

Gwaredu Sheep Scab project - An investigation of the effect of the use of diazinon sheep dip on stream water quality and biota (technical report prepared by F.H.Jones see Appendix 1)

1. Summary

Sampling of macroinvertebrate fauna at sites upstream and downstream of sheep dipping areas and post dipping grazing fields did not illustrate any toxic impacts but chemical sampling revealed consistently higher levels of diazinon at the downstream sites. Peak concentrations occurred 17 days after dipping with maximum concentrations at 90% of the Maximum Allowable Concentration Environmental Quality Standard (MAC-EQS) for diazinon. Results indicated that loss of diazinon from sheep in grazing fields and water transport to streams was the primary pollution route. Natural Resources Wales (NRW) water quality data are referenced that further illustrates the frequency and widespread occurrence of significant diazinon pollution. The outcome of this investigation and NRW's monitoring results should be taken account of in relation to future monitoring priorities and determination of pollution prevention policy. Recommendations are made for a further more comprehensive investigation to provide more detailed assessment of potential pollution routes and their impact.

2. Introduction

Sheep scab is a serious disease caused by the mite *Psoroptes ovis*. It causes distress to animals and can lead to mortalities with consequent economic impact. The use of diazinon sheep dip is considered the most viable method of control but has significant risks to the environment. It is an organophosphate insecticide – a neurotoxin which has a significant toxicity to aquatic life. The standards set for diazinon in freshwaters and for drinking water are provided below:

Freshwaters

The Maximum Allowable Concentration Environmental Quality Standard (MAC-EQS) is defined as 20 ng/l as a 95 percentile* concentration which is a short-term exposure limit determined from the toxicity of diazinon to a *Gammarus* sp. (an aquatic crustacean)¹.

The Annual Average EQS (AA-EQS) of 10 ng/l is long term exposure limit determined from the effect of diazinon on olfactory function in salmonids¹.

Drinking water

The Maximum Permitted Concentration (MPC) for diazinon in drinking water is 100 ng/l².

*The 95 percentile concentration is that which is not exceeded for 95% or conversely the value that is exceeded for 5% of the time.

Diazinon has been widely detected in NRW's Water Framework Directive (WFD) sampling programme and, markedly, on occasions at concentrations exceeding MAC-EQS values at main river lower catchment sites e.g. diazinon concentrations of

31.9 and 20.5 ng/l determined at Chain Bridge on the lower Usk in Nov 22 and Feb 24 respectively³. These are indicative of the occurrence of acute events in upper catchment sheep rearing areas. Diazinon has also been detected in other regions of the UK. Many years of spot sampling on major rivers in Devon & Cornwall have frequently revealed very large seasonal exceedances of diazinon EQS values (I.Townsend, West Country Rivers Trust pers. comm.). Studies elsewhere have established that sheep dip disposal practices and poor management of dipping operation were responsible for pollution by organophosphate sheep dip chemicals⁴. Also, previous investigations of the insecticide previously used for sheep scab control (cypermethrin) indicated a variety of pathways – surface water runoff, sheep crossing watercourse/dripping fleeces etc⁵. Diazinon has a lower toxicity than cypermethrin but is at least a thousand times more soluble⁶ and therefore has a greater potential for runoff etc.

A Welsh Government funded project which aims to eradicate sheep scab is being run by Coleg Sir Gar involving the use of the diazinon applied through mobile dippers under conditions aimed to minimize pollution risk. This is referred to as the Gwaredu Sheep Scab Project. Dipping commenced in 2023. The project aims to reduce pollution risk by requiring all used sheep dip to be transported to chemical waste treatment plants. Continuing professional development days were also organised for contract dippers to promote methods and procedures to minimise pollution risks. The training was provided by Coleg Sir Gar, NRW, the sheep dip manufacturer and safety experts. A substantially greater amount of private dipping occurs outside this project where waste is routinely disposed at permitted land-spreading sites that meet a variety of criteria designed to minimise pollution risks. Targeted monitoring at the farm level is required to better understand pollution risks and pathways. There was no provision in the project for targeted monitoring of diazinon but managers were able to allocate £3k towards water sampling costs from the amount allocated within consumables budget.

Initially F.Jones in conjunction with Coleg Sir Gar proposed a sampling programme based on the use of passive chemical sampling. However, the scope of the project proposal was restricted by the funds available and would only have provided qualitative data. NRW proposed an alternative based on spot chemical sampling. Spot sampling of one dipping site that was carried out by Dwr Cymru Welsh Water (DCWW) and the Coleg in November 2023 was cited as evidence of the viability of this method. One sample taken downstream of the dipping site was positive for diazinon with a concentration of 13 ng/l which exceeds the AA-EQS. Accordingly, an internal NRW bid was made for a spot sampling programme which was successful with a level of funding sufficient for the analysis of about 30 samples.

