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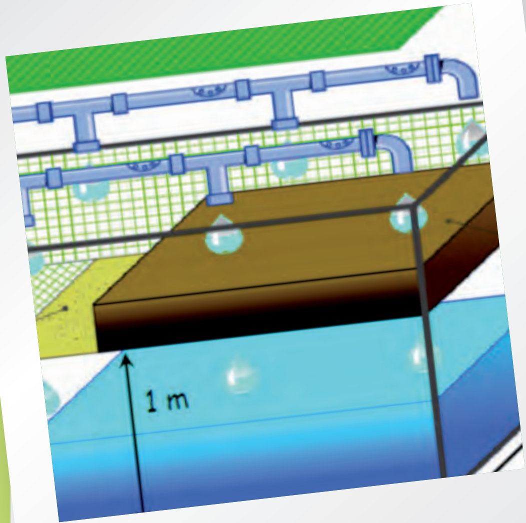
Bio purification systems

Why on-farm water management is important and how it can be achieved



UNIVERSITÀ CATTOLICA DEL SACRO CUORE

Bridging science and policy

Opera wishes to thank all the experts of the working group for their collaboration, providing informations, comments and clarifications in the preparation of this document.

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Bridging science and policy

OPERA is a young, growing think tank and a research centre of the Università Cattolica del Sacro Cuore, a major European private university.

It is an independent, non-profit scientific organization, committed in supporting the successful implementation of the agri-environmental measures within the European legislation.

The fundamental contribution of OPERA is to use the potential of existing scientific researches as well as the existing expertise and knowledge to support the stakeholders in their political and technical decisions concerning agriculture, and particularly the management of agricultural risks relating to pesticides and the environment. One objective is to provide a series of pragmatic recommendations to policy makers to bridge the interest and objectives of agriculture and environment as well as to ensure efficient implementation of the agriculture related policies in the EU.

INTRODUCTION

With the coming into force of the recently adopted European Directive 128/2009/EC on the sustainable use of pesticides it becomes a requirement for all the European Member States to find solutions to protect surface and ground water as well as all sources of drinking water supplies. Solutions to mitigate and prevent unwanted levels of substances reaching water bodies in the most easy and cost effective way is a task to be undertaken by all public bodies, private industries and scientific researchers.

This paper aims to inform farmers, advisors and authorities on possibilities to avoid contamination of surface and ground water with PPPs (Plant Protection Products) through correct management of contaminated liquids during filling and cleaning processes of spray equipment on farm. Management of contaminated liquids (remnants or collected washings) is critical but to date in many countries the aspects of remnant management has not received the necessary attention and clear recommendations and/or codes of practice are missing.

OPERA aims to offer practical information on how to implement at farm level a simple system for reducing this potential risk of point sources contamination from the in-site area where the PPPs are disposed and handled.

STORY AND EVOLUTION

In a never-ending struggle to survive: man must eat. This need spawned the development and spread of agriculture across the planet. Solutions for increasing the quantity and quality of agricultural products became successively more sophisticated with the development of PPPs. Since their introduction, farmers have been able to produce more crops on less land, recording a productivity increase between 20 and 50%. PPPs have provided farmers also the means to maximize the benefits of other inputs like quality seeds, fertilizers, and water resources.

While improving the well being of society, the uptake of technology proved to also have a positive impact on environmental protection. In developing countries, making farming more efficient has reduced deforestation and contributed to the conservation of natural resources. Intensive tillage methods, such as mouldboard ploughing, have been reduced in favour of application of herbicides, and soil erosion has decreased as a result. Appropriate use of modern PPPs to control invasive species and noxious weeds has been important for increasing farm productivity and in managing the environment.

Why is on-farm water management critical?

One of the most vital inputs to agriculture is water. Water and water scarcity affect most of the crop production activities. Farmers around the world are aware that land and water management practices are of prime importance for satisfying the needs of agriculture and ecosystems. Therefore, they endeavour to optimise the water use on their crops and those related to other farming operations. That is why over time, they have developed practices of On-Farm Water Management (OFWM).

Every planning activity relating to water bodies from streams to rivers, lakes and groundwater can be considered as water management in the broadest sense of the term. Therefore, OFWM can be defined as managing the quantity and quality of water, particularly its potential interaction with contaminants used within the borders of an individual farm, a farming plot or a field. OFWM generally seeks to optimize soil-water-plant relationships and increasingly includes reducing the potential for contaminating water bodies. The managers (farmers) usually try to achieve this desired outcome by minimizing inputs and maximizing outputs, so as to optimize production. In order to accomplish this, water has to be managed skilfully through certain practices covering areas of: soil and water conservation, irrigation and drainage practices, soil amelioration, and agronomic practices. All this has to be done within the context of the socio-economic environment of the farm and of the rural community.

PPPs as hazardous compounds

It can be assumed, at least in Europe where a thorough and systematic procedure for approval is in place, that a PPP approved is safe if all the prescriptions for its use are respected.

