

Diffuse pesticide pollution of drinking water sources: impact of legislation and UK responses

T. Dolan, P. Howsam* and D. J. Parsons

** Corresponding author. School of Applied Sciences, Cranfield University, Cranfield,
Bedfordshire, MK43 0AL, UK. E-mail p.howsam@cranfield.ac.uk*

ABSTRACT

Diffuse pesticide pollution is a problem for the environment, but it also presents a challenge for water companies managing treatment infrastructure to produce potable water. The legal framework for this context has three main components: that dealing with pesticides and pesticide use, that dealing with environmental water quality and that dealing with drinking water quality. The study set out to identify, interpret and assess the impact of the legal framework related to this challenge. The study found that the current policy and legislation do not provide a coordinated legal framework and some changes are warranted. For example the Water Framework Directive (WFD) sets environmental quality standards for some, but not all, pesticides. Article 7 provides special protection of water bodies used as sources for drinking water supply, but it is not clear whether the UK will achieve full compliance by 2015. This is a problem for water companies planning investment, because the WFD and Drinking Water Directive remain legally distinct. Further uncertainty arises from the application of Regulation (EC) 1107/2009 and the extent that restricted availability of pesticides will drive changes in agricultural practice and pesticide use.

Key words: diffuse pollution; legislation; pesticides; potable water; regulations.

1. INTRODUCTION

The presence of pesticides in “raw” water is a challenge for water companies producing potable water. Historically, a water company has applied the necessary level of treatment to remove pesticides and comply with Drinking Water Directive (DWD) (EC, 1998) standards for potable water. Protection of surface waters used for drinking water supply has been afforded under Directive 75/440/EEC (European Community, 1975), but in 2000 the Water Framework Directive (WFD) (EC, 2000) changed the emphasis away from investing in treatment infrastructure to preventing pollution at source. Special attention is given to water abstraction points, designated as Drinking Water Protected Areas (DrWPAs) in the UK. WFD obligations and targets have increased awareness of diffuse pesticide pollution and driven increased catchment management activity to prevent it. The Voluntary Initiative (VI) is one of many examples and, in parallel since 2005. Environmental stewardship schemes have increasingly encouraged land managers to consider the environment, including water quality, when making decisions. In 2009, following three years of discussion, the EU thematic strategy on pesticides was published making the criteria for pesticide approval more stringent and promoting sustainable use of all pesticides throughout Europe. This comprised Regulation (EC) 1107/2009 concerning the placing of plant protection products (PPPs) on the market (EC, 2009b), and Directive 09/128/EC establishing a framework for Community action to achieve the sustainable use of pesticides (EC, 2009a).

The combined impact of these developments on the level of pesticides found in “raw” water needs to be examined. Important questions include the meaning of WFD targets for pesticides and how they might be achieved, whether additional pesticide withdrawals will be required and what impact WFD targets for pesticides

will have on planning by water companies for DWD compliance. To answer these it is necessary to consider the impact of Regulation (EC) 1107/2009 on future pesticide use patterns, the extent to which the Directive 09/128/EC complements existing UK efforts to deliver WFD targets and whether agri-environment schemes, such as Entry Level Stewardship (ELS), can be used to deliver WFD targets for pesticides. Previous research has considered many of these issues in isolation (PSD, 2009; Garratt & Kennedy, 2006; Garrod *et al.*, 2007; Glass *et al.*, 2008; Humphrey, 2007; Hodge & Reader, 2010; Posthumus & Morris, 2010) but there has so far not been an assessment of the whole framework.

This paper analyses the role that the WFD, European pesticide legislation, and UK driven responses such as the voluntary initiative and environmental stewardship have to play in preventing diffuse pesticide pollution, improving the quality of “raw” water and reducing the level of treatment required to produce potable water to DWD standards. Additionally, the impact of these responses on long term planning for water treatment work (WTW) investment by water companies is assessed.

2. POTABLE WATER PRODUCTION AND DIFFUSE PESTICIDE POLLUTION

2.1 Potable water production

Water companies manage a transformation process, illustrated in Figure 1, in order to produce drinking water to clearly defined standards under the Drinking Water Directive (DWD) from raw materials of unknown and variable quality.

Unlike many industries, the water sector cannot define the specifications for the raw materials they work with. Instead they abstract “raw” water from the environment and operate a treatment infrastructure capable of managing variation in a broad number of substances (e.g. nitrate, phosphate, sediment, heavy metals,

pathogens and pesticides) to ensure the finished product, potable water, complies with quality standards for water intended for human consumption.

2.2 Diffuse pesticide pollution

Diffuse pollution (pollutant transport from land to water) is a major problem for “raw” water quality in many UK drinking water supply catchments. The Environment Agency of England and Wales now regards diffuse pollution as a bigger threat to river water quality than point source pollution (Environment Agency, 2007). This is, in no small measure, due to the difficulty of regulating or preventing diffuse pollution and the need for additional action to address the issue has been widely recognised (Glass *et al.*, 2006; Garrod *et al.*, 2007; Humphrey, 2007; Garthwaite *et al.*, 2008).

The largest source of diffuse pesticide pollution in most catchments is believed to be agriculture, particularly where arable agriculture is the major land use. However, in some catchments amenity use, for example on roads and railways, represents a potentially significant source of diffuse pesticide pollution. One of the most challenging diffuse pollution issues currently facing a number of water companies in the UK is the presence of pesticides such as metaldehyde and clopyralid, at levels that cannot easily be reduced by current WTW infrastructure to the potable water standards defined by the DWD.