A meeting was held on 5th Sept 2024 attended by the Coleg, F. Jones, DCWW and NRW to formulate an appropriate investigation. It was agreed that the best approach considering the limited funds available and the consequent scope of the monitoring programme would be to focus on dipping sites which, for a variety of reasons, might

be considered to have the greatest pollution risk. Key factors that were identified during the meeting included the number of sheep being dipped, the proximity of watercourses in relation to the mobile dipping operation and location of sheep holding areas, local topography and ongoing weather conditions. A formal procedure was prepared and agreed by the group to enable programme managers and technical staff to identify appropriate sites. The aim of the investigation was therefore to determine whether the procedures employed in the Gwaredu Scab project were successful in preventing pollution. Ideally, the inclusion of dipping carried out outside this project would have provided a comparison to determine the benefit of the extra precautions adopted by the Gwaredu Scab project. However, this was beyond the scope of resources available for this investigation.

3. The investigation

Three dipping sites were chosen for the survey by Coleg Sir Gar comprising two located in the Teifi and one in the Tywi catchment (Table 1) although the agreed procedure for identifying appropriate sites were not followed. This was later explained as being due to the Gwaredu scab technical officers having difficulty interpreting the procedures for determining risk and also due to problems with obtaining agreement from farmers to undertake the monitoring (N. Paton pers. comm.). It was intended that control sampling points upstream of dipping activity and subsequent grazing areas of dipped sheep would be selected in each case together with a site downstream that would potentially detect any impact from the dipping operation and subsequent grazing areas of dipped sheep. This was the case at two of the farms (Farms B and C) but the downstream site selected for Farm A was actually at higher altitude than the area where dipping took place and the post dipping holding pen. Therefore, in that case, the downstream site would only have been affected by sheep in post dipping grazing fields. Dipping took place on 16/1/25 at Farm A and 18/1/25 at Farms B and C.

Maps showing the relative location of dipping sites, sheep holding areas and sampling sites are provided in Appendix 2.

The chemical sampling regime comprised collection of samples at each site before dipping and at intervals of 2, 10 and 17 days after dipping.

Biological samples were also collected at each site 17 days after dipping with the exception of the upstream site at Farm A which proved to be very small stream that was unsuitable for the kick sampling technique. Macroinvertebrate samples were collected using the 3 minute kick sampling technique. These were processed to family level identification to give a Biological Monitoring Working Party (BMWP) score indicative of pollution⁷.

Table 1 Farm locations, flock size

Farm	Catchment	Watercourse	Flock size dipped approx.
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A	Tywi	Unnamed trib R. Cennen	1000
B	Teifi	Teifi trib	127
C	Teifi	Unnamed	220

4. Results

4.1 Macroinvertebrates

A limited range of macroinvertebrate fauna was present at the sampling sites at farms A and C (Table 2). This was to be expected given the small stream size (<0.5m wide). However, a number of taxa were present at the downstream sites which are sensitive to insecticide pollution. These included Gammaridae (freshwater shrimp), Heptageniidae (flat bodied mayfly nymphs) and Plecoptera (stonefly taxa). The number of taxa present and the BMWP scores (52-80) were what may have been expected in streams of this nature and all taxa were alive in the samples that were examined in trays on the stream bank. The stream at farm B was substantially larger (3.0m wide approx.). The downstream site supported a wide range of taxa (17 total) and a BMWP score of 114. A range of taxa sensitive to insecticide pollution were present some of which were abundant (notably mayfly and stonefly nymphs).

Table 2 Sheep Dip Investigation 4/2/25 Macroinvertebrate results

	Site*				
	d/s Farm A	u/s Farm B	d/s Farm B	u/s Farm C	d/s Farm C

Taxon					
Brachycentridae					
Chloroperlidae		1			
Heptageniidae	1	2	3	1	1
Leptophlebiidae			2		
Leuctridae	1		2		
Perlodidae	2	2	2	1	2
Sericostomidae			1		
Philopotamidae		1		2	2
Limnephilidae			1	1	1
Nemouridae	2		1	1	1
Polycentropidae		1	1	1	
Rhyacophilidae			1		1
Ancylidae			1		
Gammaridae	2	2		2	2
Dytiscidae			1		
Elmidae			1	1	1
Hydropsychidae	1		1	2	2
Simuliidae			1		1
Tipulidae			1	1	1
Baetidae	1		2		2
Oligochaeta			1	1	1
Total no. taxa	7	6	17	11	13
BMWP Score	52	49	114	61	80

*Abundance estimate (number of individuals present): 1= 1-9, 2=10-99, 3=100-999

4.2 Water Quality

Pre-dipping values for diazinon at upstream and downstream sites varied between the detection limit (<0.06) and 0.345 ng/l (<0.01 – 2% of MAC-EQS) (Table 3).

