Catchment scale risk-mitigation experiences – key issues for reducing pesticide transport to surface waters

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ABSTRACT

A monitoring project was initiated in 1990 aimed at investigating pesticide sources, pathways and occurrence in stream water within an agricultural catchment. The work was carried out in close co-operation with the farmers operating in the selected area. Since 1995, farmers in the catchment have received extensive information regarding best management practises for pesticides adapted to local conditions on the farm. The program has continued during the entire 1990's. The results demonstrate a considerable reduction in overall pesticide findings in the stream, with concentrations down by more than 90%. The most notable decrease in concentration levels and transported amounts occurred in 1995, coinciding with the onset of the site specific information efforts. The decreasing levels of pesticides in stream water from the catchment area can primarily be attributed to an increased awareness amongst the farmers on better routines for the correct handling of spraying equipment and application procedures, including the practice of total weed killing on farmyards.

INTRODUCTION

The occurrence of pesticides in Swedish aquatic environments was initially observed during the mid-1980's, when monitoring studies first revealed the frequent findings of agricultural pesticides in streams and rivers (Kreuger & Brink, 1988). The findings were more frequent and the concentrations higher than had been anticipated based on earlier laboratory and field studies. As a result, a great deal of attention during the late 1980's focused on diffuse pollution of pesticides from agricultural fields to ground- and surface waters.

To explore the reasons for pesticide contamination in stream water it was decided to initiate a monitoring program, working beyond the well-controlled conditions (e.g. laboratory, lysimeters, field plots) under which, for good reasons, many environmental fate studies are done. The intention was to investigate pesticide sources, pathways and occurrence in stream water within a small agricultural catchment. The work was carried out in close co-operation with the farmers operating in the selected area. The program was started in 1990 and has continued during the entire 1990's. In this paper we describe risk-mitigation efforts implemented in the catchment since 1995 and present the results of pesticide occurrence in stream water leaving the catchment during a 10-year period.

MATERIAL AND METHODS

Monitoring program

The Vemmenhög catchment is located in the very south of Sweden with undulating topography and glacial till-derived soils. The total catchment area is 9 km^2 (900 ha) consisting of 95% arable land, with four major crops constituting ca 95% of the cropped area (winter cereals, spring cereals, winter oilseed rape, sugar beets). None of the crops are irrigated. Sandy loam and loamy soils dominate the catchment. The climate in the region is maritime with mean annual temperature and precipitation being 7.2°C and 662 mm, respectively. Extensive drainage systems have been installed in the catchment collecting tile drainage and also runoff water from surface runoff inlets, which are often used as inspection wells and located in the lowest-lying positions in the landscape along the tile drains in the field. Surface runoff inlets can also be found along roads and in some farmyards.

Information on crops, pesticide handling and usage within this area were collected annually through interviews with the farmers. The total amount applied each crop rotation was, on average, 1300 kg of active ingredient (AI) and has been quite constant for the past seven years (Figure 1). About 35 different substances were used each year and ca 90% (by weight) of these were included in the analyses (Figure 1). Since 1990, an automatic water sampler collected time integrated water samples during May-September/November at the outlet of the catchment. Also, at different sites within the catchment, samples have been collected to assess point sources. The analyses included up to 50 different pesticides. A more detailed description of the catchment, pesticide usage, data collection and analytical methods has been reported elsewhere (Kreuger, 1998).

