Herbicide flow from two types of hard surfaces in urban areas: first results for glyphosate and diuron

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ABSTRACT

An experiment has been established in a mini-watershed to determine the contribution of urban areas to water pollution. The idea was to collect run-off from two man-made surfaces : concrete (impermeable) and compacted sandy soil (permeable). Both surfaces can be considered as hard ones if compared with agricultural soils. The losses of glyphosate and diuron sprayed at 3000 g ha^{-1} were monitored for 10.5 months after application. For diuron, 33.3% of the applied quantity is transferred to the water from concrete surface and 39.5% from the sandy zone. For glyphosate, the rates are respectively 8.5% and 12.8%. These very high results are to be compared with the data for agricultural use of herbicide indicating an average range of 0.1% to 1% loss of the applied quantity. 5 or 3 mm rainfall are enough for the leaching of 50% of the total loss of glyphosate and diuron from concrete surface. The regulatory process should be improved regarding urban uses of pesticides and herbicides with the less possible loss encouraged. A new impetus has to be given to the research of non-chemical methods in urban areas, which could be the ultimate environment friendly solution on hard surfaces.

INTRODUCTION

Extensive research has been carried out on pesticide losses from agricultural plots and fields. But the losses from hard surfaces in urban areas are an underestimated source of diffuse pollution (Shepherd & Heater 1999). This situation has been emphasized by the monitoring of surface water in Bretagne (Brittany). There, diuron is a major pollutant although not used in agriculture as orchards and vineyards are lacking in this part of France (Gillet1995).
An experimental mini-watershed has been designed to improve our understanding of the role of herbicides leaching from hard surfaces in the surface water pollution. To provide preliminary data, glyphosate and diuron have been investigated as a local diuron ban increased the use of the further.

MATERIALS AND METHODS

The experimental design is located in Pacé near Rennes, the capital city of Brittany. An existing lane (ten years old) is chosen for its conditions similar to common weeds control practice. This design is different from the one used with new surface material by Shepherd &

Heather (1999). It has a 3.8 % slope and is divided in two parts : one with an impermeable concrete surface (47m x 4 m) , the other with a permeable sandy compacted man-made soil (47m x 6.8m). There are referred thereafter as CZ (concrete zone) and SZ (sandy zone). Both surfaces are considered as hard ones if compared to agricultural soil. Each plot is protected from the other and the highest ones by a ditch preventing any undesirable water transfer.
A strip in the middle of each plot is sprayed with glyphosate and diuron on June 9th at a rate of 3000g active ingredient per hectare with a precision sprayer (ATH company, Altkirsch). The size of the strip is adjusted to get the same 50% of the surface sprayed along each plot.

The water volume/ha is 500 litres and the nozzles are Teejet 80015 VS. Downstream each plot, a ditch equipped with automatic sampler and flow-meter collects the run-off water during the rain. An automatic weather station provides the necessary rainfall data. Herbicide concentration (diuron, glyphosate and its metabolite AMPA) of the water samples is analysed by gas chromatography in the laboratory of the *Ecole Nationale de la Sante Publique* in Rennes.

The losses of the herbicide have been monitored till 10.5 months after spraying, corresponding to 23 rain events and 78 rain days (Figure 1). 79 water samples have been analysed for diuron, glyphosate and AMPA.

