

## HOW PESTICIDES GET INTO WATER – AND PROPOSED REDUCTION MEASURES

Andrée Carter from ADAS outlines the sources of pesticide entry into water and proposed reduction measures, based on a report prepared by ADAS Consulting Ltd. for the European Crop Protection Association

### Introduction

During recent years there has been increasing interest in the fate of plant protection products in the environment and their impact on ground and surface water quality. Drinking water quality and the need to ensure that there are no unacceptable effects on non-target aquatic organisms are the fundamental issues of concern. Whilst a number of pesticides have been detected in water it is essential to determine the frequency and magnitude of the contamination so that exposure assessments can be carried out to determine the risk to consumers from drinking water and to non-target aquatic organisms.

The aim of this paper is to detail the sources of pesticide entry into water and to propose measures which could be taken to minimise the environmental impact caused by such contamination.

### Water quality – EU Directives and Limits

Concerns over pesticide entry into water are divided into two distinct areas and as such the objectives for maintaining or improving water quality are:

- Protection of aquatic ecosystems
- Promotion of the sustainable use of water resources (contributing to the provision of adequate drinking water and water for other economic uses).

A number of European Directives embrace these objectives, particularly the Drinking Water Directive, 80/778/EEC (and the revised directive 98/83/EEC, which is unchanged for pesticide parameters) which requires that no individual pesticide in supplied drinking water exceeds a concentration of  $0.1 \mu\text{g L}^{-1}$  and that total pesticides do not exceed a concentration of  $0.5 \mu\text{g L}^{-1}$ . When this Directive was established in 1980 the  $0.1 \mu\text{g L}^{-1}$  limit for pesticides was representative of a surrogate zero since this was the analytical limit of detection for most active substances analysed at the time. It is not a toxicologically based standard. The limit refers to water 'from the tap' and treatment processes can be used to achieve compliance. It is the cost of treatment and the effectiveness of the procedure which is of concern to water suppliers. When water treatment is carried out most water supplies comply with the requirements of the Directive with regard to the  $0.1 \mu\text{g L}^{-1}$  standard.

The Plant Protection Products Registration Directive (91/414/EEC) requires that there is no unacceptable impact on non-target organisms in the aquatic and

terrestrial environment and that the annual average concentration of an active substance or relevant metabolite does not exceed  $0.1 \mu\text{g L}^{-1}$  in any groundwater. Directive 91/414/EEC provides a direct reference to the Drinking Water Directive 80/778/EEC (revised as 98/83/EEC) whereby no active substance or its relevant metabolite should exceed  $0.1 \mu\text{g L}^{-1}$  or exceed one tenth of the Acceptable Daily Intake (ADI) where the value is lower. Directive 91/414/EEC also refers to the abstraction of surface water intended for drinking water and the requirement for compliance with values fixed by Directive 75/440/EEC.

Both objectives have increasing importance and are key to the requirements of the proposed European Water Framework Directive (Proposal for a Council Directive establishing a framework for Community Action in the field of Water Policy - COM(97) 614, final). This Directive will rationalise the existing body of water legislation established under a range of Directives since the 1970s. It will lead to the repeal of a number of directives and will provide a framework for the remaining legislation. Fundamental to the Directive is the prevention of deterioration in water quality and the establishment of environmental objectives for all surface waters and groundwaters. Environmental Quality Standards (EQS's) for a number of pesticides will provide the basis for regulation in surface waters. It is anticipated that the Directive will be agreed in 2000 and will require implementation by Member States within two years.

The competent authority within each member state will designate surface water catchments as the management unit. Agricultural point and diffuse sources of contamination which impact on the aquatic environment and cause transgressions of environmental quality standards will be targeted for remedial action or change of activity. The Directive will help to focus attention on the assessment and monitoring of the ecotoxicological effects of contaminants in the field situation, which to date, have largely been neglected. It will also provide the opportunity for catchment specific co-operation of users, regulators and the crop protection industry to minimise potential losses of pesticides.

