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Atrazine fate on a tile drained field in northern New York: a case study

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Abstract

Only by understanding the transport and degradation mechanisms of atrazine on farms can measures be taken to minimize atrazine concentrations that reach natural environments. The fate of atrazine on a tile drained farm in northern New York during the spring was followed. The largest stream was sampled as well as individual tile lines from one field after snowmelt began in March 1994, until the flow ceased in early June 1994. Prior to the first application of atrazine on the farm in 1994, atrazine concentrations in the stream ranged between 0 and 0.4 $\mu g\ L^{-1}$. Immediately following an 0.8 inch rainfall event, 6 days after the application of 1.4 kg of atrazine on 1 ha of a tile drained field, atrazine concentrations at a tile line outlet feeding into the stream reached 34.5 $\mu g\ L^{-1}$. After mixing with other inflows, the atrazine concentration in the stream was 6.4 $\mu g\ L^{-1}$. The atrazine concentration decreased along the 1450 foot stream. Analysis of eight tile lines which drained a research field showed a direct correlation between increased flow rates with increased atrazine concentration. No-tillage practices may lead to slightly higher concentrations of atrazine in the tile lines.

Keywords: Pesticide; Herbicide; Fate; No-till; Tillage practices; Conventional tillage; Conservation tillage; Preferential flow; Macropores; Tile lines; Agricultural drainage; Management practices

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1. Introduction

Agriculture is implicated as one of the sources of pesticides in streams (Kosinski, 1984; Jurgensen and Hoagland, 1990; Kolpin and Kalkhoff, 1991; Thurman et al., 1991; Lakshmiravayana et al., 1992). By studying atrazine concentrations in streams that drain agricultural watersheds, we can gain insight into breakdown characteristics and loading rates with respect to season and flow rate. Kolpin and Kalkhoff (1993), found that atrazine concentrations decreased by as much as 60% in an 11.2 km stretch of a creek under stable, low to medium flow conditions. Moreover, by relating atrazine application times and increases in flow rate to the occurrence of atrazine concentrations in streams, transport phenomenon can be better understood. Squillace and Thurman (1992), showed that maximum concentrations of herbicide occurred when overland flow was the major component of river discharge, rather than groundwater being the major discharge. Studies done by Wauchope (1978); Glotfelty et al. (1984), and Thurman et al. (1991), all emphasize the occurrence of atrazine 'pulses' that typically occur during heavy rainfall and runoff events within 1 to 2 weeks of the application of atrazine. Shipitalo et al. (1990), observed that a light rainfall can move atrazine into the soil matrix, decreasing the amount of atrazine leached later during a heavy rainfall. Edwards et al. (1992), claimed that vertical transport of atrazine in soils was dominated by percolate volume rather than rainfall intensity.

When situations that increase stream concentrations of atrazine are identified, measures can be taken to reduce the intensity and occurrence of such events. The objective of this project was to measure atrazine concentration fluctuations in an on-farm stream during the spring flow period and to gain insight into the effect of tile drainage on atrazine transport.

2. Materials and methods

2.1. Stream study

The intermittent stream that was studied is located on the eastern boundary of the Adirondack Park at Cornell University's northern New York research farm in Willsboro. The study domain started at the junction of two tile drainage outlets and an intermittent surface stream and ended at a culvert leading to Lake Champlain, a length of 1450 feet (Fig. 1).

The stream was sampled after snowmelt began in March 1994, until the flow ceased in early June 1994. Sampling was conducted twice daily for the duration of the spring flow. Dip samples were manually taken from the center of the cross section of the stream, where the highest flow rates were observed. Samples, frozen within an hour, were analyzed for atrazine using RaPID Assays pesticide determination kits made by Ohmicron. The lower detection limit was 0.05 $\mu g\ L^{-1}$.

Sampling positions included all inflows: the two tile drainage outlets, Sites A and B; the intermittent stream, Site C, at the beginning of the study domain; and the tributary, Site H, located nine hundred feet downstream from the three primary sources. Samples