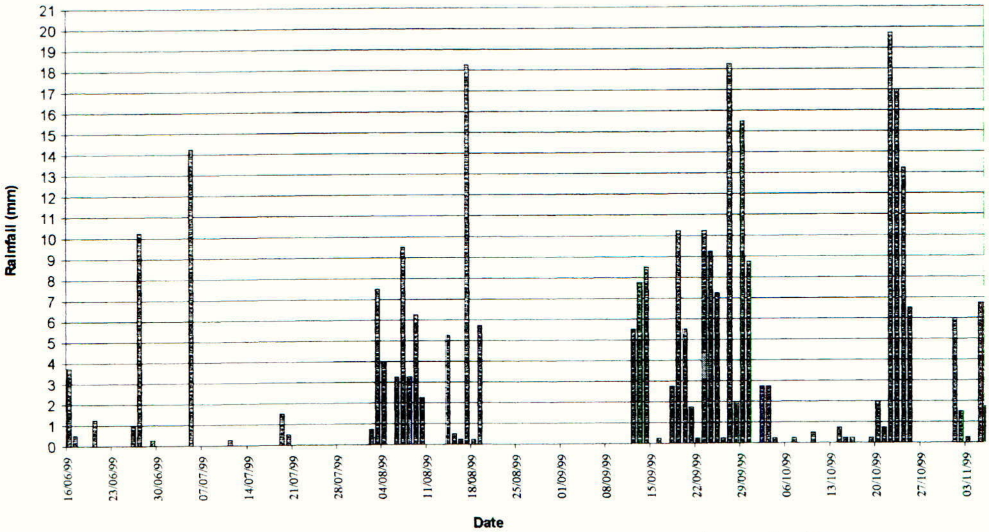

Figure 1. Rainfall data (mm) beginning 16/06/99, ending 03/11/99

RESULTS

Water run-off is observed after 0.5 to 1 mm rainfall on the impermeable zone and after 2 mm on permeable zone (Figure 2). These data confirm that the surfaces have to be considered as hard ones if compared to agricultural soils, which usually needs more than 10 mm for a significant run-off.

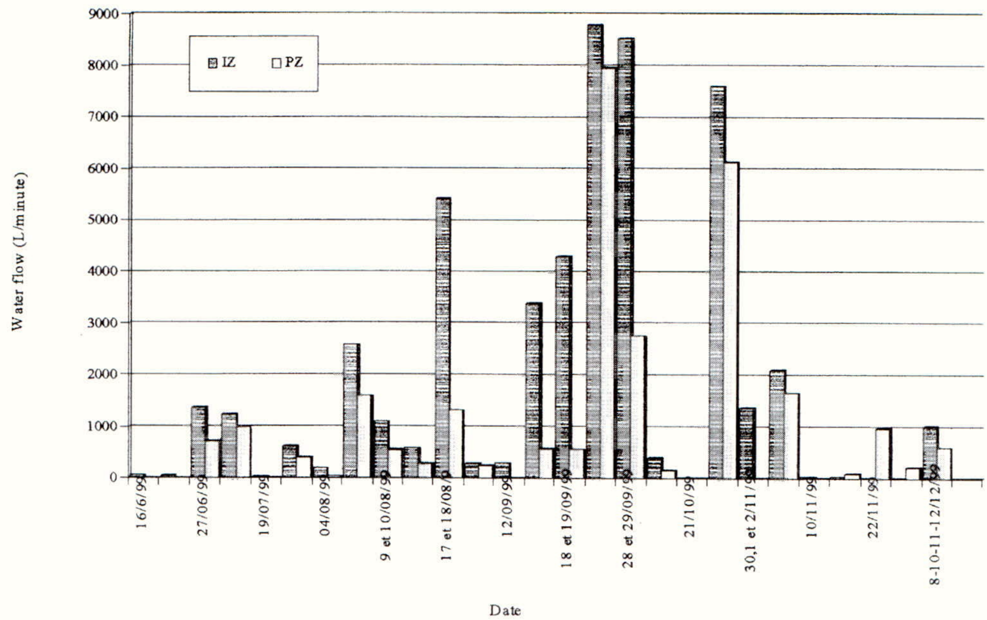

Figure 2. Relationship between rainfall and water run-off

The average concentrations for each type of surface are summarised in table 1. Data in brackets are the maximum values of the rain event.

The concentrations observed on both zones are very high during the first rains : diuron 1330 µg L^{-1} and glyphosate 8000 µg L^{-1}. Whatever the molecule, the concentrations on impermeable surface are higher than on permeable one for the first rains. The results are inverted three months after spraying.

