Watershed monitoring to address contamination source issues and remediation of these contaminants

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ABSTRACT

The Big Blue River Basin is located in southeastern Nebraska and northeastern Kansas and consists of surface water in the Big Blue River, Little Blue River, Black Vermillion River, and various tributaries draining 24,968 square kilometers. Approximately 75% of the land area in the basin is cultivated cropland. The Big Blue River flows into Tuttle Creek Reservoir near Manhattan, Kansas. Releases from the lake are used to maintain streamflow in the Kansas River during low flow periods, contributing 27 percent of the mean flow rate of the Kansas River at its confluence with the Missouri River. Tuttle Creek Reservoir and the Kansas River are used as sources of public drinking water and meet many of the municipal drinking water supply needs of the urban population in Kansas from Junction City to Kansas City.

Elevated concentrations of pesticides in the Big Blue River Basin are of growing concern in Kansas and Nebraska as concentrations may be exceeding public drinking water standards and water quality criteria for the protection of aquatic life. Pesticides cause significant problems for municipal water treatment plants in Kansas, as they are not appreciably removed during conventional water treatment processes unless activated carbon filtering is used. Pesticides have been detected during all months of the year with concentrations ranging up to 200 µg/L. If high concentration in water is associated with high flow conditions then large mass losses of pesticides can flow into the water supplies in this basin. This paper will investigate the use of a monitoring program to assess the non-point source of this atrazine contamination. Several practices have shown ability to remediate or reduce these impairments.

INTRODUCTION

Atrazine herbicide (2-chloro-4-ethylamino-6-isopropylamino-s-triazine) has been used widely in Kansas and Nebraska since the 1960s for selective control of broadleaf and grass weeds in corn (*Zea mays* L.) and grain sorghum (*Sorghum vulgare* (L.) Moench). Another factor along with atrazine effectiveness is the low cost on a per-hectare basis. It provides effective weed control when applied to fields under a wide range of practices that includes conventional tillage with limited residue cover as well as fields with residue levels near complete cover with no tillage. Added benefits include application flexibility, which might include the herbicide applied at an early preplant, preplant incorporated, crop preemergence, or postemergence. The impact of atrazine use in agriculture on water quality is a growing public concern.

During 1992, the U. S. Environmental Protection Agency (EPA) established a new drinking water standard for atrazine, which prior to that date had been proposed to be 150 μg/L. This new standard called the maximum contaminant level (MCL) was set at 3 μg/L. The MCL is calculated based on an annual average of available monitoring data. Limited monitoring data in Kansas indicated that a majority of the state surface water in streams and lakes exceeded the new MCL. An audit of the monitoring data during 1998, showed that only six (6) Kansas lakes continued to show impairment from atrazine.

The Big Blue River Basin is located in southeastern Nebraska and northeastern Kansas and consists of surface water in the Big Blue River, Little Blue River, Black Vermillion River, and various tributaries draining 25,900 square kilometers. Approximately 75% of the land area in the basin is cultivated cropland. The Big Blue River flows into Tuttle Creek Reservoir near Manhattan, Kansas. Releases from the lake are used to maintain streamflow in the Kansas River during low flow periods, contributing 27 percent of the mean flow rate of the Kansas River at its confluence with the Missouri River (Dugan et al., 1991). The largest population centers in Kansas are supplied by surface water from the Kansas River. Clean Water Act monitoring for this water supply has consistently exceeded the drinking water standard for atrazine. This monitoring requires at least an annual quarterly sample to be taken for these drinking water supplies. These data would indicate that in most cases quarterly monitoring does not accurately represent conditions in the water supply.

This paper will investigate the use of a monitoring program to assess the non-point sources of this atrazine contamination. Several practices will be examined that have shown ability to remediate or reduce these impairments.

MONITORING METHODS

The objectives of this study will provide information that can be used to, (1) determine seasonal and annual concentrations of atrazine, (2) determine seasonal and annual loading of atrazine, and (3) rank locations in the watersheds based on their contribution to the TMDL. The project objectives will be met by collecting and analyzing water samples from 10 stream sites in the Big Blue River Basin. Table 1 describes these sampling locations.

Elevated concentrations of atrazine in the Big Blue River Basin are of growing concern in Kansas and Nebraska as concentrations have been shown to exceed the public drinking water standards and water quality criteria for the protection of aquatic life. Atrazine causes significant problems for municipal water treatment plants in Kansas as it is not appreciably removed during conventional water treatment processes unless activated carbon filtering is used (Miltner et al., 1989). Atrazine has been detected during all months of the year in the Big Blue Basin with concentrations ranging from 0.1 to 166 μg/L in Nebraska from 1987 to 1992 (Frankforter, 1994). More recently, in the Recharge Lake watershed near York, Nebraska, atrazine concentrations as high as 854 μg/L were detected following a May 1995 runoff event (Upper Big Blue NRD, 1995).

Table 1. Blue River Basin sampling locations and characteristics.