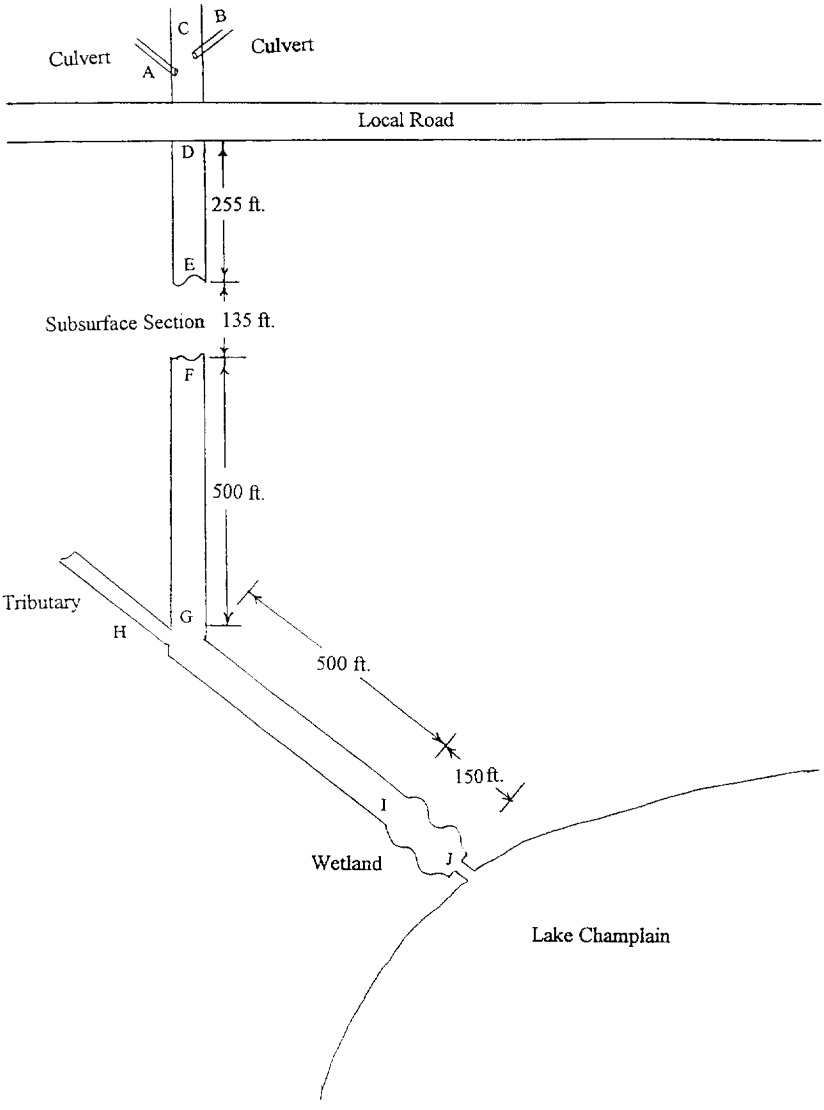


Fig. 1. Diagram of the stream at the Willsboro farm.

were also drawn from all critical positions: the exit of the walk-through culvert by the road, Site D; prior to the subsurface section, Site E; the resurfacing point, Site F; prior to the tributary, Site G; prior to the wetland area, Site I; and from the outlet culvert directly after the wetland, Site J.

2.2. Field study

A separate, but related study was conducted on a research field which drained to the stream at Sampling Location A. The soil was classified as a poorly drained Rhinebeck variant fine sandy loam. The hydraulic conductivity was approximately 0.9 m day^{-1}, the bulk density was 1.4 g cm^{-3}, and the saturated moisture content was 0.48. The land sloped downward from west to east at less than a 3% slope (Bodnar, 1995). The field was divided into eight plots. All the plots were 18 m wide and ranged in length from 110 m, at the first plot, to 150 m, at the eighth plot. Each tile line was installed at 80 cm depth, and emptied into a manhole where sampling was conducted (Bodnar, 1995).

The entire field was planted in corn. Plots 1, 3, and 6 were not tilled, while Plots 2, 4, 5, 7, and 8 were conventionally tilled the previous fall and then disked before planting. No atrazine was added before or during the 1994 growing season. The previous year, however, with the same crop and tillage scheme, atrazine was applied at the rate of 3.36 kg ha^{-1} (Bodnar, 1995).

All eight tile lines were sampled daily during the same period that stream samples were being drawn; late March till early June 1994. Samples were frozen within an hour and tested for atrazine in the same manner as the stream samples were analyzed.

3. Results and discussion

The sampling position at the walk-through culvert, Site D, will be referred to more than the other sampling positions, because Site D was the most upstream site where there was complete mixing of the water from the two tile drainage outlets and the intermittent stream. In this respect, Site D is considered the origin of the stream. Site D was also where flow rates were measured using a V-notch weir. Highest flow rates were observed in late March/early April during snowmelt, decreasing steadily to very low flow rates in early June (Fig. 2). Peaks that occurred during low flow periods coincided with storm events. The tile lines draining cultivated fields were the predominant source of water to the stream.