Table 1. Concentrations (µg L^{-1}) for each rain and type of surface (IZ, impermeable zone, PZ permeable zone). The glyphosate values are the sum of glyphosate and AMPA.

		First rain event with run-off		1 month after spraying	2 months after spraying	3 months after spraying	6 months after spraying	10.5 months after spraying
		16/06/99	27/06/99					
Glyphosate	IZ	1320		95	63	10	2	2
		(1320)		(257)	(257)	(10)	(2)	(2)
µg L^{-1}	PZ		882	255	84	69	7	2
			(1330)	(336)	(146)	(69)	(7)	(2)
Diuron	IZ	8000		387	12	0.2	0.5	0.5
		(8000)		(529)	(17)	(0.2)	(0.5)	(0.5)
µg L^{-1}	PZ		2496	1299	42	98	1	1
			(3300)	(1700)	(63)	(98)	(1)	(1)

The concentrations are presented in Figure 3 for "impermeable" zone and Figure 4 for “permeable” zone.

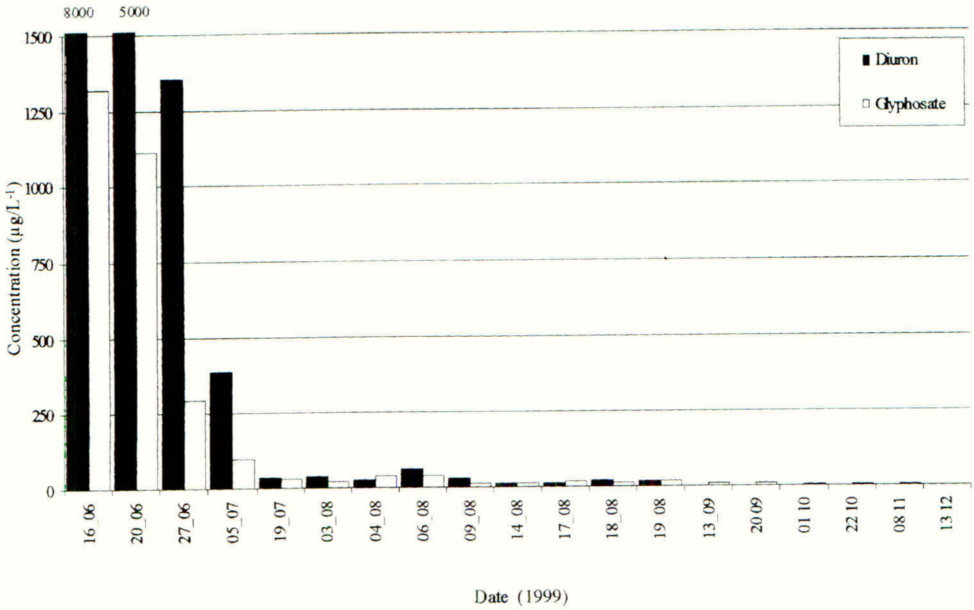

Figure 3. Evolution of the run-off water concentration for "impermeable" zone

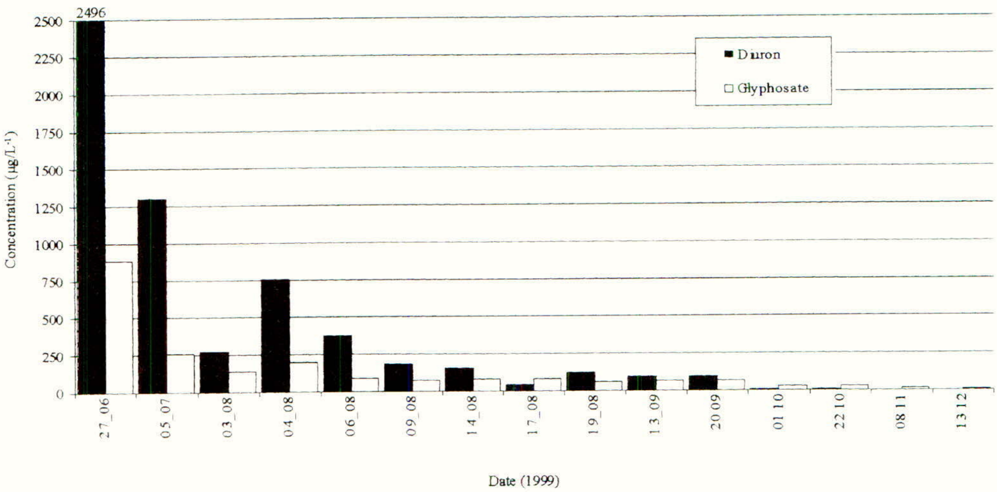

Figure 4. Evolution of the run-off water concentration for "permeable" zone