Subsequent diazinon concentrations at the upstream (control) sites varied between <0.06 – 2.275 ng/l (<0.01% - 14% of MAC-EQS). Post dipping values at downstream sites on day 3 and 10 varied between 0.269 – 4.468 ng/l (1-22% MAC-EQS). There was a substantial increase in diazinon concentrations at downstream sites at Farms

A and C on day 17 (18.146 and 17.2 ng/l respectively = 86-90% MAC-EQS) and a moderate increase at Farm B (6.89 ng/l = 34% MAC-EQS).

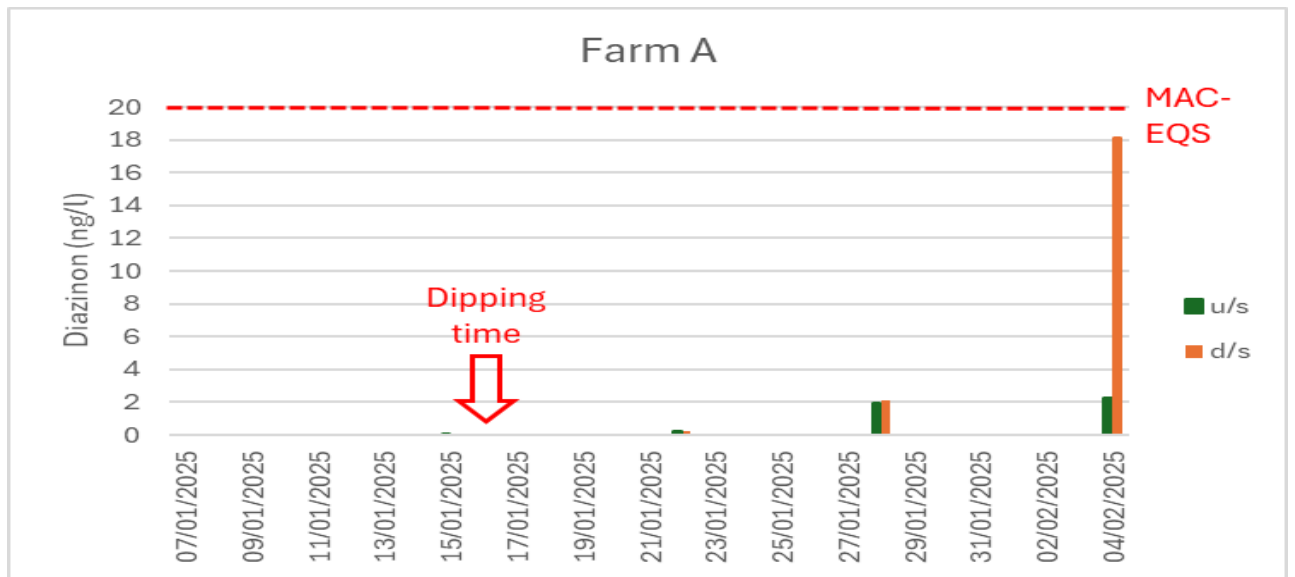
Table 3 Sheep dip survey – chemical sampling results – Diazinon ng/l

Farm	Sampling Date			
	15/01/25 (Pre)	22/01/25 (D3)	28/01/25 (D10)	04/02/25 (D17)
A u/s*	0.087	0.218	1.992	2.275
A d/s	0.109	0.269	2.089	18.146
B u/s	<0.06	<0.06	0.169	0.636
B d/s	<0.06	0.514	0.337	6.89
C u/s	0.345	1.078	0.09	1.032
C d/s	0.234	4.27	4.468	17.27