### Water quality monitoring

The European review of existing active substances and their products (Regulations 3600/92 and 451/2000) has focused attention on water quality monitoring data. Monitoring data from European countries has been sought by the crop protection industry and regulatory authorities to determine

## Water source definitions

### Groundwater

Groundwater comprises the underground water which exists in a saturated state i.e. pores, cracks and fissures in the bedrock or other matrix are water filled. The unsaturated zone lies above the surface or water table level of the groundwater and is known as the vadose zone. Not all voids in the vadose zone are water filled and consequently the travel time for water or contaminants is generally slower than in the saturated zone.

### Surface Water

Surface water is that which lies above the earth's surface and the definition can be wide ranging to include ditches or ponds which may be ephemeral (seasonal presence of water) to permanent water bodies such as canals, rivers, lakes, reservoirs and estuarine regions and seas.

whether contamination has occurred, its extent and implications. The requirement for water companies to comply with the Drinking Water Directive (80/778/EEC) has also developed continued interest in the monitoring of the quality of water resources. Given the concerns over the potential impact of plant protection products on water resource quality or non-target organisms it would perhaps be anticipated that comprehensive monitoring data would be available to determine the state of compliance with the various EC agricultural and environmental policies/directives. Whilst there are numerous examples of comprehensive monitoring in specific locations or catchments there is no mechanism available to combine this information to overview water quality monitoring data at the Member State or EU level to determine the scale and extent of the problem. Sampling methods and strategy, timing, supporting documentation, analytical methods, detection limits and reporting methods are inconsistent and consequently an overview of monitoring results can only be achieved by detailed investigation of many different datasets of varying content and quality.

The lack of co-ordination in monitoring, research and innovation was recognised in a European Commission report (1998) from DGXII the research directorate, and an action plan has been proposed which specifically recommends the need to improve monitoring and an understanding of the fate of diffuse pollutants. A further European Commission report (1998) summarises a work programme and workshop on the sustainable use of plant protection products in the European Union which was co-ordinated by from DGXI, the Environment Directorate and the Dutch Government. It endorsed the recommendations of the Carter and Brown report (1997) and recommended that a strategic guidance document was developed and co-ordinated, at the EU level, on post approval monitoring and surveillance of environmental impacts, in particular in the case of water.

The forthcoming EU Water Framework Directive will have a direct impact on monitoring strategies and when adopted will require management of water resources at the catchment level. A fundamental part of the requirements of the proposed directive is characterisation of the catchment

and appropriate monitoring. Whilst monitoring must recognise different regional and national characteristics of pesticide use and fate, there is an opportunity to harmonise certain aspects of monitoring, analysis and reporting requirements. Lessons can be learnt from existing monitoring and the results from previous and existing programmes should be interpreted to provide targeted and cost effective strategies.

## Origins of pesticide entry into water

Research over the last few years has identified a number of potential entry routes which vary according to the nature and properties of the active substance and the prevailing agroclimatic conditions *e.g.* Carter (1999), Notenboom *et al.* (1998). Investigations have focused on monitoring and understanding the processes which determine fate following application to agricultural land *e.g.* Flury *et al.* (1994). Entry of pesticides into water has been shown to occur in some circumstances and it is now increasingly recognised that there are also a number of other entry routes, in addition to diffuse losses, which arise from non-approved use, poor practice, illegal operations or misuse (Table 1).

### Diffuse Sources

#### Spray Drift

For plant protection products applied as sprays, a key potential route to surface water is from spray drift. This occurs when a spray application is made in close proximity to surface water. There is some field monitoring data available concerning the amount of product which does drift to water. For example a ground application of a pesticide to arable crops resulted in drift deposition ranging from 0.3% to 3.5% of the normal field application rate at a distance of

## Source terms

### Diffuse – (non point) indirect entry into water

Pesticides are generally applied for agricultural purposes on a field scale to land where a microbiologically active soil layer is present and where degradation and dissipation processes can take place. The active substance and/ or its metabolites usually have the opportunity to move through the soil layers in solution or sorbed to soil particles before entering water via artificial drainage systems or as surface or sub-surface flow, leaching or by-pass flow. Groundwater and surface water bodies can be affected. Spray drift and pesticides in precipitation can also considered to be a diffuse source of surface water contamination.