In principle, the best strategy to tackle diffuse pollution of any type is catchment management. Catchment management requires appropriate interventions at source to manage application of pesticides and to reduce the risk of flow through each pathway into a DrWPA. The principles of catchment management for pesticides are supported in European legislation through the WFD and the pesticide sustainable use directive (Directive 09/128/EC). In the UK, the issue is addressed by the Environment

Agency (EA), the Government's water strategy for England (Defra, 2008), the Government pesticide strategy and water action plan (Defra, 2006b; Defra, 2007) and government and industry partnerships such as the VI in the agricultural sector and the Amenity Forum (The Amenity Forum, 2011) in the amenity sector. Further initiatives include the England Catchment Sensitive Farming Delivery Initiative (ECSFDI), the code of practice for using plant protection products (Defra, 2006a) and guidance provided by industry bodies including the Metaldehyde Stewardship Group (MSG) and Water UK.

Figure 2 presents a targeted use of the driving forces–pressures–state–impact–response (DPSIR) framework to assess the problem of diffuse pesticide pollution from agriculture in the context of producing potable water to DWD standards.

The response element of the DPSIR framework is central to this paper because it includes all EU and UK driven responses to reduce pesticide use, pesticide availability and to influence pesticide user behaviour. The aim of these responses is to reduce diffuse pesticide pollution and improve the quality of “raw” water in the water environment; this paper assesses how effectively these responses deliver these objectives.

The Source-Pathway-Receptor model in Table 1 helps to identify where responses or interventions should be targeted. It illustrates the complexity of managing diffuse pesticide pollution, because pollution can arise from a number of sources and can pass through the environment by many routes before reaching the receptor, in this case the “raw” water abstraction point.

Table 2 categorises these possible responses as interventions acting at source, pathway or receptor level. Source interventions are those that reduce the availability of pesticide active substances, pathway interventions are those that aim to reduce the

concentrations applied and block pathways to the water environment and receptor interventions act once pesticides are in the “raw” water. The WFD is a significant response to water quality problems because, through Article 7, it sets targets for water quality at the receptor and then promotes the use of source and pathway interventions to achieve these. Predicting the impact of this mix of legal requirements and voluntary schemes is key to the long term planning for WTW investment by water companies.

3. DISCUSSION–RESPONSES TO IMPROVE WATER QUALITY THROUGH REDUCED DIFFUSE PESTICIDE POLLUTION

3.1 Water Framework Directive (WFD)

Introduced in 2000, the WFD is the main piece of EU legislation for the management of water quality and pollution at the river basin level. Chave (2001) describes it as “probably the most significant legislative instrument in the water field to be introduced for many years” and more broadly as “the most significant legal instrument adopted in the environmental field as it directs how an environmental sector is to be managed, institutionally and as a whole”

The first obligation under the WFD (Article 1 & Article 4) is to take all necessary measures to prevent deterioration in water quality and then to aim to achieve good status, for all bodies of water, with limited exceptions. For surface waters, status includes chemical, ecological and hydromorphological elements, whereas for ground waters only chemical and quantitative elements apply. Article 6 of the WFD requires the creation of a register of all protected areas already created under previous EU legislation as listed in Annex IV.

Article 7 requires the identification of “all bodies of water used for the abstraction of water intended for human consumption providing more than 10 m³/day as an average or serving more than 50 persons” and specifies water quality objectives

for these protected areas that must be achieved by 2015 (Article 4.1c). In England and Wales these areas have been designated as DrWPAs. These DrWPAs are subject to the objectives defined in Article 7.2 and 7.3. In effect Article 7 replaces the obligations of Directive 75/440/EC (as amended) concerning the quality required of surface water intended for the abstraction of drinking water, which was repealed in 2007.

Implementation of the WFD has led to the production of river basin management plans (RBMPs), under WFD Article 13. Annex C of each RBMP includes a programme of measures (PoMs), as required by Article 11, to specify how the objectives defined in Article 4 (no deterioration and achievement of “good” status, including special requirements for designated protected areas) will be achieved. The PoMs make reference to actions from many stakeholders under existing legislation and ongoing UK initiatives to specify how progress toward status targets and protected area objectives will be delivered.

3.1.1 Pesticides in the WFD

A pesticide active substance can only affect achievement of overall status targets if it is subject to an environmental quality standard (EQS). To be subject to an EQS the active substance must be classified as a priority substance or a priority hazardous substance in WFD Annex X (EC, 2001) or be classed as a “specific pollutant” at member state level. In the UK, the United Kingdom Technical Advisory Group (UKTAG) is responsible for identifying SPs and defining EQS for these (UKTAG, 2008b). Currently, in the UK only ten of the 278 approved pesticide active substances are subject to EQS as a priority substance or specific pollutant. This figure of ten includes six priority substances, four of which were proposed, but are yet to have EQS defined (EC, 2008), and one that is expected to be withdrawn under the

new approval regulation (Regulation (EC) 1107/2009) and four specific pollutants, three of which might be withdrawn under Regulation (EC) 1107/2009. Therefore, at most only 4% of currently available pesticide active substances can directly influence the achievement of good status targets. This is significant because the WFD as currently applied in the UK does not target all pesticides, in all water bodies; rather the WFD focus on pesticides is restricted to the protected areas (DrWPA) identified under Article 7. Furthermore, because EQS are not linked to DWD standards for pesticides, it follows that general action against pesticides is not designed to support the achievement of WFD Article 7 objectives. The main drivers in the WFD to reduce diffuse pesticide pollution and improve raw water quality are the objectives for DrWPAs, as defined in WFD Article 7 (EC, 2000). These are applicable to all pesticide active substances. For surface water DrWPAs, Article 7 objectives are additional to and do not affect the achievement of overall status targets, whereas a groundwater DrWPA cannot achieve good overall status if it is failing to achieve DrWPA objectives.