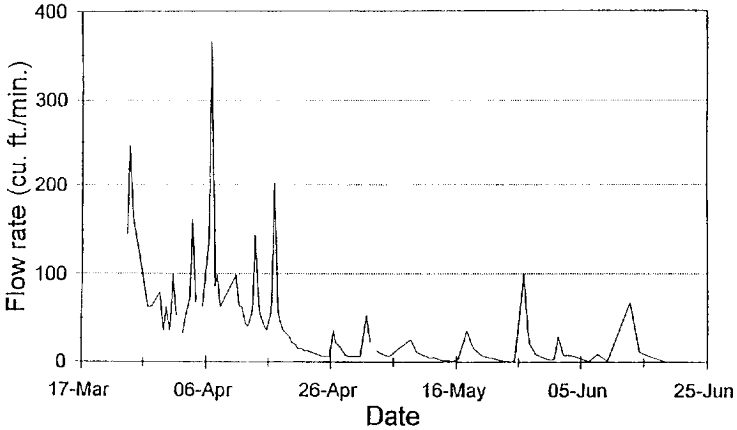
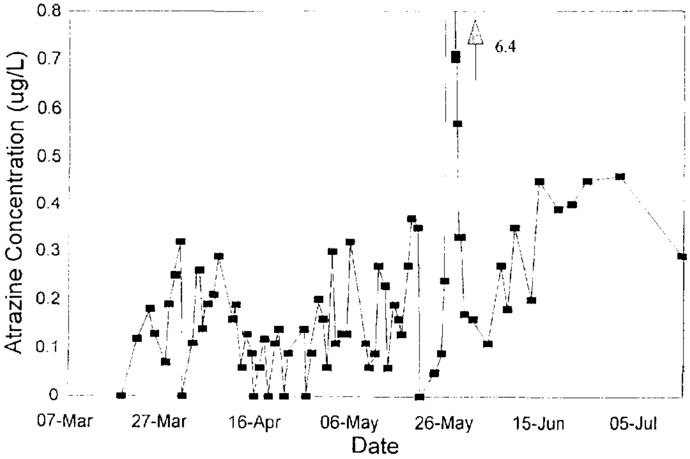


Fig. 2. Flow rates at the walk-through culvert location during spring flow, 1994.

Samples drawn from the walk-through culvert location (D, Fig. 1) were tested for atrazine throughout the study period. From mid-March until 26 May, atrazine concentrations fluctuated between zero and 0.35 μg L^{-1} and had an approximate mean of 0.15 μg L^{-1} (Fig. 3). Atrazine concentrations for the 26 May, 17.00 h sampling time showed a drastic increase after a storm event. Between 13.00 h and 17.00 h, it rained approximately 0.8 inches. The atrazine concentration at Site D was tested twice and registered 6.4 and 6.5 μg L^{-1}. After 29 May, concentrations of atrazine in the stream leveled off and the mean concentration of atrazine at the walk-through culvert location for the rest of the season was approximately 0.25 μg L^{-1}, ranging between 0.11 and 0.45 μg L^{-1}.

By testing the samples taken from Sites A, B, and C on 26 May at 17.00 h, it became evident that the likely source of the elevated atrazine concentration in the stream came from the tile drainage outlet at Site B. On 20 May, 6 days prior to an 0.8 inch rainfall event, 1 ha of land overlying tile lines was sprayed with atrazine at a rate of 1.4 kg ha^{-1}. The tile lines drained to Site B. The 26 May, 17.00 h sample at Site B tested to be 34.5 μg L^{-1} atrazine (Fig. 4). For tile line at Site A, the concentration was 0.8 μg L^{-1} atrazine which was slightly above the background level and at Site C atrazine was not detected. There was only minimal overland flow and the concentration at Site D is a weighted average of the concentrations in the tile lines. The remaining concentrations for Tile B are shown in Fig. 4. Although the concentrations were high, only a small quantity (1 or 2%) of the applied atrazine reached the tile outlet.

The atrazine concentrations that reached the stream were in accordance with earlier experiments on the same farm in which preferential flow through macropores carried high concentrations of pesticides to tile lines shortly after irrigation (Shalit, 1994; Bodnar, 1995). Shalit (1994) and Bodnar (1995) found that atrazine loss under conventional tillage was only slightly lower than no-till. Edwards et al. (1992), on a similar soil



* Concentration on 5/26 at 5:10 PM = 6.4 ppb

Fig. 3. Atrazine concentrations throughout the 1994 spring season at the walk-through culvert location.