### Point – direct entry into water

Water contamination derives from a localised situation and enters a water body at a specific or restricted number of locations. Approved point source contamination exists in the form of consented discharges *e.g.* from vegetable washing plants, whilst semi-point sources can occur when pesticides are applied to discrete or restricted locations *e.g.* roadsides or railways. Non-approved contamination events derive from spillages or discharges of product, tank mix, waste or washings directly to surfaces or drainage systems which can enter surface water or via soakaways to groundwater.

Table 1 Sources of pesticide entry into water and water source type predominantly affected

Entry source	Entry route/cause	Main water source type affected
DIFFUSE	spray drift	ditches, streams, ponds rivers
	volatilisation and precipitation	ditches, streams, ponds, rivers
	surface runoff/overland flow	ditches, streams, ponds, rivers
	leaching	groundwater
	throughflow/interflow	ditches, streams, ponds, rivers
	drainflow	ditches, streams, ponds, rivers
	base flow seepage	groundwater /surface water
POINT	tank filling	groundwater /surface water
	spillages	groundwater /surface water
	faulty equipment	groundwater /surface water
	washings and waste disposal	groundwater /surface water
	sumps, soakaways and drainage	groundwater /surface water
	direct entry including overspray	ditches, streams, ponds, rivers
	consented discharges	streams, rivers

1 m from the treatment area. For regulatory evaluations, a drift value of 4% is used which represents the 95th percentile of the observed distribution using the Ganzelmeier (1995) spray drift tables. Increasing the distance of spraying from the water's edge reduces the amount of spray drift entering water. In reality, deposition will be influenced by bankside vegetation and morphology, wind speed and direction and other weather variables. The dilution and dissipation of the product and its bioavailability to non-target organisms will be influenced by product formulation, the characteristics of the active substance and the characteristics or processes of the receiving water such as flow rate, mixing, the presence of vegetation and sediment. Depending upon the physicochemical properties of the a.s. repeated applications may result in the accumulation of residues in bottom sediments. Such residues may or may not be of any ecological significance.

#### *Volatilisation and precipitation*

Volatilisation can be another pathway by which pesticides are lost from target areas after application and whilst most losses do not exceed 20%, for very volatile chemicals losses can be as high as 90%. However, those pesticides which are typically detected in water sources are not likely to be of a volatile nature. Typical losses for atrazine would be <5% in one month, simazine 1% in 24 days, alachlor 26% during 24 days and triallate 17% over 67 days (Taylor, 1995). Incorporation into the soil profile can significantly reduce losses. Pesticide sorbed to fine soil particles may also enter the atmosphere and be re-precipitated. A number of plant protection products have been monitored in rainfall at low levels particularly during and after the application period. A desk study report (Dubus and Hollis, 1998) reviewed and summarised the existing data relating to long distance aerial transport and subsequent atmospheric deposition of pesticides. Approximately 70% of the 99 pesticides analysed for in rainwater were detected, although the limits of detection for many of these substances are considerably below any environmental quality standard.

In agricultural ecosystems, impacts of pesticides via aerial deposition are negligible and insignificant compared to that

from their direct agricultural application. There are no data available to determine whether sensitive non-target plants or ecosystems might be affected.

#### *Surface runoff / overland flow*

When the infiltration capacity of an application surface is exceeded water, soluble residues and residues sorbed to fine particles can move across an application surface. Losses from agricultural fields are typically less than 0.05% (Wauchope, 1978; Williamson and Carter, 1991) unless extreme rainfall falls within 1–2 weeks of application of the applied active substance. Losses can be environmentally significant at the local level due to specific agroclimatic conditions and those soils which have the potential to slake or cap, or are situated on steeper slopes, can be particularly susceptible to surface runoff.