A briefing note from UKTAG (UKTAG, 2008a) and Annex D of the UK RBMP (The Environment Agency, 2011) plan provide the clearest guidance on how these objectives are interpreted in the UK. The following paragraphs reproduce Article 7.2 and 7.3 of the WFD and offer interpretation of their significance to diffuse pesticide pollution and potable water production.

Article 7.2 “.....Member States shall ensure that under the water treatment regime applied and in accordance with Community legislation, the resulting water will meet the requirements of Directive 80/778/EEC as amended by Directive 98/83/EC [the DWD].”

Article 7.3 “Member States shall ensure the necessary protection for the bodies of water identified with the aim of avoiding deterioration in their quality in order to reduce the level of purification treatment required in the production of drinking water. Member States may establish safeguard zones for those bodies of water.”

Article 7.2 links Article 7 objectives for “raw” water in DrWPA to existing standards defined in the DWD. For pesticides, the DWD specifies that an individual pesticide cannot be present in drinking water at a concentration greater than $0.1 \mu\text{g l}^{-1}$ and that the total pesticide concentration must be below $0.5 \mu\text{g l}^{-1}$. Article 7.2 does not specify how DWD standards are to be met, simply that they must be met. Article 7.3 specifies the need for protection to avoid deterioration in the quality of “raw” water used for potable water production and sets the long term goal to reduce the level of treatment infrastructure. Together Article 7.2 and 7.3 imply that, in those DrWPA compliant with Article 7, a water company should be able to meet DWD standards for all pesticide active substances through continued and eventually reduced provision of existing water treatment work (WTW) infrastructure.

Given this interpretation, the achievement of Article 7 objectives for pesticides depends entirely upon the extent to which catchment management can be applied in and upstream of DrWPAs to improve “raw” water quality and prevent the presence of pesticides at concentrations that cannot be managed with the current treatment infrastructure. It follows that water company investment continually to improve the WTW infrastructure, as has historically been the case to ensure compliance with DWD standards, is against the spirit of WFD Article 7. Instead interventions should focus on stabilising and reducing pesticide concentrations in “raw” water in DrWPAs

to ensure that the current treatment infrastructure is sufficient to meet DWD standards.

Article 7.3 mentions safeguard zones as a tool to support Article 7 objectives, however no further details are provided in the WFD. In the UK, work is underway in partnership between the EA and water companies (personal communication with Simon Eyre, Anglian Water Services, 9th May 2011) to designate safeguard zones and produce catchment action plans in order to target measures at areas where the pollution that causes non-compliance with regard to Article 7 originates.

Where Article 7 cannot be achieved through catchment management and targeted use of safeguard zones, the willingness or otherwise of government to restrict use, or revoke approval, of those pesticide active substances causing Article 7 non-compliance will also be critical. Based upon the assumption that, using catchment management alone, the UK will be unable to comply with Article 7, Clarke *et al.* (2009) and Wynn *et al.* (2009) identify the possibility that WFD implementation of Article 7 objectives may require withdrawal of up to 13 widely used herbicide and fungicide active substances and many insecticide active substances. The WFD and the new pesticide approval Regulation 1107/2009 provide no mechanism for active substances to be withdrawn at EU level for reasons related to Article 7 objectives. Therefore, the loss of the active substances would have to be driven solely by UK decisions to withdraw an active substance to ensure Article 7 compliance.

The UK Government does have the authority to prohibit active substances, a power used when Isoproturon (IPU) was withdrawn in March 2007. The IPU decision was based upon reservations raised through the active substance approval process under Directive 91/414/EEC (EC, 1991) and the status of IPU as a WFD priority substance, not over concerns about the ability to achieve Article 7 objectives.

In the UK no precedent exists for the withdrawal of a pesticide active substance for WFD Article 7 objectives. Therefore, for the prediction of pesticide withdrawal to become reality, the government would need to move away from the currently stated preference for voluntary and enhanced voluntary approaches, as embodied in the Voluntary Initiative, ECSFDI and the consultation on Directive 09/128/EC (Defra, 2010b, 2010a; House of Commons: Environment Food and Rural Affairs Committee, 2005) to a more statutory approach to diffuse pesticide pollution prevention. The government's willingness to withdraw pesticide active substances will be influenced by the level of compliance expected in 2015 and UK Government perception of the risk of infraction proceedings by the EC for failure to comply with Article 7 objectives.

3.1.2 WFD impact on water company investment

For a water company aiming to optimise investment in WTW infrastructure and catchment management initiatives and ensure compliance with DWD standards for potable water, the uncertainty generated by WFD Article 7 obligations and the Regulation (EC) 1107/2009 regulatory process is of crucial importance. WFD Article 7.2 makes explicit reference to the DWD but the two Directives remain legally distinct. The Environment Agency (EA) is responsible for UK compliance with the WFD. Water companies are responsible for DWD compliance. EA failure to comply with WFD Article 7 can jeopardise water company compliance with DWD, but a water company cannot use WFD Article 7 failure to justify DWD non-compliance.

