DEVELOPMENT OF A DATABASE OF PLANT PROTECTION PRODUCTS LOADS TO INLAND SURFACE WATERS IN GREECE TO SUPPORT THE MODELLING OF PESTICIDES POLLUTION

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ABSTRACT

The work presented in this paper is related to the identification of the pressures on surface water bodies, as a result of diffuse pollution from the Plant Protection Products (PPPs) used during the agricultural activity in Greece. The pressures are quantified and expressed as loads from the PPPs' active substances that enter surface water bodies by implementing the methodology presented by the FOrum for the Co-ordination of pesticide fate models and their Use (FOCUS Surface Waters). The methodological approach and its implementation have been conducted in the framework of the Switch-On project.

A database of loads to surface waters, for the most common active substances of PPPs in Greece, has been developed through the use of numerical simulations in accordance to the methodology presented by the FOCUS Surface Waters group for establishing relevant Predicted Environmental Concentrations in surface water bodies. The database includes 15 different active substances which were identified as the most significant for Greece. Two out of ten sets of modelling parameters scenarios, developed by the FOCUS SW group as a series of standard agriculturally relevant scenarios for the European Union, were used. The relevancy of these scenarios was estimated to be more than 30% for the Greek agricultural conditions, reaching up to 56% under certain conditions. According to the simulation results, all runoff scenarios resulted to less than 1% of the substance applied to the plants entering surface waters, whereas drainage could result up to 9%. On average, the percentage of a substance that reaches the surface waters is of the order of 1% of the quantity applied, when the drainage scenarios are implemented. In the case of runoff, the amount is lower and does not exceed, on average values, 0.3%. Although drift is a small transport component as to the total amount of substance transported into surface waters, it can result to greater concentrations in the water body than drainage or runoff.

Keywords: Plant Protection Products, PPPs, Pesticides, loads, modelling, surface waters, FOCUS

1. Introduction

Plant Protection Products (PPPs) are common pollutants in inland surface waters and their impact on human health and on the environment has been of concern for decades. The hazards of PPPs and the need of protective measures against those hazards have been recognised by the European authorities (Directive 414/91/EEC, European Commission, 1991) and there has been a constant effort for the development of risk assessment methodologies combining the requirements defined by the Directives 414/91/EEC (European Commission, 1991) and 2000/60/EC (Water Framework Directive, European Commission, 2000). Directive 2009/128/EC has been adopted to establish a framework for Community action to achieve a sustainable use of pesticides and the development of National Action Plans has been supported, in order to reduce risks and impacts of pesticide use on human health and the environment.

A significant number of models has been developed (Quilbé *et al*., 2006; Holvoet *et al*., 2007; Schulz and Matthies, 2007) for the simulation of transport and fate of PPPs' active substances to the environment, in order to support management plans. Due to the complexity which characterizes the various routes of transport of PPPs (Holvoet *et al*., 2007) from the fields to the watercourses, the application of such models usually requires a large number of input data which are often scarce and site-specific. Other data requirements concern the physicochemical parameters of PPPs' active substance. In Greece, nationwide patterns of pesticide use are constantly changing (Konstantinou *et al*., 2006). Currently there are no official records regarding the sales of PPPs in Greece. Further, there has been no official scheme for monitoring and reporting of the PPPs use in the country, although preliminary schemes have been considered from the Ministry of Rural Development and Food. In view of the above, the development of a database of loads of PPPs' active substances that may enter surface waters, for the most common active substances in Greece, could facilitate the modelling of their fate in inland surface waters and would support management plans for the use and spread of PPPs in Greece. This is the main purpose of the present work.

Based on the information gathered from various sources as well as personal communication with local agronomists, local sellers and scientific experts, the most commonly used PPPs for typical arable crops in Greece were identified. Analysis of these data, combined with typical farming practices and dosage schemes, led to estimations of the applicable active substances quantities in the field. The resulted data were used as input in numerical simulations with the models and the standard, agriculturally relevant for the European Union, modelling parameters scenarios which were proposed by the **FO**rum for the **C**o-ordination of pesticide fate models and their **US**e – **S**urface **W**aters group (FOCUS, 2001), leading to the estimation of loads of PPPs (active substances) entering adjacent surface waters.

2. Plant protection products in Greece

Specific data concerning the sales and use of PPPs in Greece are not currently available in the form of official records. From January 2014, all local or regional sellers of PPPs are obliged to use the on-line system as part of the National Action Plan on Sustainable Use of Pesticides (Minister of Rural Development and Food, 02/08/2013) for the implementation of the Sustainable Use of Pesticides Directive (2009/128/EC). However, there is still no public access to the collected data from this database.