#### *Leaching*

Leaching is a major process for the transport of soluble to ground and surface water. Leaching residues may move directly to underlying groundwater or may be transported laterally to surface waters. Losses of applied active substance by leaching can, in exceptional cases be as high as 5%, but are typically less than 1%. Losses can be greater when soil water moves rapidly as preferential flow, through the soil via cracks, fissures or macropores since residues have less opportunity to dissipate. In some soil types, residues sorbed to soil or organic particles can be transported from the soil surface suspended in leachate water. Strongly sorbed active substances which do not normally leach can be transported in this way and Hardy et al. (1998) report the transport of diflufenican from a non-calcareous topsoil to surface water. The extent and ecotoxicological significance of this transport mechanism in Europe has not been determined but it will be more important for compounds with high sorption values.

#### *Drainflow and throughflow*

Land drainage design has as its objective the removal of excess water from soil or the land surface. Large scale attempts have been made for at least two centuries to

improve sub-surface water control by the installation of various underdrainage systems *e.g.* stone drains, baked clay horseshoe tiles clay pipes, and now slotted plastic pipe with permeable fill. These drains are effective and responsible for removing water from many slowly permeable soils or those with shallow water tables which would otherwise not have been cultivated. Artificial drainage has been shown to be responsible for the transport of significant quantities of dissolved pesticide or that carried on sediment particularly when rainfall and subsequent drainage occur shortly after application. Losses might represent up to 1% of the applied active substance but are typically less than this.

Throughflow is the lateral movement of water below the soil surface which occurs naturally in the absence of artificial drainage. Throughflow can enter surface water via bankside seepage but will generally contain less residues than drainflow as it has passed through the soil matrix having the opportunity for sorption and degradation of the active substance.

### *Base flow seepage*

It is possible that contaminated groundwater can seep into surface water and vice versa. This pathway is not considered to be a significant route of pesticide entry.

### **Point Sources**

*Farm yard activities (e.g. tankfilling, spillages, faulty equipment, washings and waste disposal, use of sumps, soakaways and drainage)*

Some of the most serious cases of water contamination have arisen from misuse, accidental spillage, or inadequate handling/storage conditions. In Denmark it has been shown that 2,4-D, dichlorprop, parathion, and diquat were detected in groundwater at concentrations of up to 3800 µg L<sup>-1</sup> (Helweg 1994). These high concentrations have been attributed to direct contamination from back-siphoning in the borehole during the tank filling process. Rinsing of sprayer around the borehole also contributed to the contamination. Similarly high concentrations of a herbicide in surface water in the UK were identified as having derived from illegal disposal at a landfill site. Non-approved farm soakaways, equipment washing waste have also contributed to point source contamination.

### *Direct contamination and overspray*

Overspray of surface waters during the application of pesticides is not an approved use. It is unknown how frequently it might occur but its impact could be very significant. This is illustrated by the fact that three 200 µm diameter spray droplets from a spray mix containing 1 kg ha<sup>-1</sup> of active substance can cause contamination of one litre of water to 0.12 µg L<sup>-1</sup>. Granular formulations applied using spreaders may also enter water courses directly. Spillages directly into surface water have occurred and can cause extensive contamination. Contaminated vehicles fording surface waters are also point source contributors of pesticide movement to water.

### *Consented discharges*

Industrial and agricultural activities can give rise to waste

which can be approved for discharge into surface waters. Consents vary according to concentration of residues at the discharge point and the nature of the receiving water. Consents might also be given for disposal of wastes via soakaways which might drain to surface or groundwaters. These point sources can be significant causes of water contamination.

## **Measures to reduce levels in ground and surface water**

### *Stakeholders and their interests*

Action and responsibility to prevent or minimise the presence of pesticides in water lie with a number of stakeholders (farmers/users, regulatory authorities, agrochemical companies, water companies, research and advisory organisations, environment agencies, health and safety assessors, quality assurance schemes, training agencies and the general public).

The range of stakeholders and the different interests or requirements with regard to the presence of pesticides in water means that it can be difficult to introduce measures to reduce or prevent contamination which are acceptable to all parties. There is now an increasing trend for representatives of these organisations to collaborate and to seek solutions which are acceptable to all parties. An example of this collaboration is demonstrated by the Dammbach Watershed project in Westphalia, Germany which involved the Chamber of Agriculture, three agrochemical companies, AgrEvo, Rhône-Poulenc Agro, Stefes and the water company Gelsenwasser AG. The partnership focused on tank mixing, rinsing, reductions in use and improved spraying practice. This combined stewardship has achieved a 30% reduction in IPU loadings over a two-year period (Bach 1999).