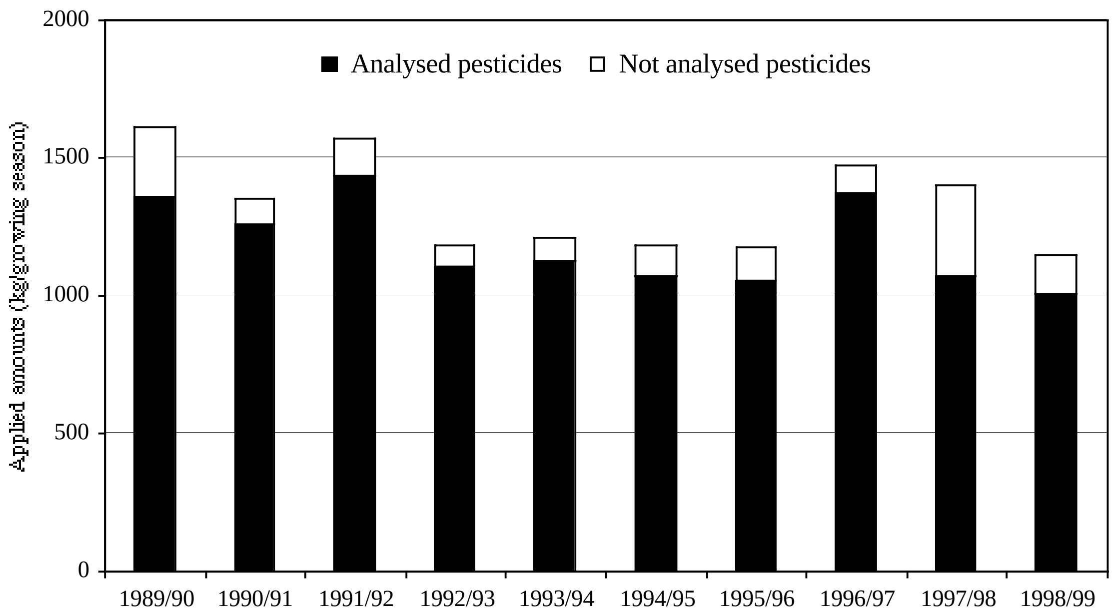

Figure 1. Total amount of pesticides applied in the catchment area during the growing seasons 1989/90-1998/1999. The columns are divided to show the distribution between pesticides included and not included in the analytical procedures.

Mitigation efforts - Implementation of best management practices for pesticides

General measures:

In 1997, new legislation was introduced with stricter demands regarding pesticide use and application. The legislation included requirements for spray-free buffer zones, regulations concerning the use of pesticides in water protection areas and compulsory book-keeping of pesticide applications. Also in 1997, an information campaign called "Safe Pesticide Use" was launched on initiative of the farmers organisations in a joint collaboration with five other organisations and authorities. The focus was to raise the awareness amongst farmers of the environmental and health risks when filling and emptying the spraying equipment and the risks for wind- and soil losses.

During 1998-1999, a program named "Sustainable conventional agriculture" was launched with EU and national money giving, mainly, small and mid-sized farmers economical compensation during a 5-year period when agreeing to comply with risk reduction measurement within agriculture. This included, for example, demands for the farmers to have spray-free buffer zones, a safe place for filling and cleaning the sprayer (i.e. on a biobed, on a concrete area with collection of the liquid or in the field on active arable soil), inspection of the sprayer and training courses.

In 1999, the Swedish sugar-beet growers and the sugar industry agreed to introduce an Environmental Management System as an integrated part of the contract for growing sugar-beets in order to improve all environmental aspects of sugar-beet growing, including the safe use of pesticides. These two last programs were aimed at giving growers an economic incentive to minimise risks when using pesticides.

Site-specific measures:

In late 1994 a meeting with farmers operating in the catchment was first held giving practical advice on the safe use of pesticides and risk reduction strategies. The advice was primarily focused on explaining to the farmers possible sources for the contamination and giving positive formulated examples how to decrease them. Farmers attending the meeting were offered, free of charge, a personal visit on the farm.

Shortly following the meeting, about one third of the farmers was visited. The farmers were guaranteed secrecy to make it easier to discuss problems. The advises were adjusted to local conditions on the specific farm, directed to safe storage of pesticides, how to avoid point sources when filling and cleaning sprayers and appropriate parking ground for the sprayer. Moreover, information about buffer zones to wells, drainage wells and open ditches when filling and spraying as well as a discussion about spraying herbicides on farmyards and other areas with low organic matter took place. The voluntary inspection of sprayers in use was also encouraged to reduce the risks for point sources caused by leaking hoses and dripping nozzles.

Moreover, in early 1995, staff involved in this work met with salespeople selling plant protection products to farmers in the region, providing them with information and practical training on the safe use of pesticides. Since these people often meet with the farmers out on the farm it was equally important to give them the same kind of information as the farmers.

Meetings with the farmers in the area have continued, providing them with feedback of the results of the monitoring program as well as new knowledge and recommendations regarding sources of contamination and practical solutions. Also, other farmers operating in the area were visited during the following years. All visits by the staff were made only on request by the farmer.