Article 7 implies that the risk of non-compliance with DWD standards using current treatment infrastructure, in compliant DrWPAs, is virtually zero. However, where compliance is not achieved, the water company risks non-compliance with DWD standards and must take action to manage this risk. In those DrWPAs where the

likelihood of WFD Article 7 compliance can be quantified with confidence, water companies can plan the level of investment required for long-term DWD compliance. Therefore, water companies need to work closely with the EA to ensure that the risk assessment process for Article 7 non-compliance for pesticides, initiated in the RBMPs, is completed. In order to support long-term planning for DWD compliance, these assessments must also be shared with water sector regulators OfWat (The Water Services Regulation Authority) and the DWI (Drinking Water Inspectorate).

An additional complication for water sector investment is that the 6 year planning cycles for RBMP under the WFD are not synchronised with the 5 year periodic review and asset management plans investment cycles in the water sector. The next periodic review (PR14) must be finalised before 2014; from a risk averse perspective, investments planned in this cycle must be based upon current knowledge of raw water quality, rather than assumptions of full compliance with Article 7 in 2015. The same applies for PR19, where the best available evidence of WFD compliance will be data in 2015, rather than the promise of future compliance in 2021.

3.2 EU pesticide thematic strategy

3.2.1 Introduction

The EU Thematic Strategy for Pesticides was published in June 2009. It comprises:

- Regulation 1107/2009 concerning the placing of plant protection products (PPPs) on the market and repealing Council Directives 79/117/EEC and 91/414/EEC.
- Directive 09/128/EC establishing a framework for Community action to achieve the sustainable use of pesticides.
- Regulation 1185/2009 concerning statistics on pesticides (EC, 2009c).

Regulation (EC) 1107/2009 and Directive 09/128/EC will have an impact as drivers affecting the type and concentration of pesticide active substances present in DrWPAs.

3.2.2 EU Regulation 1107/2009

Under Directive 91/414/EEC all pesticide active substances had to be approved at the EU level before they could be used in a PPP. Regulation (EC) 1107/2009 (EC, 2009b) replaced Directive 91/414/EEC in June 2011 as the EU level approval mechanism for pesticide active substances. It will apply hazard criteria in addition to the risk criteria already in place. The approval of every active substance will be reviewed between June 14th 2011 and 2021 as current approval periods approach their end.

While Regulation (EC) 1107/2009 is not designed to address the issue of diffuse pesticide pollution, implementation of hazard criteria will reduce the availability of pesticide active substances. This in turn will influence the type and concentrations of pesticide active substances in DrWPAs. Since Regulation (EC) 1107/2009 was first proposed in July 2006, many impact assessments have attempted to quantify the impacts at the level of active substance availability (PSD, 2009; KEMI, 2008; PSD, 2008a; PSD, 2008b; Rickard, 2009; Richardson, 2009a; Richardson, 2009b). The most recent of these (PSD, 2009) was completed after the final wording of Regulation (EC) 1107/2009 was agreed by an EU Parliament vote in January 2009. The scale of the impact remains uncertain; a minimum scenario will be the loss of the 26 list I active substances before 2021, with a further 60 identified as candidates for substitution (PSD, 2009). However, depending upon the interpretation of the endocrine disruptor criteria, more active substances may be withdrawn. How

these endocrine criteria will be interpreted depends upon European Commission guidance which is currently under development.

Candidates for substitution are those substances identified under Regulation (EC) 1107/2009 as targets for replacement by low hazard active substances in the long term. Under Article 24, a candidate for substitution will be renewed for seven years rather than the standard 10 years. (Richardson, 2009b) states that multiple 7 year renewal periods will be available for these active substances. It follows that the timescale over which candidates for substitution will act remains uncertain. Furthermore, whether identification of candidates for substitution will produce innovative solutions by chemical companies, or a slow move by land owners towards non-chemical alternatives is another uncertainty arising from Regulation (EC) 1107/2009.

The restriction in the range of available pesticide active substances will drive behavioural adaptation amongst agronomists, farmers and chemical companies involved in EU agriculture. Alternative solutions, both chemical and non-chemical, will be needed to manage pest, weed and disease problems that were previously effectively controlled by available active substances. Thus the types of pesticide active substances and their concentration in the environment, and specifically in the “raw” water of DrWPAs, will change over time.

Anticipating the impact of Regulation (EC) 1107/2009 on pesticides in water is important to support planning for WFD Article 7 objectives, targeted investment for catchment management and pesticide monitoring actions. Furthermore, the change driven by Regulation (EC) 1107/2009 is important for long-term planning of optimal WTW treatment infrastructure investment for the removal of pesticides in order to produce potable water. At the time of writing no impact assessment of how

Regulation (EC) 1107/2009 will affect water quality and WFD Article 7 compliance has been published.

3.2.3 Directive 09/128/EC

Directive 09/128/EC formally embodies many of the concepts enacted in the UK under the Voluntary Initiative and ECSFDI to promote pesticide-focused catchment management at the river basin level across the EU. The Directive prescribes the development of National Action Plans for pesticide use and specifies requirements relating to professional user training, point of sale information, public awareness, inspection and certification of application equipment, aerial application, protection of drinking water and protected areas (DrWPAs), provision for integrated pest management and monitoring trends in pesticide use.

Much of the work required to meet the requirements of this Directive is already underway in the UK. The extent to which the UK currently meets the requirements of the articles of the Directive is laid out in a consultation document (Defra, 2010b) on the implementation of the Directive in the UK. Three implementation options were offered: business as usual (BAU) requiring no extension to existing statutory and voluntary frameworks; increased use of voluntary mechanisms, with statutory support, and stronger statutory action to ensure the UK exceeds the minimum requirements of the Article. It suggests that additional statutory options will be adopted only where voluntary actions cannot deliver the requirements of the Directive.