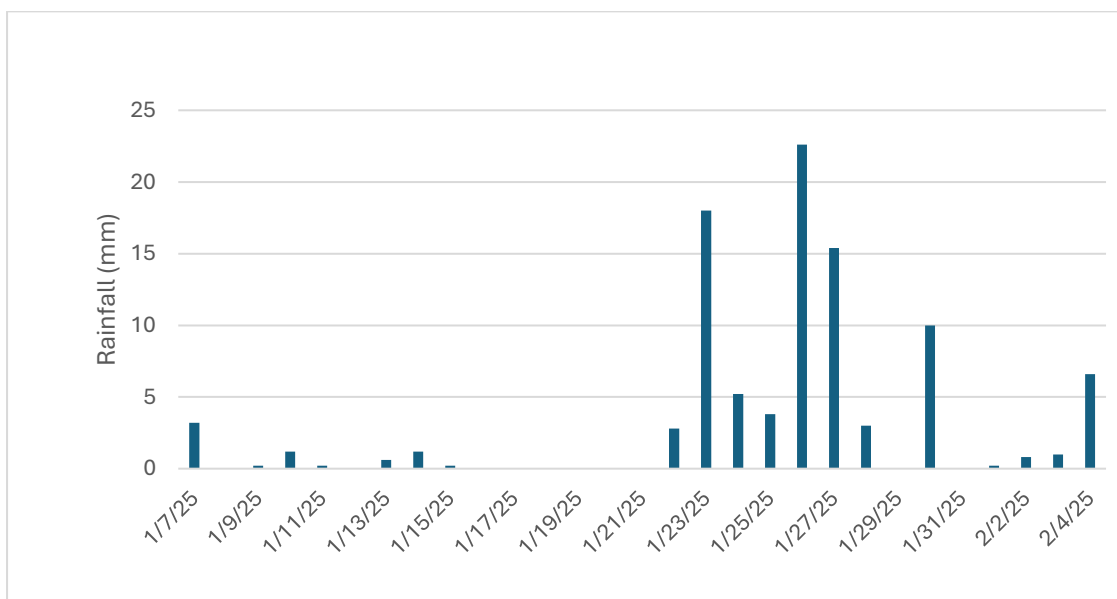
*u/s = upstream d/s = downstream

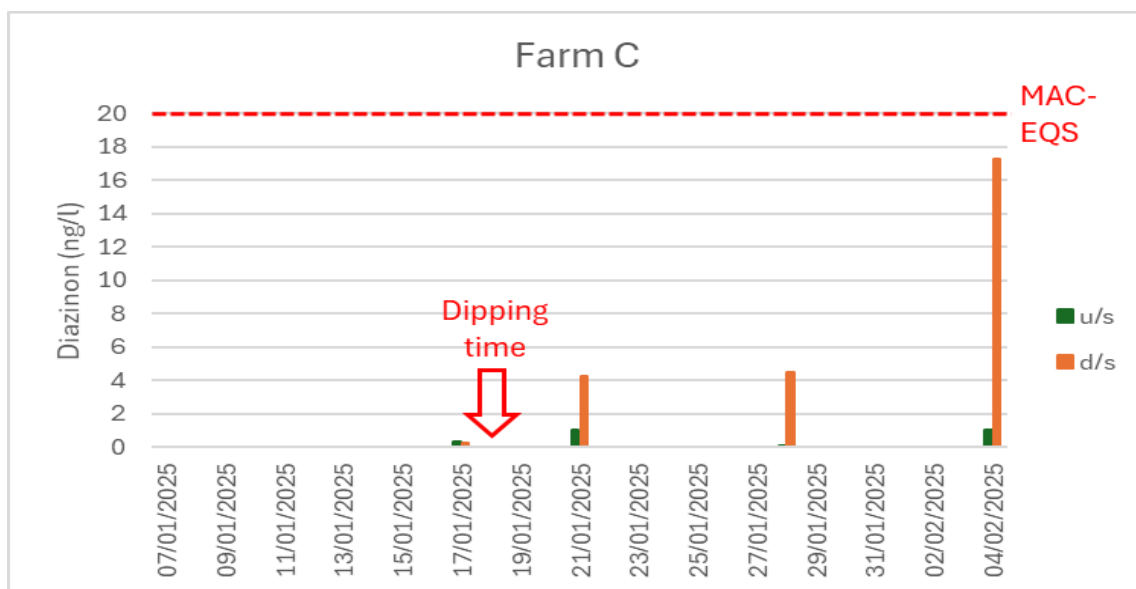
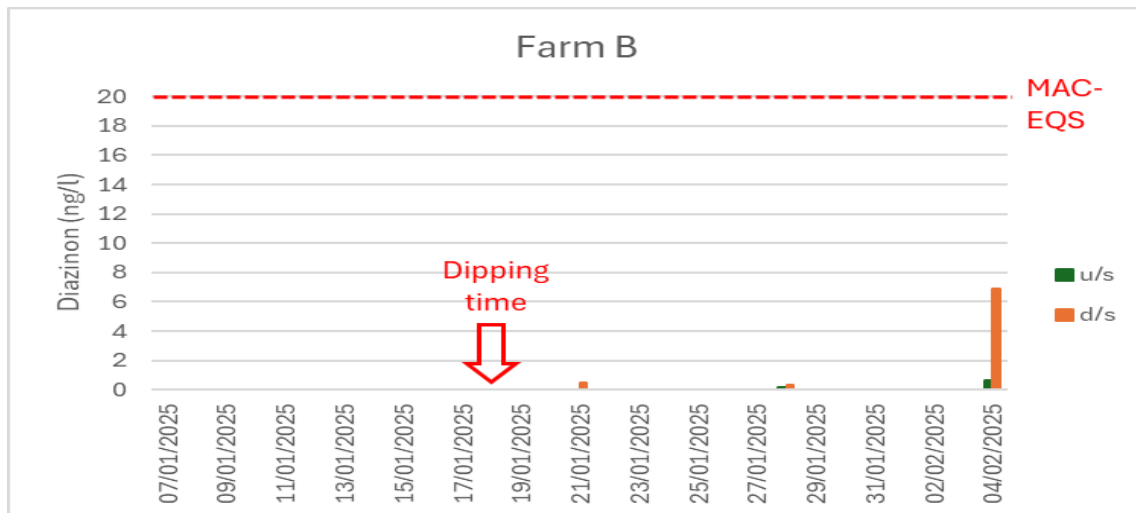
The diazinon concentrations at each sampling site are compared in Fig 1 with rainfall recorded at neighbouring rainfall gauging sites. There was relatively little rainfall in the period preceding and immediately following dipping (7-21/1/25) followed by significant amounts between 22-31/1/25 and a further event on the 4/2/25. Diazinon concentrations were generally low in samples collected in the dry period at all sites with the exception of samples collected at the downstream site at Farm C on the 21/1/25 which had moderately elevated values (4.27 ng/l = 21% of MAC-EQS). The first rainfall period did not result in substantial increases in concentration in samples collected on the 28/1/25 although again concentrations were moderately elevated (4.468 ng/l = 22% of MAC-EQS) downstream of Farm C. The substantial increase in concentrations at two of the downstream sites (Farms A and C) and moderate increase at Farm B on the 4/2/25 are not obviously associated with rainfall as indicated on Fig 1. However, this sampling occasion occurred on the same day as the collection of biological samples when a significant rainfall event occurred in the morning and significant increases in stream water flow were observed.

