of pour-ons (Stubbings 1998), let alone dipping, so there is ample scope for the mobile dip contractor.

The financial considerations which have been the driving force behind the expansion in sheep numbers are currently much less favourable, and returns from sheep production are low. Unless a good export market is restored, sheep farmers will seek the cheapest options for all inputs. It is unlikely that the pharmaceutical industry will invest in the development of new and improved dip products to service an industry which is small in global terms and which is also experiencing lower profitability. However, recent research at the Moredun Research Institute is proceeding towards the development of a vaccine that might be effective against the sheep scab mite (Farmer's Weekly, 10 April 1998, p. S16).

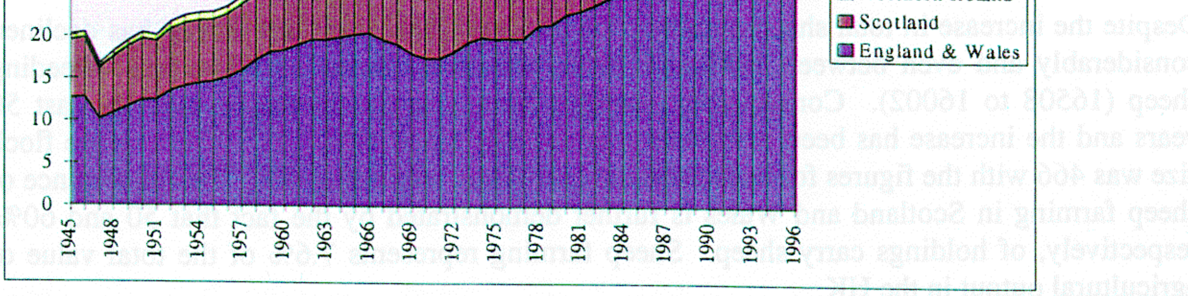

Figure 1: Sheep Numbers in UK, 1945-1996

Table 1. Number of sheep and lambs in UK, 1984-1996. thousands. (Source MAFF Statistics)

		1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
England	Ewes	7852	8007	8343	8740	9302	9897	1017	9835	9751	9819	9829	9237	9051
	Lambs	8454	8542	8995	9505	10086	10644	10759	10604	10778	10628	10405	10071	9515
	Total Sheep & Lambs	16206	16549	17339	18224	19388	20541	20776	20439	20529	20448	20235	19850	19090
Wales	Ewes	4776	4840	4567	5101	5297	5530	5647	5223	5306	5399	5428	5555	5544
	Lambs	4225	4290	4510	4695	5000	5225	5288	5235	5442	5472	5253	5277	4981
	Total Sheep & Lambs	9001	9130	9461	9796	10297	10754	10935	10851	11124	11256	11093	11191	10874
Scotland	Ewes	4318	4377	4442	4570	4642	4804	4831	4693	4667	4649	4633	4531	4447
	Lambs	3828	3981	4073	4288	4507	4572	4752	4843	4820	4756	4629	4549	4473
	Total Sheep & Lambs	8145	8358	8515	8858	9250	9376	9582	9757	9688	9586	9437	9259	9096
Northern Ireland	Ewes	789	850	908	981	1087	1206	1297	1324	1355	1335	1309	1274	1271
	Lambs	676	752	808	898	1006	1134	1237	1267	1301	1275	1221	1196	1199
	Total Sheep & Lambs	1465	1603	1716	1878	2094	2340	2534	2592	2656	2611	2531	2470	2470
UK	Ewes	17734	19073	17405	18645	19390	20428	21436	20334	20285	20563	20543	20507	20276
	Lambs	17083	17567	18387	19385	20600	21576	22036	21950	22340	22132	21510	21093	20168
	Total Sheep & Lambs	34817	35640	376031	38776	41027	43012	43828	43639	43998	43901	43294	42770	41530

1.2 The Need to Dip

Dipping is carried out to control a number of ectoparasitic infestations of sheep. The five major parasites that are of concern are scab, blow-fly, lice, keds and ticks. By far the most serious is sheep scab, which presents a major hazard to the welfare of sheep, and potential financial loss to the farmer (Bates 1998). Sheep affected by scab perform less well, and the infection, which causes severe distress to the animals, damages both the fleece and the hide (Corke, 1977). It is estimated that an infection can cause a 10% drop in flock performance (lamb and wool sales), costing in the order of £4-£5 per ewe (Stubbings, 1998).

Sheep scab has been a problem in the UK flock for a very long time (Kirkwood 1986). There are records of incidents as far back as the 13th century. Until the introduction of effective chemical control, it was however, considered an endemic problem that could be guarded against, but not cured. Legislation to control sheep scab dates back to the late 19th century (Lewis, 1997). A rigorous programme of control led to complete eradication of the problem by 1948, until the sheep scab mite was re-introduced in 1973. Consequently, twice annual dipping was introduced as a statutory requirement in 1983 (Lewis 1997). This action led to a dramatic reduction in the number of scab cases and its virtual elimination in 1988, and so in 1992 the statutory requirement to dip was removed. Since then, scab has returned as an intermittent problem that is considered endemic among the sheep flock. The Sheep Scab Order of 1997 makes it a criminal offence to fail to treat scab, or to move sheep visibly affected by scab.

In addition to the chemicals for the control of ectoparasites, some sheep dip preparations contain phenolic compounds, which are used partly for their bactericidal activity and partly because they impart a colour to the fleece which improves the appearance of the sheep and can improve sale value. The phenolic compounds also assist the emulsification of the active ingredients (insecticides) in sheep dips and aid the dispersal of the dips in the dipping tanks (Littlejohn & Melvin 1991). It has been suggested by many in the industry that bloom dipping should be banned as it is not needed for sheep health, causes unnecessary stress to the sheep, and is a potential cause of water pollution.

1.3 Sheep Treatment Options

A variety of products and application methods are available for the treatment of ectoparasites of sheep. (Table 2) Any product needs to be authorised by the Veterinary Medicine Directorate. These products may be applied either as dip, as pour-ons or by direct injection. There are three major groups of compounds involved: organophosphate products (OP), synthetic pyrethroids (SP), and injectable macrocyclic lactones.

The traditional method of controlling ectoparasites of sheep has been to dip the animals in a suitable insecticide. Showers and jetters are also used to apply the same insecticides although this method is much less common. However in the last five years alternative methods of control have been developed. Pour-on preparations are generally applied directly on to the animal, sprayed along the back and flanks and around the rump using a specially designed applicator. Two injectable products are also available for the treatment of scab. Only dipping, showering or jetting practices produce a significant amount of waste insecticide for disposal of at the end of the operation.

Table 2: Efficacy of currently authorised sheep ectoparasite control products

Product	Sheep scab		Blow fly Strike		Lice, Tics and Keds	
	Treat	Prevent	Treat	Prevent	Treat	Prevent
OP						
Diazinon	+	+	+	+	+	+
Propetamphos	+	+	+	+	+	+
SP						
Flumethrin	+	+	NO	NO	+	+
High CIS Cypermethrin	+*	NO	+	+	+	+
Amidine						
Amitraz	NO	NO	NO	NO	+	+
Macrocyclic lactones (injections)						
Ivermectin	+#	NO	NO	NO	NO	NO
Doramectin	+	NO	NO	NO	NO	NO

* Requires two applications 14 days apart.
# Requires two doses 7 days apart.

1.3.1 Mode of action of OP and SP sheep dips

The four major groups of insecticide - organochlorine, organophosphate, carbamate and pyrethroid insecticides - all act as neurotoxins. Exposure results in disturbance of the normal transmission of impulses along nerves and/or across synapses. However, a distinction can be made between those compounds (for example organophosphate compounds) which act as inhibitors of the acetylcholinesterase enzyme which breaks down acetylcholine at the nerve synapse resulting in 'overstimulation' of the receptor, and those (including the synthetic pyrethroids) which act directly on the pores or receptors situated in the nerve membrane. (Walker *et al.*, 1996)

Pyrethroids are synthetic compounds produced to duplicate the biological activity of the active principles of the pyrethrum plant. Pyrethrum is a natural botanical insecticide, the active principles of which are extracted from the flowers of the pyrethrum plant. The photostable synthetic pyrethroids are an economically important group of insecticides (Leahey 1985) widely used to control agricultural pests, and finding increasing usage for the control of arthropods of medical and veterinary importance (Miller 1988). They have been developed over the last decade as replacements for the more toxic and environmentally persistent organochlorine, organophosphate and methylcarbamate insecticides (Leahey 1985). The pyrethroids exhibit high insecticidal activity combined with low mammalian toxicity and although lipophilic are readily metabolised in biological systems (Elliott *et al.* 1978, Maloney, Maule & Smith 1992).

1.4. Current Usage

Over the past 20 years, the active ingredients in the majority of dips have mainly been organophosphate chemicals, replacing the organochlorines previously in use. However, over the past 10 years, a greater variety of products has been introduced, including synthetic pyrethroids as alternative dip formulations, and pour-on and injectable applications.

Some figures on usage were given in Blackmore & Clark (1994). More recent data that are more recent are given by The National Office of Animal Health which maintain records on the monetary size of the sheep ectoparasitics market. Figure 2 shows the UK spend over the last ten years on chemicals for control of sheep scab, blow fly, lice ticks and keds.

The market for pour-on type products (other non-dips) and SP dips has expanded rapidly over the past 5 years, largely in response to the perceived human health hazards of OPs, and the withdrawal of compulsory dipping for scab. The endectocides (ivermectin and doramectin) have only recently been authorised for use in sheep, hence the relatively low value of the current market, but this position is very likely to increase significantly in the near future. The sale of OP dips has reduced by half over the last 10 years, largely, it is thought as a consequence of human health concerns. The NOAH sales figures are supported by usage figures from a survey of farms (Table 3).

Table 3: Recent usage of sheep dip products. Source: surveys by Flexifarm Ltd. (Percentage of farms using the following products)

Dip Type	1995	1997
OP Dip	63%	42%
SP Dip	19%	29%
SP Pour-ons	9%	14%
Avermectin	4%	12%
Crymazine pour-on	27%	27%

Virtue and Clayton, (1997) present a major review of sheep dip usage in Scotland, and report that in 1993 dip usage in Scotland was 24.9 tonnes of OP compounds and 0.23 tonnes of the synthetic pyrethroid flumethrin. The majority of treatments were by dipping but other methods of treatment included spraying the compound directly onto the sheep (0.3 tonnes of the 1993 OP usage was by this method) with pour-ons accounting for 0.4 t of the pyrethroids.

Nevertheless, OPs remain the preferred treatment for the control of scab. Although pour-ons are probably the method of choice for tick control, no pour-on preparations are effective against sheep scab. In addition, there are indications that sheep scab mites are developing a resistance to SPs, a problem which is rare for OPs, (Bates, 1997) and this is a further factor which favours the continued use of OPs. Table 2 shows the efficacy of the full range of products currently available to the industry.

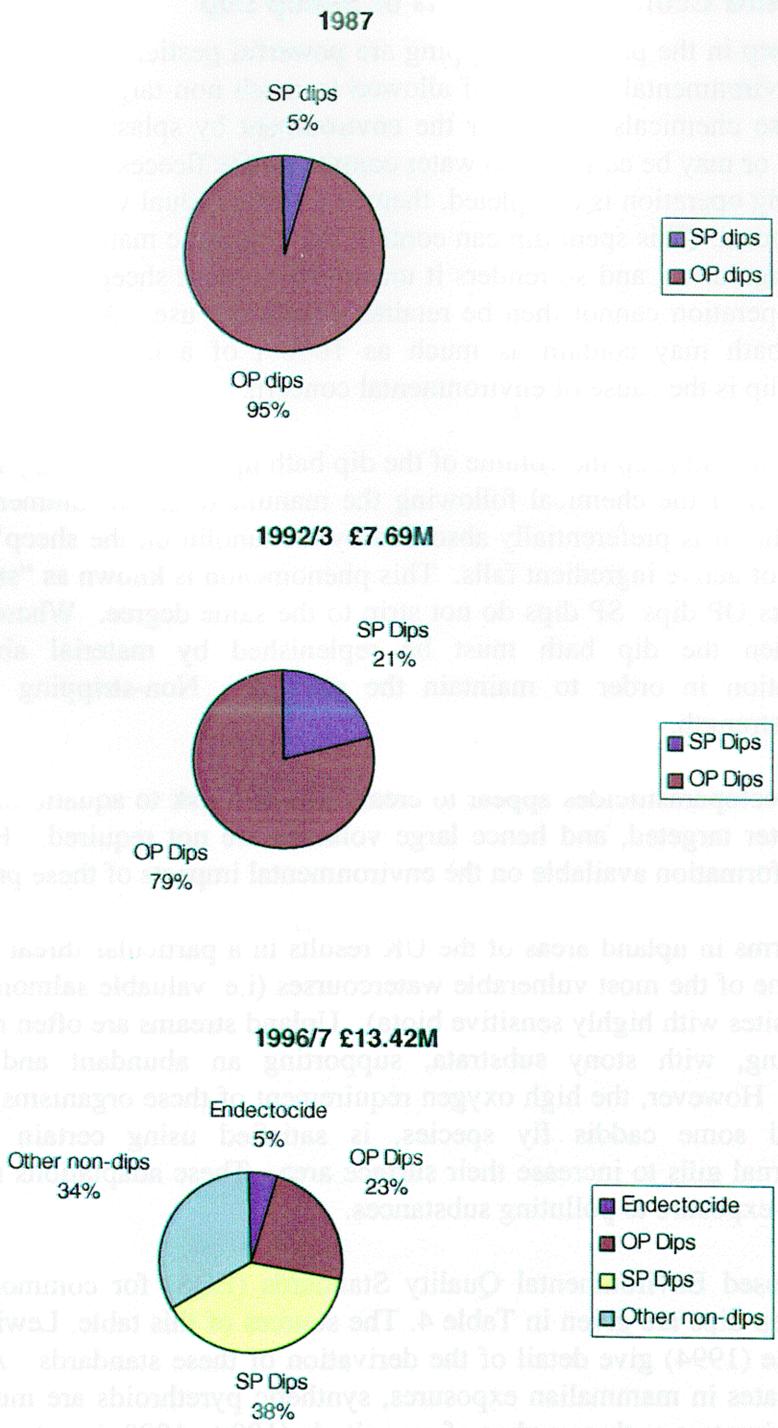

Figure 2: The market for sheep ectoparasite control products, 1987 to 1997. Data provided by NOAH.