Other stewardship initiatives include that from Novartis Agro S.A. in France who have produced a colour leaflet and CD-ROM, which takes the reader/viewer through a series of cartoon images depicting a farmer undertaking a spraying operation (Novartis, 1998). The system provides an interactive quiz to provide training which highlights bad practice and provides information on correct practice.

An example of another initiative to improve water quality is that promoted by the Belgian Federation for the Water Sector (BELGAQUA) and the Federation of Producers and Distributors of Pesticides in Belgium (FYTOFAR). After extensive discussions between the two parties agreements were reached to improve spray operator training and user systems and to encourage technological developments. Further co-operation has enabled an investigation of the procedures required for removal of pesticides by water treatment and also the publication of monitoring results. In Brittany, France, whereby a number of agencies including the industry association have developed an action plan to reduce pesticides in surface waters and similar co-operation is taking place in other regions such as Centre and Lorraine. A Danish initiative promotes good practice for mixing, spraying and waste disposal, particularly with respect to point sources of pesticides.

Such stewardship activities are amongst the actions

encouraged by the European Crop Protection Association (ECPA) who issued, in 1996, a declaration on European Water Policy which requires its national associations to comply with the following requirements:

- Development of products to ensure no harm to human health and the environment;
- Promoting the use of products in accordance with good agricultural practice;
- Ensuring that all the necessary information to avoid risk of pesticide entry into water during transportation, storage, use or disposal is available to all parties;
- Development of suitable analytical methods for water and making these available to all appropriate authorities;
- Volunteering of expertise to assist with the development of EQO's and EQS's for various water bodies;
- Any other actions or activities which aim to improve the safety and quality of all water resources.

An interesting development is the increasing influence of the consumer in determining the role of and use of pesticides. Non-statutory quality assurance schemes have been developed in response to producer and retailer requirements to minimise or prevent the potential impact of pesticides on the environment in a more general sense. Components of the many schemes which have developed across Europe require due care and diligence with regard to the use of pesticides. Schemes vary according to organiser requirements but the protection of the water environment is usually a secondary objective of most schemes and the requirements on the operator can be less stringent than for example the need to provide food with minimal pesticide residues. The promotion and adoption of Integrated Farming Systems has also increased awareness of the impact of pesticides and reductions in use are beneficial for water quality.

#### *Methods to reduce pesticide entry into water*

Table 2 summarises the methods which have been developed to reduce pesticide entry into water for the different entry routes. The complex nature of causes of water contamination means that there is no universal single solution and therefore approaches must be site specific. Site solutions will need to combine a number of these methods as several pathways may be responsible for any given contamination event. The difficulty which arises is that the cause of water contamination cannot usually be attributed to a specific location or farm. Water quality monitoring data reflects an amalgamation of water discharged within a catchment and unless intensive monitoring is taking place throughout the region it would be difficult to attribute any concentration to any particular source. Research results and some site specific monitoring must be used to determine, by extrapolation, where problems might arise in other locations and then expert judgement used to determine priorities in terms of effort to reduce risks. Actions to reduce pesticide entry may arise from voluntary effort by farmer actions, or stewardship programs or compliance may be required under national or EU legislation.

The methods listed in Table 2 can be considered as physical, engineering and educational solutions.

Physical solutions deal with the infrastructure of the farm itself. They would include the location and use of hard-standing, presence of a biological degradation system, e.g. a biobed or reed bed, the characteristics of the pesticide store, drainage systems within the yard and within fields and their connectivity to surface and groundwater and the establishment of buffer zones.

Engineering solutions refer to changes in machinery such as the adoption of low drift technology, sprayer testing and direct injection technology for tank filling.

Educational solutions are generally directed at the land owner/ spray operator through certification systems and subsequently to improve awareness of the impact of certain activities, particularly those associated with waste and washings, spillages in the yard and from spray drift or overspray.

