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Atrazine in Surface Water and Relation to Hydrologic Conditions Within the Delaware River Basin Pesticide Management Area, Northeast Kansas, July 1992 Through December 1994

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Since about 1960, atrazine has been used as an effective pre- and postemergent herbicide in the production of corn and grain sorghum. Atrazine is a triazine-class herbicide and was the most frequently detected herbicide in surface water of the lower Kansas River Basin of southeast Nebraska and northeast Kansas (Stamer and Zelt, 1994). Approximately 95 percent of the atrazine applied in the United States is used in corn and grain-sorghum production, predominately in the Mississippi River Basin where about 82 percent of the Nation's corn acreage is planted (CIBA-GEIGY Corp., 1992). Until recent changes in product labeling, atrazine commonly was applied at relatively high rates to control weeds around commercial and industrial areas and along railroad right-of-ways.

Crop yields have increased during the last 40 years due in part to the use of herbicides in reducing weed growth and competition for moisture and nutrients. However, concern on the part of water suppliers, health officials, and the public also has increased regarding the safe and responsible use of herbicides. One issue is whether the widespread use of atrazine may pose a potential threat to public-water supplies in areas where the herbicide is used because of its ability to easily dissolve in water and its possible effects on the health of humans and aquatic life.

Formation of Pesticide Management Area

In 1992, the U.S. Environmental Protection Agency (1992) established a Maximum Contaminant Level (MCL) for atrazine in finished public-water supplies of 3.0 micrograms per liter (µg/L, equivalent to parts per billion). The Kansas State Board of Agriculture (now the Kansas Department of Agriculture), in 1990, initiated an investigation of potential atrazine contamination because of concerns that some surface-water-supply sources in northeast Kansas could exceed the MCL. A Technical Advisory Committee (TAC) was formed to receive testimony and review available atrazine data. This committee was composed of representatives from State regulatory and conservation agencies, the State extension service, farm groups, chemical manufacturers, environmental groups, and interested individuals. The role of the U.S. Geological Survey (USGS) was to provide technical assistance to the TAC based on studies conducted by the USGS.

The Delaware River Basin in northeast Kansas was of particular interest to the TAC. This basin is an 1,117-square-mile area completely contained within the State. About 85 percent of the Delaware River Basin is used for agricultural activities, with about 40 percent in row crops such as corn, grain sorghum, soybeans, and wheat (Stamer and others, 1995). Mean annual precipitation in the basin is about 35 inches, and mean annual runoff is about 8 inches. Most of the precipitation occurs between April and September and coincides with the growing season.

A prominent feature of the basin is Perry Lake located on the Delaware River near its confluence with the Kansas River (fig. 1) Perry Lake serves as a water-supply source for two rural-water districts as well as several State- and Federal-owned recreational areas. The lake also serves as an indirect source of supply through discharges into the Kansas River, which in turn provides water for much of the cities of Lawrence and Kansas City, Kansas. Annually, the average discharge from Perry Lake accounts for about 9 percent of the flow in the Kansas River (Geiger and others, 1994).

Review of available data from State and Federal sources by the TAC indicated that long-term average concentrations of atrazine in Perry Lake were at or slightly above the MCL. These sources included data from the USGS National Water-Quality Assessment (NAWQA) of the lower Kansas River Basin (1986-90) in southeast Nebraska and northeast Kansas (Helgesen, 1995) of which the Delaware River Basin is a part. Samples were collected at least monthly at the outflow of Perry Lake between January 1989 and February 1990. The mean atrazine concentration for the 1989 calendar year was 3.5 µg/L(Stamer and others, 1995), greater than the 3.0-µg/L MCL.

In April 1992, the Kansas State Board of Agriculture issued an order establishing the Nation's first inland surface-water Pesticide Management Area (PMA) within the Delaware River Basin. This order established the boundaries of the PMA, banned all noncropland use of atrazine, outlined a series of voluntary provisions concerning atrazine application rates and practices, issued mandatory land-management and agricultural practices, and initiated a basinwide monitoring network. The monitoring network would consist of several streamflow and sample-collection sites. Data and results from the monitoring network would be used by State conservation, regulatory, and research agencies to (1) validate or invalidate the perception of a long-term atrazine problem in the basin, (2) determine areas of the basin where additional producer-oriented educational activities may be required, and (3) evaluate the effective-ness of selected land-management and agricultural practices.

Water-Quality Monitoring and Analysis

The basinwide monitoring network was established in July 1992 by the USGS in cooperation with the Kansas State Conservation Commission, the Kansas State Board of Agriculture, and Kansas State University (Manhattan). The network consisted of 10 stream-monitoring sites upstream of Perry Lake and a monitoring site at the outflow of Perry Lake (fig. 1). The 10 stream sites were instrumented with stream-gaging equipment and automatic water samplers.