1.5 Environmental and Ecological Impacts of Sheep Dip

Chemicals applied to sheep in the process of dipping are powerful pesticides, and they have the potential to cause environmental problems if allowed to reach non-target organisms. In the dipping process, these chemicals may enter the environment by splashing, spillage, or runoff from drying areas, or may be carried into water courses on the fleeces of freshly dipped animals. Once the dipping operation is completed, there is also a residual volume of "waste" dip that is in need of disposal. This spent dip can contain 3-5% organic matter (Bates 1998) which binds the active ingredient, and so renders it unsuitable to treat sheep. Excess dip at the end of the dipping operation cannot then be retained for future use. At the end of the operation, the dipping bath may contain as much as 1000 l of a hazardous chemical. Disposal of this "spent" dip is the cause of environmental concern.

While dipping, operators should keep the volume of the dip bath up to the necessary level and maintain the concentration of the chemical following the manufacturer's recommendations. Where the dip is lipophilic, it is preferentially absorbed by the lanolin on the sheep's' wool, and so the concentration of active ingredient falls. This phenomenon is known as "stripping" and most generally affects OP dips. SP dips do not strip to the same degree. Where the dip chemical strips out, then the dip bath must be replenished by material above the recommended concentration in order to maintain the strength. Non-stripping dips are replenished at the initial strength.

Pour-on formulations of ectoparasiticides appear to create less of a risk to aquatic organisms since the solution is better targeted, and hence large volumes are not required. However, there is currently little information available on the environmental impacts of these products.

The location of sheep farms in upland areas of the UK results in a particular threat of sheep dip contamination to some of the most vulnerable watercourses (i.e. valuable salmonid rivers or ecologically valuable sites with highly sensitive biota). Upland streams are often relatively shallow and fast flowing, with stony substrata, supporting an abundant and diverse invertebrate community. However, the high oxygen requirement of these organisms, such as mayflies, stoneflies and some caddis fly species, is satisfied using certain physical adaptations such as external gills to increase their surface area. These adaptations may also increase the potential for exposure to polluting substances.

The toxicities and proposed Environmental Quality Standards (EQS) for commonly used active ingredients in sheep dips are given in Table 4. The sources of this table, Lewis (1998) and Grimwood & Criddle (1994) give detail of the derivation of these standards. Although safer than organophosphates in mammalian exposures, synthetic pyrethroids are much more toxic to aquatic fauna, being two or three orders of magnitude (100 to 1000 times) more toxic than OP compounds. This lower toxicity of pyrethroids to mammals may have resulted in false security in the minds of the users with regards to the environmental safety of synthetic pyrethroids.

The toxicity of synthetic pyrethroids to aquatic invertebrates is such that a similar polluting incident would result in a far greater impact on the receiving watercourse than if the pollutant were an organophosphate compound. It is therefore likely that, even if the number of polluting events did not increase, the greater impact of synthetic pyrethroids would result in a higher number of reported incidents.

Table 4. Environmental Quality Standards for common active ingredients of sheep dips in fresh water

		Proposed MAC ng/l	AA ng/l
Diazinon	OP	100	30
Cypermethrin	SP	0.1	1.0
Propetamphos	OP	100	30
Flumethrin	SP	Not set	Not set
Chlorfenvinphos	OP (no longer authorised)	100	30
Coumaphos	OP (no longer authorised)	100	30
Fenchlorphos	OP (no longer authorised)	100	30

MAC is Maximum Allowable Concentration
AA is Average Annual concentration.

1.5.1 Disposal issues

Product labels for sheep dips state that used dip can be disposed of on 'a suitable area of land', but fail to define this term. Users are referred to other publications, including the MAFF/WOAD 'Code of Good Agricultural Practice for the Protection of Water', for a definition of this term.

The MAFF/WOAD code has guidelines for the disposal of sheep dips (paras 210-214). The guidelines contain suggested dilution rates and maximum application rates for SPs which are likely to be 50 times the maximum individual application dose for the same group of chemicals when used for aphid control in winter cereals. There appears to have been little if any work done on the potential effects of the disposal of used sheep dip products on soil invertebrates, or the potential for affecting nearby water courses.

Data derived from an internal survey of ADAS sheep advisors in 1996 suggests that about 80% of sheep farmers dip, although the proportion ranges from 60% in the Midlands to nearly 100% in Cumbria. There is also a wide variation in the number of times sheep are dipped. 37% farmers dipped only once. 45 % dipped twice, and 18% dipped three times. There are however regional variations in dipping frequency, with 94% of the farmers in the Southwest dipping only once, but virtually 100% of the farmers in Cumbria dipping three times, reflecting the higher incidence of ticks in this area.

The average size of a dip bath is about 1800 litres (about 400 gallons), ranging from 1350 to 3000 litres. Dip baths are generally about 70% full at the end of dipping. The best estimate of the volume of dip to be disposed of from the 66,000 holdings in England and Wales is thus around 100,000 m^3 per annum (A.Brewer, pers. comm.) Of this, it is estimated that about 30% is disposed of via soakaways, 25% directly onto nearby land, and 25% is sprayed onto other fields. The ultimate fate of the remaining 20% is unknown, although it is thought that some of this is applied to land off the farm site, or possibly directly to surface waters.

1.5.2 Potential impacts of SPs on other fauna

SPs are readily broken down in the environment and within mammalian bodies. There is little risk therefore of cumulative poisoning as occurred with organochlorine crop insecticides such as DDT which were previously in common use prior to the introduction of the OPs. However, due to their high toxicity to aquatic invertebrates SPs can have disastrous effects on aquatic food chains. Pollution incidents can cause rapid die-off of the primary consumer step in the food chain. These then have a knock-on effect on secondary and tertiary consumers, including insectivorous and predatory fish, insectivorous birds such as dippers and wagtails, piscivores such as kingfishers, herons, water shrews and otters (P.Hancocks, pers. comm.).

Following the continuing recovery of the otter population, any secondary impact on its range or numbers would be regrettable in the extreme. The Environment Agency is recording generally improving river water quality, with reports of 'The first sighting since 18.. of a salmon in the River ....' being quoted as tangible evidence. Increasingly SP pollution incidents have the potential to prevent the aquatic communities taking advantage of otherwise improving water quality.

2 RECORDED SHEEP DIP POLLUTION INCIDENTS

Although the number of reported pollution incidents attributable to sheep dip chemicals (Table 5) is small, there has been increasing concern over these incidents. The apparently large increase in incidents in 1997 is thought to be due to both a greater awareness of the possibility of sheep dip pollution which has resulted in greater reporting of incidents by the public, as well as an increase in the intensity of monitoring and a real increase in the number of incidents.

Table 5: Substantiated Sheep Dip Farm Pollution incidents, 1986-1997

	Sheep Dip	All Farm Pollution Incidents
1986	10	3427
1987	17	3890
1988	ND	4141
1989	13	2889
1990	15	3147
1991	14	2954
1992	19	2770
1993	12	3051
1994	14	3338
1995	2	2733
1996	7	2111
1997	34	1884

Information provided by the Environment Agency

Data on the general occurrence of sheep dip chemicals in water samples was collated and presented by Agency (1997). Table 6 summarises the findings, showing the percentage of water samples found to contain sheep dip chemicals. Care must be taken in interpreting these results, because the samples are taken for reasons other than the determination of the extent of the sheep dip problem, but they do demonstrate the fairly widespread occurrence of sheep dip chemicals in surface water (5% of all samples). The apparent upwards trend observed in recent years could be due as much to the increased awareness and analysis of the problem as much as to any real increase in the incidence. The same report contains maps showing the distribution of these samples, showing concentrations related to the wool processing industry (see section 9 of this report) as well as more widespread pollution associated with the main sheep areas of the North and West of England and Wales.

Table 6: National (E&W) summaries of samples having sheep dip chemicals above the limit of detection (LOD) (source, Environment Agency 1998, Table 1.)

Year	Type of sample	Pesticide	Number of samples analysed	Number of samples > LOD	Number of samples >100 ng/l
1993	Fresh surface	Chlorfenvinphos	3468	104	31
		Cypermethrin	481	5	0
		Diazinon	3431	320	63
		Propetamphos	2922	177	35
	Groundwater	Chlorfenvinphos	334	0	0
		Diazinon	335	0	0
		Propetamphos	239	1	0
1994	Fresh surface	Chlorfenvinphos	3854	110	29
		Coumaphos	540	1	0
		Cypermethrin	657	2	0
		Diazinon	3967	314	52
		Propetamphos	3455	296	55
	Groundwater	Chlorfenvinphos	258	0	0
		Coumaphos	23	0	0
		Diazinon	264	4	0
		Propetamphos	140	4	0
1995	Fresh surface	Chlorfenvinphos	3073	97	35
		Coumaphos	645	0	0
		Cypermethrin	882	35	8
		Diazinon	3147	278	82
		Flumethrin	1	0	0
		Propetamphos	2713	196	58
	Groundwater	Chlorfenvinphos	447	2	0
		Coumaphos	116	0	0
		Diazinon	446	5	1
		Propetamphos	328	7	1
1996	Fresh surface	Chlorfenvinphos	3773	157	28
		Coumaphos	1393	1	0
		Cypermethrin	1168	111	25
		Diazinon	4012	517	153
		Propetamphos	3559	389	97
	Groundwater	Chlorfenvinphos	480	1	0
		Coumaphos	162	0	0
		Diazinon	484	1	0
		Propetamphos	373	3	0

In order to further define the problem, in 1977 the Agency monitored 39 water quality points from 10 catchments in Wales with intensive sheep rearing (Environment Agency, 1998). Stream waters were sampled fortnightly and the survey found widespread contamination of watercourses by sheep dip chemicals, in a temporal pattern of detection in accordance with that expected from known dipping periods. Of the sites surveyed, 49% failed the maximum allowable concentration (MAC) environmental quality standard (EQS) and 56% failed Average Annual EQS values. The synthetic pyrethroid, cypermethrin, represented 77% of the pollution cases.

In addition, biological surveys of the rivers were undertaken, and it was observed that of the 679 km of stream examined, 33.8 km were affected or suspected to have been impacted by sheep dip. Although the biological methods used suggest that only the biggest impacts were identified, it was also clear that the role of stream chemistry in buffering the effects of some pollution, needs to be investigated. The 679 km of surveyed streams represent only 5% of the streams within the intensive sheep rearing areas. In addition, a further 75 km of streams had been confirmed as affected by separate sheep dip pollution incidents. Together, these figures lead to the estimate that in total, some 750 km of streams and rivers were affected by sheep dipping in Wales in 1997.

The same survey also visited 117 farms in the catchments, and it was found that 26% of these were found to be at high risk of polluting a watercourse from sheep dipping activities. The location of dipping structures was a major concern, with many being located within 10 m of a water course, and many of the older structures having direct discharge to a water course or discharging to a soakaway.

The implications of this survey are that the small number of substantiated pollution incidents (13 in Wales in 1997) hides a much more widespread problem of the pollution of watercourses by sheep dip. The extent to which the results from this study are replicated elsewhere in England and Wales is unknown, although the findings are very similar to the Scottish studies reported by Virtue & Clayton (1997) and Littlejohn & Melvin (1991).

In additions, cases of pollution have been recorded due to dip compounds apparently washing off sheep when they cross streams following dipping. There is a need to quantify the potential scale of this source of pollution, and to provide appropriate guidelines to farmers.

3 CURRENT AND PROPOSED NEW LEGISLATION

Legislation relating to sheep dipping and the disposal of spent dip is disparate, with responsibility for implementation falling to several organisations. This leads to the potential for duplication or omission of controls, leading to difficulties for both the regulators and those who are regulated. This section summarises the important legislation, and discusses proposed changes to the legislation.

The human health issues associated with sheep dipping have been addressed extensively by the Health and Safety Executive, and compliance with the current safety recommendations (HSE, 1998) removes much of the hazard to the operators associated with the use of sheep dip chemicals.

3.1 Environmental Protection Act 1990 (EPA) - Controlled Wastes

Under the EPA Waste management 'Duty of Care' Code of Practice, published in December 1991, spent sheep dip is not a 'controlled waste', as waste from agricultural premises is given as one of the main exceptions. It is therefore exempt from legislation that requires waste producers, carriers, importers and brokers to transport and keep waste safely and keep strict records of the origin and destination of such waste.

It has however been suggested that the definition of "controlled waste" may be extended to cover certain agricultural wastes, So revoking the exemption. If sheep dip is then classified, because of its toxic nature, as a "Special Waste", it will become subject to the Special Waste Regulation, which will impact significantly on the costs of storage, handling, and off-farm disposal. However, disposal on the farm could remain subject to the Groundwater Regulations only.