#### *Implementation of methods*

The methods listed may also be classified as statutory or voluntary with respect to their implementation. The status of each method varies according to member state, for example, Ganzelmeier (1999) investigated the management and execution of the inspection of field sprayers in different European countries. Of the nineteen countries investigated, five did not have any scheme for sprayer testing whilst testing was obligatory in nine countries and had been so for a number of years. In the remaining countries schemes existed but they were not compulsory.

Compliance with many of the regulations or voluntary schemes can be complex as they may conflict or contravene each other. In some cases requirements may be impractical without a major investment in physical or engineering solutions, e.g. the construction of a banded interception area or the purchase of direct injection technology. The proposal of a simple but practical idea of using sorbant materials to clean up spillages (rather than washing down the spill area) are then complicated by the resulting material becoming classified as hazardous waste. This must then be disposed of by a licensed waste disposal operator. In practical terms material would ideally be burnt with waste packaging but this is not acceptable.

It is clear that the driving forces for compliance are the EU directives on drinking water and groundwater and national requirements to comply with EQS's. Additional legislation in the form of the proposed Water Framework Directive will require compliance with EQS's at the surface water catchment level. A further driving force has become the influence of green consumerism. The general public is increasingly demanding that agricultural activities do not cause deleterious effects on the environment and that the quality of drinking water is not impaired. As a consequence political decisions have been made in several member states to revoke registrations of a number of active substances on the basis of the precautionary principle.

#### *Management practices*

Improvements in management practices are probably the most important actions which can be made to provide immediate improvements in water quality. A primary and essential action is to improve the awareness of spray

**Table 2 Methods to reduce pesticide entry into water**

Entry Route	Methods to reduce pesticide entry into water
<b>DIFFUSE</b>	
drainflow and interflow	<p>restrict flow when peak losses are anticipated to increase time for degradation and sorption (which may result in localised waterlogging)</p> <p>manage soil structure e.g. create fine tilth to increase sorption and water retention (which may reduce infiltration, increase runoff, cause poor drainage and cause increased root disease pressures, etc.)</p> <p>incorporate additives to soil surface e.g. organic material or stabilisers</p> <p>restricted application areas e.g. protection zones</p> <p>reduce drain intensity</p> <p>optimisation of application rates</p> <p>target timing of applications to avoid potential loss periods</p>
surface flow	<p>buffer zones with various surface treatments e.g. grass strips</p> <p>contour cultivations</p> <p>manage soil surface e.g. reservoir tillage, minimal tillage</p>
base seepage	no specific measures
leaching	<p>restricted application areas</p> <p>restrict application to products with appropriate properties to minimise leaching</p> <p>manage soil structure e.g. create fine tilth to increase sorption and retention</p> <p>incorporate additives to soil surface e.g. organic material or stabilisers</p>
precipitation	no specific measure
spray drift	<p>no-spray zones e.g. LERAPS</p> <p>manage vegetation adjacent to water e.g. hedges, interception plants</p> <p>low drift application technology</p> <p>education of operator to choose optimal conditions</p>
<b>POINT</b>	
tank filling	<p>container modifications e.g. anti-glug necks, pack size, returnable packs</p> <p>add container rinsate to the tank mix</p> <p>engineering solutions e.g. tank full alarm, direct injection</p> <p>remove operations from drained impermeable areas</p> <p>biobeds</p> <p>interception areas drained to waste collection site</p> <p>education of operator</p>
spillages	<p>remove operations from drained impermeable areas</p> <p>biobeds</p> <p>interception areas drained to waste collection site</p> <p>use of sorbent pads/material and materials to intercept spills or clean up</p> <p>use of licensed hazardous waste contractors</p> <p>immediate incineration of empty containers if permitted or storage under cover before return or disposal</p> <p>education of operator</p>
faulty equipment	<p>regular maintenance and servicing of sprayer</p> <p>sprayer testing</p>
washings and waste disposal	<p>biobeds</p> <p>other on farm treatment systems e.g. Sentinel system</p> <p>authorised waste disposal</p> <p>dispose of tank sump contents appropriately</p>
sumps, soakaways and drainage	<p>requirement for licensing</p> <p>diversion from direct discharge to water</p>
direct entry including overspray	<p>avoidance</p> <p>education of operator</p>
consented discharges	requirement for licensing and compliance with Environmental Quality Standards

operators and this can be done through compulsory training and certification, refresher courses and, in order to ensure compliance, by random inspection. Whilst many operators are generally aware of the issues concerning water protection they do not appreciate the significance of their actions relative to the stringent water quality standards.