Article 11 of 09/128/EC makes specific reference to the WFD and drinking water, to specify that measures to deliver 09/128/EC must support delivery of WFD Article 7 objectives.

“Member States shall ensure that appropriate measures to protect the aquatic environment and drinking water supplies from the impact of pesticides are adopted. Those measures shall support and be compatible with relevant provisions of Directive 2000/60/EC and Regulation (EC) No 1107/2009.”

The government position on Article 11 and therefore WFD Article 7, is stated in (Defra, 2010a):

“The WFD will, however, require a reduction in the amount of pesticides detected in surface and ground waters and water abstracted for drinking water purposes. In many cases, local approaches to local issues will be required. The government believes that this can be done using existing legal powers and through development of the existing controls. Consistent with the aim of minimising regulatory burdens, the government will primarily seek to work with the pesticide industry to enhance voluntary measures that improve knowledge transfer to pesticide users and to develop mitigation measures that can be adopted in areas where pesticides are causing problems. We will, however, keep the situation under review and will develop alternative controls using targeted regulatory powers if this proves to be necessary.”

This statement confirms that Directive 09/128/EC is seen as fully compatible with the current UK approach to voluntary measures for the control of diffuse pesticide pollution and reinforces the government belief that WFD Article 7 can be achieved without regulatory tools.

3.3 Voluntary Initiative, Pesticide Policy and other UK responses to diffuse pesticide pollution

In parallel with the WFD, a number of independent UK initiatives are ongoing to address the challenge of diffuse pesticide pollution. These include the Voluntary

Initiative (VI), England Catchment Sensitive Farming Delivery Initiative (ECSFDI), the Metaldehyde Stewardship Group (MSG), government water policy, government pesticide policy and the water action plan for pesticides. Actions from many of these initiatives have been included in the WFD PoM because they can contribute to Article 7 objectives.

The VI, launched in April 2001, is a purely voluntary partnership between government, the Crop Protection Association (CPA), farming organisations, chemical companies and water companies, to raise awareness of diffuse pesticide pollution and deliver actions to tackle it. The VI is based on three central themes: protecting water, benefiting biodiversity and changing pesticide user behaviour (Glass *et al.*, 2006). Of these themes, changing user behaviour is the most important because it provides a foundation upon which progress towards the others can be built (Garrod *et al.*, 2007; Humphrey, 2007). To measure how effectively the VI engages with the agricultural community, the VI sets behavioural targets for increased awareness of and participation in crop protection management planning (CPMP). Additionally, to ensure that VI actions are delivering observable results the VI sets long-term targets for reduced pesticide detections in the water environment.

In 2005, a House of Commons review identified the VI as “the most effective way of reducing environmental pollution associated with pesticides” (House of Commons: Environment Food and Rural Affairs Committee, 2005). This statement was qualified by criticism that (a) the behavioural and water environment targets were insufficiently ambitious and (b) the government had failed to support the VI by creating a national pesticide strategy. Following the review, the VI was extended for an additional 5 years and the England Catchment Sensitive Farming Delivery Initiative (ECSFDI) was rolled out to 52 priority DrWPA catchments for targeted

action against diffuse pesticide pollution in support of WFD DrWPA objectives. Additionally, in 2006 Defra published the UK pesticide strategy (Defra, 2006b); this was revised in 2008. The strategy has given rise to a number of action plans, including a water action plan (Defra, 2007; Health and Safety Executive, 2010) designed to “reduce contamination of surface and groundwater by pesticides” by building upon ECSFDI and VI actions, to integrate water protection policies with WFD requirements.

Reviews of the efficacy of the VI and, by association, of catchment management for pesticides (Garratt & Kennedy, 2006; Garrod *et al.*, 2007; Humphrey, 2007; Glass *et al.*, 2006; Lascelles *et al.*, 2005) all identify that catchment management interventions (timing of application, buffer zones, no spray zones, changed handling practices, spraying good practice, biobeds) can be effective. However, all state that efficacy will vary, because of pesticide properties, local environmental variables (climate, geography and soil) and implementation at the farm level. Therefore, UK experience of catchment management of pesticides demonstrates the uncertainty surrounding catchment management intervention and the scale of the challenge to identify catchment management interventions to deliver WFD Article 7 objectives for pesticides.

3.4 Role of agri-environment schemes as a response to diffuse pesticide pollution

In the UK, the impact of the 1947 Agricultural Act and the 1962 EU Common Agricultural Policy (CAP) combined to create strong economic incentives to make agriculture more efficient and improve productivity. Together these policies drove changes to agricultural practice and delivered “a 180% (weighted by value) increase in productivity, between the early 1960s and mid 1980s” (Angus *et al.*, 2009). CAP reform from 1986 onwards began a move away from incentives for increased

productivity towards greater consideration of environmental priorities and led to the emergence of agri-environment schemes (Hodge & Reader, 2010; Posthumus & Morris, 2010; Evans, 2010).

The most inclusive form of environmental stewardship, Entry Level Stewardship (ELS), is the first agri-environment scheme applicable to all farmers. By late 2008, 52% of the farmed area in the UK had joined ELS (Hodge & Reader, 2010). The stated objectives of ELS include consideration of biodiversity, landscape quality, character and history, public access and natural resource protection (including water quality). ELS allows farmers to choose the stewardship options, from an approved list of 60 options, that suit their farm operation and can be integrated into their land management practices.