Figure 1 Diazinon concentrations at sites u/s and d/s of Farms A, B and C in relation to rainfall

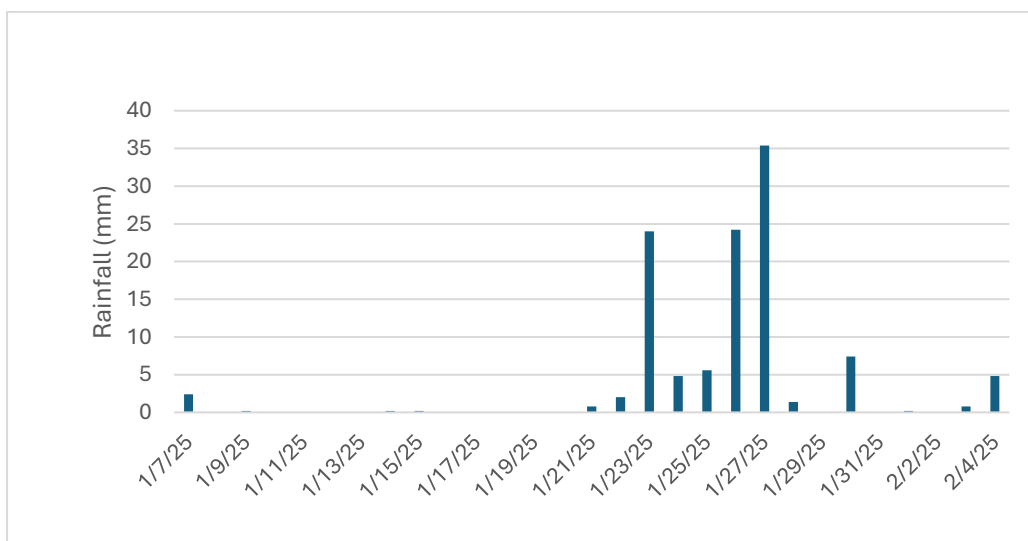


Rain gauging station in proximity of Farm A





Rain gauging station in vicinity of Farms B and C



5. Discussion

The results consistently indicate raised levels of diazinon downstream of the farms following dipping operations. Two routes could be proposed as the cause:

1. Runoff from contamination at the site of dipping or the post dipping holding pens
2. Loss of diazinon from sheep fleece directly into watercourses or indirectly onto grazing areas which was subsequently transported over or through the soil to watercourses

A number of factors point to the second route being the predominant cause. There was generally an absence of a marked increase in concentrations in the first samples taken after the significant rainfall commencing on the 23/2/25. If runoff from contaminated dipping and pen holding areas was the source then peak concentrations would be expected after the first significant rainfall event. The delay in peak concentrations indicates that the contamination occurred after the sheep were released onto grazing pasture. This is indicative of route 2 which is further evidenced by the situation at Farm A where the sampling site designated as downstream was actually at a higher gradient than the dipping and pen holding areas (see contours on map Appendix 2). The contamination at this sampling site (18.146 ng/l = 90% MAC-EQS) could only have occurred through route 2 above. This concentration is equivalent to 18% of the Maximum Permitted Concentration for drinking water (100ng/l).