Station Number	Location	Drainage Area (km^2)	Percent of Basin
1	Crete, Nebraska (Big Blue River)	7034	28
2	Beatrice, Nebraska (Big Blue River)	9919	39
3	Barneston, Nebraska (Big Blue River)	11318	45
4	Marysville, Kansas (Big Blue River)	12372	49
5	Deweese, Nebraska (Little Blue River)	2535	10
6	Fairbury, Nebraska (Little Blue River)	6086	24
7	Hollenberg, Kansas (Little Blue River)	7127	28
8	Barnes, Kansas (Little Blue River)	8609	34
9	Frankfort, Kansas (Black Vermillion River)	1061	4
10	Manhattan, Kansas (Tuttle Creek Reservoir)	24968	100

Sample collection included a protocol of grab sampling when stream flows were at or below normal base flow. Grab samples were collected at each site on a stratified fixed-frequency basis. Grab samples were collected instead of width-depth integrated samples because grab samples greatly reduce sample time and effort and were considered equivalent to depth-width samples in representing stream water quality conditions if the stream can be assumed to be well mixed. Grab samples were collected on a weekly basis from April through September during the runoff season when atrazine concentration variability is the highest, and on a monthly basis from October through March when concentration variability is low.

Automated runoff samplers collected additional samples when stream flows were above base flow conditions. These samplers were set to take discrete samples at uniform times during the runoff hydrograph. To determine the mean atrazine concentration for a particular runoff event, selected discrete samples of runoff that were collected by the automated sampler were composited into a single discharge-weighted sample. Discrete samples were selected to adequately define variations in flow rate and atrazine concentration. The method of computing the discharge-weighted value of each discrete sample to be included in the composite sample was based on the mid-interval method (Porterfield, 1977). Each sampling site was located at an existing United States Geological Survey (USGS) gage station or will have continuous flow meters equipped with the samplers.

MANAGEMENT PRACTICES METHODS

The objective of this part of the study will provide information that can be used to evaluate management practices success in reducing seasonal and annual concentrations and loading of atrazine.

The movement of atrazine from crop fields is determined by the chemical properties of the herbicide and mechanisms that led to its transport. Water quality concerns involve primarily atrazine transport by runoff to surface water and leaching to ground water. The most important chemical characteristics that influence atrazine loss from fields are adsorption and persistence. Solubility of atrazine also plays a role in atrazine losses.

Weakly adsorbed pesticides tend to leave the field in the water and not with soil particles lost in soil erosion. Atrazine is soluble in water and weakly adsorbed in soils, which leads to its loss in water leaving the field and not with eroding soil particles. It has been felt for a number of years that if soil erosion could be reduced that herbicide loss would also be reduced but that is not the case for atrazine (Baker and Laflen, 1979; Hall et al., 1972; Olsen et al., 1998). Because atrazine moves with runoff water leaving the field, the closer the rainfall occurs following atrazine application, the greater the atrazine loss. May through July are the months that have the greatest potential for runoff losses in the Big Blue Basin.

The term persistence refers to how long it takes for a herbicide to break down from chemical decomposition or microbial degradation. The longer a herbicide persists, the longer a herbicide can control weeds. However, the longer a herbicide is present in the environment, the greater the chance it will run off with surface water or leach into the ground water. Atrazine has a half-life of approximately 60 days (Olsen et al., 1998), which means that half the atrazine applied in April or May will be available to the peak runoff periods in the Blue River Basin. These factors are being considered as the primary causes for atrazine concentration in Nebraska and Kansas drinking water. This paper will examine practices that avoid these factors. Application timing, herbicide incorporation, and the use of vegetative buffers are practices that farmers in the Big Blue Basin are using to reduce surface water impairments.

MONITORING RESULTS

During 1998, the sampling stations (Table 1) had an average of 42 samples taken per station. The daily atrazine concentration was calculated by interpolating between discrete sampled concentrations. If the daily concentrations are averaged for the year the annual average concentration for atrazine at Station 1 is 2.84 μg/L, which is slightly below the drinking water MCL (3.0 μg/L).

These concentration peaks occur during the same time frame that represented the peak stream flows. If the daily flowrate is multiplied by the average daily concentration, then multiplied by a factor (0.005383), the result gives the daily atrazine load in kilograms.

The data from all the monitoring stations in the Big Blue River Basin are presented in Table 2. The data for the Big Blue River is near or above the drinking water MCL. These data would also suggest that a majority of the atrazine loading is coming out of the Big Blue River part of the basin. The Big Blue River at Marysville, Kansas represents 49 percent of the drainage area but produces 80 percent of the atrazine loading. If we examine the load per area for the Big Blue River, Station 4 at Marysville, Kansas exceeds the upper stations along the Big Blue River by as much as 1.5 times. Another surprise can be seen if the outflow versus inflow atrazine loading for Station 10, Tuttle Creek Reservoir is considered. The total inflow atrazine load is 11,509 kg while the outflow is reduced to 4,506 kg. This would indicate that Tuttle Creek Reservoir reduces the atrazine loading into the Kansas River by 61 percent.