PPPs can become a risk if applied under appropriate cropping and climatic conditions, without respecting the prescribed amounts or the specific manipulation or application procedures. Measurements indicate that trace amounts of PPPs are present on non-agricultural land, in the atmosphere, and in water. The contamination of water bodies with pesticides and their breakdown products is considered by many to be a serious threat to both public health and environmental integrity. Water is a vulnerable and important component of the environment. Competition for water poses a growing risk to the economy, communities and the ecosystems. It is expected to become even scarcer in many areas due to rising average temperatures attributed to climate change. So, it is vital to find solutions to protect this resource as less than 1% of the world's fresh water is accessible to human use.

What does EU legislation say?

The EU regulates the protection of water quality with respect to PPPs. The Water Framework Directive (WFD) provides an integrated framework for the assessment, monitoring, and management of all surface and ground waters based on their ecological and chemical status. However, the WFD is supported by other EU environmental legislation. The *REACH* Regulation controls chemicals in products other than PPPs to reduce the contamination of water bodies. The *EU Regulation 1107/2009/EC* establishes a strict procedure for the assessment and approval for the placing of plant protection products on the market and the *Biocide Products Directive* regulates pest-control and anti-microbial substances used in other sectors. The *Nitrates Directive* limits nitrogen pollution from fertilisers and manure. The *Directive on Industrial Pollution Prevention and Control (IPPC)* regulates pollution from factories and other facilities.

According to the legislation concerning water if the level of PPP's exceeds the threshold value in surface and groundwater, Member States (MS) may decide to restrict or ban the use of the respective products. Additionally, the European Sustainable Use Directive (SUD) 128/2009/EC requires Member States to develop a legislative framework and National Action Plan's (NAP) that include appropriate measures to protect aquatic environment and drinking water supplies from the potential risk associated with PPP use.

This extensive European legislative framework dealing with provisions to protect surface and ground water as well all sources of drinking water give MS's authorities a very difficult job to find practical solutions to this complex set of requirements. Solutions to mitigate and prevent unwanted levels of substances reaching water bodies in the most easy and cost effective way is a task to be undertaken by all public bodies, private industries and scientific researchers.

Within the newly adopted Pesticide package the SUD provides the framework for authorities to implement measures dealing with diffuse and point source pollution to protect the aquatic environment and drinking water supplies as well as to ensure that farm operations do not endanger human health and the environment.

HOW DO PPPS REACH THE WATER BODIES?

Point source pollution

Unsatisfactory management of PPPs and other chemicals can result in the presence of substances in surface and ground water. The potential contamination of rivers and other surface and ground water resources could be caused by both diffuse (spray drift, drain flow and run-off) and point source pollution. Point source pollution can have the largest influence on water quality at the catchment and at regional scale. It occurs due to the improper handling procedures such as storage, diluting, mixing and cleaning of application equipment after use, recovery and disposal of tank mixtures, empty packaging and remnants of PPPs. The contaminations caused by cleaning operations are usually below the effective eco toxicological and agronomic concentrations. However it is still important to ensure they do not enter water bodies. Preventative practices such as avoidance of wastewater discharges near water bodies must be implemented.

It is evident that point source pollution is mainly linked to handling and use practices, particularly in filling and cleaning areas on the farm. Therefore additional technological and infrastructure solutions are required to reduce these non-intentional PPP releases. Some solutions include:

- **A** the creation of dedicated filling, loading and cleaning areas in farmyards to minimize the release of pesticides
- **B** having environmentally optimised sprayers, so that, for example, spray equipment is cleaned in the field immediately after use
- **C** waste water and remnants treatment systems to separate and/or degrade the contaminants from the water fraction.

Point **A** and **B** are well described and harmonized in the successful TOPPS project. Therefore within this document the attention will be mainly focused on the latest proposal: development of waste water treatment systems to separate and/or degrade the PPPs from the water fraction.

Figure 1. Point source pollution

BIO-PURIFICATION SYSTEMS: HISTORY AND EVOLUTION

It is compulsory for farmers to manage the waste water coming from the cleaning of their spray equipment. The need for finding solutions for dealing with chemical remnants from the cleaning of sprayers in the field under defined conditions and for collecting and managing them with equipment which could be implemented and approved by decision makers gave specialists and private companies the idea to invent new systems to reduce the risk of point source pollution.

The biological treatment is now one of the mainstays of wastewater management systems. Bio-purification systems (bio filters) have been designed primarily for odour control at wastewater treatment plants and composting operations. Air bio-purification systems perform the removal and oxidation of compounds from contaminated air using microorganisms.

In the early 1990s the development of bio-purification systems for the treatment of waste waters containing PPPs began. The first prototype was developed in Sweden, having a similar functionality as for air, i.e. removing and degrading PPPs from waste water using microorganisms. The name given to this equipment was **biobed** and since then it has been widely adopted with over 1500 biobeds being used in Sweden alone. In short time countries as the United Kingdom, France, Germany, Italy, The Netherlands, Greece, Belgium, Chile, Guatemala, Peru, and Turkey have shown interest for this treatment system and several types have been studied taking into consideration the different climatic conditions and material availability in each the country. See Annex I. Timeline: History of bio-purification systems.