For a better understanding of the differences between the two zones, more attention has to be paid to the balance between glyphosate and its metabolite AMPA (Figures 5 and 6). On "impermeable" surface, AMPA and glyphosate are contributing roughly equally to the total glyphosate+AMPA indicating a limited degradation of the molecule. On "permeable" surface, AMPA represents about 80% of the total suggesting a higher biodegradation process.

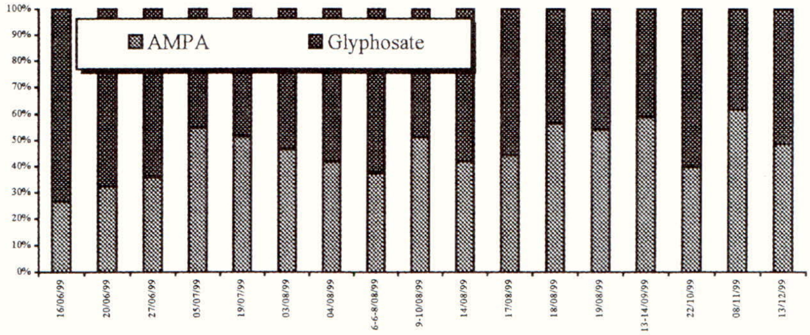

Figure 5. Evolution of the ratio glyphosate/AMPA on impermeable zone

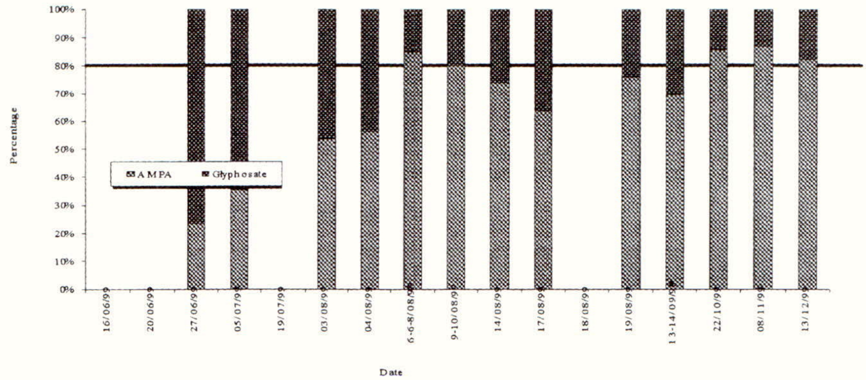

Figure 6. Evolution of the ratio glyphosate/AMPA on permeable zone.

The combination of water flows and concentrations makes it possible to calculate the active ingredient flow transferred to water for each molecule and surface. The results are as following :

- for diuron 33.3 % of the applied quantity on impermeable" zone, and 39.5 % on permeable" one,
- for glyphosate 8.5% of the applied quantity on "impermeable "zone" and 12.8% on "permeable" one.

Regarding environmental issues, the peak of flow and its relation to rainfall have a decisive influence. 5 or 3 mm are enough for the leaching of 50% of the total loss of glyphosate or diuron on "impermeable" zone (table 2).