Table 2. Blue River Basin sampling locations and atrazine annual mass loss (1998).

Station No.	Location	Atrazine Mass Loss (kg)	MCL	Percent of Total
1	Crete, Nebraska (Big Blue)	3819	2.84	33
2	Beatrice, Nebraska (Big Blue)	5333	3.78	46
3	Barneston, Nebraska (Big Blue)	7491	4.20	65
4	Marysville, Nebraska (Big Blue)	9241	4.55	80
5	Deweese, Nebraska (Little Blue)	256	1.46	2
6	Fairbury, Nebraska (Little Blue)	473	1.96	4
7	Hollenberg, Kansas (Little Blue)	791	1.88	7
8	Barnes, Kansas (Little Blue)	1665	2.31	14
9	Frankfort, Kansas (Black Vermillion)	603	2.24	5
10	Manhattan, Kansas (Tuttle Creek Reservoir)	4506	1.27	39

MANAGEMENT RESULTS

If atrazine losses are examined for each of the sampling stations, it was found that over 90 percent of loading occurs during the months of May and June. A number of studies have been performed to examine the application timing of atrazine to avoid the loss window. Farm surveys have shown that most farmers in the Big Blue Basin apply their atrazine in or near the May-June period that is showing the greatest loss potential. Application times examined included fall application, early spring application, and post application. Fall application should be made after harvest during the months of October or November before the ground is frozen. Early spring application should be made in the spring after the soil has thawed and before the primary runoff periods in May and June. The post application would be made after the crop has emerged and before the crop reaches labeled crop height. Post application is made at a quarter of the labeled atrazine rate and requires a chemical weed burn down at planting time, which has a higher cost. Alternative application timing can reduce atrazine runoff losses by 60 to 90 percent.

Chemical incorporation is another practice that farmers have used to apply their herbicides. The problem with this practice is that as the tillage tool incorporates the herbicide it also incorporates the residue cover needed to reduce soil erosion. If tillage is used prior to planting corn or grain sorghum atrazine losses can be reduced by 90 percent.

Vegetative buffer strips along the edge of fields are zones that can contain various forms of vegetation such as grass and trees. The purpose of these buffers is to reduce the runoff flow rate from the field to allow deposition of sediments and nutrients contained on the sediments (Dillaha et al., 1986, 1988; Cooper and Gilliam, 1987). Limited data is available on the effectiveness of these buffers ability to reduce herbicides in the runoff water (Arora et al., 1995). It is important to realize that the vegetation in the buffer does not remove the pesticide from the water passing through the buffer. It is the proportion of the herbicide-containing water that infiltrates into the buffer that reduces the herbicide runoff. Vegetative buffers used in the Big Blue Basin have reduced atrazine loss in runoff from fields by 30 percent.

CONCLUSIONS

This monitoring research suggests that additional management practices are needed in a portion of the Big Blue River Basin. Reducing runoff leaving fields with vegetative buffers combined with proper timing and application method can bring these parts of the Basin into compliance with the current water quality standards.

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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).

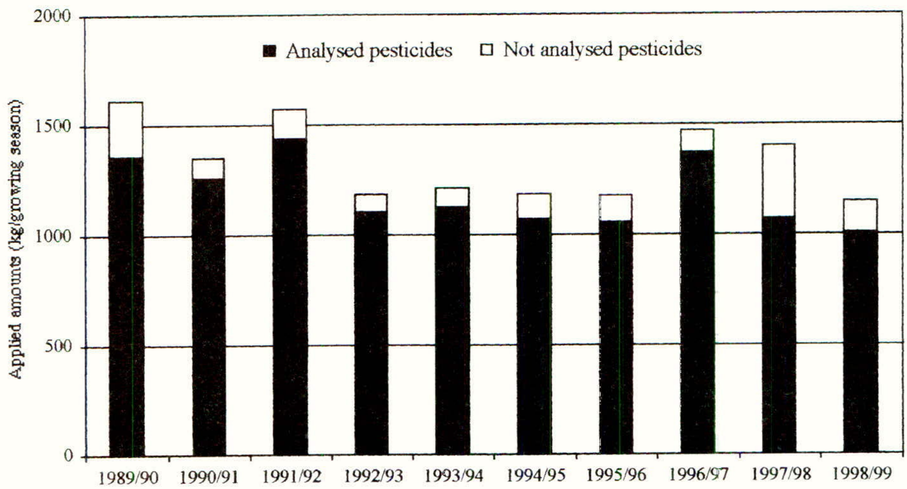

Figure 1. Total amount of pesticides applied in the catchment area during the growing seasons 1989/90-1998/1999. The columns are divided to show the distribution between pesticides included and not included in the analytical procedures.

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 using pesticides.

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) and inspection of the sprayer.

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).