The challenge for delivering reduced diffuse pesticide pollution in DrWPAs through ELS involves encouraging local action, where action is needed most and would not otherwise take place (Hodge & Reader, 2010; Posthumus & Morris, 2010). However, the design of ELS options must be careful not to undermine the willingness to take voluntary action as part of the VI, ECSFDI and Directive 09/128/EC. ELS has the potential to support the delivery of WFD Article 7 objectives for pesticides, but, like all catchment management interventions, the degree and timing of any impacts from ELS actions are difficult to quantify. This does not provide the certainty required by water companies to inform long-term investment in WTW infrastructure for pesticides.

4. CONCLUSIONS AND RECOMMENDATIONS

The current legislation does not provide a coordinated legal and regulatory framework and some changes are warranted in order to achieve the desired impact. Better coordination is needed between the key components of that framework, that is,

that dealing with pesticides and pesticide use, that dealing with environmental water quality and that dealing with drinking water quality.

To support the future achievement of Article 7 objectives and to allow water companies to optimise investment in WTW infrastructure and catchment management intervention, further research is needed:

- to quantify the impact of catchment management intervention in supporting predictive modelling of pesticide risk in DrWPAs and identification of timely catchment appropriate action to address Article 7 failures for pesticides;
- to identify high risk areas in catchments where diffuse pesticide pollution will cause Article 7 non-compliance. To enable: targeted catchment management action to prevent diffuse pesticide pollution in high risk areas; the design of ELS options for targeted use in high risk areas and; the examination of the impact of use restrictions on specific pesticide active substances causing WFD Article 7 non-compliance in high risk areas;
- to investigate how weed/pest/disease problems currently controlled by available active substance will be controlled following Regulation (EC) 1107/2009;
 - to analyse possible chemical companies', agronomists' and farmers' responses to the reduced portfolio of pesticide active substances;
 - to model the impact of reduced pesticide availability on the types and concentrations of pesticide active substance in "raw" water in DrWPAs;
 - to research non-chemical replacements for those pesticides known to be lost under Regulation (EC) 1107/2009;
 - to clarify how endocrine disruptor criteria will be applied and what this means for pesticides and water quality.

- to prepare targeted briefings for OfWat and DWI on the potential significance of Article 7 compliance and non-compliance on water company investment needs.
- to continue the development of risk assessments for Article 7 non-compliance and the preparation of safeguard zone action plans, to give clear visibility of those DrWPAs expected to not comply with Article 7 and, therefore, provide a robust base of evidence for water companies to use with OfWat when justifying the need for treatment or catchment management investment and with DWI when defending the failure to comply with DWD standards.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the support of Anglian Water Services Ltd and EPSRC for funding the EngD research from which this article is produced.

REFERENCES

- Angus, A., Burgess, P.J., Morris, J. & Lingard, J. (2009). Agriculture and land use: Demand for and supply of agricultural commodities, characteristics of the farming and food industries and implications for land use in the UK. *Land Use Policy*, 26, 230–242.
- Chave, P. (2001). *The EU Water Framework Directive: An Introduction*. IWA, London.
- Clarke, J., Wynn, S., Twining, S., Berry, P., Cook, S., Ellis, S. & Gladders, P. (2009). *Pesticide Availability for Cereals and Oilseeds Following Revision of Directive 91/414/EEC; Effects of Losses and New Research Priorities*. ADAS Boxworth, Cambridge.
- Defra (2006a). *Pesticides: Code of Practise for using Plant Protection Products (PB 11090)*. Defra, London.

Defra (2006b). *UK Pesticides Strategy: A Strategy for the Sustainable use of Plant Protection Products (PB 13035)*. Defra, London.

Defra (2007). *Strategy for the Sustainable use of Plant Protection Products: Water Action Plan, Version 6*. Defra, London.

Defra (2008). *Future Water: The Government's Water Strategy for England (CM 7319)*. HM Government, London.

Defra (2010a). *Consultation on the Implementation of EU Pesticides Legislation; Summary and Government Response*. Defra, London.

Defra (2010b). *Consultation on the Implementation of Pesticide Legislation*. Defra, London.

EC (1975). *Directive 1975/440/EEC Concerning the Quality Required of Surface Water Intended for the Abstraction of Drinking Water, L 195*. Official Journal of the European Communities, Brussels.

EC (1991). *Council Directive Concerning the Placing of Plant Protection Products on the Market (91/414/EEC), OJ L 230*. Official Journal of the European Communities, Brussels.

EC (1998). *Council Directive 98/83/EC on the Quality of Water Intended for Human Consumption, L 330/32 ed*. Official Journal of the European Communities, Brussels.

EC (2000). *Directive 2000/60/EC Establishing a Framework for Community Action in the Field of Water Policy, L 327*. Official Journal of the European Communities, Brussels.

EC (2001). *Decision no. 2455/2001/EC Establishing the List of Priority Substances in the Field of Water Policy and Amending Directive 2000/60/EC, L 331/1*. Official Journal of the European Communities, Brussels.

EC (2008). *Directive 2008/105/EC on Environmental Quality Standards in the Field of Water Policy*, L 348/84. Official Journal of the European Communities, Brussels.

EC (2009a). *Directive 2009/128/EC Establishing a Framework for Community Action to Achieve the Sustainable use of Pesticides*, L 309/71. Official Journal of the European Communities, Brussels.

EC (2009b). *Regulation 1107/2009 Concerning the Placing of Plant Protection Products on the Market*, L 309/1. Official Journal of the European Communities, Brussels.