Therefore, Italy developed the first biomassbed, France (Bayer Crop Science) adapted the biobed principle and developed the so called the Phytobac, Belgium created a multibox system, the biofilter and the multinational company Syngenta developed the Heliosec system. In time, the systems have been extensively adopted; the Phytobac saw adoptions in France but also Belgium and Italy , the biofilter system has been adopted mainly in Belgium, Italy adopted some of the biomassbed prototypes, while Heliosec prototypes were installed in France, Italy, Spain, Portugal and Greece.

Defining the water bio-purification system and its types

Two types of bio-purification systems have been developed: with substrate and without substrate. The Bio-purification system **with substrate** consists of a biological active matrix which retains the PPPs into organic matter or soil particles, where enhanced or rapid microbial degradation of the PPPs occurs. The greatest challenge for the systems with substrate is finding a method for the disposal of the organic matter after use. The internationally best developed and tested bio-purification systems with substrate, for treating spray leftovers and PPP spillages in agriculture, are the **biobed**, the **Phytobac**, the **biofilter (multiboxes)** and the **biomassbed**.

The Biobed in its simplest form is a clay-lined hole in the ground with concrete walls and sealed at bottom with clay filled with the original biological active matrix which consists of peat, soil and straw. The biological active matrix should be left for some time, prior to loading, in the biobed pit in order to allow the composting to begin, making the matrix effective at retaining and degrading the pesticide residues. The biological active matrix is covered with a grass or turf layer. The grass layer maintains an optimal level of temperature for microbial activity, regulates the moisture in the bed and serves as an indicator of pesticide spillage.

Figure 2. Example of first biobed in Sweden

1 • In this context the term bio-purification should be considered as a complex cleaning practice in natural aerobic and anaerobic conditions due to biological, physical and chemical processes.

Another bio-purification system which is mainly based on the biobed concept is the **Phytobac**. The Phytobac was developed by Bayer Crop Science and consists of a basin made of watertight materials to ensure complete retention of contaminants and effluents. No grass layer is placed on the top, and a cover protects the bed from rainfall. The water in the Phytobac is regulated by evaporation only, so moisture has to be managed to avoid saturation or drying of the materials.

Figure 3. Example of Phytobac

The **Biofilters (multiboxes)** consist of two or three units of plastic containers stacked in a vertical pile and connected with plastic valves and pipes. The effluents are recycled with a pump whereas the substrate use could be different from box to box. The choice between using a two-unit or a three-unit system depends on the sprayer (if it has a clean water reservoir), the amount of water to be treated, and the total pesticide load. The biofilter substrate is a homogenized mixture of local soil, chopped straw and peat or composted material and/or other materials.

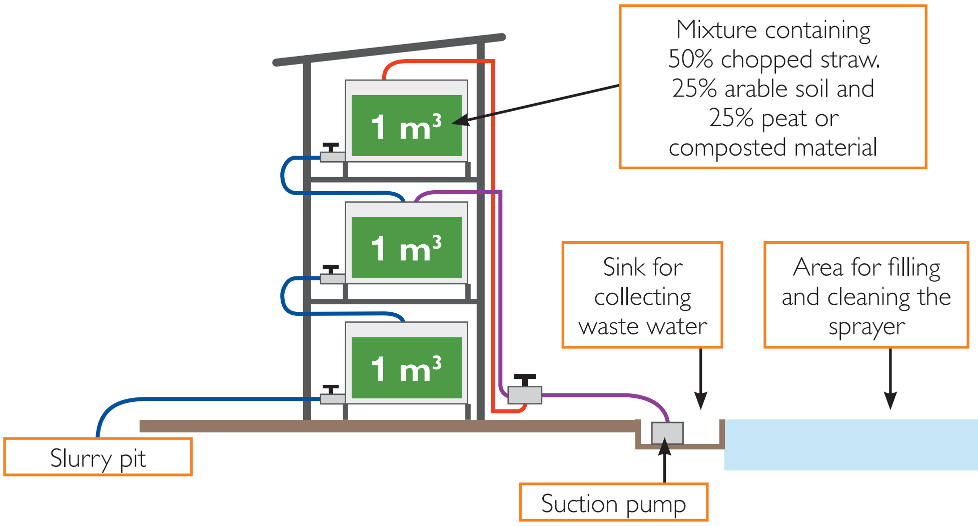

Figure 4. Example of Biofilter

An Italian biobed system is the **Biomassbed** which utilizes biomixtures as filters through which pesticide-contaminated water is circulated and decontaminated (www.biomassbed.it). This system was mainly tested for large amounts of PPPs contaminated water from the filling and washing of spraying equipment and for the use of local organic materials. The straw was mainly replaced by urban and garden composts, peach stones, vine branches, and citrus peel.

Figure 5. Example of Biomassbed

A bio-purification system **without substrate** which is based on physical processes is Syngenta's **Heliosec system**. The contaminated water is placed in a plastic-lined tub where heat and wind action cause the evaporation of the water resulting in PPP dry residues remaining in the liner.

However, the degradation of the PPPs in the water by biological and chemical processes may also occur in some cases. The capacity of the Heliosec system is of 2500L and in addition to the biobed it can also treat copper and sulphur remnants.