3.2 Legislation re Road Transport

It is considered that spent sheep dip would be subject to the provisions of the Dangerous Substances (Conveyance by Road in Road Tankers and Tank Containers) Regulations 1981 or the Road Traffic (Carriage of Dangerous Substances in Packages etc.) Regulations 1986 if it were to be transported on a public road, either by a farmer, contractor or waste carrier. This may be important both in relation to the option for 'shared' authorised disposal sites and if spent dip was to be transported to a central point for treatment or disposal.

3.3 Water Resources Act 1991

The Water Resources Act 1991 consolidated previous legislation on water pollution. Sections 85-89 of this Act describe the principal offences relating to pollution of controlled waters and enable the Environment Agency to retrospectively prosecute a farmer or contractor who caused or knowingly permitted any poisonous, noxious or polluting matter (such as sheep dip) to enter any controlled water (which includes all surface and groundwaters). Section 86 gives the Agency powers to prohibit discharges from a building or a fixed plant, including a direct discharge of spent dip onto land, e.g. via a soakaway.

Sections 92 -97 of this Act describes powers to prevent pollution. Section 93 enables the Secretary of State to set up water protection zones (for instance, round a borehole). This legislation could be used to prevent the spreading of spent dip to land in particularly sensitive situations, but the procedures involved are complex and have currently only been used to designate Nitrate Vulnerable Zones.

Section 97 relates to codes of good agricultural practice, giving ministers powers to approve any code of practice issued, "giving practical guidance....promoting what appear to them to be desirable practices for avoiding or minimising the pollution of controlled waters". Section 97 also states that "contravention of a code of practice shall not of itself give rise to any criminal or civil liability".

Section 161 of the act allows the Agency provision to issue works notices once the appropriate regulations have been laid in parliament. These will be issued pursuant to section 61 of the Water Resources Act 1991 as amended by S162 of the Environment Act 1995. Works notices relate to the pollution of controlled waters and will give the Agency the opportunity to remedy or forestall pollution and retrieve reasonable cost and so to be proactive in preventing water pollution. Works notices will require a person to prevent pollution of controlled waters or to remedy or mitigate the effects of water pollution. Their use will be directly applicable to fixed sheep dipping facilities where Agency officers believe them to be substandard and that they pose a potential pollution risk. The DETR consulted on draft regulations for works notices during August 1997 and is currently working the final transition into law.

The current version of the MAFF/WOAD Code of Good Agricultural Practice for the Protection of Water (MAFF/WOAD, 1991), fulfils this role in that it is a statutory code under the act. Section 10, Paras 203-214 of this code outline current recommendations for installation and location of dipping facilities, recommended spreading rates (see Section 5 below) and type of land suitable for spent dip disposal. It does not totally rule out the use of soakaways, subject to the then NRA approving a specific site. (The Scottish Prevention of Environmental Pollution from Agricultural Activity Code of Good Practice, however explicitly states that "at no time should a soakaway be used to dispose of spent sheep dip"). A draft revised code was issued for public consultation in July 1997, with various detailed amendments proposed to the section on sheep dip, including revised wording advising that soakaways should not be used. The revised code is expected to be published in 1998.

There are currently no regulations relating to the construction, size and location of sheep dipping facilities. Some other facilities, namely those for storing animal slurries, silage and agricultural fuel oil are subject to the Control of Pollution (Slurry, Silage and Agricultural Fuel Oil) Regulations 1991 as amended in 1997. These regulations are secondary legislation under the Water Resources Act that lay down minimum constructional and sizing standards for such structures and specify that they must normally be located at least 10 m from a watercourse. It has been observed that the incidence of pollution from these stores has decreased since the introduction of these regulations.

3.4 Proposed Groundwater Regulations

A consultation paper on the proposed Groundwater Regulations was issued by Department of the Environment, Transport and the Regions (DETR) on 12 January 1998. The proposed regulations relate to processes or activities which discharge List I or List II substances onto land or directly into groundwater. Therefore, in the agricultural sector, farmers who dispose of waste pesticides to land and sheep farmers/mobile dip operators who dispose of sheep dip will be affected. It is proposed that the regulations will include provisions to deal with "disposal, tipping or other activities on or in the ground which may lead to an indirect discharge" (to ground water). Spreading of spent sheep dip to land and the use of soakaways would fall under these provisions and land spreading would require granting of an authorisation from the Environment Agency.

Current advice from DETR is that spent sheep dip will be treated as a List I substance (as defined in the annexe to the proposed groundwater regulations). Any farmer wishing to dispose of wastes containing List I substances, must firstly arrange for a hydrogeological investigation of the disposal area in order to ensure that List 1 substances would not enter groundwater and that List II substances would not cause pollution of groundwater. Any disposal must then be subject to an authorisation issued by the Environment Agency (or in Scotland the Scottish Environment Protection Agency). Monitoring will be necessary to ensure compliance with the conditions of authorisation.

The proposed regulations will thus make it an offence to apply sheep dip to land unless authorisation has been granted by the Agency. Any authorisation would be site specific and carry necessary technical conditions to prevent pollution. Costs of applying for and obtaining such an authorisation would depend upon a number of factors, including whether a site visit was required from the Agency, and the extent of the site investigation needed. Estimated initial costs suggested by DETR range from £700 to £1500 per site, with annual recurring costs ranging from £124 to £871.

Many pollution incidents may arise from the dipping facility itself rather than from spreading spent dip on land. The proposed regulations cover this aspect by making provision for the serving of a notice to make improvements or to cease dipping.

3.4.1 Likely Effect of New Regulations on Dipping Practice

The DETR discussion document suggests that initial costs for the granting of an authorisation for the disposal of dip to land will be between £700 and £1500 in the first year, covering the cost of the hydrogeological evaluation as well as the administration costs. Costs in subsequent years will be in the order of £125 - £870 per year, to cover the cost of the necessary monitoring to ensure compliance.

The proposed charges for authorisation to dispose of spent dip on land are likely to be a major factor in persuading many farmers to stop dipping their flocks. This is most likely to affect the smaller flock holder where the charges would be spread over fewer sheep, and perhaps a scale of charges should be introduced according to flock size. Two major dip chemical manufacturers are convinced that their sales of dip concentrate will fall dramatically if the charges are introduced at the proposed rates.

Initial reaction from many associated with the agricultural industry is that the charges will discourage many farmers from dipping altogether, and given the current financial status of many sheep farmers they will simply not be prepared to pay. This raises concerns over the welfare of the national flock, in terms of blow-fly strike and sheep scab. Sheep scab is already widespread in the UK and these proposals could lead to less effective control of the disease. The need to dip all sheep for scab protection should however be considered carefully, since tight flock security can play a part in avoiding the disease (see section 5).

Individual farmers and dipping contractors face the following choices in relation to disposal of spent dip:

- Comply with the regulations and seek individual authorisations for sites for the disposal of dip onto suitable land.
- Seek joint authorisations between groups of neighbouring farmers to dispose of dip onto suitable and authorised land.
- Adopt flock management practices that minimise the risk of sheep ectoparasite infestation, and thus reduce the need for dipping.
- Send spent dip for off- site treatment or disposal via a licensed waste disposal contractor.
- Seek to provide centralised treatment plant dedicated to dip (see section 8.1).
- Ignore regulations and continue as at present. Some farmers or dip operators in remote areas may see this as a low-cost alternative.

The costs of these options are evaluated in Chapters 8 and 10.

3.5 The Case for Regulation of Sheep Dipping

It is considered that current legislation offers only very limited control over the dipping operation and its potential to damage the environment. The agricultural industry is operating within an historical legacy of unregulated dipping, using installations and practices which were developed at a time when the major concern was the control of disease within the sheep flock, and with little concern (or knowledge) of the side effects on human or environmental health.

The DETR consultation paper on groundwater proposes a shift in the legislative framework in that it gives the Environment Agency a preventative role, by requiring it to authorise disposal sites; as opposed to the current framework which gave powers only to react to pollution incidents. This preventative role could (if additional legislation were to be introduced) be extended much further by requiring inspection and licensing of all dipping installations and operations, which could then be extended to the development of a total dip management plan for each farm.

Although there is little enthusiasm within the agricultural industry for a strengthening of the regulatory framework within which dipping could be continued, it has been argued that practices will not change unless supported by a legislative framework with an element of compulsion. The dangers posed by the unsuitable use or disposal of dip chemicals are such that wrongful disposal by only a small number of unprincipled or ill-educated operators could cause great environmental damage. Single pollution incidents can affect tens of kilometres of river, and if only a small proportion of those dipping sheep fail to abide by the current codes of good practice, the effects can be widespread. If, for example, only 1% of the 50,000 sheep farmers fail to dispose of dip properly, and all these failures lead to damage to stream ecosystems over as much as 10 km, nationally 5,000 km of river will be affected. Even a 99% observance of the code would therefore still be unacceptable. Clearly then, there is a need to ensure almost complete pollution avoidance, which may be best achieved through a strict legislative framework. The Sheep Scab Order of 1997 offers an example of regulation applicable to all farmers without exception, so this sort of regulation is not beyond the experience of the sheep industry.

A regulatory framework for the control of dipping could thus be put into place, in which the Environment Agency was given the role, not only to authorise disposal sites (as in the proposed groundwater regulations), but for registering and licensing of all dipping installations. This would require careful consideration of the respective roles of the Agency and bodies such as the Veterinary Medicines Directorate, but would improve the Agency's knowledge of the location and timing of dipping, enabling them to identify the source of any pollution incident; but more importantly enable it to interact with the farming community to develop an on-farm strategy to prevent pollution incidents ever happening. It is suggested that legislation be put in place which requires each farm to complete (and agree with the Agency) a total dip management plan, which would embrace not only the disposal of spent sheep dip material, but would also include issues such as the siting and construction of dipping and sheep handling facilities, and the strategy for flock management to define the risks and benefits of dipping as applicable to the particular flock.

4 CURRENT PRACTICE

Both the Agency survey of streams in Wales, and much anecdotal evidence suggests that the majority of pollution incidents are due in part to inappropriate practice. Many of these practices were established many years ago, and have not been updated as the environmental impact has been identified. These practices can be identified as related to dipping facilities, management of the dipping operation and the practices of mobile dipping operators.

4.1 Certificate Of Competence Scheme

The Certificate of Competence in the Safe Use, Storage and Disposal of Sheep Dips was developed to meet the requirements of The Medicines (Veterinary Drugs) (Pharmacy and Merchants List) (Amendment) Order 1994. On 1 April 1995, it became illegal for registered agricultural merchants to sell or supply organophosphate (OP) sheep dips except to holders of the Certificate of Competence administered by the National Proficiency Test Council (NPTC). This requirement was extended to other dip products in May 1998 and applies to all sheep dips purchased after 30 December 1998. The certificate records that, on the date of last assessment the holder was competent in the use of sheep dips, including preparation before dipping, work during and after dipping and safe use and disposal. By omission, the original scheme was wrongly interpreted by some farmers to infer that SP dips were safer than OP dips.

A total of 13,000 individuals currently hold a certificate of competence (NPTC, pers. comm., March 1998) but this falls well short of the actual number of people registered as keeping sheep which was 80,000 in the June 1997 census. Of these, however, only 56,000 would be considered to keep a significant sized flock. The National Proficiency Test Council (NPTC) predicts a significant up turn in applications following the extension of the requirement to include SPs and hope that another 10-13,000 will apply. The cost for taking the test and gaining the certificate was £49 but this increased to £79 on 1 April 1998. Current figures suggest that only one quarter of sheep farmers have the relevant certificate, the remainder relying on qualified neighbours to purchase products on their behalf, or using non-OP dips.

The certificate is currently a legal requirement only for purchase of dip chemicals and is therefore not required for the actual dipping operation. Should any person dipping sheep need to demonstrate competence to dip sheep and to dispose of the spent dip (for example to an officer of the Health and Safety Executive), this can conveniently be done by the certificate, although this can also be achieved by practical demonstration and discussion.

If the certificate were to be required by law by the person in charge of the dipping operation then it is probable that many more farmers and shepherds would apply for the test. At the moment a farmer with a certificate may (and anecdotally frequently does) purchase dip for neighbours, thus avoiding the need for many to take the test. Some farmers may be put off dipping by the new proposal but some will continue to buy dip concentrate through another party. It is recommended that the possession of a certificate of competence should be required of all farmers and operators dipping sheep. This offers a significant opportunity for a farmer education, which should be pursued on both environmental and human health grounds.

4.2 Dip Installations

The Code of Good Agricultural Practice for the Protection of Water (MAFF/WOAD 1991) stipulates that dipping baths should be sited as far away as practical from any watercourse, spring, well or borehole. The same guidance applies to mobile facilities while they are being used.

Dip installations vary in design and age considerably from farm to farm. Many modern ones are part of a well planned handling system with appropriate draining pens and full splash guards etc., sited well away from a watercourse. However, despite adequate advice on dip construction, and much recent advice on dip usage, it is clear that many installations do not meet modern standards of dip design, and there are numerous examples of poor practice. Traditionally sheep dips were sited close to a watercourse, which served as a ready supply of water for diluting the dip concentrate.

In the past, ADAS/MAFF has produced examples of good dipping facility design (e.g. MAFF 1986). The aim of a good dipping facility is to allow thorough treatment of stock, ease of handling, and protection of the environment by containing the dip. The bath needs to be sufficient to ensure that sheep remain immersed for the required time. There should also be adequate handling facilities for gathering sheep before dipping, for draining, and for holding the sheep after dipping. The draining pens should drain back into the dip bath (which requires that they have an impervious floor on a slope of at least 1 in 60 draining back into the dip, and be sufficient in size to hold the sheep for at least 10 minutes), and the post-dipping holding areas should be isolated from water courses. Dip baths should not have a drain hole.