Water samples for analysis of atrazine were collected automatically at the stream sites during storm runoff and manually during low flow and at the outlet of Perry Lake. Because atrazine concentrations in streams can vary substantially in runoff, it was necessary to collect several samples per day at each site to adequately calculate time-weighted, daily mean concentrations during high flow. During low flow, samples were collected at a minimum of once every 1 to 2 weeks depending upon the season. Generally, daily mean concentrations for low-flow days without samples were calculated by linear interpolation between days with measured concentrations.

Atrazine concentrations were estimated using immunoassay procedures as described by Baum (1991). Although these procedures are sensitive to the presence of atrazine (0.04-µg/L detection level), the procedures are not totally specific to atrazine; other triazine compounds such as ametryn, propazine, prometryn, and prometon can be detected. Therefore, results of these procedures are reported as concentrations of triazine herbicides even though only small concentrations, if any, of these other compounds are detected by gas chromatography/mass spectrometry (GC/MS) procedures. A comparison of triazine herbicide concentrations determined by immunoassay with concentrations of atrazine determined by GC/MS indicated that this particular immunoassay procedure tended to overestimate the actual atrazine concentration by about 10 percent.

Monitoring Results

Daily mean triazine concentrations in streams of the Delaware River Basin commonly exceeded the MCL for atrazine during the months of May, June, and July (fig. 2). Daily mean concentrations at or above 20 µg/L were not uncommon during this period. However, daily mean concentrations greater than the MCL were rare at other times of the year. In fact, most daily mean concentrations were less than 1.0 µg/L from August through April.

Daily mean triazine concentrations in Perry Lake, as determined from samples of the lake outflow (sampling site 11, fig. 1), are affected largely by the timing and magnitude of inflow (fig. 3). Late-season runoff in November and December 1992, combined with preapplication runoff in March and April 1993 (fig. 2), decreased daily mean concentrations in the lake from 3.0 µg/L in October 1992 to about 0.5 µg/L in May 1993. Runoff from the basin (upstream of the lake) during these periods contained small triazine concentrations ranging from about 0.1 to 1.0 µg/L. Generally, atrazine application in 1993 was delayed until mid- to late spring because of wet field conditions.

Postapplication runoff in 1993 produced substantial increases in daily mean triazine concentrations in the outflow of Perry Lake. These concentrations peaked at about 3.8 µg/L in mid-July during a period of severe flooding, as shown by the increase in lake-surface elevation (fig. 3); however, much of the floodwater (inflow to the lake) from mid- to late July generally contained triazine concentrations less than 2.0 µg/L. This, combined with daily mean triazine concentrations less than 1.0 µg/L in inflow from August 1993 through March 1994, generally produced decreasing daily mean triazine concentrations in the outflow of the lake until postapplication runoff in 1994.

Early-season, postapplication runoff in 1994 caused triazine concentrations in Perry Lake to exceed the MCL for atrazine even though inflow volumes were small relative to lake volume. Most of the basin runoff occurred in May and early July as evidenced by the small increase in lake-surface elevation during this period (fig. 3). By late July 1994, concentrations in the outflow of the lake were greater than 3.0 µg/L. Less-than-average late-season runoff, which normally tends to dilute existing concentrations, did not temper the effects of early-season runoff in 1994. Concentrations in the lake outflow were greater than 3.0 µg/L through the end of 1994.

Time-weighted annual mean triazine concentrations did not exceed the MCL for atrazine at any sampling site during the first complete application year (April 1, 1993, through March 31, 1994, fig. 4). The largest concentrations were at those sites draining areas in the north-eastern or northern part of the basin. However, when the annual mean concentrations of total flow volumes were computed (flow-weighted), triazine concentrations at several sites exceeded the MCL for atrazine. Because flow-weighted concentrations represent the average concentration of a specified volume of streamflow, they can be used to evaluate subbasins relative to each other. Time-weighted concentrations can be used to evaluate compliance with Federal drinking-water-quality regulations which, by the nature of the regulation's sampling requirements, approximate time-weighted averages.

Conclusions And Implications

Within the Delaware River Basin in northeast Kansas, hydrologic conditions (timing and magnitude of runoff) in relation to the timing of herbicide application are important in determining stream and lake triazine concentrations. Runoff potential was greatest from about mid-May to mid-July of 1993 and 1994. Based on these results, limited herbicide application during this part of the year would help optimize water quality.

Substantial differences in average concentrations are apparent among streams in the Delaware River Basin. Factors other than hydrologic conditions probably are responsible for these differences. These factors may include differences in: (1) natural factors such as surface topography and soil characteristics; (2) percentage of subbasin acreage in corn and grain-sorghum production; (3) method of herbicide application such as surface broadcast or soil incorporation; (4) rate of herbicide application; (5) tillage practices such as conventional tillage, reduced till, ridge till, or no till; and (6) land-management techniques such as the utilization of terrace systems, field-buffer strips, grass-filter strips, and maintenance of crop residue. Additional investigation to describe and quantify the effects of these factors would be useful for improved understanding of the movement of atrazine into the surface-water system.

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