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Identification and quantification of point sources of surface water contamination in fruit culture in the Netherlands

By M WENNEKER[1], W H J BELTMAN[2], H A E DE WERD[3] and J C VAN DE ZANDE[4]

[1]*Wageningen University & Research Centre - Applied Plant Research, Research Unit Fruit, P.O. Box 200, 6670 AE Zetten, The Netherlands*
[2]*Wageningen University & Research Centre – Alterra, P.O. Box 47, 6700 AA Wageningen, The Netherlands*
[3]*Wageningen University & Research Centre - Applied Plant Research, Research Unit Flower Bulbs, P.O. Box 85, 2160 AB Lisse, The Netherlands*
[4]*Wageningen University & Research Centre – Plant Research International (WUR-PRI), P.O. Box 16, 6700 AA Wageningen, The Netherlands*
marcel.wenneker@wur.nl

Summary

Measurements of pesticide concentrations in surface water by the water boards show that they have decreased less than was expected from 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 fruit culture. From a survey it was concluded that the majority of fruit growers do not posses the mandatory equipment regarding filling and cleaning of sprayers. This creates a potential environmental risk for surface water contamination. Further research is focused on: internal and external cleaning of sprayers, environmental impact of the washings, discharge of transport water from fruit sorting installations, and bioremediation systems for processing contaminated water.

Key words: Point source pollution, pesticides, surface water, sprayer cleaning, biobeds, fruit grading

Introduction

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 major direct losses of pesticides to the environment (Basford *et al*., 2004; Debaer & Jaeken, 2006*a,b*; De Wilde *et al*., 2007; Jaeken & Debaer, 2005; Wenneker, 2004). 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; Kreuger & Nilsson, 2001; Mason *et al*., 1999). Over the past years, several field surveys and measurements campaigns tried to quantify the relative importance of various practices and actions in the contamination of water by PPP (Bach *et al*., 2005; Huber *et al*., 2000; Kreuger & Nilsson, 2001; Müller *et al*., 2002).

In the Netherlands, legislation is introduced for the reduction of the contamination of plant protection products to soil, surface water and air. In the last decades 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 are introduced, to minimize the risk (Water Pollution Act, Plant Protection Act). However, measurements 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. Since the model does not take point sources into account for fruit culture we can assume that the impact of point sources is underestimated. Also, single events, such as spilling of spray liquid, might have strong implications for the environment, as low concentrations (µg L^{-1}) are often harmful to the aquatic ecosystem.

In this paper, results are presented of a project that has recently started to quantify and qualify possible point source pollution risks in fruit culture.

Materials and methods

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. The inquiry was used to gain insight into practices such as applied spraying pressure, spray volume, internal and external sprayer cleaning activities, handling of waste water *et cetera*. In addition, several farms were visited to examine filling and washing locations, and to discuss the function, maintenance and adjustment of sprayers and nozzles. 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.

Results

Watercourses and drift reducing methods

Fruit growing in the Netherlands is characterized by the presence of many waterways near orchards. In this perspective, spray drift reduction has been a key issue over the past decades. Recently, new legislation is set into force (VW *et al*., 2007). Fruit growers have to achieve 90% drift reduction (compared to standard spray applications with a cross flow sprayer). At this moment 7 drift mitigation measures for fruit growing are accepted by water control authorities; e.g. crop free zone of 9 m, windbreaks (hedgerows), tunnel spraying and specific coarse droplet applications. Other initiatives taken to reduce pesticide emissions are mandatory sprayer inspections, recycling of empty containers and licensing of sprayer operators.

In this inquiry, 98% of the fruit growers had at least one orchard bordering a watercourse. Windbreaks (mainly Alder-species) were present on all farms. In those cases, where windbreaks were lacking, drift reducing nozzles in combination with single sided spraying of the outer tree row was used as a drift reducing measure.

Spraying machines

In the Netherlands, most fruit growers use cross flow sprayers which is in contrast to many other countries where axial fan sprayers are mostly in practice; for example, in Belgium 50% of the sprayers are axial fan sprayers (Debaer & Jaeken, 2006*b*). In our inquiry amongst fruit growers, 81% and 17% of the fruit growers used cross flow sprayers and axial fan sprayers, respectively. In general, spray machines were mounted with nozzles producing fine droplets (e.g. Albuz lilac, brown or yellow), with a spray volume of approximately 200–250 L ha^{-1}.