Annual statistics from the Scottish Farm Waste Liaison Group (1982-1994) showed that of the 122 pollution incidents caused by sheep dip, 35 of these were due to structural failure of the dip itself and 87 were due to poor dipping management. The Tweed River Purification Board's survey (Virtue & Clayton 1997) showed poor siting to be one of the main contributory factors to water pollution by sheep dip on the 795 dips investigated. 42 of the dips inspected were deemed to be 'high risk' with the risk of dip leaking directly into a watercourse, evidence of direct run-off of overspill or incorrect disposal of spent dip directly to a drain or watercourse.

A further survey carried out in south Ayrshire (Morris, 1997) showed that of the 73 dipping facilities visited 50 were unsatisfactory. A variety of factors contributed to this, including: proximity to a water course (22% were less than 10 m from a watercourse); problems of construction (19% were in a poor state of repair); and poor disposal arrangements (30% were connected to a soakaway and on 23% undiluted spent dip was being disposed of to land).

Similar results were obtained in a survey of sheep dip in Wales in 1997 (Environment Agency, 1998). A total of 117 farms were visited in 10 catchments and, of these, 26% were found to be at high risk of polluting a water course from sheep dipping activities. The major concerns were: the location of dipping structures, many being located within 10m of a water course; leaky or poorly maintained dip baths; and presence of drain holes in the baths, some of which discharged directly to streams. Although most structures were in a reasonable state of repair, 25% discharged to soakaways, contrary to current advice. 70% of farmers visited disposed of dip by spreading on land. However, a residual 5% of the dipping structures had a direct discharge to a watercourse.

It is therefore likely that there are a significant number of poorly sited, badly designed and neglected dipping facilities throughout the country which will be directly contributing to the pollution of watercourses by dip.

4.3 Management of the Dipping Operation

Two surveys (Environment Agency 1998; Scottish Agricultural Pollution Group 1997) also indicated that poor management of the dipping operation was a major factor responsible for water pollution by sheep dip chemicals. Allowing insufficient time for sheep to drain off after dipping is a common failing in an effort to speed up throughput. Sheep should be allowed a minimum of 10 minutes to drain off before moving and preferably longer if space allows. This will also reduce the amount of sheep dip chemical needed for replenishment. Draining pens can be inadequate in size relative to the number of sheep being dipped and ideally two pens should be provided, one for freshly dipped sheep and the other as a holding area for sheep dipped earlier. Freshly dipped sheep should never be allowed to walk into a river or stream and if possible, for the first few days after dipping should be turned into a field with no access to a watercourse.

A further cause for concern is the disposal of spent dip, with many disposing of spent dip carelessly close to watercourses or on ground that is prone to rapid run-off. Ideally once dipping is complete used dip should be sucked out of the dip bath and disposed of immediately. It appears that this is not always the case and dip baths are sometimes left full for long periods of time, during which there may be an inflow of rain water and the potential for overflow into drains and watercourses. There appears to be a degree of ignorance in the farming community as to the correct methods for disposal. Further promotion of the Certificate of Competence could help to overcome this ignorance.

Any dip concentrate containers should be rinsed into the dip bath and then disposed of carefully. Likewise, unused dip concentrate should be stored securely. Dip containers are not always carefully disposed of and are often seen dumped in a corner of the handling system together with other medicine/drench containers (Blackmore & Clark, 1994).

4.4 Mobile Dip Contractors

A large proportion of sheep in England and Wales are now dipped by mobile dip contractors. The National Association of Agricultural Contractors register (1997/98) contains 15 mobile dip operators, 13 in England and 2 in Wales. However, there are believed to be significantly more in the country with one estimate of around 100 currently in business. There is believed to be a significant move to contract dipping, particularly in the midlands and south of England. The number of sheep dipped by these contractors varies widely according to area, but in some counties more than half the sheep are dipped in mobile dip facilities. The contractors are therefore likely to be responsible for the disposal of a large quantity of spent sheep dip as well as the management of the dipping operation.

Mobile dip baths have a drain plug, which can be easily removed to release the spent dip directly onto the ground with no consideration of the suitability of the site for disposal. Although one of the contractors interviewed always stipulates that the farmer should have a slurry tank and pump to remove the spent dipwash from the bath before diluting 3:1 with slurry or water and spreading at $5m^3$/ha, this degree of care (by anecdote) appears to be unusual.

The draining pens on mobile dippers are generally not large enough to allow sheep 5 to 10 minutes to drain before moving off the dipper. Freshly dipped sheep can therefore roam over grassland and potentially get into a water course very shortly after dipping. The Environment Agencies leaflet 'Mobile Sheep Dipping' (1998) gives very useful guidance on this issue and recommends that sheep are kept in draining pens until free drainage stops, and then held in an area with no access to watercourses or wetlands until sheep are dry.

Apparently, there is wide variation in the practices of mobile dip operators and there needs to be a general improvement and standardisation of dipping management, especially the practices for dip disposal. There have been a number of anecdotal reports of mobile dip operators dumping spent dip directly into a drain or watercourse. ADAS interviews with two contractors confirm these reports. It is suggested that the legal responsibilities for the disposal of dip by contract dip operators be identified and clarified, particularly as it relates to the division of responsibilities between farmer and contractor.

It is thus suggested that there needs to be a national system for the registration and licensing of mobile dipping facilities, their operatives, and their operations, and that for the granting of the licence, the operators should be assessed for their competence to dip safely and to dispose of dip. Proposals for this level of regulation received some support from one dipping contractor interviewed by ADAS. It is also recommended that the operators should be required to maintain and submit to the Environment Agency a log of the locations, the dip used, and the means of disposal.

4.5 Shared Disposal Facilities

Some farmers currently share both dipping and dip disposal facilities. This practice has much to recommend it, particularly where flocks are small. A number of well managed dipping facilities, for which suitable disposal facilities have been identified, offer the prospect of reducing the pollution risk.

Even if they do not share the dip facilities, some farmers may find it advantageous to seek joint authorisations for groups of neighbouring farmers to all dispose of dip onto suitable land. Provided that transport of spent dip by farm equipment (for example, tractor and slurry tanker) was not contrary to specific regulations (see 3.2 above), this would appear to be an obvious option for a group of farmers (within perhaps a 15 km radius) who could propose a suitable shared site that would be acceptable to the Environment Agency.

For example, based on currently recommended rates, a 5 ha area could accept $25m^3$ of undiluted spent dip at a single application at the rate of $5m^3$ maximum rate suggested by the current MAFF Code of Good Agricultural Practice (MAFF/WOAD 1991). Even if $5m^3$/ha was to be made a maximum annual application rate, the area could accept the waste dip from at least 6 farms with $4m^3$ each to dispose of per year.

4.6 Implications

The surveys of dipping installations and dipping practices show that many farmers and contractors do not follow current voluntary guidelines for the location of dips, the dipping of sheep, or the disposal of spent sheep dip. Many follow methods and use installations that are now out of date. There is thus a need for a programme of awareness and education of all those involved in the dipping operation. However, this needs to include more than just the technical issues of dip bath construction and spent dip disposal, but needs to embrace the whole issue of flock management. The techniques to be discussed in the next section, which offer alternatives to dipping, need to be included in a total education package, bringing the latest information to the farming industry.

However, there is also no prospect of achieving an immediate change of practice by the creation of yet another leaflet, to be distributed to an industry already inundated with advisory leaflets. It is essential that any code of practice for the control of ectoparasites in sheep be backed up with a pro-active programme of farmer education, including targeted visiting, presentations at shows, and articles in the farming press.

5. ALTERNATIVES TO PLUNGE DIPPING

The safety and well being of the sheep flock is a major concern, and control of parasites is an essential component of good flock management. However, this may not necessarily require the use of frequent dipping. Alternative chemicals, either poured on the animal, or injected into the animal are also available. Equally, adoption of good flock management techniques could also reduce the need for regular dipping.

5.1 Injectables

The currently available systemic injectable treatments (Table 2) may prevent the introduction of scab into a flock provided they are used in conjunction with "quarantine" management of flock imports, but not all provide protection. None protect against blow-fly strike. Injectables have advantages over dipping in that there are fewer disposal problems and welfare issues, both human and animal. There are also however environmental considerations, such as the impact of the faeces on the population of dung beetles. Injectables are particularly useful for the protection of lambs too young for dipping or for pregnant ewes. There are however long withdrawal periods (up to 70 days for doramectin), during which the animals may not be slaughtered for meat, so they cannot be used on lambs close to market, nor for ewes producing milk for human consumption.

Ivermectin was the first injectable authorised in UK for the control of sheep scab, and requires two sub-cutaneous injections, 7 days apart. Under-dosing must be avoided for all injectables and dose rates based on the weight of the heaviest sheep in the group are advised. After the second injection there is no protection against re-infection and treated animals should be kept away from any site where they had previously been held, for 16 days i.e. the period of time the mite can live away from the body of the sheep.

Doramectin is the only other injectable product currently (March 1998) authorised in the UK for sheep scab control. Only one injection is required, but there is no protection against re-infection. This injection is intra-muscular which is advantageous in practical situations and where recommended dosage rates must be given (Purnell, 1997).

Moxidectin is licensed in southern Ireland and is expected by the manufacturer to be authorised for sale in the UK in 1998. This product not only eliminates existing infection but is also claimed to protect clean sheep against mite infection for 35 days after treatment.

5.2 Pour-ons

These products are applied by pouring a measured dose on to the sheep or spraying on via an applicator gun. They are administered in small volumes - typically 10 to 50 ml of relatively concentrated insecticide. The products are non-systemic and are effective on the skin and on the wool, persisting for 6 to 8 weeks. However, pour-ons provide no control of sheep scab but are effective against other ectoparasites. Like injectables, pour-ons have fewer disposal problems than dips, and are useful for protection of lambs too young for dipping.

Two major products are currently in use. One is an insect growth regulator cyromazine, which disrupts the normal growth and development of the early stages of blowfly maggots. It is not effective against other sheep parasites. The other class is based on synthetic pyrethroid insecticides of which the most commonly used is cypermethrin. Cypermethrin acts in two ways. When used for the control of lice and ticks, and for the treatment of blowfly strike, it acts directly against the parasites and kills them. When used for the prevention of blowfly strike and for headflies it acts as a repellent.

Pour-ons have become the most significant means of tick control because of the practical benefits of use at the most effective treatment times i.e. near lambing. Logistic considerations have led to increased use of pour-ons for fly strike prevention, despite the higher materials cost. Some express doubts about the length of time for which pour-ons confer protection in wet summers, but this is anecdotal. Correct application rates are important not only to provide the required protection but also to prevent the potential for ectoparasite resistance developing from the use of low dosage rates.

5.3 Use of Showers and Jetters

The same chemicals that are contained in dips can also be applied by showers and jetters for protection against fly strike. However, only plunge dipping provides the degree of immersion necessary for sheep scab control and prevention. Typically, a shower is a circular galvanised structure, 2.2 m in diameter, with a recirculating pump and sump, accommodating 12 to 20 sheep at a time. The cost of the installation is around £1500. It is claimed that the process is less stressful for the sheep but the most obvious advantage is that less than 150 l of surplus dip is left over at the end of the treatment for disposal. The practice is uncommon in the UK.

Jetting involves applying dip via high pressure nozzles as the sheep pass through a race. There is little surplus dip at the site of operation, but "draining" primarily occurs as the sheep return to the fields. A major problem is the pollution of the immediate working environment with dip charged vapour, which presents a health hazard to the operator and presumably, also to the sheep. Although widespread in Australia and New Zealand, this practice is rarely used in the UK, presumably because it fails to control the most troublesome problem of scab

5.4 Flock Management Alternatives

Strategic planning of ectoparasite control to utilise all the benefits of the available products and good flock management could reduce the amount of dipping considerably. The majority of farmers purchase breeding stock every year but very few isolate these before adding to their main flock. In most cases, a quarantine period of about three weeks would allow time for sheep scab to develop and clinical symptoms to be apparent. However, on occasions development of scab may happen after as long as 50 days (Lewis, pers. comm.).The replacements could then be treated by injection or dipping. Only when treatment was complete should the new stock be added to the rest of the flock. This practice would markedly reduce the number of sheep that would need dipping.

If flock security is good, only new stock (ewes, rams, store lambs) which develop symptoms in the quarantine period would need to be treated as a group which would markedly reduce the amount of chemical required whether dip or injection. The isolation period would also be very useful to detect and treat many other diseases.

Many hill flocks operate a 'closed flock' policy with only pedigree rams being brought on to the farm. All breeding females are home bred so isolation and treatment of the few rams bought each year is therefore very simple. In contrast, most lowland flocks buy crossbred females produced in the hills as flock replacements. If lowland farmers were to consider producing their own flock replacements then very careful planning of the breeding programme would be necessary to avoid the loss of desirable production traits (e.g. mothering ability, prolificacy etc.). However, this is possible and there are some good examples to demonstrate successful systems in the lowlands.

The provision of good, secure boundary fences on lowland farms would help to reduce the risks of disease spread by stray animals. In the uplands, improved co-operation between farmers in terms of times of gathering and treatment would also be of significant benefit. The new legislation introduced on 1 July 1997 (New Controls for Sheep Scab, The Sheep Scab Order 1997 PB3158) could be more rigorously enforced and persistent offenders penalised heavily.