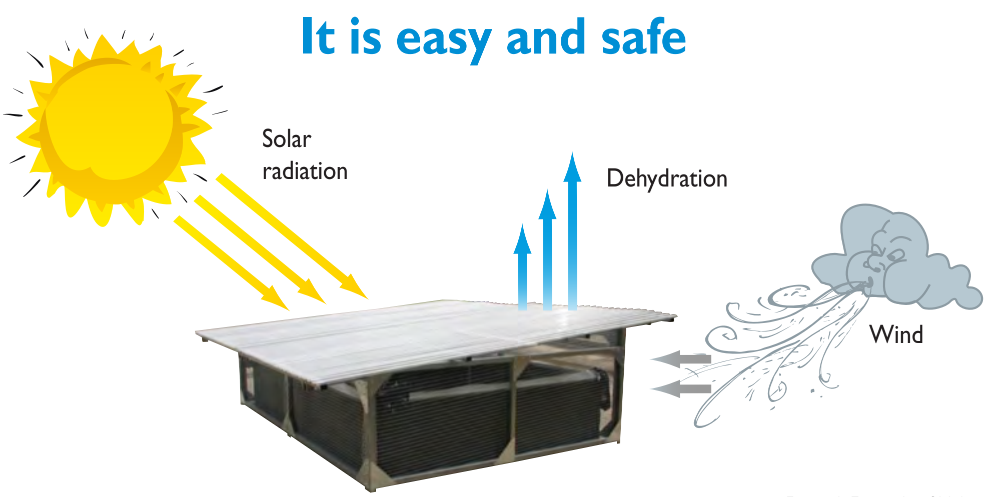

Figure 6. Example of Heliosec

Benefits and disadvantages of water bio-purification systems

The economic materials and the simple construction of the **biobed** make it a valid and accessible bio-purification system. However there are some limitations including increasing water volume due to precipitation and possible leaching of the contaminated water to the surrounding soil. In the case of the Swedish biobed the need to replace the biomix after 5-10 years, and possible presence of the more persistent PPPs on the biomix, could be solved with appropriate modifications to the system like distribution of the biomix in the field, or like in the UK version a liner to prevent possible leaching . The utilization of **Phytobac** is resolving some of the problems such as precipitation and possible leaching of contaminated water as it is also lined, but as the system is regulated by evaporation only measures to avoid saturation or drying of the materials should be taken.

The advantage of using **biofilters** includes the ability to treat large volumes of contaminated water, to use different types of biomix at the same time and it offers a broad flexibility with very little organic matter. It works very effective when the polluted water goes from one container to the next and might be evaporated completely at the end by adding a container containing plants. However, due to the size (number of containers) and the principle of its functioning (leaching) it can bring limitations to its use and pose some environmental concerns.

The **Biomassbed** has the advantage of faster operating cycles (from one day to two weeks depending on the type of PPP), allowing the treatment of high volumes of contaminated water. Maintenance of the bioreactor is simple. The higher cost and the complexity of the system are possible limitations.

The **Heliosec** is a simple and economical system, provided with a diagnostic software system for its setting up, management and guidance on how to reduce the volume of waste water produced. The advantage of this system is that it guarantees the removal of all residues captured in the tank by disposal of the plastic liner with all the dried remnants into a specific container to be destroyed at hazardous waste centres. The system needs minimum maintenance, the disposal volume is small and it can help assess the water consumption. However, a disadvantage could be that not in all cases the biological degradation occurs, nevertheless, due to dehydration and other physical processes a good dissipation of the remaining substances is done.

GOOD AGRICULTURAL PRACTICE

The use of bio-purification systems, which are directly linked with SUD implementation requirements, should be part of Good Agricultural Practices (GAPs). GAPs are defined to ensure farmers to know what needs to be done to comply with the legislative requirements, whereas Best Management Practices (BMPs) help define farmers how they can meet legal requirements, particularly if they need to be brought into compliance quickly, or even go beyond them. Hence, with time and evolution of practices on the farm, the BMPs often become the standard for new Good Agricultural Practices. To help reach these very stringent targets for water legislation, specific local risk mitigation measures as well as general and widespread adoption of BMPs will be necessary.

Although Good Agricultural Practice (GAP) is taken into account during the registration of PPPs not all general recommendations can be placed on labels and therefore one of the most important elements in prevention of unwanted effects of chemical contamination in water bodies is farmer education.

Training of farmers done by both public and private bodies is essential to help identify and mitigate the risks associated with pesticide use and provide the solutions for preventing contamination of soil and water. The correct use of precise pesticide application equipment together with other farm prevention and mitigation measures like introduction of field margins, artificial wetlands and use of bio purification systems give farmers solutions to address both unwanted risks of pesticide use and compliance with legislative requirements.

Figure 7 presents the diagram flow of activities, included in the Italian guidelines for sustainable use of PPPs, which farmers should undertake for the disposal of the remaining spray tank mixtures after crop treatment and of the washing waste waters.

Two main ways of disposal have been identified: one is for remnant disposal in the field immediately after the treatment; the second is for remnant disposal on the farm using containers for disposal and reuse.

