

Executive Summary

This is the final report of Project WT1246 - Understanding changes in pesticide usage to inform water company risk assessments.

The Drinking Water Inspectorate (DWI) is the independent regulator of water quality with the responsibility for ensuring that consumers receive safe, clean drinking water. The DWI responsibilities include a research programme to underpin policy decisions and evaluating pesticide monitoring strategies of water companies. There have been several changes in the regulations governing pesticide approvals and usage in recent years which are likely to change pesticide availability and usage in the future which may impact on water monitoring strategies.

The overall objective of this research is to examine how regulatory changes at European and national level will impact on future pesticide usage, and how in turn, this will impact on water monitoring strategies.

Specific objectives were to:

1. Describe current usage and recent trends in pesticide usage in England and Wales
2. Describe recent and future regulatory changes and their potential impacts and the timings of those impacts
3. Develop a series of scenarios to estimate the possible range of impacts of recent and future regulatory changes might have on pesticide usage
4. Based on the knowledge of pesticide properties, estimate how usage might affect concentrations in raw water and identify any pesticides that are likely to exceed 0.1 µg/l in source waters in the future
5. Assess the likely removal of pesticides identified in (4) by existing drinking water pesticide removal processes.

Trends in Pesticide Usage

Pesticide Usage Survey data from 1990 to 2010, along with other pesticide usage data from other sources, were analysed to provide insight into changing patterns of usage in agriculture, horticulture and amenity sectors.

One of the major drivers of pesticide usage in England and Wales is the area of crops grown. The predominant crops grown that have large quantities of pesticides use are cereals, especially wheat, and oilseed rape. Changes in the pesticide usage on these crops can have widespread impacts across the country. If a pesticide is approved for use in these crops it has the potential to be used across a large area. In contrast, there are some crops with a relatively low area, but have high pesticide usage such as many horticultural crops, and may therefore have a very localised impacts.

Analysis of trends in pesticide usage show that:

- There have been some significant changes in crop areas over the last 20 years with increases in oilseed rape and maize. This has resulted in gradual increases in use of the pesticides that are approved for use on these crops. There was a large increase in wheat area in 2008, due to the removal of set-aside, and this coincided with a peak in use of wheat pesticides. This increase in pesticides was in part due to the area, but also due to a very wet autumn period.
- There has been a reduction in the weight of total pesticides used since 1990 (from 28 M kg active substance in 1990 to 15.1 M kg active substance in 2010), although there are occasional peaks in use that coincide with cropping changes, e.g. in 2008 there was an increase that coincided with the increased wheat area. The reduction in use of sulphuric acid for potato desiccation accounts for almost half of this reduction (6.8 M kg).
- There have been a number of new active substances that have been introduced over the last 20 years that have had fairly rapid increases in use. This includes the introduction of;

