WATERSHED SCALE EVALUATION OF CONSERVATION PRACTICE EFFECTS

E.A. Warnemuende, C.H. Huang, D.R. Smith, D.C. Flanagan, and D.E. Stott
United States Department of Agriculture, Agricultural Research Service, West Lafayette, IN, USA.

Abstract

Pesticides, nutrients, and sediment released through agricultural activities to surface waters and drinking water systems represent a major risk to human and environmental health, as well as great cost to municipalities. This study is designed to evaluate the ability of voluntary best management practices to reduce pesticide and nutrient loadings to surface drinking water sources. A paired and nested watershed monitoring scheme was implemented within the St. Joseph River watershed at NE Indiana (USA). Within one of every pair of watersheds, producers are heavily encouraged to adopt pesticide best management practices. Currently, nine watersheds ranging in size from 2.5 to 4290 ha are instrumented with automatic samplers and monitored for baseline data. Initial data indicate that pesticide concentrations tend to be greatest during the first one or two large storm events following application. The most prevalent pesticide detected is atrazine, with a peak concentration of 66 ppb. Further monitoring and research is ongoing to evaluate the ability of voluntary management practices to reduce pesticide loadings and to assess other environmental effects of these practices.

Additional Keywords: pesticide, water quality, agricultural management

Introduction

In the United States, many municipalities rely on surface waters, such as rivers, as sources of domestic water supply. This water is treated by the municipal water utility and distributed to residents as potable water. Where largely agricultural watersheds drain to rivers which serve as drinking water sources, the transport of agricultural chemicals into the water supply is a growing concern. Pesticides, nutrients, and sediment released through agricultural activities to surface waters and drinking water systems represent a major risk to human and environmental health, as well as great cost to municipalities. The Natural Resources Inventory - Conservation Effects Assessment Project (CEAP) was initiated in 2003 by the US Department of Agriculture in order to determine the effects of the US Government's soil conservation programs. The CEAP effort includes watershed assessment studies to detail the environmental effects of conservation practices in selected watersheds. This study is a part of this effort and focuses on pesticides (acetochlor, alachlor, atrazine, metolachlor, simazine, and glyphosate) and nutrients (nitrate, ammonia, Total Kjeldahl Nitrogen (TKN), ortho-phosphate (ortho-P), total phosphorus (P), and dissolved organic carbon (DOC)) in surface waters in the midwest USA.

The St. Joseph River watershed is a largely agricultural watershed that provides the drinking water supply for the city of Fort Wayne, Indiana (USA) and more than 200,000 residents. Fort Wayne tap water has a history of excessive atrazine contamination (Cohen *et al.* 2003), and requires extensive treatment in order to meet the safe drinking water standard set forth by the US Environmental Protection Agency (EPA). The objective of this study is to evaluate the ability of voluntary best management practices to reduce the loading of agricultural chemicals to surface drinking water sources.

Materials and Methods

Site Description

The St. Joseph River watershed, located in an agricultural region of the Midwest USA, covers 280,852 ha, extending from NE Indiana, NW Ohio, and S Michigan (Figure 1). Agricultural lands comprise 79% of the watershed. The predominant management system on these lands is annual rotation of corn and soybeans. Natural lands, primarily wooded or wetland areas, cover 10% of the watershed, and residential, commercial, and other land uses comprise the remaining 11%. This study focuses on the area along Cedar Creek, which is the largest tributary to the St. Joseph River. The Cedar Creek sub-watershed comprises 70,820 ha (approximately 25%) of the St. Joseph River watershed. A network of dredged ditches drains runoff and subsurface tile drain water from agricultural fields into Cedar Creek and ultimately into the St. Joseph River. Along these ditches, experimental watersheds ranging from 2.5 to 4290 ha in size were selected for study. Paired experimental watersheds of similar size were selected in order to allow comparison of treatments at similar scales, and smaller watersheds were nested within larger watersheds. Within one of every pair of watersheds, producers are heavily encouraged to adopt pesticide best management practices (BMPs). Water quality data from these watersheds will be compared to water quality data from counterpart control (CTL) watersheds, where producers are not encouraged to adopt best management practices. After our initial selection of the medium (M) and large (L) CTL watersheds, we learned that the ditch that drains these two watersheds is scheduled to be dredged. Therefore, a second set of CTL-M(2) and CTL-L(2) watersheds were selected for study. This addition will allow the study of dredging effects on water quality. Because the BMP-M and L watersheds are located within an extra large (XL) watershed that has been regularly monitored for water quality since 1996, BMP-XL watershed was included in the study. Characteristics of the experimental watersheds are given in Table 1 (adapted from Flanagan *et al.* 2003).

Figure 1. The St. Joseph River watershed, extending through northeastern Indiana, southeastern Michigan, and northwestern Ohio.

Table 1. Experimental watershed characteristics.