On field disposal mainly focuses on the dilution of the residue mixture (1/10 times) with the washing water and the retreatment of the initial area. If there are residues after, a second dilution is possible. The second dilution can be discharged on grass cover far away from water courses (at least 50 m). Alternatively, residue mixtures can be collected in a treatment decontamination system.

The disposal on the farm of the remaining mixtures after application as well as washing waste waters is subject to treatment by using decontamination systems as described above. The option provides the reuse of the residual volumes of mixture within one week if a container to deposit the mixture is available. If both the decontamination system and stock container are not available then the use of a disposal container is mandatory.

However, on both cases the use of a decontamination system is a key activity which will allow a safe final discharge of the liquids involved.

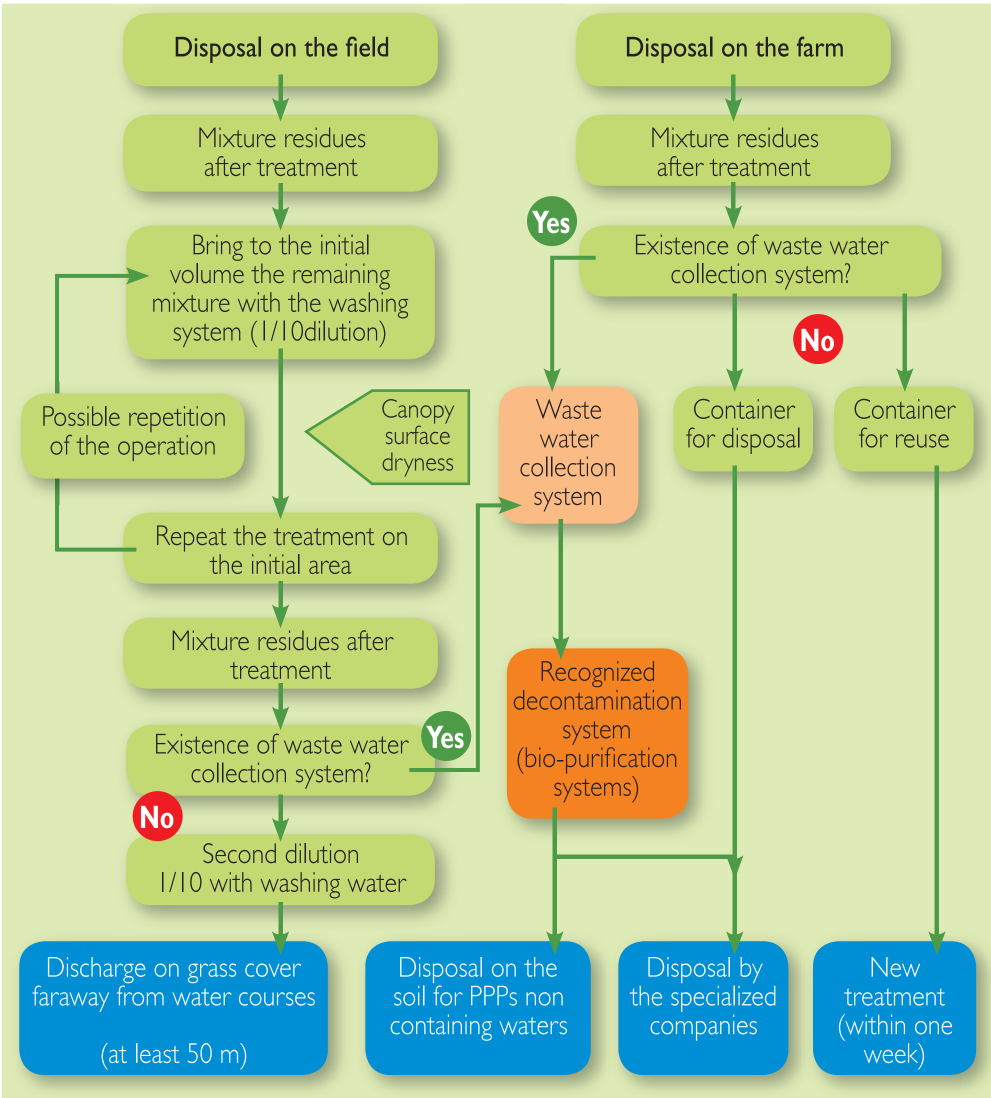

Figure 7. Disposal of PPPs liquid remnants based on the available structures

Annex II of the document contains a series of identified possible problems and needs of the future operators of bio-purification systems.

REQUIREMENTS OF PPPS LEGISLATION-SUSTAINABLE USE DIRECTIVE (SUD)

With the coming into force of the recently adopted European Directive 128/2009/EC on the sustainable use of pesticides it becomes a requirement for all the European Member States to find solutions to answer to the European risk reduction requirements.

Regarding the implementation of the Directive at national level, each Member State has to transpose into national legislation the SUD provisions and set up their NAP's.

The provisions for implementation cover measures including training for users, sales requirements, pesticide application equipment, aerial spraying, information to the public, measures to protect water and aquatic environment, reduction of pesticide uses in specific areas, handling, storage and treatment of their packaging and remnants and IPM.