Sheep scab can be introduced to a farm by transport lorries, shearing equipment, clothing etc., hence good hygiene should be practised by all contractors. Current legislation allows the movement of scab infected animals for treatment or slaughter hence lorries are a potential source of infection for other sheep. It is virtually impossible to clean out lorries between consignments of sheep so prohibition of movement of scab infected sheep at any time and treatment on site should be advocated.

5.4 Compulsory Dipping

It has been suggested that one way of reducing the long-term need to dip is to return to compulsory dipping for sheep scab, with the aim of complete elimination of scab from the national flock. Once eradicated, dipping for scab control would no longer be necessary. A consequence of adopting this strategy, would have to be the re-imposition of extremely rigorous import controls, to prevent the re-introduction of the problem as happened in 1973. It is however, suggested that the short-term environmental implications of such a campaign might be large, unless it were accompanied by a rigorous control of the dipping operation itself. In addition, it may no longer be possible, within the context of European legislation, to impose the necessary restrictions on sheep necessary to maintain the disease free status of the national flock. The complete elimination of sheep scab in UK thus remains unlikely.

5.5 Withdrawal of Dipping

Another alternative that has been suggested is the complete cessation of dipping as a practice. It has been observed that some farmers, particularly those that maintain closed flocks, ceased dipping sheep when compulsory dipping was withdrawn and have maintained healthy flocks without dipping ever since. These farmers have relied on the use of alternatives to protect against other diseases, and to prevent the re-introduction of scab by imported sheep. The argument is that if some farmers can manage without dipping, then all should be able to do so. Unfortunately, the realities of grazing common land militate against such a policy where cross infection between flocks cannot easily be prevented. It has been suggested by those concerned with sheep welfare that many farmers would have significant problems in maintaining the health of their flocks if they were unable to dip. Should there be a major outbreak of scab in a flock, even those farmers who have not dipped at all in the recent past, would wish to retain the ability to control the disease by dipping.

6: DISPOSAL OF SPENT DIP TO LAND

The active ingredients of spent sheep dip have the potential to cause pollution of surface or groundwaters if disposed of inappropriately. The aim of land disposal is to retain the contaminants close to the surface of the soil where they are applied, and where biological processes can degrade the active ingredients. However, these active ingredients also have the potential to have a detrimental impact on soil fauna. Although this review is being conducted mainly within the context of water pollution, it is important to note that sheep dip has an adverse effect on fauna wherever it is disposed of, and it should be recognised that inappropriate disposal could have detrimental effects on land (so causing a "soil pollution" incident) without it ever reaching a water course. There is little detailed information on the effects of application of spent sheep dip on terrestrial invertebrates, and this effect needs to be investigated. However, because it is highly toxic to invertebrates, spent sheep dip should not be applied to sites of high ecological interest. Nevertheless, it is generally considered that disposal to land offers a practical means of disposal, provided the active ingredients are not then transported to adjacent water bodies (either surface or ground waters), or that sensitive terrestrial ecosystems are not damaged.

The factors controlling the risk of pollution from disposal of sheep dip are no different in principle to those governing the losses following application of any other agrochemical used in farming. Thus if the material is strongly adsorbed to the soil, or has limited persistence, pollution is less likely. If on the other hand it is weakly adsorbed or long-lived then the risk is increased. In general, any means by which the time of interaction with the soil, and volume of soil concerned, can be involved will lead to a decrease in pollution risk.

Most sheep dip ingredients are neither highly mobile nor highly persistent (Inch *et al.*, 1972). The available data (PSD 1991, 1994; Tomlin, 1997; Wauchope *et al.*, 1992) indicate that chlorfenvinphos and diazinon are slightly to moderately persistent and slightly to moderately mobile in soil, using PSD's classification (Hollis, 1991). The data for propetamphos is limited, because it has no use in crop protection, but the data available suggests the parent molecule is also slightly to moderately persistent and slightly mobile in soils. However, metabolites might be formed which are biologically active and more mobile, (P. Nicholls, Rothamsted: personal communication). The properties of cypermethrin and deltamethrin (Tomlin, 1997; Wauchope *et al.*, 1992) have properties which indicate that they are moderately persistent and non-mobile in soils using the same classification system. There is very little soil fate and behaviour data available for flumethrin, again because it is not used in crop protection in the UK. However, the non-mobile nature of the SPs, does not mean they are unlikely to reach surface water following land application, since strongly-adsorbed pesticides have the potential to move while attached to soil particles, (Harris, 1995).

There are at least three routes whereby water carrying sheep dip residues may reach a water source: overland flow (surface runoff), flow through the soil to a surface channel (through-flow) or movement downwards to a water table. Where any of these processes are rapid, the chemicals carried by the water are less likely to interact with their surroundings, and so be carried directly to the receiving areas. In general, rapid movement of water, either over or through the soil should thus be prevented. Consequently, care should be taken to avoid situations, such as those where infiltration is limited due to saturation, compaction, or ground-frost; or where rapid routes of movement such as cracks opened up by high soil moisture deficits. The application of material to a heavily cracked soil, or one where new mole drains have just been installed, could result in applications of spent dip reaching surface or ground waters directly.

6.1 Current Guidance for Disposal

The current recommended procedures for the disposal of spent sheep dip by farmers are set out in the "Code of Good Agricultural Practice for the Protection of Water" (MAFF/WOAD 1991) which is currently under revision. This code operates on two fundamental principles. Firstly, identifying areas on which the spreading of wastes is inappropriate at any time and secondly estimating the risk of pollution from those areas that are deemed potentially suitable for application. The same criteria are used for both organic wastes and sheep dip, which is not unreasonable since the modes of transport by which pollution from either source will move are similar although the contaminants and maximum allowable concentrations differ. The current code states that no waste dip should be applied to non spreading or very high risk areas.

The code states that waste is not to be disposed of under any circumstances to land within 10 m of any watercourse. The rationale is that surface runoff can easily transport applied material directly into the watercourse if the distance to be travelled is less than 10 m. However, on steeply sloping sites, surface runoff could easily cross a 10 m zone and reach a watercourse and this distance should be increased. Application within 10 m of a watercourse also carries the risk of direct contamination due to drift. An uncultivated buffer strip along the edge of a watercourse will reduce the risk of causing pollution.

The code also advises against application within 50 m of, or in the same field as a spring, well or borehole that supplies water for human consumption, or is to be used in farm dairies. In addition, consideration should be given to the underlying strata in identifying the risk of the material reaching groundwater. If the industry moved towards a licensing system that encouraged farmers to group together to set up licensed disposal then it would become even more important to consider the underlying strata and the degree of connectivity with aquifers.

Fields that have been pipe drained, mole drained or subsoiled, over a pipe or mole drainage system, within the last 12 months are very high risk areas, and are deemed unsuitable for disposal of sheep dip. Soils that are cracked due to desiccation are similarly unsuitable for disposal. However the findings of Williams and Nicholson, (1995) relating to dirty water disposal suggest that in practice up to $50m^3$/ha can be applied to cracked soils without generating drain flow, although applications directly over drains which had a good connection to the surface horizons could produce instant drainflow (Williams pers. comm.).

Shallow soils over fractured bedrock are similarly unsuitable for disposal of spent dip, as they often have complex but rapid flow paths through such soils, leading to rapid movement through the shallow rock to surface waters.

Compaction of the soil (poaching) also contributes to runoff risk, and so renders land unsuitable for dip disposal. Assessing the amount of poaching may be an important factor in determining site suitability for disposal. Although hard to measure in objective terms, consistent visual assessment of poaching risk is possible, and poached land should not be used for the disposal of spent dip.

6.2 Risk Assessment

If the COGAP guidelines are followed to identify the areas most suitable, disposal of spent dip by land spreading may not carry a great risk of immediate contamination of the water environment. Much of the material spread should be retained in the soil and degraded there. The greatest risk of pollution is then presented when there is heavy rainfall immediately after land spreading. However, this risk has not been assessed in a scientific study.

It is thus suggested that a detailed risk evaluation be undertaken using a modelling approach to define the rate of movement of dip to both groundwater and surface water. The risk could then be quantified in terms of the time interval between disposal and the first subsequent rainfall, and also taking into account the soil type and topography (slope). The degradation rates and sorption properties of most sheep dip active ingredients have been identified by laboratory studies, and there should also be a programme of field studies, to identify their behaviour in field soils.

Pesticide fate models that have already been developed could be used to simulate the disposal of diluted waste dip at a variety of rates and under a number of climate and soil scenarios. This will supplement the risk assessment studies so far undertaken which have mainly focused on the consequences of dumping a large quantity of spent dip directly into or near to surface waters (Littlejohn and Melvin, 1989). It would also be advisable to carry out a small scale field trial relating to dip disposal to validate the results of such a modelling exercise.

6.3 Application Rates

The COGAP for the Protection of Water currently suggests a rate of $5m^3$/ha for application of spent dip to land. This figure was arrived at when the code was written in 1991 by taking advice from the Veterinary Medicines Directorate (VMD) and others, such as ADAS sheep specialists, on what were felt to be 'safe' spreading rates for spent dip containing organophosphates; and on the basis of what was practical and realistic. There is too much solid matter in spent dip for it to be applied by a crop sprayer, as the small orifices in the spray nozzles would rapidly block. It is also important to note that these guidelines were drawn up for OP dips, and that their suitability for SP dips (which pose a higher risk to the aquatic environment) has not been evaluated.

The item of equipment that is commonly available on livestock farms (or via neighbours or an agricultural contractor) and is capable of dealing with liquids containing solids, is the tractor-drawn 'vacuum' tanker for handling slurry. The majority of these tankers was and still is fitted with a simple splash plate device to break up and spread the stream of liquid as it is discharged. Application rates at typical tractor forward speeds were in the order of $20m^3$/ha for most machines of this type. The deduction was that a practical and 'safe' spreading rate for used dip, was in the order of $5m^3$/ha, provided it could be diluted 3:1 with water, dirty water or slurry and the resultant mixture spread at $20m^3$/ha. The majority of tankers have a capacity of between $4m^3$ and $7m^3$ and the majority of dip baths would contain 0.75 to 2.0 m^3 of spent dip. This dilution rate is therefore often possible with a single tanker load per dip bath emptying. A recent study of machines on the UK market (for the purposes of spreading pig slurry at rates likely to comply with proposed IPPC controls) indicated that this is still the case. An application rate of $20m^3$/ha would still appear to be a practical upper limit with generally available equipment. However, it is thought that some upland farmers will not even have this equipment, and so some development is needed to identify alternative equipment suitable for the disposal of dip.

Addition of spent dip to slurry in store could result in dilution rates as high as 1000:1 and breakdown of active ingredients is likely to occur during storage, before spreading to land. This practice is however discouraged in the COGAP on the basis that the location of fields on which dip had been spread would not be known with any certainty (A.Brewer, pers., comm). The implications for breakdown of spent dip in slurry or manure stores should however be examined (section 7.2.)

It is still, however, uncertain whether the application rates presented in the Code of Good Agricultural Practice for the Protection of Water are in fact appropriate. It can be argued that if, even after dilution, the rates are still highly toxic (particularly the newer SP dips) to the terrestrial ecosystem, then diluting the spent dip and spreading it on a wider area of land merely spreads the problem over a wider area. It can be argued that the concentrated application on a smaller "sacrificial" area might be better, in the long run, for the terrestrial ecosystem. The issues of the actual toxicity of spent dip under varying dilution rates need to be investigated in a systematic way, so that the correct dilution and disposal options can be better informed.

7 TREATMENT OF USED DIP

Several treatments have been proposed which may reduce the impact of spreading spent sheep dip by reducing its biological activity before disposal. These treatments are added to the spent dip in the bath, (or some other temporary container) where they "neutralise" its activity, so that the material can then be more safely spread. This option is appealing in principle, but is as yet only partly developed in practice. Factors that must be considered in the development of a chemical-based approach to dip wastes include:

a) The identity of breakdown products and the possible environmental impact of the treated waste.
b) The robustness of treatments in wastes with high organic loading. The amount of faecal matter, wool, oils and soil in the waste dipwash may influence the efficacy of any treatment.

Maloney *et al.* (1998,1992) have demonstrated the potential use of certain bacteria to detoxify pyrethroids. *Bacillus stearothermophillus* SM4, *Achromobacter sp., Pseudomonas fluorescans* and *Bacillus cereus* have been used in these studies. However, these biological treatments have not been developed to commercially available systems, and in general, the treatments that have been proposed all rely on the active ingredients in dip being chemically unstable in highly alkaline (high pH) solutions.

7.1 High Alkali Additions

Various alkaline or oxidising additives have been identified which might be expected to lead to the breakdown of the active ingredients of sheep dip pesticides. Although there is much variation in the reported degradation rates, there is a consistent trend of the OPs degrading more rapidly at alkaline than neutral pH values. This work now forms the basis of manufacturers' recommended additions to reduce the toxicity of spent dip. Major alkalis that have been identified as possible additives include sodium hydroxide, sodium hypochlorite and slaked lime.

7.1.1. Sodium hydroxide

Sodium hydroxide alone was found to be inadequate to deactivate high-cis cypermethrin (HCC) from the oil phase, and the addition of a surfactant was necessary to release the HCC. A non-ionic surfactant in combination with sodium hydroxide rapidly degrades the HCC in 5 to 10 hours. The manufacturers claim that the degradation products have no insecticidal activity and are further degraded in the soil after disposal to land. The 'disposal system' is sold in a standard pack (£25), sufficient to degrade 1000 litres of dipwash. It contains five litres of surfactant and 5 kg of sodium hydroxide pearls. The two products are added to the bath at the end of dipping and mixed thoroughly to dissolve the sodium hydroxide. After 12 hours, the spent dip can be disposed of to land following MAFF guidelines. Whilst the dip is still alkaline, disposal as recommended on to pasture showed no observable effect on grass. The manufacturers have also claimed the safety of treated dipwash on sensitive water crustacea.

