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Quantifying point source entries of pesticides in surface waters

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Summary

Measurements of the water boards have shown that pesticide concentrations in surface water have decreased less than was expected based on model calculations. Possibly, the implementation of spray drift reducing techniques is overestimated in the model calculation. The impact of point sources is probably underestimated. A project was initiated for the quantification and qualification of possible point sources in Dutch agriculture. Several point source entries were identified: e.g. internal and external cleaning of sprayers, filling stations and discharge of transport water from fruit sorting installations. A method was developed to discriminate the contamination of the pesticide activities in their possible impact on surface waters; the POint Source SUrface waters Model (POSSUM).

Key words: Point source pollution, pesticides, surface water, modeling

Introduction

The contamination of ground and surface waters with pesticides is a major environmental issue in Europe as emphasized in the Water Frame Work Directive. The risk of surface water contamination is most often associated with diffuse or non-point sources (subsurface drains, runoff and spray drift). However, point sources or farmyard activities are also significant contributors to pesticide pollution of surface water. On-farm activities such as spillage of plant protection products (PPP) during filling, leakages of the spray equipment, poor control of left over spray liquid, internal and external contamination of the sprayer, may result in the main direct losses of pesticides to the environment (Basford *et al*., 2004; De Wilde *et al*., 2007; Jaeken & Debaer, 2005; Wenneker, 2004).

Several field studies and measurement campaigns tried to quantify the relative importance of various practices and actions in the contamination of water by pesticides (Bach *et al*., 2005; Huber *et al*., 2000; Kreuger & Nilsson, 2001; Müller *et al*., 2002). In certain countries, e.g. Belgium and Germany, the fraction of point source input from farmyard waste water to the total river load of agricultural pesticides is estimated from 40% up to 70–90% (Carter, 2000; Mason *et al*., 1999).

In The Netherlands, legislation has been introduced for the reduction of the contamination of plant protection products to soil, surface water and air. In the last decade much research was focused on spray drift deposition, and its contribution to the contamination of surface water. Based on this research spray free and crop free buffer zones ahave been introduced, to minimize the risk (Water Pollution Act, Plant Protection Act). However, measurements taken by the water boards showed less decrease of the pesticide concentrations in surface water than was expected from the model based calculations (MNP, 2006). Possibly, the implementation of spray drift reducing techniques is overestimated in the model calculation. Also, single events, such as spillages of spray liquid, might have strong implications for the environment, as low concentrations (µg L^{-1}) are often harmful to the aquatic ecosystem.

Point source entries of pesticides arising from activities at the farm yard contribute to contamination of surface waters. Which activity attributes most to the contamination is difficult to determine. Therefore, we developed a method to discriminate the contamination of the pesticide activities in their possible impact on surface water. In this paper first results are presented of a recently developed model for the quantification and qualification of possible point source pollutions in agriculture – The Point Source Surface waters Model (POSSUM) (Beltman *et al*., 2009).

Materials and Methods

POSSUM calculates pesticide concentrations in a 100 m ditch with a volume of 21 m^3 from the mass deposited during an activity at a location and the fraction emitted along a pathway. The description of the activity's location and its corresponding pathway is based on descriptions given by 36 arable farmers and 42 fruit growers. The emitted fraction depends on the location and its pathway to surface water. The mass is related to the frequency of the activities. Via Monte Carlo simulations, combining emission fractions and deposited masses randomly, concentrations are calculated in a ditch close by. We assume that a ditch is present next to the farm yard for the purpose of comparative assessment. Data on activity, pathways and masses are derived from studies by Wenneker (2004); van de Zande (2007); van Zeeland & van der Weide (2008).

Results

Point source schemes

Arable farming

We derived a point source scheme for arable farming, see Fig. 1. To determine which pesticide activity gives the highest risk, we explored the use of terbuthylazine for weed control in maize by calculating terbuthylazine concentrations in surface water for the following activities: (i) filling of the spray tank, (ii) internal cleaning, and (iii) external cleaning of the sprayer. The scheme shows that all three activities (filling, internal cleaning, external cleaning) take place at three possible locations (farm yard, filling/cleaning facility and field). Fig. 2 shows the calculation results as the cumulative frequency distribution of the calculated concentrations. Filling of spray tanks results in the highest terbuthylazine concentrations, but occur relatively seldom compared to the other two activities. Internal cleaning might result in concentrations exceeding the Dutch standard (MTR) with a factor of 100, and occurs more frequently.

Fruit growing

We derived a point source scheme for fruit growing, see Fig. 3. The information for this scheme was derived from an inquiry carried out in 2007. In total, 41 fruit growers (in total 418 ha apples and 254 ha pears) in four fruit growing areas participated in an inquiry. The average farm size was 16.9 ha, with a range from 5–34 ha. Although the outcome of the inquiry reflects only 2.5% of the total number of fruit growers in The Netherlands, it shows general trends concerning use of plant protection products and emission risks.