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 (semi-) impervious material. In 20% of the farmyards, a stream or watercourse was present within 10 m. The inquiry revealed that, though compulsory, 66% of the locations did not posses the mandatory equipment, such as an impervious floor for filling and cleaning with a collection unit.

Cleaning of sprayers – internal cleaning

Internal cleaning of the complete sprayer -,including the tank,- is common practice in arable farming, as herbicides, insecticides and fungicides are mostly sprayed with the same sprayer. In contrast, in fruit growing, herbicides are applied with specific spraying machines. Hence, sprayers for orchard spraying 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 stored for the winter period.
However, cleaning of the pumps, hoses and nozzles is common practice at the end of the spraying day. Nearly 95% of the growers will perform these routines. This activity is carried out in the orchard, with water from the clean water tank. Spray remnants are sometimes stored until the next spray application. None of the fruit growers discharge spray remnants at the farmyard.

Table 1. *Frequency of internal cleaning of complete sprayer including the tank (times/year)*

Frequency	**Farms (%) (n=41)**
0	12
1	51
2	20
3	7
4	2
5	2
>5	5
Total	100

Cleaning of sprayers – external cleaning

The majority of the fruit growers (78%) clean the outside of the sprayer more than once a year. In certain regions, external cleaning is carried out after each spraying day. The reason is that these fruit growers use public roads to reach their orchards. In 70% of the cases, external cleaning is carried out at the farmyard. However, only 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 system that transports fruit in water. This is to avoid the damaging of fruit during the sorting and grading process. During the period that apples and pears are conveyed in this transporting water that fraction of pesticide in and on the fruits will be transferred into this water (Beltman *et al*., 2007). Concentrations of 550 µg L^{-1} carbendazim, and 160 µg L^{-1} DMST (metabolite of tolylfluanide) have been reported (Beltman *et al*., 2007). An inquiry into the practices of 32 fruit growers, who use the wet sorting system for their own production showed that - on average - 915 tonnes of fruits are sorted annually (range from 150–2500 tonnes). In most cases 50–80 tonnes were sorted weekly, in a 20 week

Table 2. *Frequency of external cleaning of complete sprayer (times/year)*

Frequency	Farms (%) (n=41)
0	2
1	10
2-5	37
6-10	12
11-15	12
16-20	15
> 20	2
Total	100

period. Discharge and replenishing of transport water (3–4 m^3) occurred weekly.

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 regions with significant numbers of fruit sorters/graders this contributes significantly to point source contamination.

Discussion

Quality standards for drinking water regarding pesticide concentrations are specified by the EU directive with a maximum residue of 0.1 µg L^{-1} for an active ingredient and 0.5 µg L^{-1} for the total pesticide load (98/83/EEC). Water boards use quality standard based on eco-toxicological risks. These differ between pesticides; e.g. atrazine 2.9 µg L^{-1}; carbendazim 0.5 µg L^{-1}; pirimicarb 0.09 µg L^{-1}, and fenoxycarb 0.0014 µg L^{-1}. In the Netherlands, the surface water quality is continuously monitored and results are available on the internet (CML, 2007). Maps chart where and at what concentrations pesticides are found in the surface water at a network of surface water measuring points. Several fruit culture related pesticides; e.g. imidacloprid, dithianon and carbendazim have been identified as problems. Computer Modeling is also used to estimate the possible risk of environmental contamination by pesticides (Anon., 2007). However, the measurements of the water control organizations showed that the decrease in pesticide concentrations in surface water was less than was expected based on that 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.

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 most direct losses of pesticides to the environment. Single events, such as spilling of spray liquid, might have strong implications for the environment, as low concentrations (µg L^{-1}) are often harmful. Therefore, point sources should be regarded as potential sources of surface water contamination. However, although the relevance of different sources should be clear, the quantification of pathways is difficult (Bach *et al*., 2001, 2005).

In the Netherlands, the number of spray applications in apple and pear growing can be as high as 20–30 per year. Assuming an average spraying volume of 200 L ha^{-1} and an average of 15 ha treated with a 1000 L tank, this results in 60–90 filling events per growing season. These are 60–90 occasions that could create point source pollution. Also transportation of a filled or externally contaminated sprayer to the farmyard or the orchard might be an environmental risk. This underlines the necessity for inspection of sprayers to reduce the risk for point sources by leaking hoses and dripping nozzles.