7.1.2 Sodium hypochlorite

Stephen (1997) has demonstrated the effectiveness of sodium hypochlorite in breaking down the organophosphate, propetamphos where the addition of sodium hypochlorite (11% available chlorine) to a propetamphos containing dip waste at 2.5% v/v resulted in 84% disappearance of the insecticide after 24 hours at 15 ± 2°C. In a field trial using sodium hypochlorite, 80% disappearance was observed after 24 hours at 6.5 ± 2°C.

Sodium hypochlorite solution (10%) is now recommended by one dip manufacturer for degradation of propetamphos. The solution should be added at a rate of 1:40 to spent dip i.e. 25 litres of solution to every 1000 litres of dipwash. The two should be mixed and left for 24 hours before spreading on land.

However, care must be taken, not to add sodium hypochlorite to dips containing diazinon residues, as this can produce very hazardous toxic oxon derivatives, nor to phenol residues, as this can produce highly stable and toxic chlorinated phenols. This treatment should therefore be used only in very specific circumstances, for the degradation of mixtures containing propetamphos only.

7.1.3 Slaked Lime

Slaked lime (or its chemically pure form, calcium hydroxide) has been advocated by some dip chemical manufacturers as an additive for the detoxification of flumethrin, cypermethrin and diazinon. The slaked lime, however, tends to sink to the bottom of the dip bath and requires periodic re-suspension to keep from solidifying. The dip wash/lime mixture should remain in the dip bath for between 1 to 2 weeks before disposal to land in the normal way. Watson *et al.,* (1997) describe the breakdown of flumethrin by slaked lime into bayticolic acid and flurophenoxybenzaldehyde. These products increased in concentration with time after addition of lime and it has been assumed that they pose little risk to the environment since they are not believed to be biologically active. Although relatively cheap, slaked lime is not easy to handle, and there are significant risks to the handler.

7.1.4 Disposal

Despite publicity by the manufacturers, on-farm treatment of spent dip has not become common practice. Although toxicity of the spent dip may be reduced by treatment, it is unlikely to be totally harmless, and it must therefore be subject to the same careful disposal practice as the normal spent dip, although with a potentially reduced environmental risk. Clearly, farmers see that the environmental benefit, if any, is outweighed by the extra effort and cost involved. In addition to the problems associated with the normal disposal of the spent dip, there is the additional problem caused by the high pH of the treated dip, which may have deleterious effects on both flora and fauna. Although it is claimed (e.g. Watson *et al.,* 1997) that disposal will not scorch grass, this is clearly a possibility which farmers would wish to avoid. From an environmental viewpoint, it is far from clear what the impact might be on the flora and fauna of the field, and the impact that such a high pH material might have on any receiving water course. If any were to get into a small water course, the disruption of the stream chemistry could have effects that are potentially disastrous, even if there were no direct toxic effects.

The environmental dangers involved in the use of these treatments can be illustrated by an example of a substantiated pollution incident (information provided by Alan Virtue, Scottish Environment Protection Agency). The farmer in question had used the detoxification pack supplied by the manufacturer to detoxify a cypermethrin dip. The dipper had been left full after dipping, and in addition to the chemical degradation, considerable dilution by rainfall occurred.

Nevertheless, despite nearly complete degradation and dilution, severe invertebrate impoverishment was recorded from a marshy area between the dip bath and the stream, and in the stream 50 m from the pollution entry point. This single, unreplicated, incident suggests that treated (detoxified) dip still presents a significant risk to the environment, and must itself be disposed of correctly.

In summary, there is still much that is unknown about these treatments, and additional research and documentation of both the principles and the procedures involved, is required before they can be used safely. Although they appear to offer a way forward, these treatments cannot be recommended at present.

7.2 Addition to Organic Materials

One possible method for on-farm disposal of spent dip is to add the spent sheep dip to a well maintained farm waste system, either an aerobic manure heap or an anaerobic slurry store. Assuming that the facility is sufficiently well designed that there are no leakages from the store, then the high rate of biological activity within farm waste stores might result in the rapid degradation of the active ingredients of the sheep dip. Once the relevant chemical had degraded, then the resulting wastes could be disposed of to land in the normal way. This procedure might also result in the degradation of the other components of the spent dip (notably sheep faeces and lanolin). However, there are many uncertainties associated with this treatment. At present disposal of spent dip in slurry stores is not within the Code of Good Agricultural Practice, because of the uncertainty about the eventual fate of the active ingredients should they not degrade (A.Brewer, pers. comm.). Nor are there any readily available tests or guidelines to see whether these wastes are safe for disposal.

Although it is plausible that sheep dip chemicals might degrade more rapidly in suitable waste heaps (Entry and Emmingham, 1995; Katayama *et al.*, 1995; Winterlin *et al.*, 1989, Lovell and Jarvis, 1996), there is also the potential for the opposite effect as chemicals absorbed onto organic matter are protected from degradation (Barriuso *et al.*, 1997; PSD 1991, 1994; Torstensson, 1996, Hill, 1985; Winterlin *et al.*, 1989; Barriuso and Koskinen, 1996). The balance between these two effects is not known in detail, and may vary between chemicals and with conditions in the waste heaps (Xie *et al.*, 1997).

There is less information on the effect of anaerobic environments (such as would be found in a slurry store) on many sheep dip chemicals. A single study (PSD 1991) reports faster degradation of diazinon in a flooded soil compared to one non-flooded. Conversely, degradation of SPs in sediment-water systems is usually slightly slower than in soil and low concentrations of residues can be recovered from bottom sediments after considerable periods of time, (Hill, 1985).

A further factor which will affect degradation is the phenomenon of enhanced degradation, that has been observed with some OPs in soil (e.g. Suett and Walker, 1988). Repeated applications to the same site can result in much-increased rates of degradation and the effect can persist for more than one season. Such enhanced degradation has also been observed with diazinon. The problem has been reported less for SPs because they have only recently been used as soil-applied rather than foliar treatments, but it is known (e.g. Chapman *et al.*, 1993).

The variation in pesticide degradation and its potential mechanisms may be indicative of the complex set of factors that control the process. On the evidence available, we cannot predict how the persistence of sheep dip components will change in manure heaps or in slurry, compared to the soil (Torstensson and del Pilar Castillo, 1997). The mechanisms involved in both sorption and degradation of sheep dip residues are poorly understood and it is thus suggested that experimental studies need be undertaken to identify the effectiveness of this treatment before it is widely advocated.

7.3 Filter Systems

It has been suggested that some on-farm disposal systems might offer a viable alternative to disposal on the land (Blackmore & Clark, 1994). The Allman/ICI "Sentinel" system is one such system that has been developed for the disposal of pesticide residues using carbon filters. Preliminary experiments with the use of this system for the treatment of spent dip were reported by Blackmore & Clark (1994), who stated that the major problem with the system at present was that of filtering out the biosolids and the lanolin from the spent sheep dip. The system seemed incapable of filtering out pesticides bound to these organic materials. There is also the problem of disposal of the spent filter material from the treatment plant, which is considered as a hazardous waste which needs specialist (and therefore expensive) disposal. It may be that with the implementation of the groundwater regulations that this (or an alternative) system may be developed further, but there is no prospect of an immediate widespread adoption of this system. Until the commercial development is taken further, this system remains only a theoretical possibility.

8. OTHER OPTIONS FOR SAFE DISPOSAL: OFF-SITE TREATMENT OR DISPOSAL

Current disposal practices rely heavily on the application of used sheep dip to land. However, it has been considered by some that the proposed goundwater regulations will provide the economic stimulus for new disposal techniques, involving either on-site or off site treatment, or the better stewardship of the sheep dip products themselves. The information below has been gathered from discussions with a number of contacts in the water and waste disposal and treatment industries. The general findings and estimated costs are supported by statements elsewhere in ENDS Report 230 (ENDS 1994) and Blackmore & Clarke (1994). Possible options considered (not all of them viable) included: discharge to sewer, specialised treatment plant, landfill, incineration, purpose-built treatment plant and other methods (e.g. reedbeds). Transport logistics and costs will also a have a major influence on whether such options are viable.

8.1 Discharge to Sewer

Despite the fact that spent dip is probably similar in organic matter content and Biochemical Oxygen Demand to domestic sewage, it is highly unlikely that the material would be accepted by any sewage treatment works. Most works would not be licensed to take such waste and would need an additional licence. Certainly none of the small rural works, nearest to sheep dipping operations, would be licensed in this way. The main reason for the unacceptability of this material is because of the OP or SP content, which, despite the dilution likely to occur, could end up in the treated outflow and could well cause the plant to fail the discharge consent conditions set by the Environment Agency, and cause Environmental Quality Standards (EQS) failures in receiving water courses. Some companies operate specialised pre-treatment plant at sewage works sites but even in these cases are unlikely to accept effluents containing SPs or OPs as the plants are generally geared up to deal with non-hazardous, non-toxic material, such as food wastes.

8.2 Specialised Chemical Effluent Treatment Plants

A number of specialist waste disposal companies operate treatment plant that is capable of dealing with a variety of potentially hazardous contaminants by processes such as neutralisation or precipitation. Some of these have subsequent discharge consent to sewer or landfill. None of the companies contacted was prepared to take sheep dip or other material containing pesticides.

8.3 Landfill

A limited number of landfill sites are licensed to take liquid wastes. Anaerobic degradation would then take place within the organic solid material contained within the landfill mass. The number of landfills with a site licence to take this type of waste is estimated at no more than a dozen nation-wide. Locations of all these are not known, but most are likely to be remote from the main sheep rearing areas. Costs, excluding transport is likely to be £50 -100/m^3. The logistics of organising such an operation and the high costs of collecting and transporting small quantities for long distances are likely to be prohibitive in most cases. Generally, therefore this appears not to be a viable option for the majority of sheep farmers at present. It is possible however that in the longer term, the impact of the proposed groundwater regulations may lead waste treatment companies to invest in suitable plant at strategic locations if they see a commercial advantage in doing so.

8.4 Incineration

It is understood that there are currently five commercial incinerators capable of 'wet' incineration and licensed to take this type of waste. Locations are believed to be Southampton, Avonmouth , South Wales, Southport and Sheffield. Costs of incineration of liquid wastes, excluding transport are likely to be in the order of £250/m^3. The problems and costs associated with transporting spent dip to these locations are as great as that for taking the product to landfill sites. Unless operators see some long-term commercial advantage in investing in purpose-built plant at strategic locations that can also take other wastes, this option is unlikely to be viable.

8.5 Reedbeds and Biobeds

Reedbed treatment has been shown to reduce concentrations of OPs considerably, but is likely to be unacceptable to the Agency if a discharge consent is involved and discharge concentrations of contaminants could not be guaranteed.

Biobeds (described by Tortensson & del Pilar Castillo, 1997), offer the opportunity to capture the pesticide component of water draining to a mixture of topsoil, peat and straw. This system was developed for the disposal of pesticide residues, but could be adapted for the disposal of sheep dip residues. Biobeds rely on the microbiological decomposition of the pesticides and have been shown, under laboratory conditions, to be successful in degrading commonly used agricultural pesticides (but not sheep dip chemicals). Many practical issues need to be resolved before biobeds could be suggested as a practicable method for the safe disposal of sheep dip.

8.6 Product Stewardship

"Product stewardship" includes the potential for better labelling of containers, better guidance regarding environmental safeguards in product literature and the potential to retail dips and treatment products as a single package. Other less practical options include the return of used dip to manufacturers and the suggestion that dip compounds be "leased" to farmers. These last two will involve the same large (and hence prohibitive) transport costs identified for all off-site disposals.

8.7 Transport Logistics

Transport logistics and costs are a major consideration for off-site treatment. Many dipping locations are not easily accessible, or may be inaccessible, to a large articulated or rigid bodied 18-20m^3 capacity road tanker of the type typically operated by waste transport and treatment companies. Transport by such a vehicle would however be virtually essential if one of the limited number of locations were to be used by a large number of farms. The alternative would be to transport spent dip in sealed containers, collected on a suitable flat bed vehicle fitted with a hoist. In either case it would probably be necessary to set up licensed transfer stations, possibly with bunded storage tanks, at strategic locations in order to deal with spent dip from those dipping facilities not accessible by lorry-based tanker, but accessible by farm tractor.

Apart from the difficulties of organising such an operation, transport costs are likely to be high. Operating charges for a $20m^3$ road tanker are likely to be £400-500/day (Commercial Motor, 1998). If a round trip to collect a full load and deliver it to the point of treatment might take two to three working days, transport costs for this element of the operation alone could add £40 to £75/m^3. If the costs of setting up transfer stations and administration are included, total handling costs might amount to £100-200m/^{3}.

It is concluded that only incineration or landfill are possible options at present, although specialist companies might invest in suitable facilities in future. Costs are likely to be in the order of £100/m^3 to £250/m^3 of spent dip. Transport and handling will add another £100-£200/m^3, unless the dip facility happens to be close to a suitable plant or landfill site. It therefore seems likely that the off-site treatment option will only be adopted by those in favourable locations that minimise transport difficulties and hence costs.