Therefore the Directive provides for specific measures to be implemented by MS's addressing activities like handling of PPPs, including storage, diluting and mixing of pesticides and cleaning of application equipment after use, recovery and disposal of tank mixtures, empty packaging and remnants as a complement to the measures provided for under Directive 2006/12/EC on waste, and Council Directive 91/689/EEC on hazardous waste.

Furthermore the Directive requires measures to reduce exposure of water bodies to off-site pollution caused by spray drift, drain flow and run-off. The aquatic environment is considered in the Directive especially sensitive to pesticides and it is therefore necessary for particular attention to be paid to avoid pollution of surface and groundwater by taking appropriate measures. Additionally the directive considers that the use of pesticides in areas for the abstraction of drinking water can lead to higher risks of pollution of the aquatic environment.

In this sense the implementation of biopurification systems should be considered as specific solutions to prevent and mitigate water contamination by PPP point and diffuse source pollution thus answering to the EU legislation requirements to reduce risk of unwanted exposure of humans and the environment.

Article 13 of the Directive requires Member States to take all necessary measures to ensure that environment and human health are not endangered by activities concerning handling and storage of pesticides and treatment of their packaging and remnants. Therefore the existence of an area (biobed, collection system together to the other bio-purification system) where the diluting and mixing of pesticides before application can occur, and to collect possible spills, to dispose of pesticide remnants and tank mixtures after application, and waste water after cleaning the equipment used, would represent a viable solution to prevent and mitigate water contamination by pesticide point source pollution.

Furthermore avoiding these accidental losses and hazardous discharges will also certainly minimize any off-site pollution caused by these operations. By implementing these bio purification systems on the farm, operators avoid not only contamination due to point source pollution but can also prevent diffuse source pollution. With these systems in place the prevention of drain flow and run-off, can be ensured and, measures to protect aquatic environments and drinking water supplies highlighted by article 11 on the SUD can be achieved.

In practice, the use of decontamination systems will permit farmers to treat and dispose of pesticide waste after and during applications, avoiding, therefore, the contamination of the farm surrounding water bodies by both on-site and off-site sources. Farmers will be able to continue their activities in a clean and safe environment compliant with the European legislation requirements.

For good implementation of the systems a complex set of tools needs to be put in place comprising of training for farmers in adopting GAPs and BMPs, measures to improve the communication between different categories of PPP users and finally measures to establish confidence of the bystanders and residents. Correct calibration of spray machinery and accurate calculation of the amount of diluted spray liquid necessary for the field, crop and pest in question should be always considered as an essential element of prevention to limit as far as possible the need for remnant handling on the farm.

Furthermore, the implementation of the bio-purification systems is expected to provide benefits concerning biodiversity (improving the microbial biodiversity; aquatic plants), water footprint (improving the green and grey water footprint), carbon footprint (reducing mineralization by recovering and reusing the organic matter), risk prevention (preventing the source of contamination), risk reduction (reducing water and soil environmental concentration), air quality (reducing exposure of bystanders and residents).

2 • *Note that retention ponds are now also beginning to be used as biopurification systems for treating larger volumes of water contaminated from diffuse sources, such as runoff and drainage water, where it is not possible to prevent contamination in more extreme situations.*

SCIENTIFIC EVIDENCE

Studies performed for most of the used PPP's have shown the efficacy of the bio purification systems to retain and degrade pesticides to a level of more than 95%. The range of available systems, operating conditions and PPPs monitored, clearly indicate the robustness of the system as a viable solution for reducing the risk of water body contamination by pesticides and their breakdown products.

Two major processes are governing the removal of PPPs from the contaminated water: sorption and degradation. Several factors influence the efficiency of the removal, such as type of PPPs, matrix composition, homogeneity age, temperature and moisture. As already specified, several countries with different climatic conditions and material availability undertook studies to test and adapt the systems to their conditions. By the excellent communication between different research groups developing more and more user friendly bio-purification systems, large amounts of data were generated to give solid conclusions and indications for the management and future implementation of these systems.

Annex III of this document contains examples of countries where bio-degradation studies have been conducted together with their obtained results. The main conclusion drawn is that bio-purification systems have a good capacity to retain and degrade pesticides.

The solutions can be used in different climatic conditions and with different types of biomix, even organic materials available in farms. Therefore it was possible to undertake studies using different systems in the same country or region. This flexibility is very important as it gives the farmer the possibility to choose the most appropriate system for his needs.

The annex additionally includes a list with the main factors influencing the efficiency of the systems as well as recommendations on how to avoid low functionality.

CONCLUSIONS

Proactive management of contaminated liquids coming from agricultural sectors, by using bio-purification systems, will play an essential role in fulfilling the needs for a cleaner environment and secure water resources. Such solutions address in an active way the requirements of the recently adopted European legislation concerning the sustainable use of pesticides. Moreover, scientists also identify the need to adopt emerging technologies for better water management (Pereira et al., 2002).

One of the issues that has to be discussed in order to implement a safe farm water management systems is good communication of the importance of adopting technical solutions to reduce workers' exposure and to develop good practices in environmental protection. Authorities need to step up their communication activities and recommend these solutions as an important element for risk reduction and for building up Good Agricultural Practice and Best Management Practices.