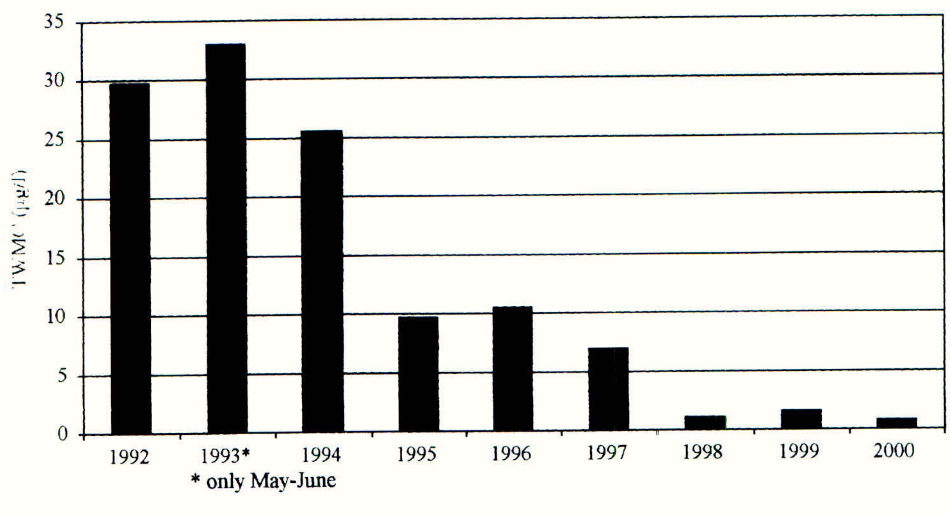

Figure 2. Time-weighted mean concentration (TWMC) for the sum of pesticides in stream water during May-September 1992-2000.

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.

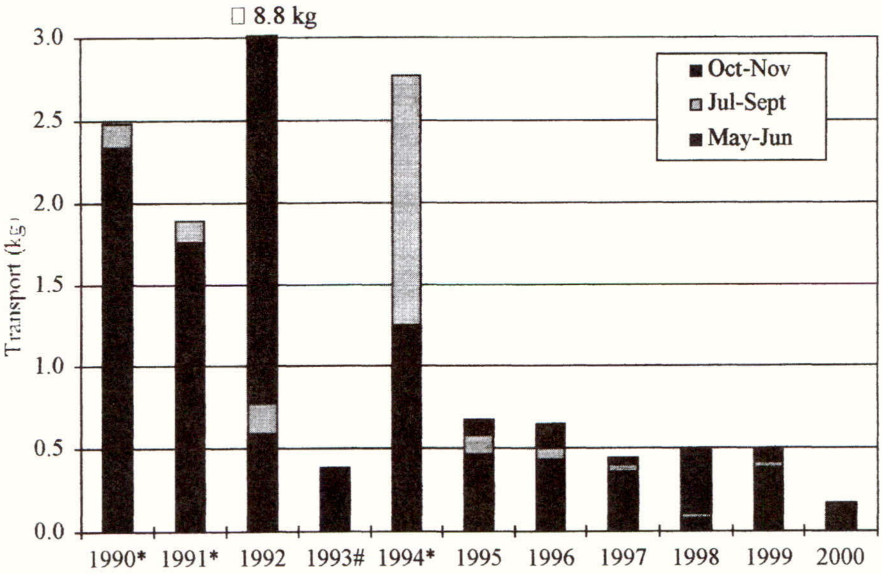

Figure 3. Total amount of pesticides transported in stream water during 1990-2000. The columns are divided to show different time periods.

* 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.

ACKNOWLEDGEMENTS

This study was supported through funds provided by the following organisations: Association of Swedish Plant and Wood Protection Industries, County Government Board in Scania county, DuPont de Nemours (Agro) A/S, Environmental Foundation of the Scania county council, European Union, Federation of Swedish Farmers, Swedish Board of Agriculture, Swedish Environmental Protection Agency and Swedish National Chemicals Inspectorate.

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The effectiveness of a stewardship campaign in Severn Trent Water

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ABSTRACT

Many water companies as part of their commitment to environmental protection have introduced stewardship campaigns. These schemes encourage farmers to consider how their working practices impact on the environment and the measures that can be taken to prevent pollution. It has always proved difficult, given that many factors will impact on a campaign, to evaluate how effective such schemes have been in mitigating the negative impact of farming practices on the environment. This study has chosen to monitor the level of pesticides in a catchment and has used any significant changes as an indicator of the effectiveness of such a stewardship campaign.

In 1999, the levels of pesticide in a catchment were monitored. The results of this monitoring were presented to farmers in the area and advice on how to reduce the levels of pesticides entering the water given. The following years monitoring showed a reduction in general levels of pesticides, however there still remained some high peaks of pesticide believed to be from point source pollution events such as drips or spillage. The results were again presented to the farmers and further advice on better practice given.

This year's study has continued to monitor the area and has also included the monitoring of an adjoining catchment of similar size, with a similar farming regime but where at present no advice has been given to the farmers. This study will allow a direct comparison between the two areas which will show how effective our farmsafe campaign has been and additionally whether or not such campaigns are viable methods to use to reduce pesticide losses to water. The study will allow us to consider ways in which the campaign can be improved with a view to extending the scheme to other problem areas within other catchments.