9. OTHER SOURCES OF POLLUTION

Wool used in the textile industry has been identified as a potential source of pollution by sheep dip chemicals (Eke, 1997). Because the EQS are very low, even very small residues can still cause exceedences to be recorded. Because much of the wool is imported, the fleeces may contain chemicals that are not authorised for sale in the UK as sheep dip, but which still cause problems when released in discharges from wool treatment plants. The first stage in preparing wool involves the processing of the fibre through a series of water washes at temperatures up to 65°C. Raw wool scouring removes 90-96% of the fat-soluble pesticides present in the wool at the time of shearing. The effluent from the scouring process is normally treated for the removal of pollutants, which is not always completely successful, and can lead to an exceedence of the Environmental Quality Standards (EQS), Table 4. In addition, the EQSs are very low, and therefore even very small residues can cause exceedences to be recorded. Data on freshwater EQS failures for sheep dip chemicals are given in table 7.

Table 7: Number of sites exceeding EQS for sheep dip chemicals, 1993 to 1997
(From Eke, 1977, with additional data provided by A.Croxford, Environment Agency).

Chemical	1993	1994	1995	1996
Diazinon	42	30	37	52
Propetamphos	No Data	31	16	34
Cypermethrin	No EQS set	No EQS set	27	60

The distribution of EQS failures (Eke 1997 figures 3 and 4) demonstrate quite clearly that the problems are associated with the wool processing industries of Yorkshire and the Midlands, as well as in the sheep dipping areas themselves.

The problem of the discharge of pesticides from the wool processing industry can be tackled by a three-fold approach (Eke, 1997):

- First, the amount of pesticide present in the wool can be reduced. It is good practice not to shear close to dipping to avoid undue pesticide residues in the fleece. In addition, the degree of pest control is reduced if the fleece is full. However, where parasite infestation becomes a problem, farmers will dip when necessary for flock health reasons, irrespective of planned shearing.
- Secondly, by using market forces to increase the value of "pesticide free wool", which would be sold at a premium rate to the textile industry;
- Thirdly, by adopting better treatment of the effluent, either at the works or at the sewage plant, in a way which will reduce the total pollutant load.

A second major source of sheep dip pollution, that has recently been identified, but not quantified, is that associated with live-stock markets. It has been reported that some livestock markets insist that sheep be dipped before coming to market. This may have the required welfare effect of restricting the spread of disease, but has the potential that runoff from stock markets may contain sheep dip chemicals washed off the fleeces of recently dipped sheep.

10. COSTS OF SHEEP TREATMENT AND DIP DISPOSAL

A major concern expressed by many close to the farming industry is that any disposal operation must not add large costs to the sheep industry, which is already in a difficult financial situation. If the costs of legal disposal are very high, then a moderate rate of illegal disposal might be anticipated.

It is difficult to estimate the total costs of the sheep dipping operation. For the purposes of this analysis, the following indicative costs per application are used (Table 8 based on Stubbings, 1998). Costs for any particular farmer vary with the amount purchased, the supplier and the choice of chemical.

Table 8. Costs of disease treatments

Material	cost/sheep
OP dip	£0.20
SP dip	£0.50
Pour-ons	£0.85
Injectables	£1.40

Other costs include the fixed costs of the installation, and the additional labour costs of dipping. For this analysis, fixed costs (associated with the provision of the dipping and sheep handling facilities) are not considered, because most of these will already be in place. Labour costs involved in gathering sheep are rarely costed commercially, but use the farmer's own labour. The only labour cost that can be immediately identified is that dipping is commonly considered to require an additional person to control and move the sheep. For these calculations, it is assumed that the labour cost of dipping can be identified as that of employing one extra person for one day. Allowing a wage rate of £5/hour, this is £40 for an 8 hour day. The labour costs of gathering and examining the sheep are common to all treatment strategies, and can be considered part of the normal practice of good shepherding

The costs that the farmer identifies in sheep dipping are thus associated with the purchase of materials, and the additional labour required to manage the sheep. These can then be converted to costs for the flock management option, by the use of four scenarios, for which the costs have been identified. These have been based on the assumption of a 500 ewe flock that requires control of blow fly in the spring and scab in the autumn

Scenario A. Traditional dipping.
Based on dipping sheep twice a year, using an OP dip, each dip costs 20p/ewe. Additional labour is equivalent to one person per day, which is £40 per dipping. Totals cost is thus 40p/ewe plus £80 labour. For a 500 ewe flock, this is £280 per year.

Scenario B. A normal dipping regime using SP dips:
A single high-cis cypermethrin dip for blow fly in the spring and a double dip for scab control in the autumn. Dip cost per ewe is 50p, and the additional labour is 3 days, £120. For a 500-ewe flock this then costs £870 per year.

Scenario C. No dipping.
Using a cyromazine pour-on, cost 85p/ewe, for the control of blowfly, plus double injection of avermectin for the control of scab, cost £1.40 per ewe. The costs are thus £2.25 per ewe. For a 500-ewe flock, this comes to £1125 per year.

Scenario D. No dipping.
Using a cypermethrin pour-on for fly strike at 50p/ewe, and doramectin for scab treatment in the autumn at 75p/ewe. The costs are thus £1.25 per ewe. For a 500-ewe flock, this comes to £625 per year.

There is a very clear cost gradient. Traditional dipping methods using an OP dip are by far and away the cheapest. Non-dipping alternatives are significantly more expensive. However, when used in conjunction with positive flock management techniques that reduce the number of animals requiring treatment to a fraction of the total flock numbers, they can become financially attractive.

These costs can then be compared to the costs of site authorisation for disposal of spent dip contained in the DETR proposals for groundwater regulations, and the costs of adopting non-dipping flock management strategies. Assuming that the incidence of ectoparasites does not alter, and therefore that the frequency of dipping remains the same, it is possible to establish an analysis of the cost of implementing the regulations discussed in the DETR consultation document as opposed to using alternative parasite control strategies. The DETR consultation document identifies the range of possible costs for compliance (Table 9).

Table 9: Possible costs of compliance with proposed groundwater regulations.

	Lowest	medium	highest
Initial cost	£712	£120	£1529
recurrent cost/year	£125	£498	£872
Total cost over 5 years	£1334	£3610	£5886
cost/year	£269	£722	£1177

Although the proposed costs for authorising disposal of spent dip to land will effectively double the annual cost of dipping for an average flock, the cost of adopting a non-dipping strategy for the whole flock is more expensive. There is thus a significant cost advantage in remaining with traditional dipping techniques for large flocks and the larger the flock, the greater the incentive. However, it is also likely that small flocks will move towards non-dipping programmes, bearing the higher cost of alternative treatments rather than the costs of authorisation of a disposal site.

These costs can also be placed within the context of the overall costs to the sheep industry and the value of parasite control. Stubbings (1998) states that failure to control ectoparasites in a sheep flock can cause a loss of between £4 and £5 per ewe. For a 500-ewe flock, this translates into an annual loss of around £2000 to £2500.

These costs should be assessed in the light of gross margin data for sheep in the UK. Table 10 shows average gross margins for a small number (320 flocks in total in 1996) of lowland, upland and hill flocks as recorded by Signet (MLC, 1997) over the last three years.

Table 10: Gross Margin data, 1994 - 1996 (MLC, 1997)

£ per ewe	1994	1995	1996
Lowland	43.4	45.2	53.3
Upland	48.0	51.9	61.0
Hill	39.1	42.4	48.9

Taking the average of these and applying to a 500 ewe flock, suggest an annual gross margin of the order of £24000. The costs of a disease infestation are thus of the order of 10% of the gross margin, whereas the anticipated costs of authorisation for dip disposal to land is between 1 and 5% of the total gross margin. Even with the additional costs of authorisation of disposal, the dipping of sheep, where necessary, remains an economic option for the sheep farmer.

11 CONCLUSIONS AND RECOMMENDATIONS

11.1 The Need to Dip

It is clear that the agricultural industry must have the ability to control outbreaks of scab and other ectoparasites in sheep. Sheep scab in particular is considered a major hazard, and the Sheep Scab Order of 1997 imposes a legal obligation on farmers to treat sheep with the infestation. The most effective, and the cheapest, option for doing this is by dipping sheep. Of the chemicals available, the organophosphate (OP) dips are considered the most effective for control of scab. The more recently introduced synthetic pyrethroid (SP) dips have been perceived as less dangerous to the operator, but have proved less effective in the control of scab and have a much greater potential to cause environmental damage.

Sheep dips are effective at killing the ectoparasites that cause diseases of sheep. However, the same chemicals can have a similarly lethal effect on non-target organisms, should they be transferred to surface or ground waters. Recent surveys have shown that pollution of surface waters by sheep dip is widespread, and that action needs to be taken to reduce this pollution. It is considered that the recent move from OP dips to SP dips has brought to light a problem that has remained undetected for some years. SP dips may present less of a health hazard to the dip operators, but are many times more toxic in the environment.

There is thus an urgent need to identify methods to reduce pollution by sheep dip. This can be addressed by a combination of farmer education in the management of the dipping operation, including the eventual disposal of dip, the development of on-farm treatments to detoxify the dip; and positive flock management to reduce the total use of dip within the UK sheep industry.

11.2 Disposal of Spent Dip

At the end of the dipping operation, surplus dip is contaminated with faeces and organic matter (including lanolin from the fleece) which bind the active ingredients, and render the dip ineffective in controlling diseases. Such surplus dip cannot be stored for re-use, and must be disposed of. There are insufficient facilities for industrial disposal, which is thought to be prohibitively expensive, and raises the issue of transportation of spent dip - with its attendant risks. The traditional method for the disposal of spent dip, and the practical option for most farmers is to spread it on land in a dilute solution, where it is degraded by chemical and biological processes, and its movement restricted by adsorption onto soil organic matter. However, there need to be strict controls on this operation, as incorrect disposal can lead to the direct movement of contaminated water either to groundwater or directly to surface waters. Contamination of surface waters has been observed to be widespread in the main sheep keeping areas.

Because of the extremely toxic nature of most dip materials, criteria to define land that is acceptable for the disposal of sheep dip must be at least as stringent as those defined in the Code of Good Agricultural Practice (COGAP) for the Protection of Water. However, if the COGAP guidelines are followed, disposal of spent dip by land spreading may not carry a great risk of immediate contamination of the water environment. A high risk of pollution is presented when there is heavy rainfall immediately after land spreading. However, this risk has not been assessed in a scientific study. It is thus suggested that a detailed risk evaluation be undertaken using a modelling approach to define the rate of movement of dip to both groundwater and surface water. It would also be advisable to carry out a small scale field trial relating to dip disposal to validate the results of such a modelling exercise.

On-farm treatments which render the spent dip less toxic before disposal to land include the addition of chemicals (notably alkalis) to the dip, or the disposal of the dip in farm waste stores. There are however a number of gaps in our existing knowledge. The mechanisms involved in both sorption and degradation of sheep dip residues are poorly understood and it is thus suggested that experimental studies need to be undertaken to identify the effectiveness of on-farm treatments (disposal of spent dip in manure heaps and slurry stores, and on-farm treatment by addition of alkalis) before these treatments can be widely advocated.

11.3 Positive Flock Management

In the past, disease control has been by a "blanket" treatment, involving the dipping of whole flocks, or in the case of the compulsory dipping programme, the entire national flock. However, there is a case for alternative approaches, which would significantly reduce the total amount of dip used. This is particularly the case for sheep scab (by far the biggest problem) which is passed from sheep to sheep, and via contaminated objects. By isolating and treating specific flocks, it is then possible to reduce the spread of scab, and so using dips or alternative formulations on only a very much reduced number of sheep.

Many farmers could adopt a "closed flock" policy, in which all animals that are introduced to the flock (normally only a few each year) are treated on arrival or quarantined if necessary before being introduced into the main flock. By rigorous application of this policy, it is possible to establish and maintain scab-free flocks, which would not normally require dipping for scab control. This option would however, be difficult for those farmers grazing common land. Even those attempting to maintain "clean" flocks however, may need to dip sheep should infestation be introduced accidentally.

A second element of such a management strategy would be the use of non-dip treatments on targeted animals. If infected animals are identified before the disease spreads then treatment can be applied to infected animals only. Although the current range of injectables offers only cure, not prophylactic protection, this should not be a problem if the sheep can be released post-treatment into a known scab-free environment.

It is concluded that for the continued welfare of sheep in the UK farmers need the option to be able to dip their sheep for the control of ectoparasites

11.4 Industrial Effluents

Because the British textile industry processes imported wool, it cannot rely solely on internal controls on the UK sheep flock. As with other aspects of the sheep industry, reduction of the pollutant load from wool processing, is best achieved by a combination of flock management, market incentives, and improved effluent treatment, and not relying on a single method of control alone. An emerging problem is the practice of dipping sheep before moving them to market and the resultant pollution in runoff from the market areas. The magnitude of this problem needs to be assessed.

11.5 Farmer Awareness: The Need for a Code of Good Practice

The evidence collected suggests that one of the major reasons for the environmental problems arises from the lack of farmer awareness, and the need for improved standards of dip installation and sheep management. It is thus recommended that a forward programme for the control of environmental damage should concentrate on the development of a code of good practice for the control of ectoparasites in sheep. This code of good practice would include all aspects of flock management to reduce the need to dip, the construction and use of dipping facilities (including guidelines for the use of mobile dipping units), and the management of sheep immediately post dipping, as well as the correct disposal of spent dip. A targeted programme of farmer and operator education (based on farmer contact as well as distribution of printed information), leading to the more widespread adoption of best practices, is needed to significantly reduce the number of pollution incidents from current dipping policy. However, where these two measures fail, it will be necessary to rely on the legislative framework for the control or prevention of environmental damage by disposal of spent sheep dip.