The quantities of PPPs used were estimated per River Basin District, mainly through the Ministry of Rural Development and Food database for all registered PPPs (wwww.minagric.gr/syspest), data provided by Hellenic Crop Protection Association (ESYF) which represents most companies involved in the crop protection industry (http://www.esyf.gr/index_en.php), data provided by the European Crop Protection Association (ECPA, http://www.ecpa.eu/) and the databases developed for construction of baseline surveys and monitoring studies of PPPs as part of specific projects (e.g. LIFE+ EcoPest, www.ecopest.gr; LIFE+ Hydrosense, www.hydrosense.org.gr). Personal records and communications were also engaged. Critical assessment of these data was performed and as a conclusion 43 herbicides, 30 insecticides and 47 fungicides were identified as common PPPs (active substances) used in Greece.

Further screening process was employed in order to narrow down the number of 120 substances initially identified. The registered PPPs were categorized based on the crops they are used on and the crops which hold the largest coverage of agricultural land were identified (e.g. cereals hold more than 45% of the total agricultural land, olive trees - 15%, corn - 10% and cotton - 7%) based on the data of Corine Land Cover 2000 (Copyright holder: EEA). Following this procedure, fifteen different active substances were selected as the most significant for Greece, based both on the number of crops that they are used on and the percentage of total agricultural land that each type of crop represents. The selected substances along with the associated number of crops and respective percentage of agricultural land are presented in Figure 1. Other criteria that were also taken into account during the screening process are (i) the characterisation of a substance as a priority substance (Directives 2008/105/EC and 2013/39/EU), (ii) the existence of a relative

Environmental Quality Standard at a European or national level, (iii) the availability of physicochemical parameters data for implementation of FOCUS simulation methodology and (iv) the existence of river water quality data. For each of the 15 active substances two additional sets of data were specified for each type of crops: the dose of PPP applied and the specific application regime.

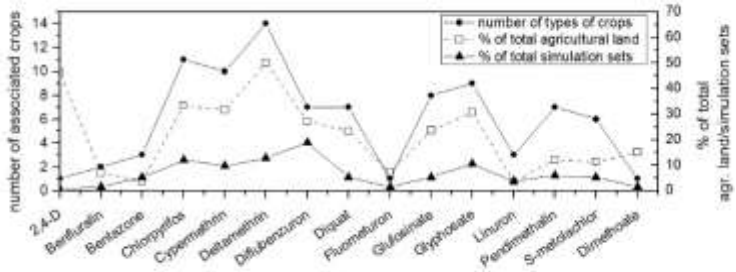

Figure 1: Selected substances with associated number of simulation sets, number of types of crops and respective agricultural land coverage.

3. Numerical simulation

The SWASH shell versions of MACRO and PRZM (FOCUS, 2001; http://focus.jrc.ec.europa.eu/sw/index.html, accessed 24/03/2015) numerical models were used for the simulation of PPPs' active substances transport through the routes of drift, drainage, runoff and erosion, into near field water bodies, under the Step 3 level of FOCUS SW methodology. For this approach, the group has developed a series of standard agriculturally relevant scenarios for the European Union that can be used as a reliable input to a combination of numerical models, in order to establish relevant Predicted Environmental Concentrations (PECs) in surface water bodies under an 'edge-of-field' risk assessment.

Two out of ten sets of the modelling parameters scenarios, drainage scenario D6 and runoff scenario R4, were used as most relevant to the Greek conditions. The relevancy of these scenarios to Greek conditions was investigated based on the combinations of soil properties (European Soil DataBase, Panagos *et al*., 2012), landscape characteristics (DEM) and climate conditions (CRU CL 2.0 data, New *et al*., 2000), which are the data used by the FOCUS group for the development of the modelling scenarios. It was found that R4 and D6 are relevant for more than 30% for the Greek agricultural conditions, reaching up to 56% under certain conditions, while scenario R4 is more relative to Greek conditions than D6. Information about the required physicochemical parameters of substances, as well as information about their metabolites (if any) were retrieved by the relevant review reports of the European Commission (Health & Consumers Directorate-General, Directorate E – Safety of the food chain) and by the Pesticide Properties DataBase (University of Hertfordshire, 2013).