RESULTS AND DISCUSSION

A total of 39 pesticides (31 herbicides, 4 fungicides and 4 insecticides) and 3 herbicide metabolites have been detected in stream water samples collected during the 10-year period, with ca 10 pesticides having a detection frequency of >50% during individual years. Monitoring results obtained during the first years revealed elevated concentrations (up to 200 µg/l for single pesticides) and also pesticide residues entering the stream without preceding rainfall clearly a result of accidental spillage when filling or cleaning the spraying equipment on surfaces with drainage in direct connection to the stream. Investigations also demonstrated very high concentrations (up to 2000 µg/l) in run-off water entering surface water inlet wells on farmyards close to areas where filling of sprayers had taken place and, also, where the farmyard had been treated with herbicides to keep it free of weeds. Calculations showed that pesticide application for weed control on farmyards alone contributed to ~ 20% of the overall pesticide load in stream water. A more detailed presentation of the results have been reported elsewhere (Kreuger, 1998).

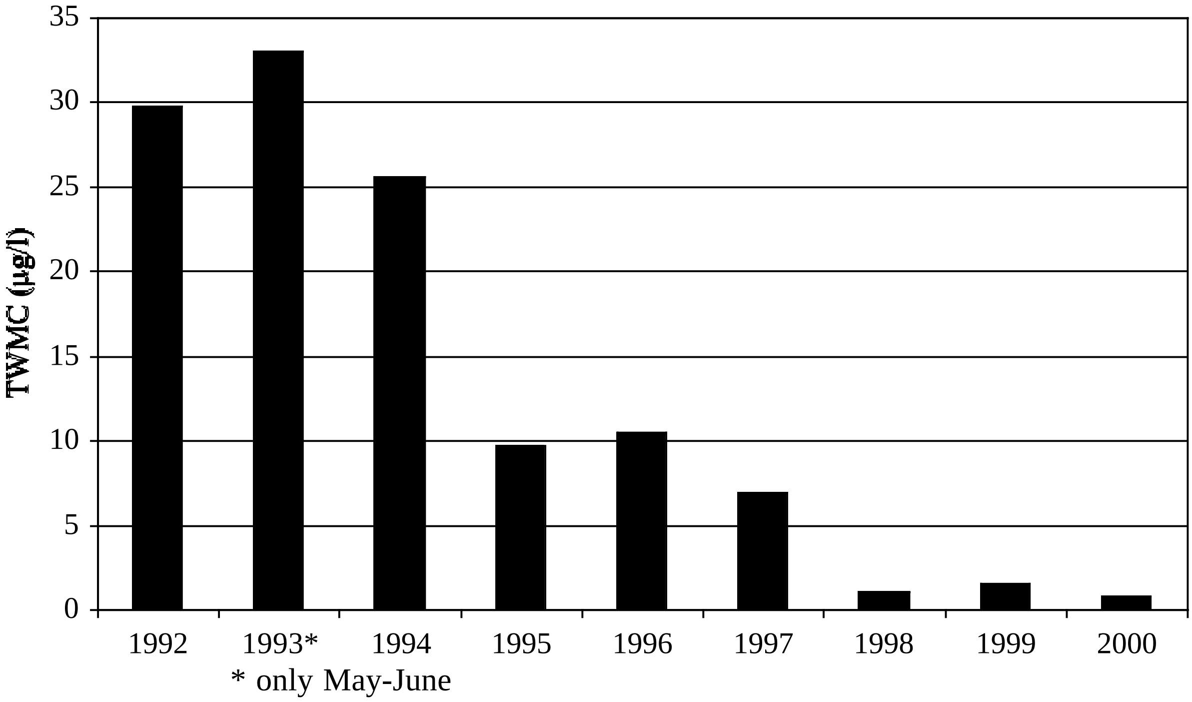

Figure 2. Time-weighted mean concentration (TWMC) for the sum of pesticides in stream water during May-September 1992-2000.

During recent years there has been a decrease in pesticide concentrations in stream water. The results demonstrate a considerable reduction in overall pesticide findings in the stream, with concentrations down by more than 90% (Figure 2). Also, transported amounts have declined significantly during the past 10 years (Figure 3). The most notable decrease in concentration levels and transported amount occurred in 1995, coinciding with the onset of the information efforts that first took place in the area before the 1995 application season.

The decreasing levels of pesticides in stream water from the catchment area can primarily be attributed to an increased awareness amongst the farmers on better routines for the correct handling of spraying equipment and application procedures (including the practice of total weed killing on farmyards). During late 1998, the first biobed (Torstensson & Castillo, 1997) was constructed in the catchment and since 2000 all farmers use either a biobed, a concrete area with collection of liquid or active arable soil when filling and cleaning the sprayer. The use of all kinds of herbicides on farmyards, also those not registered for application on yards and hard surfaces, has discontinued and today only mechanical methods and glyphosate (which is registered for those purposes) is used on these areas.