One of the limitations in the use of bio-purifications is the cost of the equipment itself that is reflected in the production cost, but the advantages in reducing point source pollution are clear.

Our experience shows that farmers have difficulties in adopting and applying new and innovative proposals. Thus, economic support by the National Authorities would push them to invest and be more interested in this direction.

A series of supporting measures need to be put in place by National Authorities such as promoting Good Agricultural Practice in farm water management. Based on the requirements of 2009/128/EC Directive, all the actors involved in the distribution and use of pesticides (farmers, distributors, advisors, etc.) should have access to appropriate training. The content of the education should comply with the essential health, safety and environmental requirements. In such training programmes information on water bio-purification technologies should play a significant role to provide a positive contribution to risk reduction.

Apart from the measures taken at national level, companies that develop and produce the equipment should be given the opportunity to take a leading role in promoting their wider use. Training materials, presentations and seminars should be prepared and organized for farmers.

The advantages of bio-purification systems bring an important contribution to the implementation of on-farm water management. Some of them have the ability to treat a large volume of contaminated water and some are able to operate in fast cycles, where a big volume of water is filtered in short period of time. Their great advantage is that they are valid and accessible systems for the removal of residues from water.

The adoption of these simple and efficient systems, easily adaptable to different climatic conditions using materials available on the farm (organic materials), will help farmers to become more sustainable and competitive.

Such innovative methods for on farm water management should benefit from the proper training and support of the National Authorities as well as from the involvement of the equipment providers.

The performance of the bio-purification systems provides solutions to avoid unwanted risks of pesticide use but also comply with legislative requirements.

Annex I. Timeline: History of bio-purification systems

1923

The first proposition to use biological methods to treat odorous compounds as H_2S was as early as 1923.

1960s

Air bio-filtration was first used for the treatment of gaseous pollutants both in Germany and US; research was intensified.

1990s

There are more than 500 air bio-purification systems operating both in Germany and Netherlands, and it is spreading in the US.

1990s

Sweden developed the first bio-purification system to treat PPPs containing waste waters and France the Phytobac.

2000s

The Biofilter and the Biomassbed have been developed, using the biobed functionality principle, by Belgium and Italy.

2000s

Several non European countries, as Guatemala, Peru, Chile, and Canada start research and possible adoption of biobeds.

2006

Syngenta developed a bio-purification system based on physical processes, the Heliosec.

Annex II. Possible problems and needs of future operators of bio-purification systems

A End user needs:

- A full appreciation of the legislation development towards pollution of natural resources and the potential consequences from their day to day activities in the form of financial penalties, losses of potential incentives as well as social respect in their communities.
- To be fully aware of available codes of practice in their respective country (sufficient background information on regulation and compliance needed at the local level).
- A deeper understanding of all the options available to deal with contaminated unused material including those options which can improve on farm handling beyond minimum compliance e.g. to meet higher standards e.g. Agri-environmental incentive schemes or ICM/Global Gap criteria to access new market opportunities.

B Stress need for workable system:

- Farmers will only adopt pragmatic and easy to use systems in the long term; therefore, once the water treating facility has been installed it should not require too much time and effort to maintain.
- Checks needed to monitor the functioning of the system and ensure that any effluent or leachate subsequently produced containing PPPs should be undertaken at regular intervals and with the help of the system provider.

C Site investigation and assessment to decide the type and the dimension of the system to install:

- It is important to undertake a comprehensive evaluation of the farms use of PPPs and the potential site for the water treating facility before deciding which type of system to install.
- The chosen system must always be protected from any rain fall.
- The installation of the bio-purification systems should be in accordance with the rules established by the safety norms of each Member State.

D From the origin of the waste to the method for disposal:

- Prevention or reduction in volume of waste (washings or remnants) which is handled on the farmyard must be a priority.
- Correct calibration of spray machinery and accurate calculation of the amount of diluted spray liquid necessary for the field, crop and pest in question should be always considered to limit as far as possible the need for remnant handling on the farm.
- Training courses and provision of practical information on practices such as on washing and cleaning the sprayers using optimum water volumes should be available for the farmers.

E System records = Maintenance Functionality check Log book Inspection and Audit:

- Records of the field operations undertaken and concentrations and volumes of washings or remnant managed through the chosen system should be accurately archived.

For more detail on the above systems when making the choice, please refer to the TOPPS publication on Bio purification systems for spray remnants on farm. The web link (www.topps-life.org) is also available on the OPERA website.

Annex III. Examples of systems with substrate efficiency and main factors influencing the PPP's bio degradation.

In Table 1 are presented some examples of systems efficiency on retaining the PPPs from water and their dissipation/degradation after the retention on the biomix. The data show efficiency of retaining pesticides of more than 97% of a Biomassbed, developed in Italy, after one agricultural season (3-4 months) and between 30-99% after just 9 days. The degradation/dissipation after biomix retention was not reported. Studies conducted in Germany and Sweden for a biobed show a degradation/dissipation after retention of more than 99% after 5 years for 7 different pesticides and between 50-98 % in less than one year for 22 pesticides studied. Studies on the Biofilter efficiency have been developed in The Netherlands and Belgium and the data show retention between 85≤99% after one agricultural season for 14 pesticides studied and more that 95% after 2 years for 5 herbicides. The Phytobac bio-degradation efficiency has been tested in France and Belgium. The French studies show efficiency on degrading the adsorbed residues of 13 herbicides between 97-100% after two years. The data reported in the Belgian studies show retention of 5 pesticides on less than 2 weeks and their degradation/dissipation between 33 and almost 100% (bellow detection limit) in less than 1 year.