Most important point source entries in fruit growing appear to be:

Filling of sprayers: Without exception all sprayers are filled at the farmyard. Filling in the field or orchard does not happen. In 80% of the 'cases' the filling and cleaning location consists of

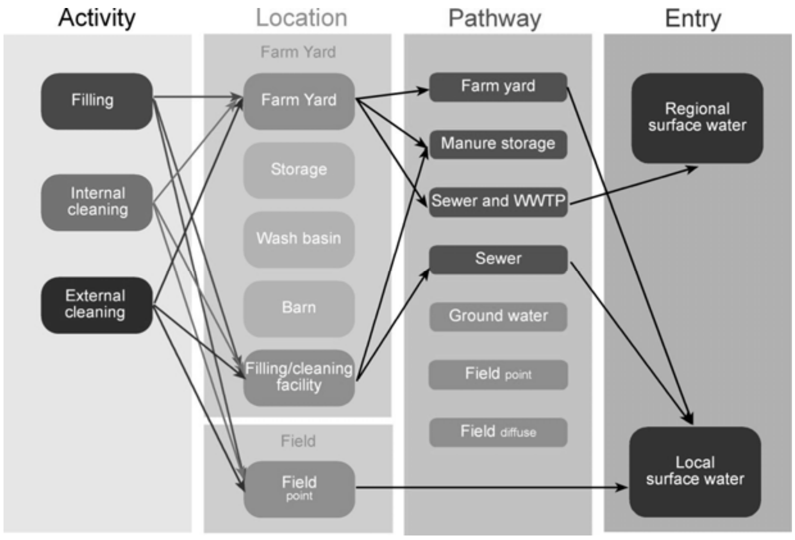

Fig. 1. Point source scheme for use of sprayers in arable farming in the Netherlands. Activities are performed at locations. Depending on the location a pathway may exist to regional or local surface water (WWTP = Waste Water Treatment Plant).

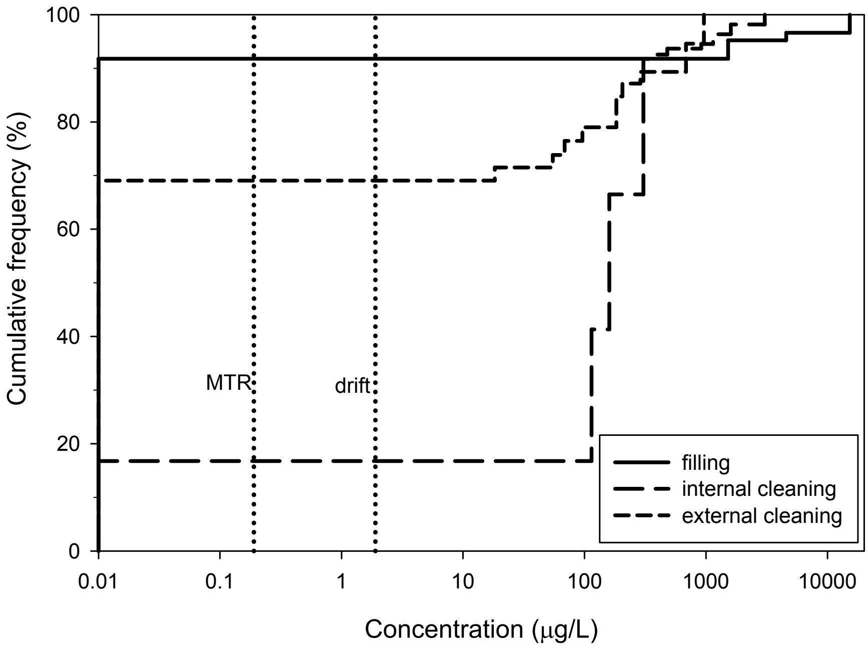

Fig. 2. Cumulative frequency distribution of concentrations of terbuthylazine in local surface water due to point sources linked to use of sprayers in arable farming in the Netherlands. The vertical MTR line indicates the Dutch terbuthylazine standard for surface water. The vertical 'drift' line is the terbutylazin concentration from spray drift applied in the Dutch registration.