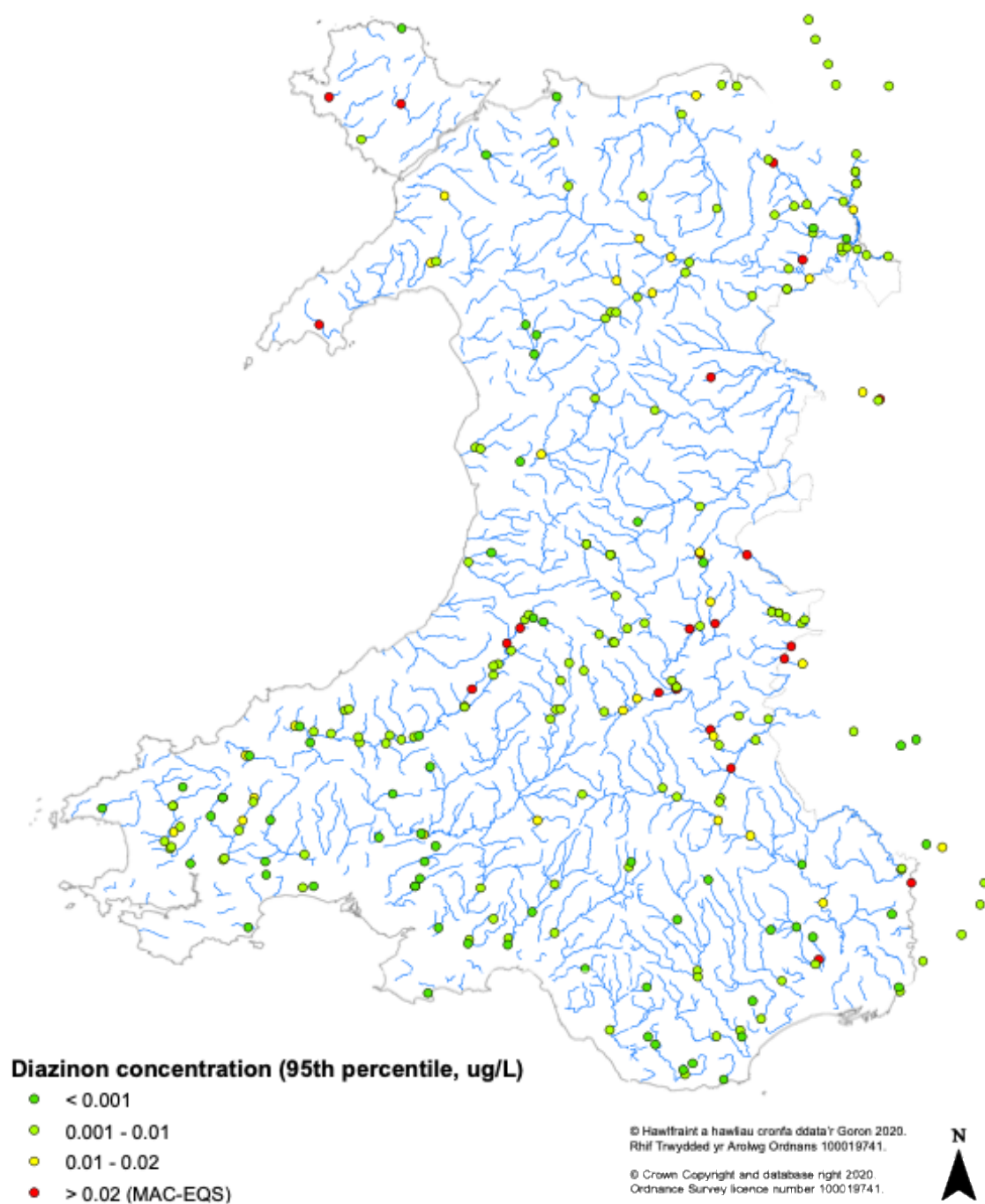
More intensive sampling might have revealed higher peak concentrations than the relatively few spot samples collected in this monitoring exercise. However, no toxic impact could be determined from examination of the macroinvertebrate fauna which suggests that concentrations did not attain a level toxic to the macroinvertebrate fauna. Comparison of diazinon concentrations (data as shown in Fig 2) with macroinvertebrate data carried out by NRW using the Spear index (a method specifically designed to detect the response of macroinvertebrates to pesticide pollution) also failed to determine any causative relationship (T. Andrez pers. comm.) However, these data were generally for larger streams and watercourses where any diazinon pollution would be significantly diluted. It should also be noted that the long-term AA-EQS for diazinon (10 ng/l) was determined from research on the effect of diazinon disrupting olfactory function in salmonids which occurs at a concentration below that toxic to invertebrates (96-hour LC50 of the freshwater shrimp *Gammarus fasciatus* = 200 ng/l)¹. Disruption of olfactory function threatens breeding success in salmonids because of the importance of odorants and pheromones in stimulating reproductive behaviour. This may be one of the causative factors of the poor status of salmonid stocks in Welsh rivers. Poor fish population is the most common cause of failure to meet Water Framework Directive standards in the latest classification⁸.