INTRODUCTION

Many raw drinking water resources in the UK have shown a range of pesticides to be present including atrazine, simazine, isoproturon (IPU), diuron, mecoprop and bentazone. To maintain the drinking water standard such residues are removed by expensive treatment. Clearly a reduction of contamination levels would lower these costs and present the need for new treatment. A number of projects targeted at the end-user aim to reduce contamination by encouraging best practice. These have had limited success. The experience gained has shown that to further reduce and sustain low levels of contamination requires stronger incentives and full participation of all users.

Severn Trent Water (STW) have a comprehensive monitoring programme which gathers information on pesticide usage in their catchments and measures levels at abstraction points.

The company has developed and implemented a Farmsafe stewardship campaign, in collaboration with ADAS, EA, FWAG and NFU, to encourage best practice in areas where potential or actual problems have been identified. Despite these efforts pesticides are still being found in some raw waters at unacceptable levels.

Campion Hills Treatment Works, Leamington Spa has the highest pesticide loading of all STW's surface water works. Therefore Severn Trent chose this catchment to evaluate the effectiveness of the Farmsafe campaign. Several recent studies have investigated the appearance of IPU, a residual herbicide, in water. Less is known about Mecoprop, a more soluble herbicide identified as relatively difficult to remove from water. Therefore this campaign was targeted to the application period of Mecoprop. Comparison of results with previous IPU studies will help to identify factors common to pesticide applications in general and thus indicate areas where improvements may be particularly effective.

The Leam catchment covers 373km^2 with one of the highest agricultural coverages in the STW region. Many crops are planted in close proximity to the river on soils with high runoff potential and susceptibility to flooding increasing possible pesticide losses to water. The full catchment was considered too large for a detailed study of pesticide usage so in 1999 a pilot investigation commenced along the River Itchen, a tributary of the Leam. The Itchen catchment is about 37% of the Leam catchment and its land use and topography is typical of the whole area. The pilot study identified an area of the Itchen where high levels of pesticide had occurred and therefore this was a suitable target for a Farmsafe presentation the following year. Local farmers were invited to meetings (with a choice of dates) where the monitoring results were presented and advice on reducing the levels of pesticide loss to water was given. Pesticide levels in the Itchen were monitored during the following season's applications. Pesticide levels were generally reduced. However, some peak concentrations in water remained. These were probably from point sources such as drips or spillage, with the overall reduction mainly reflecting lower contamination from diffuse sources (leaching). These results were presented to the farmers with further advice on good practice.

In 2001, the monitoring study in the Itchen catchment was continued but farmers were not reminded of Farmsafe. As a further comparator monitoring was extended to the upper Leam catchment (upstream of the confluence of the Leam and the Itchen at Marton). The upper Leam comprises 2 distinct legs which join to the south of Draycote Water. Sample points along both these legs allowed comparisons of the specific contribution of each. In addition, information from this 'new' area, which has a similar topography and land use, was compared with the current and previous data from the Itchen, to evaluate the relative success of the Farmsafe campaign.

METHODS

Sample points

9 sample points were chosen for monitoring across the Leam catchment. These were chosen to represent conditions over the full length of the river, taking into account differences in land use and crop species. Consideration was also given to access, safety and repeatability of sampling. All points were on bridges across the river allowing midstream samples to be taken.

Sampling period

The study was timed to coincide with the application period for Mecoprop, expected to approximate to the months April and May. However, this years application period was uncertain due to prolonged wet weather during winter and early spring and because of problems for spray contractors due to Foot and Mouth Disease precautions. A sample plan, covering late March to early June, was updated weekly based on information from the Met Office, spray contractors, farmers and visual evidence in the catchment. This ensured samples were taken when pesticides were most likely applied.

Sampling Technique

Midstream samples were collected from each point in 1-litre glass bottles. After direct delivery to the analytical laboratory, samples were stored in refrigerators.

Sample Analysis

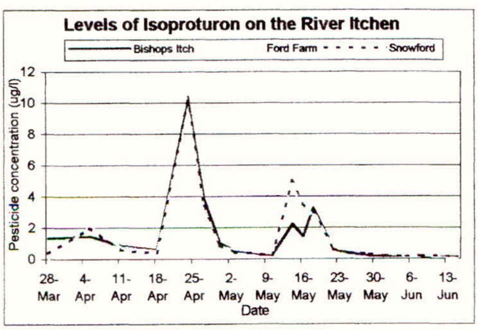
Samples were analysed by Severn Trent Laboratories using the System for the Automated Monitoring of Organic Substances (SAMOS). This equipment allowed simultaneous analysis of 10 compounds.
Turnaround time, no more than 1 week, was reduced towards the end of the study to allow the decrease in pesticide levels to be monitored closely.