EC (2009c). *Regulation no 1185/2009 Concerning Statistics on Pesticides*, L 324/1. Official Journal of the European Communities, Brussels.

Environment Agency (2007). *The Hidden Threat to Water Quality: Diffuse Water Pollution in England and Wales Report*. Environment Agency, Bristol.

Evans, R. (2010). Runoff and soil erosion in arable Britain: changes in perception and policy since 1945. *Environmental Science and Policy*, 13, 141–149.

Garratt, J. & Kennedy, A. (2006). Use of models to assess the reduction in contamination of water bodies by agricultural pesticides through the implementation of policy instruments: a case study of the Voluntary Initiative in the UK. *Pest Management Science (formerly Pesticide Science)*, 62, 1138–1149.

Garrod, G.D., Garratt, J.A., Kennedy, A. & Willis, K.G. (2007). A mixed methodology framework for the assessment of the Voluntary Initiative. *Pest Management Science*, 63, 157–170.

Garthwaite, D.G., Thomas, M.R., Parrish, G., Smith, L. & Barker, I. (2008). *Pesticide Usage Survey Report 224: Arable Crops in Britain 2008*. FERA, York.

Glass, C.R., Boatman, N.D., Brown, C.B., Garthwaite, D. & Thomas, M. (2008).

Evaluation of the performance of the voluntary initiative for pesticides in the United Kingdom. *Aspects of Applied Biology*, 163–166.

Glass, C.R., Boatman, N.D., Brown, C.B., Garthwaite, D. & Thomas, M. (2006).

Evaluation of the Performance of the Voluntary Initiative for Pesticides in the United Kingdom (P3OG1001). Voluntary Initiative, Available at:

<http://www.voluntaryinitiative.org.uk>

Hodge, I. & Reader, M. (2010). The introduction of Entry Level Stewardship in

England: Extension or dilution in agri-environment policy? *Land Use Policy*, 27, 270–282.

House of Commons: Environment Food and Rural Affairs Committee (2005).

Progress on the use of Pesticides: The Voluntary Initiative (HC258). The Stationary Office Ltd, London.

Humphrey, N.C.B. (2007). *The Voluntary Initiative Pilot Catchment Project*,

07/WR/26/2. UK Water Industry Research Ltd, London.

KEMI (2008). *Interpretation in Sweden of the Impact of the "Cut-Off" Criteria*

Adopted in the Common Position of the Council Concerning the Regulation of Placing Plant Protection Products on the Market, Document 11119/08.

KEMI, Sweden.

Kristensen, P. (2004). *The DPSIR Framework*. European Topic Centre on Water,

European Environment Agency, Copenhagen.

Lascelles, B., Turley, E., Davies, J., Knight, L., Kelly, M., Pemberton, E. & Wells, C.

(2005). *The Effect of the Voluntary Initiative on Water Quality (SC030191)*.

Environment Agency, Bristol.

Posthumus, H. & Morris, J. (2010). Implications of CAP reform for land management and runoff control in England and Wales. *Land Use Policy*, 27, 42–50.

PSD (2008a). *Assessment of the Impact on Crop Protection in the UK of the “Cut-Off Criteria” and Substitution Provisions in the Proposed Regulation of the European Parliament and of the Council Concerning the Placing of Plant Protection Products in the Market*. Pesticide Safety Directorate, York.

PSD (2008b). *Revised Assessment of the Impact on Crop Protection in the UK of the “Cut-Off Criteria” and Substitution Provisions in the Proposed Regulation of the European Parliament and of the Council Concerning the Placing of Plant Protection Products on the Market*. Pesticide Safety Directorate, York.

PSD (2009). *Proposal for a Regulation of the European Parliament and of the Council Concerning the Placing of Plant Protection Products on the Market: Summary Impact Assessment*. Pesticide Safety Directorate, York.

Richardson, D.M. (2009a). Agronomic implications from the UK about availability of plant protection products. *Aspects of Applied Biology*, 91, 1–6.

Richardson, D.M. (2009b). Assessment of the impact of crop protection by the “cut-off criteria” in a new regulation for authorisation of plant protection products. *Communications in Agricultural and Applied Biological Sciences*, 74, 3–8.

Rickard, S. (2009). *What Price Protection?: Economic Assessment of the Impact of Proposed Restrictions on Crop Protection Substances*. Cranfield University School of Management, Cranfield.

UKTAG (2008b). *UK Technical Advisory Group on the Water Framework Directive: Proposals for Environmental Quality Standards for Annex VIII Substances*.

UK Technical Advisory Group, Available at:

http://www.wfduk.org/UK_Environmental_Standards/LibraryPublicDocs/final_specific_pollutants

Wynn, S., Garstang, P., Gladders, P., Cook, S., Ellis, S., Clarke, J. & Twining, S. (2009). *Crop Protection Priorities for Grass and Forage Crops in Light of Proposed EU Pesticide Regulations and Other Changes*. ADAS Boxworth, Cambridge.

WEB REFERENCES

Health and Safety Executive (2010). *High Level Water Action Plan: Summary of activity and aims*. Available at:

<http://www.pesticides.gov.uk/environment.asp?id=1833> (accessed 10/31).

The Amenity Forum (2011). *Amenity Forum*. Available at:

<http://www.amenityforum.co.uk/> (accessed 05/25).