Simulation sets were formed for a combination of the major crops categories as related to FOCUS crops categories, the 15 active substances and the two FOCUS parameters scenarios. Further, additional sets resulted for crops with more than one cultivation period within a year, leading to a total of 133 simulation sets. The number of simulation sets for each substance is given in Figure 1 as a percentage of total simulation sets. The distribution of simulation sets among the PPPs correlates well, as expected, to the associated number of type of crops and the respective percentage of agricultural land, with the exception of 2,4-D and Dimethoate.

The adaptation of the FOCUS SW methodology for estimating loads of PPPs' active substances to support the modelling of pesticides pollution in inland surface waters is based on the assumptions that: (i) the same substance is used in a field for a period of more than six years (residual balance, especially under drainage scenario) and (ii) the "worst case" nature of the estimated loads could be mitigated by an averaging of the results (not all applications take place in the same time inside a large catchment) while maintaining a conservative approach of the estimated environmental pressures on inland surface waters. It should be noticed that the use of

FOCUS SW methodology for licencing of new PPPs has been incorporated in Greek legislation since December 2014 (Ministerial Decree 14309/162816/2014).

4. Results and discussion

According to the simulation results presented in Figure 2, all runoff scenarios resulted to less than 1% of the substance applied entering surface waters, whereas drainage could result up to 9%. On average, the percentage of a substance that reaches the surface waters is of the order of 1% of the quantity applied, when the drainage scenario is implemented. In the case of runoff, the amount is lower and does not exceed, on average values, 0.3%.

In runoff scenarios the timing of PPPs entering the waterbody coincides with the first significant rainfall events following the application. In drainage scenarios, PPPs' transport into a near-field waterbody is characterised by grater timescales and longer duration, following the characteristics of base flow. In cases where drainage loads are significant, transport of PPPs into the waterbody occurs even months after the application.

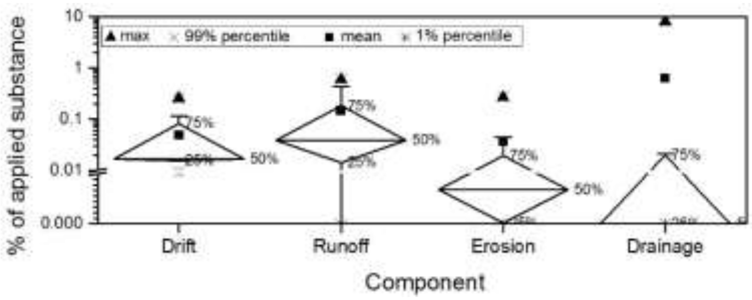

Figure 2: Box chart (Whisker plot) of simulation results of the resulting active substances load to the near-field water body (as % of application), per transport component.

Increased loads to surface waters due to runoff are related to the substances Bentazone, Chlorpyrifos, Deltamethrin, Linuron, Pendimethalin, and S-metolachlor, as presented in Figure 3. These are related mainly to crops of vegetables, legumes, tobacco and cotton. Drainage is a significant transport component for Bentazone, Linuron, S-metolachlor and Fluometuron (Figure 3) and is relevant mainly to vegetables, potatoes and cotton. Bentazone, Fluometuron and Linuron contribute more than 2,5% of the quantity applied to the surface waters in drainage scenarios while for runoff, more substances have a contribution to surface waters, mainly due to the drift component.

Drift is more significant for R4 scenarios (runoff scenarios), which is attributed to the fact that more tree-crops are represented in R4 than D6 scenarios and the amount of drift is larger for these crops. Although drift is a small transport component as to the total amount of substance transported into surface waters, it can result to higher concentrations in the water body than drainage or runoff, because it coincides with the time of application, when the discharge rates of the near-field waterbodies may be low.

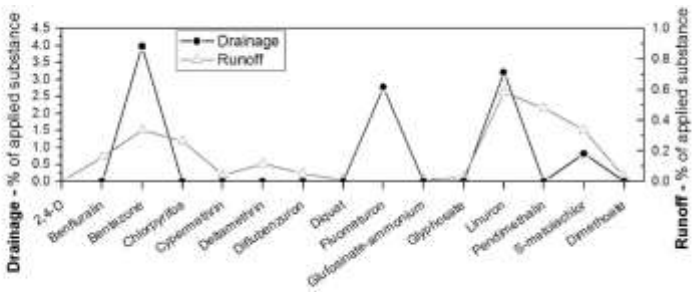

Figure 3: Drainage and runoff transport components for the 15 active substances considered.

ACKNOWLEDGMENTS

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