Treatment-Size	Area (ha)	Soil Types	Land Management
BMP-XL	4303	Blount silt loam, Pewamo silty clay, Glynwood loam, Rawson sandy loam, Rensselaer loam, Sebewa sandy loam	78% Agriculture 14% Grass/Pasture 6% Forest
BMP-L	1934	Blount silt loam, Pewamo silty clay, Glynwood loam, Rawson sandy loam, Morley silty clay loam	77% Agriculture 16% Grass/Pasture 6% Forest
CTL-L	1417	Blount silt loam, Pewamo silty clay, Glynwood loam, Sebewa sandy loam, Rensselaer loam	83% Agriculture 12% Grass/Pasture 3% Forest
CTL-L (2)	1380	Blount silt loam, Pewamo silty clay, Glynwood loam, Morley silty clay loam	73% Agriculture 17% Grass/Pasture 5% Forest
BMP-M	298	Rawson sandy loam, Pewamo silty clay, Morley silty clay loam, Blount silt loam	79% Agriculture 15% Grass/Pasture 4% Forest
CTL-M	311	Blount silt loam, Pewamo silty clay, Glynwood loam	85% Agriculture 8% Grass/Pasture 6% Forest
CTL-M (2)	921	Glynwood loam, Blount silt loam, Pewamo silty clay	83% Agriculture 10% Grass/Pasture 4% Forest
BMP-S	2.2	Pewamo silty clay, Glynwood loam, Morley silty clay loam	100% Agriculture
CTL-S	2.7	Glynwood loam, Blount silt loam	100% Agriculture

Treatment Implementation

Producers and landowners within the BMP watersheds have been encouraged to implement BMPs for the 2004 growing season and thereafter for the duration of the study. Prescribed BMPs will be based upon the CORE 4 conservation practices (Conservation Technology Information Center 2003) and new BMPs in development. Producers will be compensated for keeping detailed records of their management practices.

Monitoring and Analyses

Field instrumentation was installed on the BMP-XL, BMP-L, CTL-L, BMP-M, and CTL-M watersheds in 2002 and CTL-L (2), CTL-M (2), BMP-S and CTL-S in 2003. Instrumentation includes two automatic recording weather stations, drop box weirs for the small watersheds, water level recorder and automated samplers (ISCO 6712 Portable Samplers). Since field treatments have not yet been implemented, field data collected to date provide baseline measurements. Meteorological parameters (temperature, barometric pressure, wind, precipitation, and relative humidity) are monitored every 15 minutes. Water quality and hydrology are monitored at the outlet of each experimental watershed. Water quality samples are collected through Teflon tubing and into glass bottles according to the sampling schedule given in Table 2. Water stage within the ditches is monitored every 10 minutes and a rise of approximately three cm in a two-hr period triggers event flow sampling. The automated samplers are chilled using ice and will be upgraded with refrigeration where sufficient power supply exists.

Table 2. Water sampling regime.

Flow Type	Sample Interval (hr)	Sample Size (mL)	Composite Frequency (hr)
Base Flow	4.0	50	24
Event Flow	0.5	100	1.5

Within four days of collection, samples are transported from the samplers to a field laboratory, where they are divided into subsamples for specific pesticide and nutrient analyses. Subsamples for pesticide analysis are vacuum filtered using 0.45 micron nylon filters and frozen in 60 mL glass sample bottles with Teflon-lined lids. Subsamples for nutrient analyses are filtered and acidified with H_2SO_4 if appropriate and frozen in plastic sample bottles. Frozen subsamples are transported from the field laboratory to the US Department of Agriculture Agricultural Research Service National Soil Erosion Research Laboratory for analyses.

After thawing at 4°C, pesticide subsamples are saturated with NaCl and analyzed for acetochlor, alachlor, atrazine, metolachlor, and simazine using gas chromatography (Varian CP 3800) and mass spectrometry (Varian Saturn 2200) with automated solid-phase microextraction (SPME) (CTC Analytics CombiPal). Using a 100 µm polydimethyl siloxane SPME fibre, a 50-min adsorption time with 500 rpm agitation at 40 °C, and a 15-min desorption time, SPME extraction followed by GC/MS can be used to quantify pesticides ≥ 0.25 ppb for acetochlor, alachlor, atrazine, and metolachlor, and ≥ 0.5 ppb for simazine. During the development of automated SPME methods in 2002, pesticide samples were analyzed by an external laboratory using US EPA Method #525.2. For this, every four samples were composited in order to provide adequate sample volume for extraction and analysis. Beginning in 2004, select samples are also analysed for glyphosate and its primary metabolite, aminomethylphosphonic acid (AMPA) using liquid chromatography (Waters 2650) with post-column derivitization and fluorescence detection (Waters 2475). Using these methods, glyphosate and AMPA can be quantified ≥ 2.0 ppb. Nitrate, ammonia, TKN, P, and ortho-P are determined by flow-injection-analysis and colorimetric methods (Lachat Quik Chem Series 8000, Thermo Electron Konelab Aqua 20), and DOC is determined by UV-Persulfate wet oxidation (Shimadzu TOC-Vws).