The Environment Agency (2011). *Water for Life and Livelihoods: River Basin Management Plans*. Available at: [http://www.environment-](http://www.environment-agency.gov.uk/research/planning/33106.aspx)

[agency.gov.uk/research/planning/33106.aspx](http://www.environment-agency.gov.uk/research/planning/33106.aspx) (accessed 05/25).

UKTAG (2008). *Assessing the achievement of Drinking Water Protected Area objectives*. Available at:

http://www.wfduk.org/tag_guidance/article_4/drinking_water_objectives/view (accessed 05/25).

Received 16 August 2011; accepted in revised form 10 November 2011. Available online

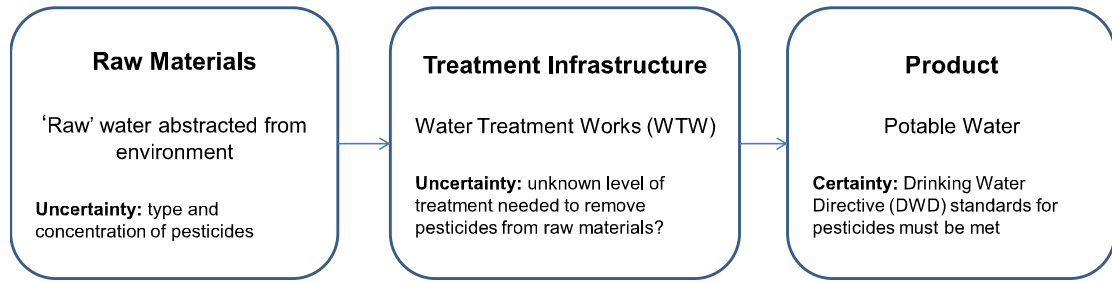


Fig. 1. Transformational model for potable water production.

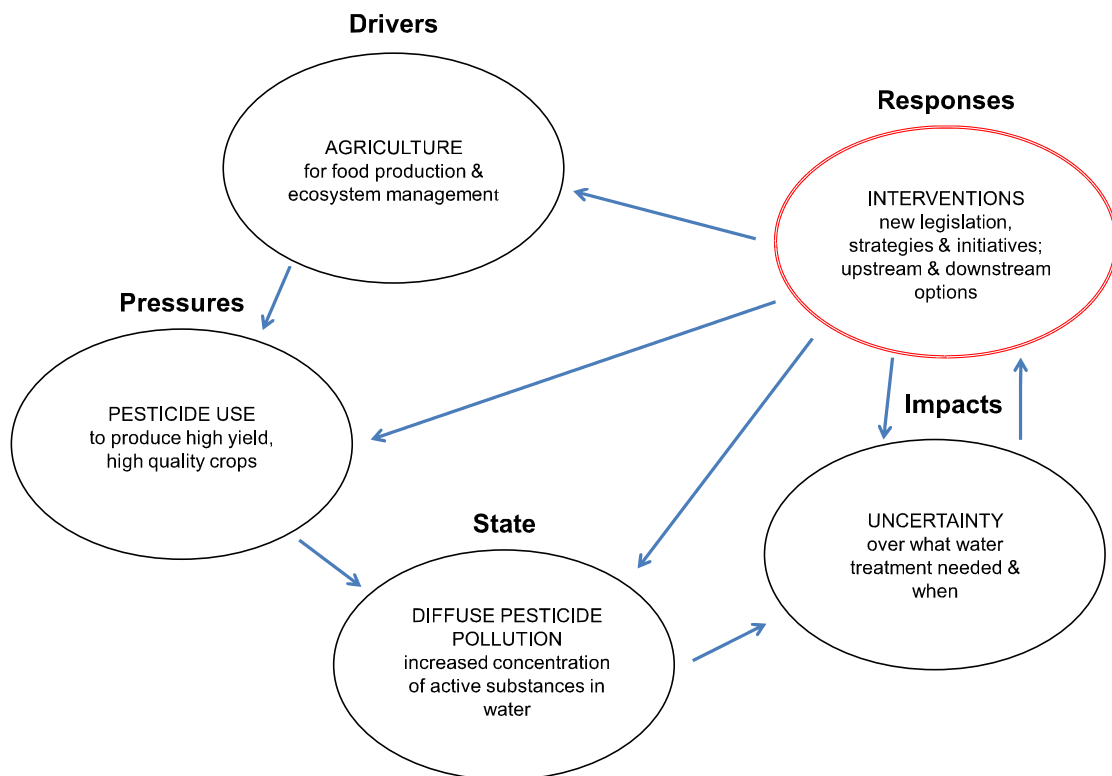


Fig. 2. DPSIR analysis of diffuse pesticide pollution by agriculture (adapted from Kristensen, 2004).

Table 1. Source–pathway–receptor analysis of diffuse pesticide pollution.

Source (diffuse pollution)	Pathway	Receptor
Agricultural application	<ul style="list-style-type: none"> • Surface runoff • Spray drift • Drainflow • Handling • Mixing • Storage • Disposal 	Surface water abstraction point
Professional amenity use		
Non professional amenity use		

Table 2. Source–pathway–receptor interventions to manage diffuse pollution.

Source Interventions	Pathway Interventions	Receptor Interventions
Mixed methodology interventions Water Framework Directive (WFD)		
Hard Regulation to limit pesticide availability <ul style="list-style-type: none"> • Dir. 91/414/EEC • Reg. 1107/2009 • UK approval decisions 	Catchment Management <ul style="list-style-type: none"> • Dir. 09/128/EC • VI, ECSFDI • ELS, HLS, OELS, SPS • UK Pesticide Strategy 	Treatment to remove pollutants from the water supply