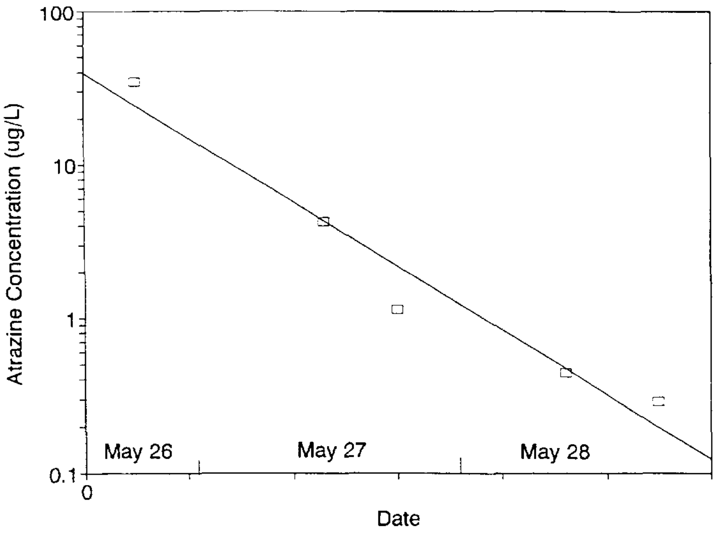


Fig. 4. Log of the atrazine concentrations from the tile drainage outlet that caused the atrazine spike in the stream vs. time.

in Ohio, claimed that no-till soils can lead to greater amounts of pesticide movement than tilled soils, since macropores become more developed and are not disrupted in no-till soils. On the 1 ha field that had atrazine applied to it, half of the area was not tilled.

After it stopped raining, both Shalit (1994) and Bodnar (1995) observed an exponentional decrease concentration coming from the tile lines. By plotting the natural log of the atrazine concentration with respect to time after the 26 May rainfall event, a straight line results as shown in Fig. 4 (a linear regression of ln C vs. time gives $R^2 = 0.96$) confirming that for these plots an exponentional relationship is also valid for this event.

3.1. Atrazine fluctuations between sampling positions in the stream

When the atrazine concentration was low, there was no appreciable decrease in atrazine concentration along the length of the stream during the season. During the atrazine pulse, some decrease in atrazine concentration occurred in the subsurface and wetland portions of the stream for the 26 May, 17.00 h sampling time (Fig. 5). Site I is the sampling location prior to the wetland and Site J is at the outlet culvert to Lake Champlain downstream of the wetland.

The decrease in atrazine concentration in the subsurface portion of the stream could have been due to adsorption to soil particles or dilution from groundwater. Adsorption of atrazine to organic matter and soil matter could have contributed to the decrease in atrazine concentration in the wetland on 26 May at 17.00 h, but no decreases in concentration were observed in samples taken from the wetland on the days after 26 May.

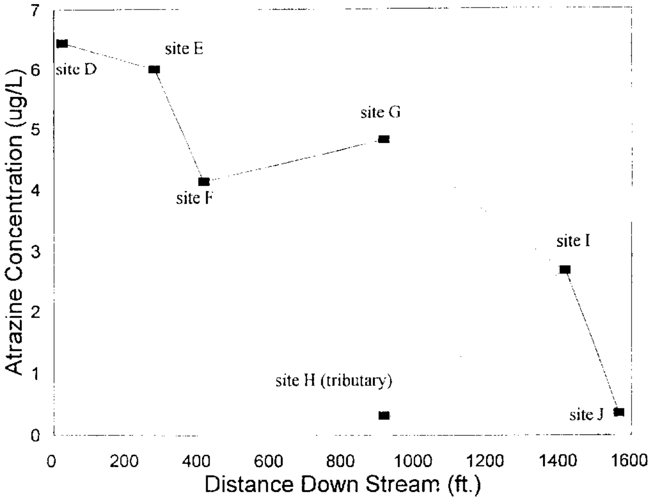


Fig. 5. Atrazine concentrations along the length of the stream on 26 May at 17.00 h.

The concentration prior to the wetland was approximately 2.5 μg L^{-1} and decreased to below 0.5 μg L^{-1} at the outlet on the evening of 26 May. The literature cites possible causes of atrazine reduction as surface-catalyzed hydrolysis (Glotfelty et al., 1984); adsorption to estuarine colloidal organic matter (which is 10 to 35 times more adsorptive than sediment or soil organic matter) (Glotfelty et al., 1984); photolysis (Kolpin and Kalkhoff, 1993); and aquatic plant internal degradation or storage (Kolpin and Kalkhoff, 1993). Dilution in the wetland may have also occurred.