Table 2. Rainfall necessary for the leaching of 50% and 90% of the total loss.

		percentage of the total loss	
		50%	90%
IZ	Glyphosate	5 mm	570 mm
	Diuron	3 mm	65 mm
PZ	Glyphosate	22 mm	490 mm
	Diuron	13 mm	190 mm

DISCUSSION

Most of the data concerning agricultural use of pesticides indicate that the herbicide transported to the water is in the range of 0.1 to 1 % of the applied quantity. On hard surfaces, the percentages for glyphosate (8 to 12%) and of diuron (33 to 39%) show a very different behaviour of pesticide in urban areas. The very high peak of concentration in run-off water during the first rain leads probably to unacceptable pesticide presence in surface water if not enough dilution.

With the development of urbanisation, the always-increasing acreage of hard surface could play an important role in water pollution. If up to a third of the applied herbicide sprayed on roads, pavements, car parks, etc.. is rapidly transported to surface water, the regulation process based on agricultural soils and conditions could be questionable. However, with a multiplying factor 3-4 between diuron and glyphosate flows, herbicides with a better environmental profile (high K_{OC}, very low rate/ha) should be encouraged. A new impetus has also to be given to the research of non-chemical methods in urban areas that could be the ultimate environment friendly solution for weed control on hard surface (ANGOUJARD *et al.* 2001).

The decisive influence of the first rainfall after spraying for transferring the peak of herbicide to the water should be considered to improve weed control strategies. The standard practice of spraying before the rainfall is most aggressive to the environment. If only a limited number of herbicide sprays are to be used they should be scheduled when the rainfall hazard is reduced to the minimum after application.

ACKNOWLEDGMENTS

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REFERENCES

Shepherd A J; Heather A I J (1999). Factors affecting the loss of six herbicides from hard surfaces. In : *Proceedings of the 1999 BCPC Conference, Weeds.* **2:** pp. 669 – 674.

Angoujard G ; Lefèvre L; Blanchet P J (2000). Techniques alternatives au désherbage chimique des surfaces imperméabilisées en zone urbaine. In: *Proceedings XIth International Conference on Weed Biology.*, 6-8 septembre 2000, AFPP. pp. 445-452.

Gillet H (1995). Contamination des eaux superficielles de l'Ouest de la France par les produits phytosanitaires: du diagnostic à quelques propositions d'action. In: *Proceedings of: ANPP seizième conférence COLUMA, Journées internationales sur la lutte contre les mauvaise herbes*, Reims 6,7 et 8 décembre 1995., pp.1 – 7.

Modelling pesticide residues in irrigation water: - Managing their impact on non-target cultures and the environment

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ABSTRACT

Three compartmental models (rice paddy, canal and leaching) are being linked to simulate the flux of water and herbicides in an agricultural ecosystem in Portugal. The water-quality of drainage canals is of paramount importance in this ecosystem for further re-use in crop irrigation downstream. The application and dissipation of an active substance and its metabolites in a rice paddy and associated drainage canal are being monitored by biological and chemical means in order to assess for phytotoxicity effects on non-target cultures. The time-series will be used to calibrate and validate a mathematical model to manage the quality of water from canals for the irrigation of tomato crops downstream. This tool aims to help in decision making on the use of herbicides, to minimize the risk of soil and groundwater contamination, and to optimize agricultural practices. It works by predicting the right timing for water consumption, when the risk of phytotoxic effects to non-target crops is minimal, avoiding its use during events of herbicide contamination in the stream. This model will optimize the use and preservation of water resources.

INTRODUCTION

In Portugal, it is still common practice to re-use water from drainage canals to irrigate crops, especially in areas not yet served by a modern network of irrigation canals that bring good quality water from far-off sources. Waters from drainage canals carry herbicide chemical residues (active substance and/or metabolites) that contaminate soils and surface waters and underground waters. These waters may cause phytotoxic damage to plants and crops and are harmful to the environment and to the farmer too, because they undermine the crop production levels.

The marshland of the Paul de Magos, in the Tagus/Sorraia valley is an area where the water from drainage canals is still re-used to irrigate tomato, melon, spring beetroot and maize crops that are cultivated downstream of the rice paddies.