- **Iodosulfuron-methyl-sodium + mesosulfuron-methyl** for grass weed control in wheat, introduced in 2003, used on over 1M spray ha by 2010. These active substances are used at a low rate and therefore only 3,000 kg and 12,000 kg active substance respectively were required to treat this area.
- **Flufenacet** for grass weed control, used in cereals. Introduced in 2002, used on 1M spray ha by 2010, with 251,000 kg active substance used.
- **Epoxiconazole** a cereal fungicide. Introduced in 1995 and over 4M spray ha treated (with up to 70% of the cereal crop area treated and over 45% of the crop receiving two or more applications). In total 197,000 kg active substance was used in 2010.
- **Prothioconazole** a fungicide with widespread use in cereals and oilseeds. Introduced in 2006, used over 3.7M spray ha of wheat treated and over 400,000 spray ha of oilseeds treated by 2010. About 25% of crops received at least two applications. In 2010 there were almost 300,000 kg active substance used.
- As new active substances with greater efficacy have been introduced to the market they have replaced older active substances that were no longer as effective. Active substances that have seen declining use during the survey period include;
 - **Isoproturon (IPU)** a herbicide used in cereal crops. At its peak in 1999 IPU was used on 3.5M spray ha of cereals (3.5 M kg active substance), as resistance developed and more effective active substances, such as iodosulfuron-methyl-sodium + mesosulfuron-methyl, became available, use gradually declined with about 1.5M spray ha treated in 2008 (using 1.5 M kg active substance), prior to its withdrawal.
 - **Azoxystrobin** a fungicide used in cereals arrived on the market in about 1997, by 2000 almost 2M spray ha of wheat were treated with 225,000 kg active substance. But as disease resistance started to develop and new strobilurin fungicides, such as **pyraclostrobin**, came to the market, its use declined to just under 500,000 spray ha treated in 2010 with 140,000 kg active substance.
 - **Dimethoate**, an insecticide used in a range of crops including cereals. At its peak in 1996 112,000 kg dimethoate was used on 0.5M spray ha of crops, but as resistance developed (such as in the peach potato aphid) its use declined with only a small area of crops treated in 2010.
 - **Mecoprop** a herbicide has been replaced by the new formulation **mecoprop-p**. The total weight of product used has declined (by almost 50%) since 1990 partly as a result of the introduction of **diflufenican** in the early 1990s and **flufenacet** in the early 2000s
- During the survey period a number of important active substances have been withdrawn from the market. Analysis of the impact of withdrawal of widely used active substances shows that;
 - **Isoproturon (IPU)**, a herbicide used in cereals, was withdrawn from the market in the UK in 2007 with final use in 2009. In the following survey year (2010) there were notable increases in the use of **diflufenican** (increasing from 30% cereal area treated to 65% cereal area treated, with 83,000kg active substance) and **chlorotoluron** (increasing from 7% cereal area treated in 2008 to 12% cereal area treated with 580,000 kg active substance in 2010).
 - **Trifluralin**, a herbicide used in both cereals and oilseeds, was withdrawn at the same time as IPU. The changes in cereal herbicide use were also in part in a response to the loss of trifluralin. In oilseeds there was a noticeable increase in the use of **metazachlor** (to 260,000 kg active substance), **propyzamide** (to 180,000 kg active substance) and **glyphosate** (650,000 kg active substance), although given that there is only a single survey that has taken place since the withdrawal it is difficult to see if this is a continuing trend.
 - **Atrazine**, a herbicide used in maize was withdrawn in 2007. Immediately following its withdrawal there was an increase in use of **terbuthylazine** (from nothing in 2008 to 50,000 spray ha treated, with 18,000 kg active substance in 2010) and **mesotrione** increasing from less than 10,000 spray ha treated in 2008 to almost 100,000 spray ha treated with 7,800 kg active substance in 2010.

Review of legislative changes and their potential impacts

There are a number of pieces of legislation that impact on the availability of pesticide active substances to the UK market. Some legislation has a direct influence on the availability of active substance through controlling whether or not an active substance is approved. The current approvals legislation Regulation (EC) No. 1107/2009 is expected to bring about the loss of about 20 active substances that are currently used in the UK market when their approvals are due for renewal. The losses that might cause significant shifts in pesticide usage would be the loss of **pendimethalin** (herbicide) and **epoxiconazole** (fungicide). These active substances both have important uses on a large area of arable crops and therefore there is expected to be a large shift to other active substances if or when these products are withdrawn from the market.

There is legislation aimed at protecting water which has an indirect influence on pesticide active substances through putting limitations on the levels that can be present in water (Drinking Water Directive (DWD) Council Directive 98/83/EC and Water Framework Directive – 2000/60/EC (WFD)). Although the legislation can not directly bring about the withdrawal of active substances the fact that active substances cause problems in water is taken into account at re-registration.