During the 26 May, 17.00 h sampling time, the flow rate through the wetland was approximately 200 feet^3 min^{-1}. The volume of the wetland was approximately 4500 feet^3 which resulted in a retention time of between 20 and 30 min in the wetland. Bodnar (1995) observed that peak concentrations of atrazine being leached through tile lines coincided with peak flow rates, which typically occurred within an hour after the stoppage of irrigation. The storm on 26 May ended around 17.00 h. The atrazine pulse in the stream had not yet reached Site J, the outlet culvert downstream of the wetland, at the time of sampling on the evening of 26 May.

3.2. *The field study*

To better understand the origin of the low, but consistent concentration of atrazine in the stream, we tested tile line samples taken from a field that had atrazine applied to it in past seasons, but none applied in 1994. The eight plots that were studied drained to the stream at Sampling Location A. Average atrazine concentrations were lowest on the 27 April sampling period for both no-till and conventionally tilled plots. No-till plots and tilled plots averaged 0.76 and 0.53 μg L^{-1} atrazine, respectively. Prior to 27 April, the highest average atrazine concentrations, occurring on 7 April, were 1.21 and 1.38 μg L^{-1} for no-till and tilled plots, respectively. After 27 April, average atrazine concentra-

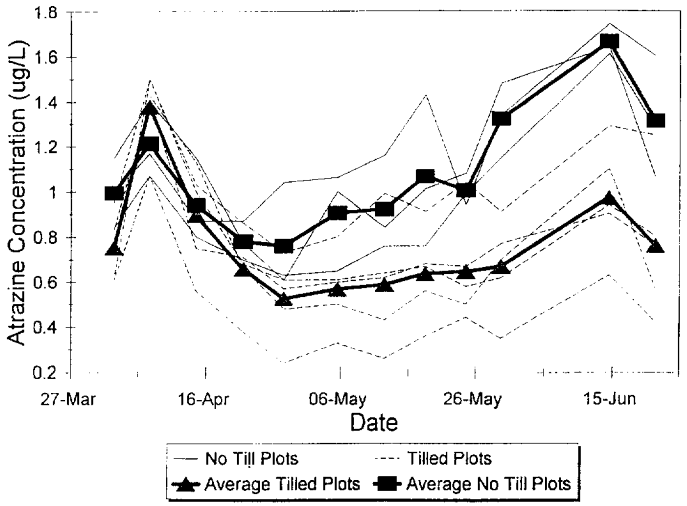


Fig. 6. Atrazine concentration fluctuations for tile line effluent from tilled and no-tilled plots.

tions peaked on 14 June with no-till plots at 1.66 $\mu g L^{-1}$ and tilled plots at 0.97 $\mu g L^{-1}$ (Fig. 6).

Higher concentrations of atrazine leached through the no-till plots than the tilled plots after the spring disking of the conventionally tilled plots in early May 1994. Average atrazine concentrations from both no-till and conventionally tilled plots followed the same pattern throughout the year. During April, atrazine concentrations and flow rates had a direct correlation, with sharpest increases and decreases in flow rate corresponding with the sharpest increases and decreases in atrazine concentrations, respectively. (The flow rates were measured at the walk-through culvert in the stream, and not in the manholes where the samples were taken. Since approximately 90% of the flow in the stream came from subsurface drainage, the assumption was made that increases in stream flow corresponded with increases in tile line flow.)

After April, the general trend was an increase in atrazine concentrations, with large concentration increases with increases in flow rate, and smaller increases in atrazine concentrations when flow rates decreased. It was also after April when the average atrazine concentrations for the no-till plots were noticeably higher than the concentrations from the conventionally tilled plots. The beginning of the increased differential between average atrazine concentrations from the tilled and no-till plots coincided with the spring disking date. The macropores in the plots that were tilled were disturbed in the plow layer, decreasing the amount of atrazine being leached to the tile lines.

4. Conclusion

When the primary source to a stream is from tile lines, special considerations with respect to pesticide contamination result. Because of preferential flow to tile lines, minor quantities of atrazine that were surface applied to a field leached quickly to the stream. Atrazine concentrations tended to increase with increased flow rates. Tillage may aid in decreasing atrazine leaching through tile lines by disturbing preferential pathways in the soil that lead to the tile lines.

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