River water quality samples taken by NRW between 2022 and 2024 demonstrate the frequent occurrence of significant concentrations of diazinon. Of 1799 spot samples analysed for diazinon in this period 91 (5.1%) exceeded MAC-EQS and a further 101 samples (5.6%) were between 50 -100% of MAC-EQS (data provided by NRW). Evidence of the widespread contamination of Welsh rivers is provided by calculation of 95 percentile concentrations at each sampling site (2018-2024 data). This showed that EQS was exceeded at 20 sites (11% of total sites - see red dots in Fig 2) and a further 26 sites (15% of total sites) where the 95 percentile value was between 50 and 100% of EQS (see yellow dots in Fig 2). The interim classification of water bodies for 2024 identified diazinon pollution as the cause of failure to meet WFD standards at 7 classified water bodies⁸. This represents 11% of the total number of waterbodies (64) where there was sufficient data to determine diazinon compliance.

The risk assessment procedure agreed at the outset was not carried out to select the farms chosen for this survey but if it had been applied, two of the farms (Farms B and C) would have been assessed as low risk in terms of the relatively small size of the flocks dipped. Farm A would have been of higher risk in this respect (1000 sheep dipped) but this was irrelevant in terms of the chosen downstream sampling site which was at some distance from the dipping area (500m approx.) and was at a higher altitude. Therefore, higher levels of contamination of watercourses than was detected in this investigation would have been expected if sites of greater risk had been included and it is possible that concentrations would have exceeded the acute short-term limit (MAC-EQS 20 ng/l) and may have resulted in detectable impacts on macroinvertebrate fauna. The results of the survey are indicative of route 2 above being the most likely cause of contamination but route 1 could have been more significant if higher risk sites had been included.

Figure 2

Peaks in diazinon concentration in surface waters (2018 - Jul/2024)



6. Conclusions

Although limited in its scope, this investigation points to the fact that significant contamination of surface waters occurred despite the pollution prevention safeguards adopted by the Gwaredu project. The moderate solubility of diazinon present difficulties for containment and pollution prevention. NRW data also illustrates the widespread and frequent diazinon contamination of streams and rivers. No acute toxic impact could be determined on macroinvertebrate fauna in this survey or NRW's monitoring data. But the smaller streams and headwaters so important for spawning fish and river ecology generally are not generally covered by NRW's monitoring programme. Most dipping normally occurs between August and January which includes the peak season for salmonid spawning. Significant impact could be occurring that is one of the factors causing deterioration such as the monitored decline in fish populations.

The outcome of this investigation should be taken account of in relation to future monitoring priorities and determination of pollution prevention policy. NRW have recently announced that no new land-spreading permits would be issued for waste sheep dip⁹. But the results of this investigation bring into question the continuation of the land-spreading of waste sheep dip at existing permitted sites since they evidence ease of transport of diazinon from grazing land. Higher levels of contamination would be expected from land-spreading sites. Targeted monitoring at an appropriate scale should be undertaken as an urgent priority to properly evaluate the various routes and environmental impacts of diazinon. The use of passive samplers may be of advantage to better describe average conditions, trends and estimates of compliance with AA-MAC standards whereas spot samples can give better estimates of peak concentrations and compliance with MAC-EQS.

Although not of direct relevance to the current study it is clear from NRW data that the pesticide previously used for sheep dipping (cypermethrin) is still detected in significant amounts. The interim classification of water bodies for 2024 identified cypermethrin pollution as the cause of failure to meet WFD standards at 21 classified water bodies⁸ which represents 33% of the total number of waterbodies (64) where there was sufficient data to determine diazinon compliance. Cypermethrin is still licensed for specified uses including spot treatments for blowflies and other parasites on sheep. As noted previously, cypermethrin has a high toxicity for aquatic organisms. It is important that there is a better understanding of sources and pathways to watercourses and its ecological impact.

7. Recommendations

- i) **Further action should be identified to address the risk of contamination from grazing sheep post dipping.** Further evaluation of the Code of Practice is required to determine specific recommendations.
- ii) **A further monitoring programme targeted at a wider range of farms taking account of the risk factors should be carried out to enable a more detailed assessment of the relative effect of the two potential pollution routes identified in this investigation.** This would enable identification of processes that may need improving. Monitoring should include passive and spot chemical sampling to provide estimates of average and peak concentrations that will enable evaluation of AA and MAC-EQS. Although, currently impacts on macroinvertebrate fauna were not detected in this investigation, it may well occur particularly at high-risk sites and therefore macroinvertebrate sampling should be included. Ideally, the inclusion of dipping outside this project would provide a comparison to determine the benefit of the extra precautions adopted by the Gwaredu Scab project. The monitoring should be organised and conducted in a manner to avoid some of the problems encountered in this survey in relation to the selection of farms and sampling locations. Assurance that there would be no action taken in the event of pollution being detected and that results would be treated anonymously (as in this report) should address any farmer concerns about participating in the survey.
- iii) **Further investigation should be carried out to determine the impact of other parts of the dipping process and in particular the impact of licensed land-spreading sites.**

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Cymru, Nathaniel James and Brian Jones (volunteer) West Wales Rivers Trust and Guy Mawle.