There are a number of important active substances that are currently being detected in water at levels that are causing concern. These are mainly herbicides (for weed control) and a molluscicide (for slug control). The three major active substances affected are **propyzamide** (herbicide), **carbetamide** (herbicide) and **metaldehyde** (molluscicide). These active substances are all being targeted through the Voluntary Initiative and in the case of metaldehyde also by the Metaldehyde Stewardship group 'Get Pellet Wise' campaigns, with the aim of improving farmer awareness over the problems caused by these active substances and the ways to minimise the risk of these active substances getting into water. Ultimately it may not help water quality if too many active substances are lost, as this increases the risk of a larger area of crops being treated with a smaller number of active substances, therefore increasing the risk of high concentrations of an alternative active substance being detected in water. However, wider availability of chemical options with a combination of improved risk mitigation, reduced rates or restricted timing could reduce the overall amount of any single active substance used and result in overall reduction of levels in water.

Scenario selection

Based on the trends in pesticide usage and the potential legislative impacts on pesticide usage in the future a series of groups were developed to identify potential future changes in pesticide use. These groups were then modelled through a simple modelling process to determine their initial impact before being refined. The refined scenarios were then run through the full modelling process.

The final scenarios selected for further analysis were:

- Scenario 1 - Replacement of selected triazoles (bixafen, carbendazim, cyproconazole, epoxiconazole, flusilazole, metconazole, prochloraz, propiconazole, tebuconazole) with prothioconazole. (**High risk, within 10 years**) – based on active substances that are expected to fail to meet the requirements of new approvals legislation
- Scenario 2 - Replacement of mancozeb with folpet, fenamidone and thiophanate methyl. (**High risk, within 10 years**) as above but for non triazoles fungicides
- Scenario 3 - Replacement of pendimethalin with alternatives chlorotoluron, diflufenican, flupyrsulfuron, prosulfocarb, tri-allate. (**High risk, within 10 years**) as above but herbicides
- Scenario 4 - Replacement of selected herbicides (2,4-D, bentazone, carbetamide, chlorotoluron, MCPA, mecoprop-P and propyzamide) with aminopyralid, clopyralid, florasulam, flufenacet, fluroxypyr, MCPB, metazachlor, pendimethalin, triclopyr [This scenario would be accompanied by a change in crop area as oilseed rape production is reduced on heavier soils]. (**Medium risk 0-5 years**) based on active substances that are repeatedly detected in water
- Scenario 5 - Replacement of metaldehyde with ferric phosphate and methiocarb. (**Medium risk 0-5 years**) as above.
- Scenario 6 - Replacement of chlorothalonil with folpet. (**Medium risk – 5 years**) active substances currently identified as potential priority substances or potential UK specific pollutants
- Scenario 7 - Replacement of a wide range of fungicides (difenoconazole, fluquinconazole, myclobutanil, penconazole, prochloraz, propiconazole, prothioconazole, tetraconazole, triadimenol, triticonazole, folpet, thiram) with alternates (azoxystrobin, pyraclostrobin, bixafen,

fluxapyroxad, isopyrazam, picoxystrobin, boscalid, cymoxanil, fludioxonil, metalaxyl) based on active substances that may fail endocrine disruptor criteria under new approvals legislation, depending upon the final definition used

Analysis

The impacts of the seven identified scenarios on surface water and groundwater drinking supplies was assessed using a screening pesticide fate modelling framework that ADAS employ for water companies designing their water quality compliance monitoring programmes. The modelling framework considers not only the cropping, soil/geology and weather characteristics of each drinking water protected area but also the compound properties and the changes in cropping, compound and usage regimes defined by the scenarios.

The simulation modelling of the seven scenarios for surface waters produced estimates of potential risk, or the likelihood of a pesticide being detected in source waters above 0.1ug/L. For two scenarios there was a small reduction in potential risk and for a third scenario potential risk was largely be the same, with one compound simply replacing the other. While there was a small increase in potential risk associated with two scenarios and a small to moderate increase associated with a further two. The increases in potential risk are generally small relative to current use within the baseline with the exception of a small number of compounds, for example aminopyralid, folpet and azoxystrobin.

With respect to groundwater the simulation modelling suggests that there is little or no impact on potential risk owing to the scenarios with five indicating no change while for two scenarios there is a small reduction in potential risk.