(semi-) impervious material. Though compulsory, the majority of the locations do not posses the mandatory equipment, such as an impervious floor for filling and cleaning with a collection unit
Cleaning of sprayers – internal cleaning: Sprayers for orchard applications are not frequently internally cleaned. Internal cleaning occurs 1-2 times per season, mostly for maintenance reasons. Internal cleaning of the tank is mostly carried out at the end of the spraying season, before the sprayer is stalled for the winter period. Spray remnants are sometimes stored until the next spray application. None of the fruit growers discharges spray remnants at the farmyard.
Cleaning of sprayers – external cleaning: The majority of the fruit growers clean the outside of the prayer more than once a year. In certain regions external cleaning is carried out after each spraying day. In 70% of the cases external cleaning is carried out at the farmyard. However, only

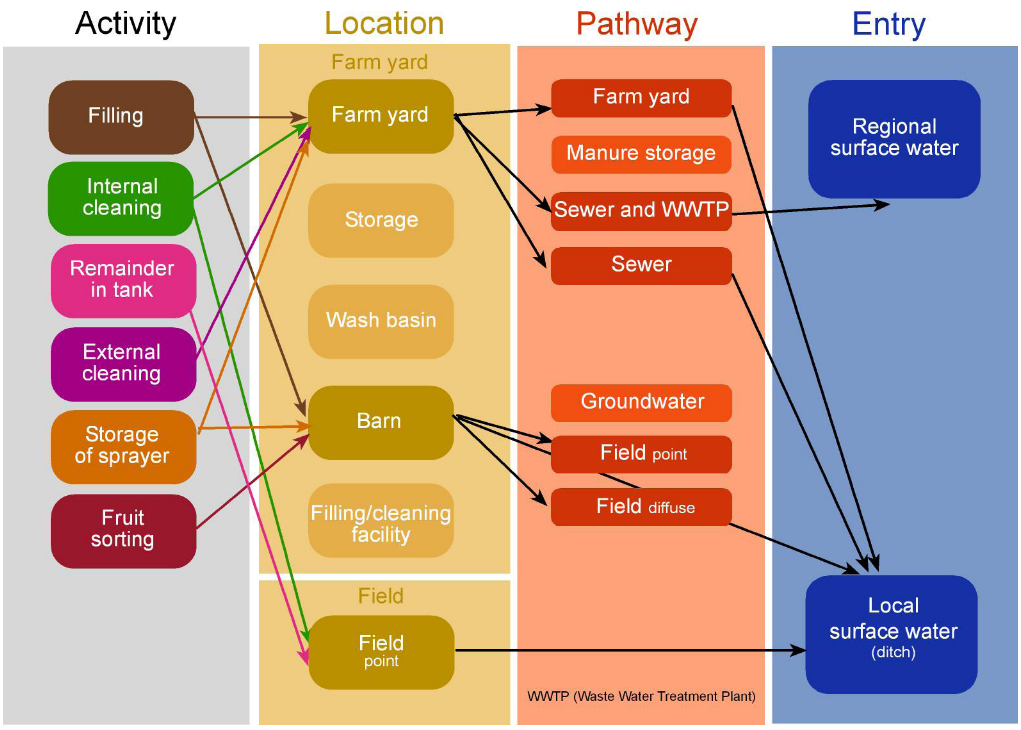

Fig. 3. Point source scheme for use of sprayers in fruit growing in the Netherlands. Activities are performed at locations. Depending on the location a pathway may exist to regional or local surface water (WWTP = Waste Water Treatment Plant).

a minority of the farmyards (24%) is equipped with storage facilities for waste water.

Grading and sorting of fruit: In the Netherlands, fruit sorting installations are often equipped with a transport device, which transports fruit in water. This is to avoid damaging of fruit during the sorting and grading process. During the period that apples and pears are present in this transport water, part of the pesticides in and on the fruits will be transferred into this water (Beltman *et al*., 2007). Discharge of waste water contaminated with pesticides into surface water or sewage systems is forbidden under Dutch law. However, due to the lack of simple and cheap purification systems, it is common practice to discharge directly into watercourses.

In the POSSUM model for fruit growing the cumulative frequency distribution of concentrations were calculated for the insecticide imidacloprid in local surface water due to different point sources entries. In this case external cleaning seems to contribute most to the imidacloprid concentrations in surface water.

Discussion

In the Netherlands the surface water quality is continuously monitored and results are available on the internet (CML, 2007). Also modeling is used to estimate the possible risk of environmental contamination by pesticides (Anon., 2007). However, the measurements of the water control organizations showed that less pesticide concentrations in surface water decrease less than was expected based on from the model based calculations. Possibly, the implementation of spray drift reducing techniques is overestimated in the model calculation or the impact of point sources is under estimated. However, although the relevance of different sources should be clear, the quantification of pathways is difficult (Bach *et al*., 2001, 2005).

In order to get a better understanding of the importance and contribution of point source entries to surface waters the POint Source SUrface waters Model (POSSUM) was developed. From the first results it shows that comparing the arable farming activities; filling of spray tanks, internal cleaning and external cleaning of spraying equipment, shows that internal cleaning contributes most to terbuthylazine concentrations in local surface waters. For fruit growing external cleaning seems to contribute most to the imidacloprid concentrations in surface water. These results pinpoint the activities where losses have to be reduced and where appropriate cleaning methods need to be implemented.

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