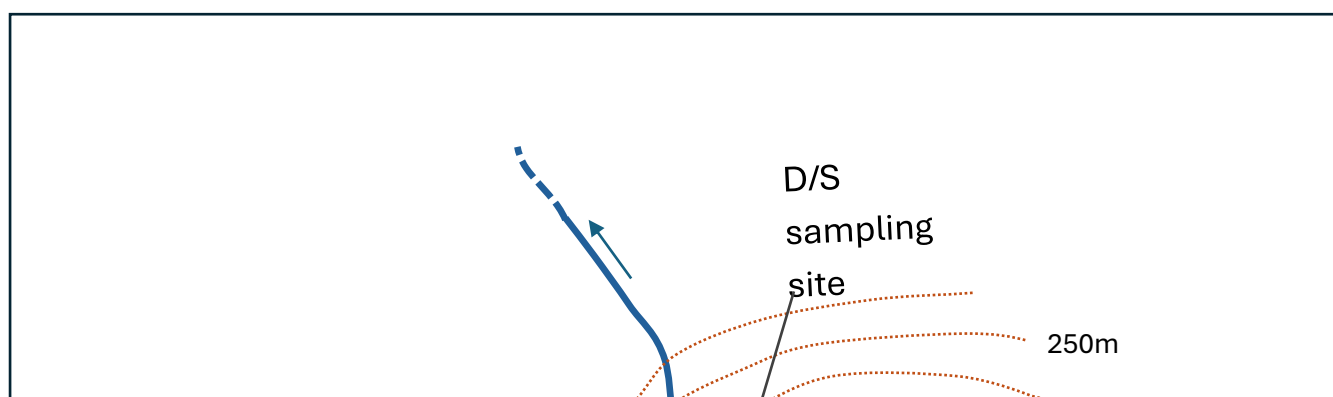
Appendix 1

Qualifications and experience of the author F.H.Jones

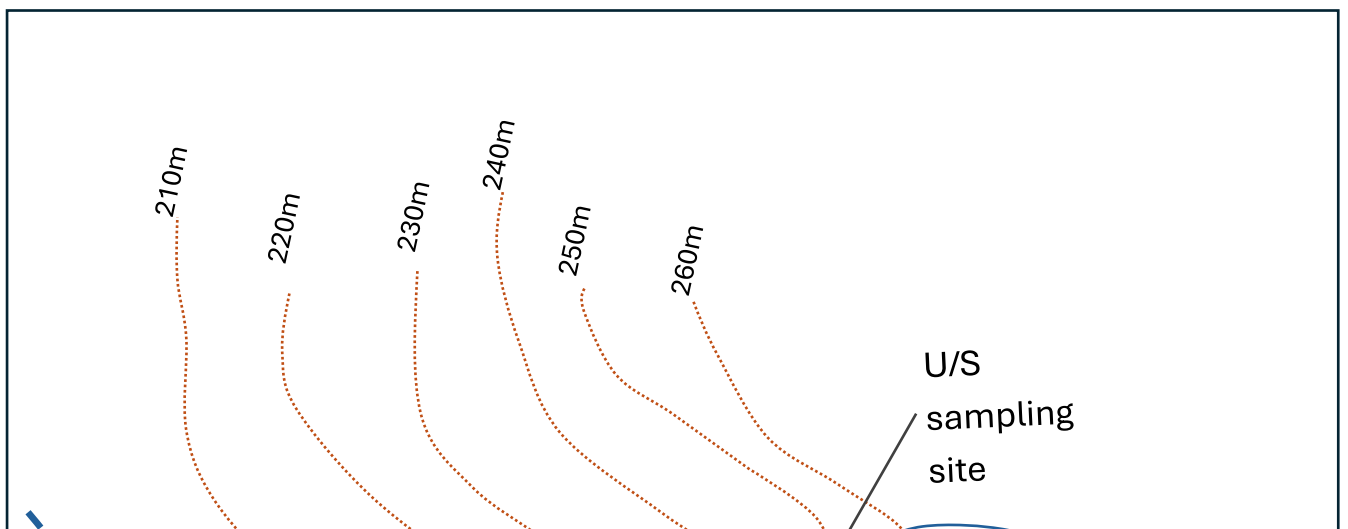
BSc Biology QMC London, MSc water management Aston University, Diploma of the Institute of Fisheries Management. Employed in the water industry as a biologist and environmental scientist between 1974-2006. Key role in the investigations that evidenced the environmental impact of cypermethrin which led to its ban for sheep dipping and later for forestry spraying. Led on the production of the first State of the Environment report for Wales produced in 2000 for the newly formed Welsh Assembly. Developed the environmental strategy and its implementation in the European Funding programmes between 2000 and 2006 whilst seconded to the Welsh European Funding Office.

Appendix 2 maps

Farm A



Farm B



Farm C