Table 1. PPP's retention and degradation/dissipation on the bio-purification systems.

Bio-purification system	Country of the study	PPPs type and nr. tested	Time	Retention efficiency (%)	Degradation/ dissipation from biomix (%)	Literature resource
Biomassbed	Italy	Fungicides (4)	one agric. season	97,6 - 99,9	-	Ferrari et al. 2010a
		Insecticide (1)	one agric. season	99,41	-	Fait et al. 2007 Vischetti et al. 2004
		Herbicides (6)	9 days	30,4 - 99,1	-	Ferrari et al. 2010b
		Insecticides (2)	9 days	90,3 - 89,9	-	
		Fungicides (2)	9 days	45,6 - 95,9	-	
Heliosec	Italy	Fungicides (3)	one agric. season	100% (only dehydration)	-	Ferrari et al. 2010c
Biobed	Germany	Fungicides (4)	< 5 years	-	99,99	Felgentreu and Bischoff 2010
		Herbicides (3)	< 5 years	-	99,99	
Biobed	Sweden	Fungicides (3)	< 1 years	-	50 - 98	Castillo and Torstensson 2008
		Herbicides (14)	< 1 years	-	75 - 98	
		Insecticides (5)	< 1 years	-	50 - 88	
Biofilter	Netherlands	Fungicides (9)	one agric. season	85 - 99	-	De Werd 2010
		Insecticides (4)	one agric. season	> 99	-	
Biofilter	Belgium	Herbicides (5)	2 years	> 95	-	Pigeon et al. 2005
Phytobac	France	Herbicides (13)	2 years	-	97,7 - 100	Fournier 2004
Phytobac	Belgium	Herbicides (4)	2 weeks	100	-	Spanoghe et al. 2009
			1 year	-	33 - no able to detect	
		Insecticide (1)	2 weeks	100	-	
			1 year	-	no able to detect	

A Role of the biomixture composition

- The lignin content of organic material is an important factor for the degradation of PPPs and the use of straw as lignocelluloses material has been shown to increase the degradation of PPPs. For practical reasons, not more than 50% straw can be used.
- The soil type was found to have less influence on the efficiency of the system but should be rich in humus and have low clay content.
- The use of local soils in the construction of each system is possible. Local PPP treated field soils might contain naturally occurring and potentially pesticide adapted microbiological populations.
- Agricultural waste by-products such as vine branches, citrus peel; green and urban waste compost, sun-flower crop residues, olive leaves, etc. have been studied as alternatives to straw.

B Effect of pesticide concentration

- In case PPPs are used as carbon source by micro-organisms, the PPP concentration must be sufficient to provide the pesticide degrading organisms with sufficient nutrients to grow in the biomix.
- At PPP concentrations ranging from half to 20 times the maximum recommended application rate the rate of PPP degradation decreased with increasing concentration.
- To avoid high concentrations of pesticides on the biobed, internal cleaning of the spraying equipment with water from a freshwater tank should be performed in the field after application.

C Effect of pesticide mixtures

- Biopurification systems are likely to receive complex mixtures of more than one active substance, often applied repeatedly.
- Biobeds are capable of treating high concentrations of a combination of pesticides.
- Studies performed with a mixture of six active substances showed that degradation of the compounds applied to the biomix as a mixture was slower than when the compounds were applied individually.
- The problem of combined effects is very complex and cannot be studied in all possible combinations. Possible interactions can for the moment only be studied ad hoc.

D Moisture Content and Hydraulic Loading

- The moisture content in a biopurification system should be sufficiently high to allow activity of the pesticide-degrading microorganisms, but not so high that leakage of pesticides becomes a risk and that anaerobic conditions are created.
- In laboratory biobeds moisture at 60% of water holding capacity (WHC) gave the highest dissipation of most of the pesticides tested, while moisture at 30 and 90% of WHC limited the microbial activity.
- Increasing the soil moisture, an increase in the rate of pesticide removal has been observed.
- Pesticide leaching was shown to be affected by the hydraulic load. Increasing the water input on the biobed, resulted in increased leaching. By controlling the water inputs and increasing the retention time within the biobed by increasing the depth, less leaching will occur for mobile pesticides.

E Repeated use of PPPs

- Repeated use of certain compounds over a number of seasons can result in enhanced degradation.
- Repeated treatments with certain PPPs increased the degradation potential of the microflora in a Phytobac© system. Therefore it was suggested to farmers to fill their Phytobac© with adapted or pesticide-primed soil.
- In a biobed system the rate of PPP degradation decreased with each additional application which could be explained by the existence of two differential microbial systems, a co-metabolic, mainly fungal, system occurring in the biobed that is not enhanced by repeated applications of pesticides and a metabolic system, mainly bacterial, occurring in the Phytobac.

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