A number of actions can be taken to provide improved application technology, many of which are listed in Table 2. Short term improvements include a change to low drift application technology, provision of tank full alarms and the testing of sprayer performance. Longer-term solutions include a changeover to direct injection of closed transfer systems.

There are a number of actions which could be taken to improve farm yard management of pesticides but these are often site specific depending on the current infrastructure. The physical infrastructure of the farm yard can be changed in the short term to provide a safer tank mixing environment whereby spillages can be contained and cleaned up, appropriate container incineration facilities provided. Longer-term changes may require dedicated mixing areas with bunding, and provision for water interception and treatment. Other physical improvements include the use of vegetation barriers to reduce drift, or surface run-off.

The integrated approach to land management can be applied at the catchment level and is the basis for the proposed Water Framework Directive. Delineation of vulnerable resources and actions plans to avoid pesticide entry into water would assist the reduction of point and diffuse source contamination. Statutory, voluntary actions and product stewardship will be required to ensure implementation. Agreements between all stakeholders will also be necessary.

#### *Decision making*

Before a plant protection product is applied a number of decisions are taken prior to its selection and use. These decisions have historically been based mainly on the need for efficacy and economy. Increasingly decisions are being made to also minimise the environmental impact of pesticide use. Integrated Pest Management (IPM), Integrated Farm Management (IFM), Integrated Crop Management (ICM) are farming or crop management systems which provide farmers with a decision making framework to optimise the use of plant protection products and encourage management practices which ultimately protect water.

Because no adequate baseline data concerning population diversity, health and potential for recovery, exists concerning the environmental impact of pesticides, it is difficult to accurately determine the effect of minimisation or optimisation policies. EC Directive 91/414 requires that data are submitted concerning the potential for an active substance to leach to groundwater or enter surface water. The first tier predictive modelling developed by the FOCUS group will assist in providing a harmonised approach in the assessment process. Ecotoxicological risk assessments are also made and these initially based on laboratory studies. Where concerns are raised further higher tier studies may be required to determine risk in microcosm, mesocosm or field

situations. Examples of field based studies are rare. Potential impacts can be measured indirectly using environmental indicators, for example, assessment of the total tonnage applied or area treated per annum, or the trend in sorption and mobility of an active substance. However, these indicators are hazard based and should not be used in isolation to infer risk. For a proper assessment of risk all the available information should be taken into account.

The recent provision of Environmental Information Sheets, by some representatives of the UK agrochemical industry, provide a user or adviser with the necessary information to decide whether there is a risk of pesticide entry into water. The pilot scheme is now being expanded and it is hoped that all companies will develop these data sheets all registered products.

Other schemes, such as grower protocols and crop assurance, transfer some decisions from the grower concerning pesticide use. The schemes do encourage environmental protection but water quality is not usually a top priority but could become so.

Since decision making can be complex and often requires expert judgement a number of computer based decision making systems are being developed to aid non-experts to make choices *e.g.* Pesticide in the Environment, Economic Trade-Offs (Hornsby 1994) provides the adviser with alternative products for pest control and identifies water contamination risk and the impact of using an alternative on gross margins.

Many farmers or pesticide users are advised on the need for and use of appropriate plant protection product by specialist advisers. In the UK it is estimated that up to 70% of farmers take specialist crop protection advice and each adviser must be registered with the statutory accreditation scheme (BASIS) which also requires evidence of continuing personal development and training.

In order to protect water from pesticide entry there is also a need to define, at member state level, safe use scenarios to enable continued use of a product. Where these scenarios are located, how they are identified and implemented will be a member state decision and responsibility.

*The full report on which this article is based will be available from ECPA, 6 Avenue E. Van Nieuwenhuysse, 1160 Brussels, Belgium.*

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