However, there has also been a slight change to the usage of pesticides active at lower doses, although, as can been seen in Figure 1, the total amount used in the area has been quite constant for the past seven years. Moreover, the number of farmers applying pesticides in the area has gradually decreased (ca 50% since 1990), resulting in fewer possible point sources.

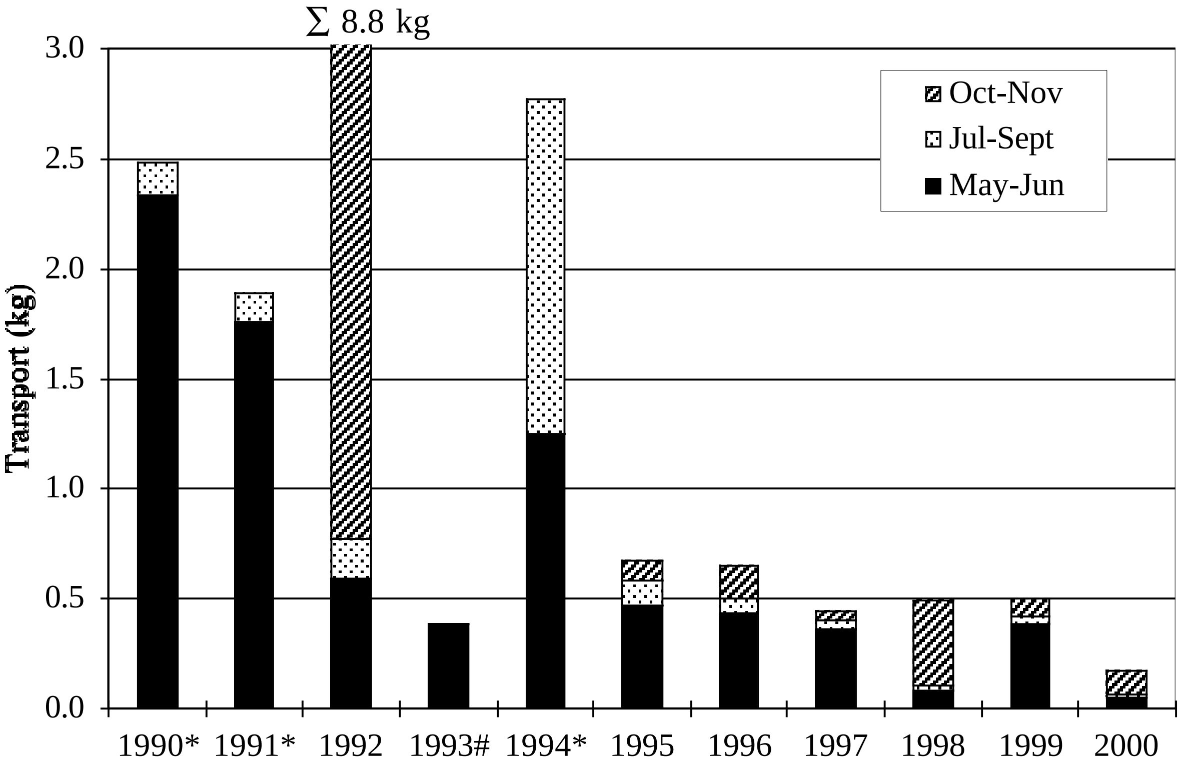

Figure 3. Total amount of pesticides transported in stream water during 1990-2000. The columns are divided to show different time periods. * Sampled only during May-September. # Sampled only during May-June.

Another factor is the increased use of glyphosate, both in the field and as a total weed killer on farmyards, which has more than doubled and is not reflected by the monitoring results since glyphosate has not yet been included in the analytical procedures.

CONCLUSIONS

Based on the study results it can be concluded that the occurrence of pesticides in surface water was a result of (*i*) natural processes influenced by soil and weather conditions, together with the intrinsic properties of the compound, as well as (*ii*) point sources such as spills and non-agricultural application (e.g. in farmyards).

In order to reduce the level of pesticides in streams and rivers, more effort should be directed towards education and information to those using pesticides with the aim of minimising applied quantities (e.g. by better calibrated spraying equipment and dose adjustment) and to avoid unintentional misuse and spillage.

The farmers were more willing to "accept" information when given personally and adjusted to site specific conditions than when received through general letters and pamphlets.

Essential to involve the farmers in the work and give them regular positive feed-back on the progress.

The implementation of agricultural best mamagement practices appears to have a positive effect on water quality in this area. However, both stream and ground water monitoring will be continued for several years to assess more definitively the changes in water quality.

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