The farmyard appears to be the most important location for filling and external cleaning of the sprayers. The potential risk for point source contamination is determined by the characteristics of the farmyard surface and associated drainage, and grower behavior. In this survey 80% of the farmyards consisted of (semi-) impervious material. Also 20% of the farm yards had surface water within 10 m distance.

In general, external cleaning of sprayers is not carried out frequently and the efficiency of this cleaning is unknown. Hence, the quantity of the external residues on a sprayer is unknown, and therefore it is not possible to assess the environmental fate of these residues. Ramwell *et al*. (2004) suggests that regular cleaning would reduce the risk of build-up of residues and overdosing during cleaning activities or rain would be minimized. Further research is required to investigate the efficiency of cleaning methods and the environmental impact of washings. The residues can also have potential health implications for the persons coming into contact with the sprayer (Ramwell *et al*., 2005).

Internal cleaning of sprayers in the Netherlands is mostly limited to rinsing of pumps, supply hoses and nozzles after spray applications. This is mainly done to avoid clogging of nozzles. This activity is carried out with water from a clean water tank and in the orchard. The minority also rinses the tank. So, fitting new sprayers with clean water tanks and internal cleaning devices will encourage farmers to clean in the last field of use.

Transporting a contaminated sprayer back to the farmyard presents questions to the safety of the wash site and the destiny of the waste water from the washings. These point source pollutions can easily be prevented by cleaning the sprayer in the last field of use (Wehmann, 2006). It is important to note that spray remnants (high concentrations of PPP) are not discharged in the field or at the farmyard, but stored in the tank until the next spray application.

Cleaning the sprayer in the farmyard has been identified as a potential significant source of pesticides detected in surface waters (Fischer *et al*., 1998). Contaminated water is washed from the paved farmyard by rain or wash water entering the sewage system or a watercourse directly. A possible solution to this problem is to collect PPP-contaminated waste water in a tank and - followed by a waste water treatment - to degrade the contaminants from the water fraction. Various treatment systems exist or are under investigation. Systems that work on physical and/or chemical principles can be very effective. However, they are in most cases too expensive and difficult to operate for average farmers. Systems that that rely on biodegradation of PPP, like the biobed (Torstensson, 2000) the biobed/phytobac (Basford *et al*., 2004) and the biofilter (Pussemier *et al*., 2004), are often low-cost and easy to use. In Belgium, various phytobac and biofilter systems are tested (Debaer & Jaeken, 2006*a*; Jaeken & Debaer, 2005). An extensive overview of on-farm bioremediation systems is given by De Wilde *et al*. (2007).

From the survey amongst fruit growers it is estimated that fruit growers in the Netherlands produce approximately 500–1000 L of waste water annually in the process of filling and cleaning the sprayer. These quantities appear to be suitable for decontamination via biofilters (De Wilde *et al*., 2007). For the decontamination of waste water from fruit grading and sorting systems solutions as filtration over active carbon (e.g. Sentinel), or the Carbo flow process (Maaskant, 1993) are more suitable, due to the high volumes of waste water.

The inquiry revealed that a significant number of fruit growers do not work according to the legislation for filling and washing stations. It is, however, important to recognise the main reasons for this situation; e.g. economical considerations or ignorance. In general, it looks that campaigns to increase the farmer's awareness should be intensified, possibly in cooperation with initiatives such as TOPPS 'Train the Operators to Prevent Pollution from Point Sources' (TOPPS, 2007). It should be emphasized that careless handling of spraying equipment and material on paved or impervious areas, such as farmyards, leads to point source contamination of the surface water.

Conclusions

In this paper, results are presented of a recently started project for the quantification and qualification of possible point sources in fruit culture. From on farm surveys, it was concluded that the majority of the fruit growers do not posses the mandatory equipment regarding filling and cleaning of sprayers. This results in high potential risk of surface water contamination. Literature on methodologies about measuring external contamination of sprayers is quite extensive. However, data about total pesticide loads during the spraying season are very limited. Therefore, risk assessments about pesticides in washing water are difficult, and measurements are required. Part of the project is to identify possible cost effective clean up systems; e.g. biofilters or biobeds. Based on the results, further research is focused on: internal and external cleaning of sprayers, environmental impact of the washings, discharge of transport water from fruit sorting installations, and on farm systems for processing contaminated water. In our opinion, on-farm bioremediation systems can improve the quality of surface water dramatically.

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