Bearing in mind the need for this agricultural practice and the inherent difficulty to characterize the quality of water from drainage canals, we set out to evaluate the phytotoxicity of those waters for crop irrigation.

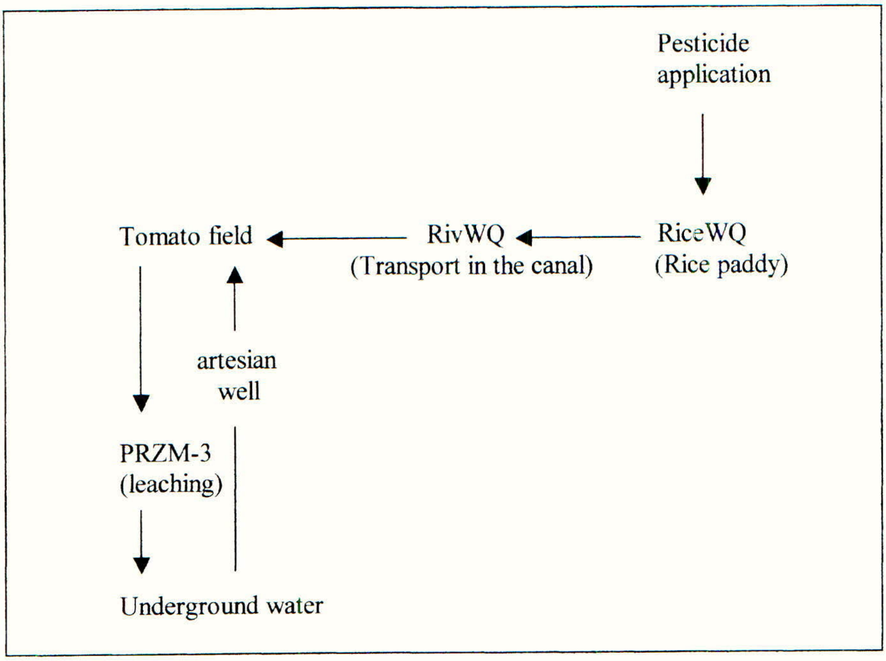

Figure 1. Diagram of the conceptual model showing the proposed linkage of existing sub-models to simulate the flow of pesticide contaminants into irrigation water used in agricultural lands.

This working tool to address pesticide contamination of irrigation water serves a practical purpose - to give advice to local farmers:

1- on the safeguard waiting time for crop irrigation. This is the time interval to be respected once the floodgate from the rice paddy is opened and before the abstraction of water from the drainage canal can begin, given the flow speed and herbicide degradation in the waters of the drainage canal.
2- on the minimum safety distance to the discharge point, for the use and consumption of water from the drainage canal.
3- on estimated phytotoxic damages to plants and crop production levels, if the farmer chooses to ignore the advice and abstracts water from the drainage canal, for crop irrigation during the safeguard waiting time.
4- on the estimated value of groundwater contamination by leaching of herbicides, if the farmer chooses to ignore the advice and abstracts water from the drainage canal, for crop irrigation during the safeguard waiting time.

The project 'Herbicides And Irrigation' has already achieved some of its aims. The three compartmental models were linked, to simulate the flux of water and herbicides in an agricultural ecosystem. The calibration and validation of this meta-model is now underway.

MATERIALS AND METHODS

An agricultural ecosystem comprising a rice paddy, a drainage/irrigation canal, a tomato field and six wells was studied from spring to autumn 2001 during the rice campaign in the Tagus/Sorraia valley.