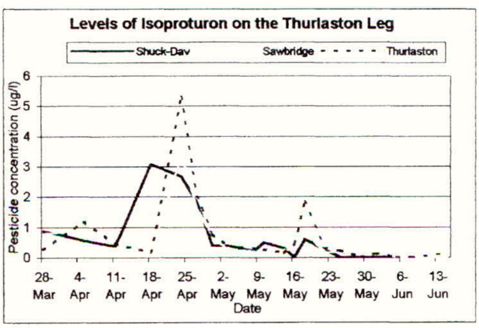
The integrity of the SAMOS analysis was measured using conventional laboratory analysis of 3 additional samples taken from one of the sample points each week for Triazines, Sub Ureas and Acid Herbs. Results were compared to those produced by SAMOS.

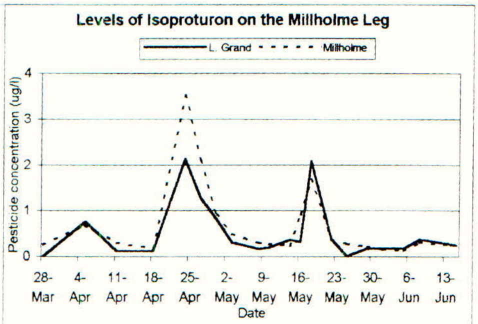
RESULTS

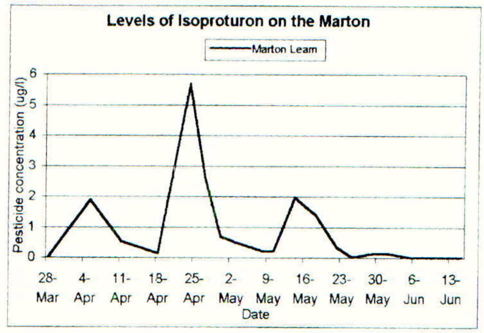
Pesticides were recorded at all sample points during the study. IPU, Mecoprop and Simazine were most prevalent. IPU and Mecoprop levels were similar to previous years but Simazine was found at much higher levels in the Itchen. MCPA and Chlorotoluron were recorded at low levels at some sample points but are not presented. The graphs in Figure 1 show the levels of IPU, Mecoprop and Simazine at each sample point.

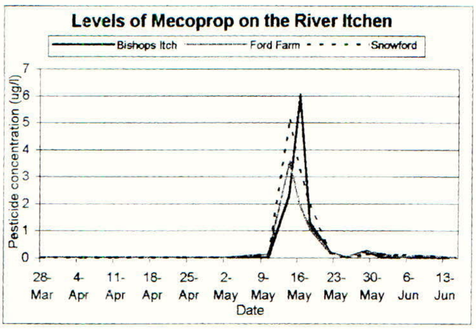
Figure 1: Graphs showing pesticide levels in the Leam Catchment

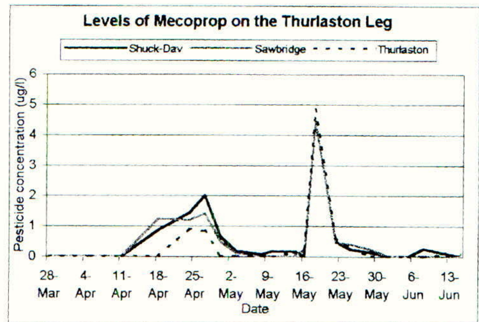


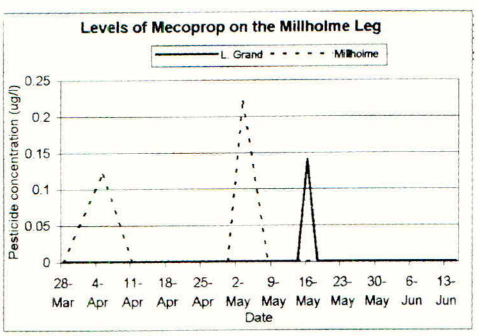


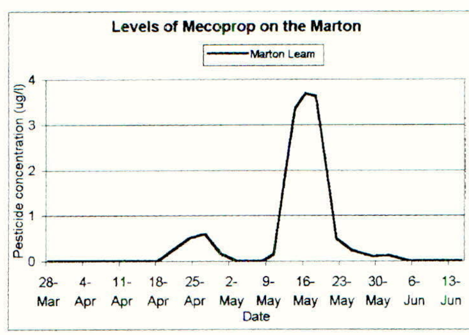

Levels of Isoproturon on the Millholme Leg
L. Grand
Millholme
Pesticide concentration (ug/l)
0
1
2
3
4
28- Mar
4- Apr
11- Apr
18- Apr
25- Apr
2- May
9- May
16- May
23- May
30- May
6- Jun
13- Jun
Date

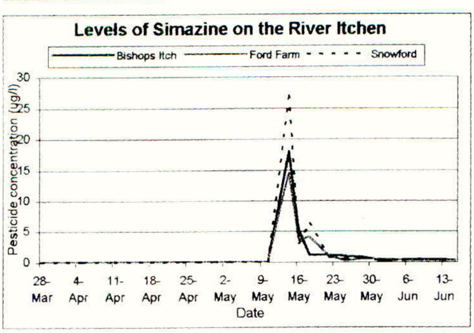

Levels of Isoproturon on the Marton
Marton Leam
Pesticide concentration (ug/l)
0
1
2
3
4
5
6
28- Mar
4- Apr
11- Apr
18- Apr
25- Apr
2- May
9- May
16- May
23- May
30- May
6- Jun
13- Jun
Date