Table 1 The expected probability of removal by GAC for the identified pesticides

Identified Pesticide	Anticipated Removal Probability
Aminopyralid	High
Azoxystrobin	Very high
Clopyralid	Low
Chlorotoluron	High
Flufenacet	Very high
Flupyrsulfuron-methyl	High
Fluroxypyr	High
Fluzapyroxad	Very high
Folpet	Very high
MCPB	High
Metazachlor	Very high
Prosulfocarb	Very high
Thiophanate-methyl	Very high
Triclopyr	Very high

The probabilities of removal shown in the above table relate to the expected removal from a well designed and well operated GAC installation. The removal effectiveness of GAC for a particular compound cannot be easily predicted due to the many factors that influence its removal *e.g.* carbon type, presence of other pesticides and organic content of the water. For example, a compound that is very well removed would be expected to be removed by a well designed and well operated GAC installation, to concentrations at or below the limit of detection of that particular pesticide and within the regeneration timescale of the carbon column *i.e.* no breakthrough of the pesticides would be expected in the times between regeneration for a particular column. Correspondingly, an increase in the background concentration of a particular pesticide entering the plant would be expected to be effectively removed. Some breakthrough may occur, but the degree of which depends on the inlet concentration and remaining adsorptive capacity of the carbon.

There are several methods available for the removal or reduction of pesticide concentrations in treatment of drinking water with granular activated carbon (GAC) perhaps the simplest and most commonly used method. While there is little published data regarding removal of many of the higher potential risk scenario compounds using GAC there are a series of "rules of thumb" that can be used

relating to the compounds molecular weight/size, solubility and hydrophobicity. The additional consideration of the impacts of GAC removal as part of water treatment moderates the simulation results even further with almost all of the compounds where there is an increased potential risk that might exceed the drinking water PCV having at least a high probability of being removed by GAC. The notable exception is clopyralid which is known to be poorly removed by conventional water treatment processes.

The results from this study suggest that the impacts on drinking water quality of changing pesticide availability as a result of regulation are likely to be fairly small and most likely dealt with by conventional water treatment processes, in particular GAC, where increases in potential risk are suggested. However, it should be noted that these results are limited to a small suite of scenarios that are by necessity founded on assumptions of what pesticide users might do in the event of a range of products becoming unavailable, the modelled fate of pesticides in the environment as predicted by simulation models with their concomitant uncertainty and estimates of removal by GAC largely derived through expert assessment.

Conclusions

There is a great deal of uncertainty over the withdrawal of pesticide active substance from the market. Where active substances have been identified as at risk from legislative changes chemical companies that currently have a good market for that active substance will make every effort to retain the approval, with further research and evidence developed to support their case. However, these active substances are the ones that there is the greatest risk of withdrawal, even if it may take place over a longer period. When it comes to active substances that are being detected in water there is even more uncertainty over whether or not the active substance will be withdrawn. Once an active substance is withdrawn there are typically a range of options that a farmer might take in order to maintain the profitability of his crop. This report has aimed to capture the most likely option that the majority of farmers will take and worked out where the greatest impact to water quality might come.

There will be a range of impacts on surface and ground water drinking water sources owing to changes in usage brought about by changes in regulation. Across the seven scenarios investigated through simulation modelling there was a range of results from a small decrease in potential risk to a small to moderate increase in potential risk. However, for most there was little or no change in potential risk, either as there was little risk in the first place or the current potential risk is simply replaced by that from another compound. Consideration of the potential removal of higher risk compounds, that the simulation modelling suggests might exceed the drinking water PCV, by water treatment like GAC further moderates any increased potential risk with almost all compounds having at least a high probability of being removed by GAC.

It should also be noted that while existing water treatment technologies may effectively deal with any changes in risk owing to changes in pesticide approvals, there is currently a move within the industry towards finding more sustainable and lower carbon footprint solutions to water treatment, often through exploring catchment management approaches. The withdrawal of large numbers of compounds and increasing use and dependence on others may make the attainment of these aspirations more difficult.

Suggestions:

It is emphasised that to estimate the true removal potential of GAC for different pesticides, then actual testing should be performed.