11.6 Legislative Framework: The Need for Control

The current legislation offers an insufficient degree of control over the dipping operation and the disposal of spent dip. The agricultural industry is operating within an historical legacy of unregulated dipping, using installations and practices which were developed at a time when the major concern was the control of disease within the sheep flock, and with little concern (or knowledge) of the side effects on human health or the environment. There is a need to strengthen the regulatory framework. Because the dangers posed by unsuitable use or disposal of dip chemicals are so great, a very small number of unprincipled or ill-educated operators could cause great environmental damage. Complete observance of the recommendations for use and disposal of dip is only possible through a strict legislative framework.

A regulatory framework for the control of dipping could thus be put in place, in which the Agency was given the role of licensing both dipping installations and disposal sites. It is suggested that each farm would be required to complete a dip management plan, which would embrace not only the disposal of spent sheep dip material, but would also include issues such as the siting and construction of dipping and sheep handling facilities, and a strategy for flock management to define the risks and benefits of dipping as applicable to the particular flock.

To be comprehensive, these proposals would also need to apply to mobile dipping contractors and their operations. A register of all contractors is recommended, who should be required to have the certificate of competence to dip safely and to dispose of dip. It is also suggested that mobile dip operators should be targeted for an education programme, both because they dip many sheep, and because they are perceived to be less careful in, or lack suitable equipment for, the safe disposal of spent dip.

11.7 Recommendations

A national strategy for sheep dip must achieve a balance between the requirements of the agricultural industry and the need to protect the environment. Sheep dipping should remain a component of good flock management, ensuring animal welfare at both the individual and national flock levels. Consequently there is a need to develop strategies to achieve two parallel aims: the safe use of dipping where it is carried out; and the reduction in the overall need to dip by the use of alternative flock management strategies. These can perhaps be best achieved by the following action points which present a pattern of education and development, in which the farming industry and the Environment Agency can work in collaboration, to address the very real risks to the environment posed by the necessary continued use of sheep dip.

1. Developing and promoting positive flock management methods to reduce the need to dip, including the use of alternatives to dipping (pour-ons and injectables) for disease control where practical.
2. Increasing of farmer awareness and education by the production and dissemination of a code of good practice for disease control in sheep, to include all aspects of the siting, construction, and use of dipping facilities, the correct storage and disposal of spent dip; the management of sheep to reduce the need for dipping; and the codes should be promoted though a positive campaign of farmer education.
3. Requiring the certificate of competence for all (both farmers and contractors) who purchase, use and dispose of sheep dip chemicals;
4. Extending the ban on the movement of animals infected with sheep scab to the transport of all animals, even to slaughter.
5. Strengthening the legislative framework for the control of dipping, for example by requiring the collaboration between farmer and the agency in the preparation of a dip management plans for each farm involved in dipping sheep.
6. Developing a national register and licensing of mobile dip contractors; an increased dialogue with the dipping contractors, including both a clarification of responsibilities regarding spent dip disposal and the adoption of acceptable dipping practices.
7. Developing methods to reduce dip chemicals in effluent from the wool treatment industry.
8. Research into the effects and methods of disposal of spent dip. The main areas where research are needed include:

   A. Examination of the impact of spent dip on terrestrial ecosystems

   B. A scientific review of the current recommendations dip dilution before spreading.

   C. Examination of the effectiveness of on-farm treatments for detoxification of spent dip.

   D. Risk evaluation of the movement of spent dip to surface and ground waters..

   E. Evaluation of biobeds and reed-beds as means of disposal of spent dip.

   F. Investigation of the environmental hazards of dipping of sheep prior to market.

   G. Examination of the role of stream chemistry in buffering of toxicity effects.

   H. Investigation of the extent to which dip components wash off sheep.

11.8 Research Needs

This review has identified a number of significant weaknesses in current knowledge. There is still much that we do not know about sheep dip, and in particular research is needed to identify the effects of disposal of sheep dip on terrestrial ecosystems. Further research is also needed to evaluate methods of treating spent dip, to render it less harmful. The research topics that have been identified in this review are:

1. The impact of spent dip on terrestrial ecosystems is poorly documented, especially the impact on terrestrial invertebrates and the subsequent effect on the natural food chains. Field studies are needed which examine the degradation and mobility of sheep dip chemicals in field situations, and their ecological impact, coupled with direct ecotoxicological studies of the impact of spent dip and its degradation products.
2. A scientific review of the current recommendations on dilution of dip before spreading on land. This will require evaluation of the toxicity of dilute spent dip, leading to the formulation of recommended rates of dilution for application of spent dip to land.
3. The value of on-farm treatments for detoxification of spent dip requires further research. This will include both treatment with high alkali solutions, and the addition to manure heaps and slurry stores. Studies should also include assessment of the toxicity of the degraded mix when applied to land, and the impact on terrestrial fauna.
4. Development of risk evaluation for the movement of spent dip to surface and ground waters, using a combination of field studies and modelling techniques. The use of pesticide modelling studies will identify the combinations of soil, weather, and application practice that could generate a leaching risk.
5. Research into biobeds and reed-beds as means of disposal of spent dip.
6. Investigation of the environmental hazards posed by the dipping of sheep prior to market.
7. The role of stream chemistry in buffering of toxicity effects of some pollution should be investigated.
8. Investigation of the extent to which dip components wash off sheep immediately after dipping, in order to develop farmer recommendations for the management of sheep after dipping.

12 REFERENCES

Barriuso, E, Houot, S. and Serra-Wittling, C. (1997). Influence of compost additions to soil on the behaviour of herbicides. *Pesticide Science* **49**, 65-75.

Barriuso, E. and Koskinen, W. C. (1996). Incorporating non-extractable atrazine residues into soil size fractions as a function of time. *Soil Science Society of America Journal* **60**, 150-157.

Bates, P. (1997) Acaricide resistance in sheep scab mites. *Proceedings of the Sheep Veterinary Society* **21:** 117-122

Bates, P. (1998) A practical guide to the control of sheep scab. Sheep Health Matters No 4, Meat & Livestock Commission, Milton Keynes. p 4-11.

Blackmore, J. & Clark, L. (1994) *The disposal of sheep dip waste: effects on water quality.* NRA R&D Report no 11.42 pp.

Chapman, R.A., Harris, C.R., Tolman, J.H., Moy, P., Henning C. And Carol Harris, 1993. Further comparison of the persistence in clay loam of single and repeated annual applications of some granular insecticides. *J. Environ. Sci. Health,* **b28(2),** 151-170.

Commercial Motor (1998) Tables of Operating Costs.

Corke, M.J. (1997) The welfare aspects of sheep scab. *Proceedings of the Sheep Vetinerary Society,* **21** 99-102

DETR (1998) Proposed Groundwater Regulations : Consultation Paper and Compliance Cost Assessment. DETR, January 1998.

Environment Agency (1997) Mobile sheep dipping: a guide to reducing pollution risks. Environment Agency leaflet.

Environment Agency (1998) Welsh Sheep Dip Monitoring Program 1997. Environment Agency Wales, Cardiff & Environment Agency Midlands, Solihull. 60 pp.

Eke, K.R. (1977) Water pollution problems with pesticides from the UK textile industry. *Pesticide Outlook* June 1997, 6-10.

ENDS (1994) Government Rejects ban on sheep dip soakaways. ENDS Report 230, March 1994 pp11-12.

Entry, J. A. and Emmingham, W. H. (1995). The influence of dairy manure on atrazine and 2, 4-dichlorophenoxyacetic acid mineralisation in pasture soils. *Canadian Journal of Soil Science* **75,** 379-383.

Grimwood, M.J. & Criddle, J. (1994) Proposed environmental quality standards for cypermethrin in water. Draft R&D note 341. National Rivers Authority.

Harris, G. 1995. Pesticide loss to water - a review of possible agricultural management opportunities to minimise pesticide movement. In "Pesticide movement to water", (A. Walker *et al*,. eds.), BCPC Monograph 62, British Crop Protection Council.

Hill, I. R. 1985. Pyrethroid residues in soil and aquatic environments. Pestic. Sci. 16, 192-193.

Hollis, J.M. (1991) Mapping the vulnerability of aquifers and surface waters to pesticide contamination at the national/regional scale. BCPC Monograph **47** (*Pesticides in soils and water,* ed. A.Walker), 165-174

Inch T. D., Ley R.V., and Utley D., (1972) The mobility of some organophosphorus sheep dip insecticides in soil. *Pesticide Science* **3** , 243-253

Katayama, A., Mori, T. and Kuwatsuka, S. (1995). Abiotic dissipation of chlorothalonil in soil accelerated by amendment with high applications of farmyard manure. *Soil Biology and Biochemistry* **27,** (2), 147-151.

Lewis, S. (1998) Proposed environmental quality standards for sheep dip chemicals in water. Chlorfenvinphos, Coumaphos, Diazinon, Fenchlorphos, Flumethrin and Propetamphos -

an update. Environment Agency, Draft R&D Technical Report P128

Lewis, C. (1997) Sheep scab - an update on history, control and present situation. *Proceedings of the Sheep Vetinerary Society,* **21** 99-102

Littlejohn J W. and Melvin M. A.L. (1989) A theoretical calculation of the pollution potential of sheep dip preparations. *Environmental Technology Letters* **19** 1051-1056

Littlejohn, J.W. & Melvin, M.A.L. (1991) Sheep-dips as a source of pollution of freshwater - a study in Grampian region. *J.IWEM,* **5: 21-27**

Lovell, R. D. and Jarvis, S. C. (1996). Effect of cattle dung on soil microbial biomass C and N in a permanent pasture soil. *Soil Biology and Biochemistry* **28 (3),** 291-299.

MAFF (1986) Sheep: handling and dipping. Agricultural Development & Advisory Service Advisory Leaflet P2332, MAFF Alnwick, 4pp..

MAFF/WOAD (1991) Code of Good Agricultural Practice for the Protection of Water. Ministry of Agriculture, Fisheries and Food and Welsh Office Agriculture Department, MAFF Publication, London, 80 pp.

Maloney, S. E., Maule, A. & Smith, A.R.W. (1988) Microbial Transformation of the Pyrethroid Insecticides: Permethrin, Deltamethrin, Fastac, Fenvalerate and Fluvalinate. Applied and Environmental Microbiology, Nov. 1988. p. 2874-2876

Maloney, S. E., Maule, A. & Smith, A.R.W. (1992) Transformation of synthetic pyrethroid insecticides by a thermophilic *Bacillus* sp.. *Archives of Microbiology* **158**: 282-286)

MLC (1997) Meat and Livestock commission, Sheep year book, 1997. MLC Milton Keynes.

Morris, R.C. (1997) Sheep Dipping Practices - A study within one river catchment in south Ayrshire. In Conference proceedings 'Organophosphates, Agriculture and the Environment' Edinburgh

Morrison, D. (1998) Sheep dip treatment: current position and associated issues. SEP Mss.

NRA (1994) The Disposal of Sheep Dip Waste, Effects on Water Quality, NRA 1994.

Pollott, G. (1998) 1996 Sheep Breed Survey. Meat & Livestock Commission, Milton Keynes.

PSD 1991. Evaluation on diazinon (1). Evaluation no. 35. MAFF, PSD, York.

PSD 1994. Evaluation on chlorfenvinphos. Evaluation no. 107. MAFF, PSD, York.

Purnell, R.E. (1997) Use of injectable doramectin in the treatment and control of sheep scab. *proceedings of the Sheep Vetinerary Society,* **21:** 113-116

Stephen, N. H. (1997) Chemical Approaches to Waste Sheep Dipwash Treatment and Disposal. Conference proceedings ' OPs, Agriculture and the Environment' Edinburgh

Stubbings, L. (1998) Economics of ectoparasites in sheep - the farmers' perspective. paper presented to the Welsh Pest management Forum, 1998.

Suett, D.L.. and Walker, A. 1988. Accelerated degradation of soil-applied pesticides - implications for UK horticulture. *Aspects of Applied Biology* **17,** 213-222.

Tomlin, C.D.S. 1997. The Pesticide Manual, (eleventh edition). British Crop Protection Council.

Torstensson, L. (1996). Herbicides in the environment. Proceedings of 2nd International Weed Control Congress 1996, Copenhagen, Denmark p267-274.

Torstensson, L. and del Pilar Castillo, M. (1997). Use of biobeds to minimise environmental spillages from agricultural spraying equipment. *Pesticide Outlook,* **June 1997**, 24-27.

Virtue, W.A. & Clayton, J.W. (1997) Sheep dip chemicals and water pollution *The Science of the Total Environment* **194/5:** 207-217

Walker, C.H., Hopkin, S.P., Sibly, R.M. and Peakall, D.B. (1996) *Principles of Ecotoxicology,* Taylor and Francis, 1996.

Wauchope, R.D., Butler, T.M., Hornsby, A.G., Augustijn-Beckers, P.W.M. and Burt, J.P. 1992. The SCS/ARS/CES pesticide properties database for environmental decision-making. Reviews of Environmental Contamination and Toxicology 123, 1-155.

Watson, P.M., Sieveking, H.U. and Dixon, M.J. (1997) A method of degrading flumethrin (Bayticol) in spent dipwash prior to disposal using agricultural slaked lime. Bayer, Bury St. Edmunds;.

Williams J. R. and Nicholson, R. J. (1995) Low rate application of dirty water and its effect on drainage water quality. *Agricultural Engineer* **50** 24-28.

Winterlin, W., Seiber, J. N., Craignull, A., Baier, T., Woodrow, J. and Walker, G. (1989). Degradation of pesticide waste taken from a highly contaminated soil evaporation pit in California. *Archives of Environmental Contamination and Toxicology* **18,** 734-747.

Xie, H., Geutzloff, T. F. and Rice, J. A. (1997). Fractionation of pesticide residues bound to Lumin. *Soil Science* **162,** 421-429.