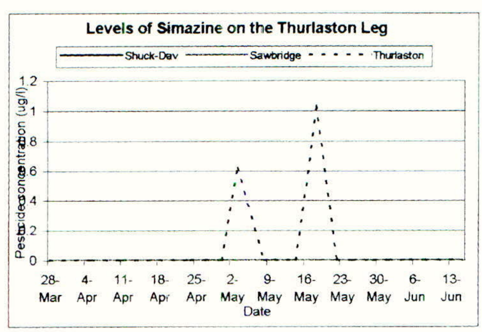

Levels of Mecoprop on the River Itchen
Bishops Itch
Ford Farm
Snowford
Pesticide concentration (ug/l)
0
1
2
3
4
5
6
7
28- Mar
4- Apr
11- Apr
18- Apr
25- Apr
2- May
9- May
16- May
23- May
30- May
6- Jun
13- Jun
Date

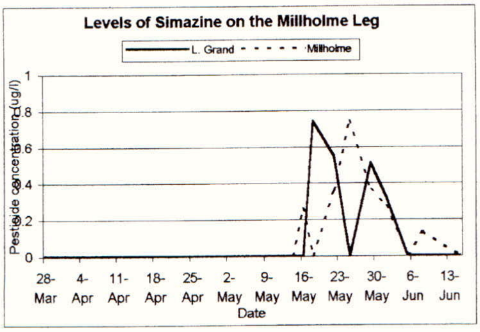

Levels of Mecoprop on the Thurlaston Leg
Shuck-Dav
Sawbridge
Thurlaston
Pesticide concentration (ug/l)
0
1
2
3
4
5
6
28- Mar
4- Apr
11- Apr
18- Apr
25- Apr
2- May
9- May
16- May
23- May
30- May
6- Jun
13- Jun
Date

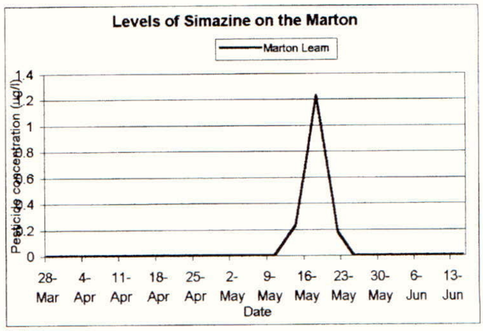

Levels of Mecoprop on the Millholme Leg
L. Grand
Millholme
Pesticide concentration (ug/l)
0
0.05
0.1
0.15
0.2
0.25
28- Mar
4- Apr
11- Apr
18- Apr
25- Apr
2- May
9- May
16- May
23- May
30- May
6- Jun
13- Jun
Date


Levels of Mecoprop on the Marton
Marton Leam
Pesticide concentration (ug/l)
0
1
2
3
4
28- Mar
4- Apr
11- Apr
18- Apr
25- Apr
2- May
9- May
16- May
23- May
30- May
6- Jun
13- Jun
Date


Levels of Simazine on the River Itchen
Bishops Itch
Ford Farm
Snowford
Pesticide concentration (ug/l)
0
5
10
15
20
25
30
28- Mar
4- Apr
11- Apr
18- Apr
25- Apr
2- May
9- May
16- May
23- May
30- May
6- Jun
13- Jun
Date


Levels of Simazine on the Thurlaston Leg
Shuck-Dav
Sawbridge
Thurlaston
Pesticide concentration (ug/l)
0
0.2
0.4
0.6
0.8
1
1.2
28- Mar
4- Apr
11- Apr
18- Apr
25- Apr
2- May
9- May
16- May
23- May
30- May
6- Jun
13- Jun
Date





DISCUSSION

The approval period for pesticide usage can result in a limited window for application. One of the most critical factors to consider before application is rainfall, therefore this was the main tool used to decide when to take samples. There were three dry spells in mid April, early May and late May (see figure 2) when applications may have occurred. Information from farmers and contractors confirmed that the periods in mid April and early May included the majority of pesticide application, with the later dry spell being too late for application to many of the crops. The two application periods were both followed by heavy rainfall and thus runoff from the field is the probable origin of pesticides seen as peaks in graphs 1 – 12.