The rice paddy was treated with molinate (4,500g a.s./ha), bentazone (2,400g a.s./ha) and propanil (3,600g a.s./ha) herbicides in standard agricultural fashion for rice crops. Five sampling points in the rice paddy and six sampling points in the drainage canal along the transect to the tomato field, were chosen for the collection of water and sediment samples. Measurements of dissolved oxygen, conductivity, pH and temperature were also taken. Biological methods for the identification, the detection and the dosage of herbicide residues in water were set-up and are being evaluated under greenhouse conditions. Furthermore, herbicide chemical residues in water from this agricultural ecosystem are being monitored by biological and chemical means. The time-series contains daily data on active substance and its metabolites for the first week after each herbicide application and weekly data thereafter. This study has been conceived in order to provide data to calibrate and validate a mathematical model for the management of those waters for irrigation purposes.

DISCUSSION

The issue of pesticide contamination of irrigation water used in agricultural lands is an ever increasing problem and needs to be addressed. Previous work on this subject has centered on monitoring programmes of pesticides in surface water (Barceló *et al.,* 2000; Azevedo *et al.,* 2000). However, the present ongoing project on herbicide application in rice paddies and their effect on the quality of surface waters and groundwater is a new approach to the problem. The core of the project is a conceptual model (Figure 1) which links three existing compartmental models (rice paddy, canal and leaching models) to simulate the flux of water and herbicides in an agricultural ecosystem in Portugal. The individual components are:

- RICEWQ (Williams *et al.,* 1999), a water quality simulation model for rice paddies that can be used to evaluate the dissipation of herbicides in an aquatic system and to predict the runoff losses of those herbicides to receiving waters;
- its companion RIVWQ (Williams *et al.,* 1999) is a transport model for pesticide contaminated water in ditch/ canals;
- PRZM-3 (Carsel *et al.,* 1998), a model to simulate the leaching processes of pesticides in soil which enables the concentration of pesticides reaching groundwater to be estimated.

The three models are used in pesticide registration studies by the US EPA.

The pesticide is applied to the rice paddy and its dissipation plus runoff losses to receiving waters, by overflow and drainage, is processed by the RICEWQ model. The drained part is transported by the RIVWQ model and is used to irrigate a farmed field (tomato, melon, beetroot or maize). The pesticide residue in this irrigation water is now transferred to the PRZM-3 model which calculates the pesticide mass reaching groundwater by leaching.

The monitoring of herbicide residues in groundwater and surface waters (in the rice paddy and canals) by chemical means has been carried-out, in order to obtain a time-series to calibrate and validate the models.

However, there are other tasks that have yet to be accomplished:

- the best strategy for herbicide application in the rice paddy using the validated model needs to be defined. It is aimed at using the water from the drainage canal with a minimal risk to non-target crops (with regard to phytotoxic effects), and to minimize the risks of groundwater contamination by improving the agricultural practice.
- the knowledge gained must be passed on to the extension advisors in the production sector .

The model is a tool that will help in decision-making on the use of new and existing herbicides. It will also help to optimize the use and preservation of water resources.

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REFERENCES

Azevedo D; Lacorte S; Vinhas T; Viana P; Barceló D (2000). Monitoring of priority pesticides and other organic pollutants in river water from Portugal by gas chromatography-mass spectrometry and liquid chromatography-atmospherc pressure chemical ionization mass spectrometry. *Journal of Chromatography A*, **879:** 13-26.

Barceló D; Vinhas T; Lacorte S; Viana P (2000). Advanced Monitoring Program from Portuguese Surface Waters of 132 Volatile and Semivolatile Organic Compounds included in the 76/464/EEC Directive. *Waste Water Cluster Newsletter 2000*,**3.**

Carsel R F; Imhoff J C; Hummel P R; Cheplick J M; Donigian Jr A S (1998). PRZM-3, A *Model for Predicting Pesticide and Nitrogen Fate in the Crop Root and Unsaturated Soil Zones*. Users Manual for Release 3.0.

Williams W M; Ritter A M; Cheplick J M (1999). RICEWQ: *Pesticide runoff model for rice crops*. User's manual and program documentation version 1.6.1.

Williams W M; O'Flaherty C; Cheplick J M; Singh P; Ritter A M (1999). RIVWQ: *Chemical transport model for riverine environments.* User's manual and program documentation version 2.0.