Results and Discussion

To date, baseline data have been collected. A complete data set exists for the 2002 growing season from the BMP-XL, BMP-L, CTL-L, BMP-M, and CTL-M watersheds. Base flow pesticide and stage data for the CTL-L watershed are presented in Figure 2. These data, as well as data collected from all experimental watersheds, illustrate that the presence of pesticides in ditch water at the outlet is highly associated with early season periods of high flow following pesticide application. Peak atrazine concentrations in base flow samples ranged from 9 ppb at the BMP-XL and L watersheds to 32 ppb at the CTL-L watershed. Atrazine levels in base flow samples exceeded the EPA drinking water limit of 3 ppb several times during the spring and early summer, especially in the CTL-L watershed. Concentrations of other pesticides in base flow were generally below 3 ppb and rarely exceeded EPA drinking water standards. Differences in pesticide loading between watersheds may be due to differences in current baseline practices, variability in rainfall and hydrology, and consequent variability in stage response.

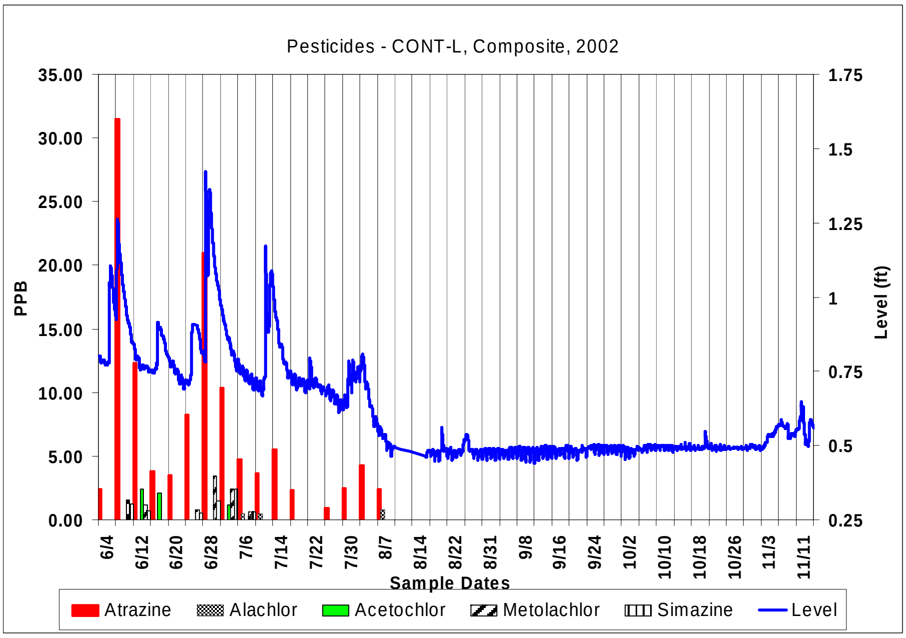

Figure 2. Measured stage and pesticide concentrations from 2002 base flow for CTL-L watershed.

More intensive sampling during runoff events revealed that paired watersheds yielded similar atrazine loss responses during early season storm events. The first event sample drawn from the CTL-L watershed outlet represented the highest atrazine level of the season, with a concentration of 66 ppb. Peak atrazine concentrations during runoff events in the BMP-XL, BMP-L, CTL-M, and BMP-M watersheds were 44, 49, 42, and 20 ppb, respectively, and exceeded the EPA drinking water standard of 3 ppb. Metolachlor and acetochlor were the next most prevalent of the measured pesticides with peak concentrations of 18 and 16 ppb during event flow, respectively. Simazine and alachlor were detected at low levels and rarely exceeded their respective EPA drinking water limits of 4 and 2 ppb.

Conclusions

Nine experimental watersheds within the St. Joseph River watershed and ranging from 2.5 to 4290 hectares in size are instrumented and monitored for pesticide and other water quality parameters. The St. Joseph River serves as a drinking water source for the city of Ft. Wayne, IN (USA), where historically atrazine contamination of drinking water has occurred. Initial data from this study indicate that the most prevalent pesticide detected at the outlet of sub watersheds is atrazine, with a peak concentration of 66 ppb. Pesticide concentrations were greatest during the first one or two large storm events following pesticide application. Further monitoring and research is ongoing to evaluate the ability of voluntary best management practices to reduce pesticide loadings as well as to assess other environmental effects of these practices.

Acknowledgements

The authors would like to acknowledge Stanley J. Livingston, Sara Walling, and local producers and cooperators for their valuable assistance with this project.

References

Cohen, B., Wiles R., and Bondoc, E. (2003). Weed killers by the glass – a citizens' tapwater monitoring project in 29 cities. Environmental Working Group (EWG). (http://www.ewg.org/pub/home/Reports/Weed_Killer/Weed_Home.html)
Conservation Technology Information Center. (2003). Core 4 – Conservation for Agriculture's Future. (http://www.ctic.purdue.edu/Core4/whatC4.html).
Flanagan, D.C., Livingston, S.J., Huang, C.H., and Warnemuende, E.A. (2003). Runoff and pesticide discharge from agricultural watersheds in NE Indiana. ASAE meeting paper number 032006. American Society of Agricultural Engineers, St. Joseph, MI (USA).