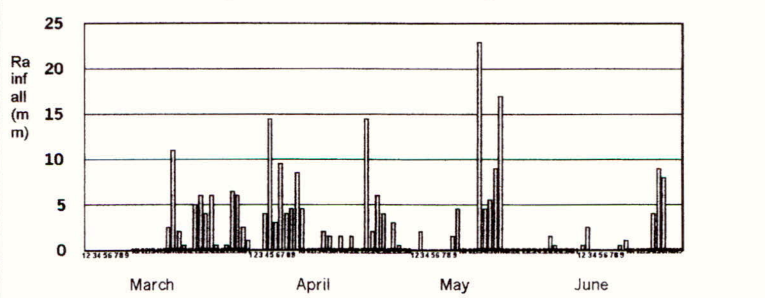
IPU

IPU occurred at all sample points at similar times. The levels in the Itchen were higher than in the rest of the catchment.

The small peak of IPU on 5th April is thought to be residue from the Autumn application as rainfall figures indicate that conditions were not suitable for spraying before this date.

The second peak on 24th April is most likely to be from Spring application. This occurred early in the season following the first application opportunity. Farmer concerns at being

Figure 2: Rainfall data at Knightcote, 2001



unable to spray in the Autumn may have resulted in an application when conditions were less than ideal resulting in a large peak in surface water following the subsequent rainfall.

The third lower peak in mid May is likely to be secondary to the April application.

Mecoprop

Mecoprop was detected sporadically throughout the catchment but only in mid May in the Itchen. The herbicide has a relatively short half life in the field so this pattern almost certainly reflects the time of application which is related to the growth stage of the crop. Levels were generally similar to previous years but the peak concentrations were lower. This may indicate reduced contamination from point sources.

Unusually, concentrations were similar throughout the catchment, with little evidence for flow dilution downstream. This may indicate a number of diffuse sources within the catchment, or an unusual flow pattern in the river at this time. It is notable that ADAS predicted an increased use of Mecoprop this season and this was confirmed by farmers and contractors. As increased use has not resulted in higher levels in water, it is evident that contamination is not an inevitable consequence of all uses.

Simazine

Simazine was found at higher levels than previous years in the Itchen catchment Following difficulties in drilling winter cereal in the Autumn, Spring beans had been sown as an alternative crop. The increased area of beans resulted in increased use of simazine. Cropping patterns showed large areas of beans in the Itchen catchment area with few in the upper Leam. Some of the beans were on land alongside the river with steep slopes. These have a high potential for runoff and hence are probable pollution sources.

CONCLUSIONS

The results indicate that the Farmsafe campaigns had limited impact. Following the presentations, pesticides were still found in surface waters at levels above those allowed for drinking water. A major problem with all such campaigns is to ensure that the target audience is reached. Even when all relevant farmers in a catchment are contacted and the presentation arranged at a local venue, take up tends to be low and those farmers who do attend are generally already committed to good practices.

Thus, the events are probably most suitable for disseminating new information and reinforcing the importance of existing advice. If local contractors are involved, the event may help to avoid them being put under pressure to spray in unsuitable conditions to meet specific needs. Although there may be value in continuing with similar campaigns the use of alternative methods should also be investigated.

Levels of Simazine and IPU were found in the Itchen at higher levels than the upper Leam and Mecoprop at similar levels. In the Itchen catchment pesticides were recorded at similar levels to previous years. However, in 2000 it was observed that pesticides were at similar levels at all the sample points (no flow dilution, suggesting diffuse sources) and this year the very sharp peaks attributed to point source pollution, were not seen.

This may be a consequence of the Farmsafe presentation, and in particular an application of the findings from the 'Cherwell Catchment Study' project which illustrated the importance of point sources in the contamination of water courses. At least one local contractor decided to fill his equipment in the field rather than on hard standing as previously recommended. Examples of spray drift/bad practice were also recorded in previous years. These included typical signs of phenoxy herbicide damage to weeds in a ditch.

This suggested a need for further education of spray users and/or poor practice by a (possibly small) proportion of users. As the proportion of applied pesticide which finds its way into surface waters is generally < 1% a few examples of poor technique, even if related to minor use, could account for the observed contamination. Not all users attended the Farmsafe presentation but it is possible that indirect communication has contributed to the lack of any similar observations this season.

The "Cherwell Valley" project was instrumental in demonstrating the potential importance of point source contamination in surface waters. This used IPU to exemplify the problems. IPU is a residual herbicide and dissolves relatively slowly. Similar investigations with a more soluble and shorter-lived herbicide such as Mecoprop would provide useful additional information on the relative importance of leaching and point source contributions to the burden in surface water. This is important, as different strategies are required to combat contamination from the two routes. Observations suggest that both routes may be important in this catchment and therefore alternative approaches will need to take account of this.

Such approaches which may be considered include: the adoption of uncultivated "buffer strips" along major waterways; review of the buffer zones required; modified equipment to reduce spray drift; improved training/licensing of applicators and reduced application rates. It is believed that some pesticides may leach at significant levels even when applied according to best practice and therefore in such circumstances alternative products should be considered. If such approaches are adopted it will be important to ensure full compliance to maximise the benefits, as a few, apparently minor, infringements of good practice can result in very significant additional contamination of surface waters.

ACKNOWLEDGEMENTS

We thank Dr Geoff Pigott and Robert Joice for their technical assistance during the study and in the preparation of this paper.

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