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***EQUUS* BEDS GROUND-WATER RECHARGE DEMONSTRATION PROJECT**

Atrazine in Source Water Intended for Artificial Ground-Water Recharge, South-Central Kansas

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Atrazine, an herbicide commonly applied to row crops, is of concern because of potential effects on water quality. This fact sheet describes atrazine in water from the Little Arkansas River in south-central Kansas. The river is being evaluated as a source of artificial recharge into the Equus Beds aquifer, which provides water for the city of Wichita.

Introduction

Currently, the city of Wichita water supply comes from two primary sources—the Wichita well field and Cheney Reservoir (fig. 1). The well field withdraws water from the *Equus* Beds aquifer, which is the easternmost part of the High Plains aquifer in Kansas (fig. 1). Because of expected population growth in the region, the available water supply is not expected to meet future demands (Warren and others, 1995). The ongoing *Equus* Beds Ground-Water Recharge Demonstration Project is evaluating two ground-water recharge techniques, surface-spreading basins and direct-injection recharge wells, to help meet these increased demands. The project is a collaborative effort among the following agencies and engineering consulting firms: city of Wichita, Groundwater Management District No. 2 (Halstead, Kansas), Bureau of Reclamation and U.S. Geological Survey (both U.S. Department of the Interior agencies), U.S. Environmental Protection Agency, various Kansas State agencies, Burns and McDonnell Engineering Consultants (Kansas City, Missouri), and Mid-Kansas Engineering Consultants (Wichita, Kansas).

The description of atrazine in the Little Arkansas River, presented herein, includes an examination of daily stream discharge, atrazine concentrations, seasonal atrazine load distribution, and atrazine yields as related to hydrologic conditions and herbicide-application practices from January 1995 through

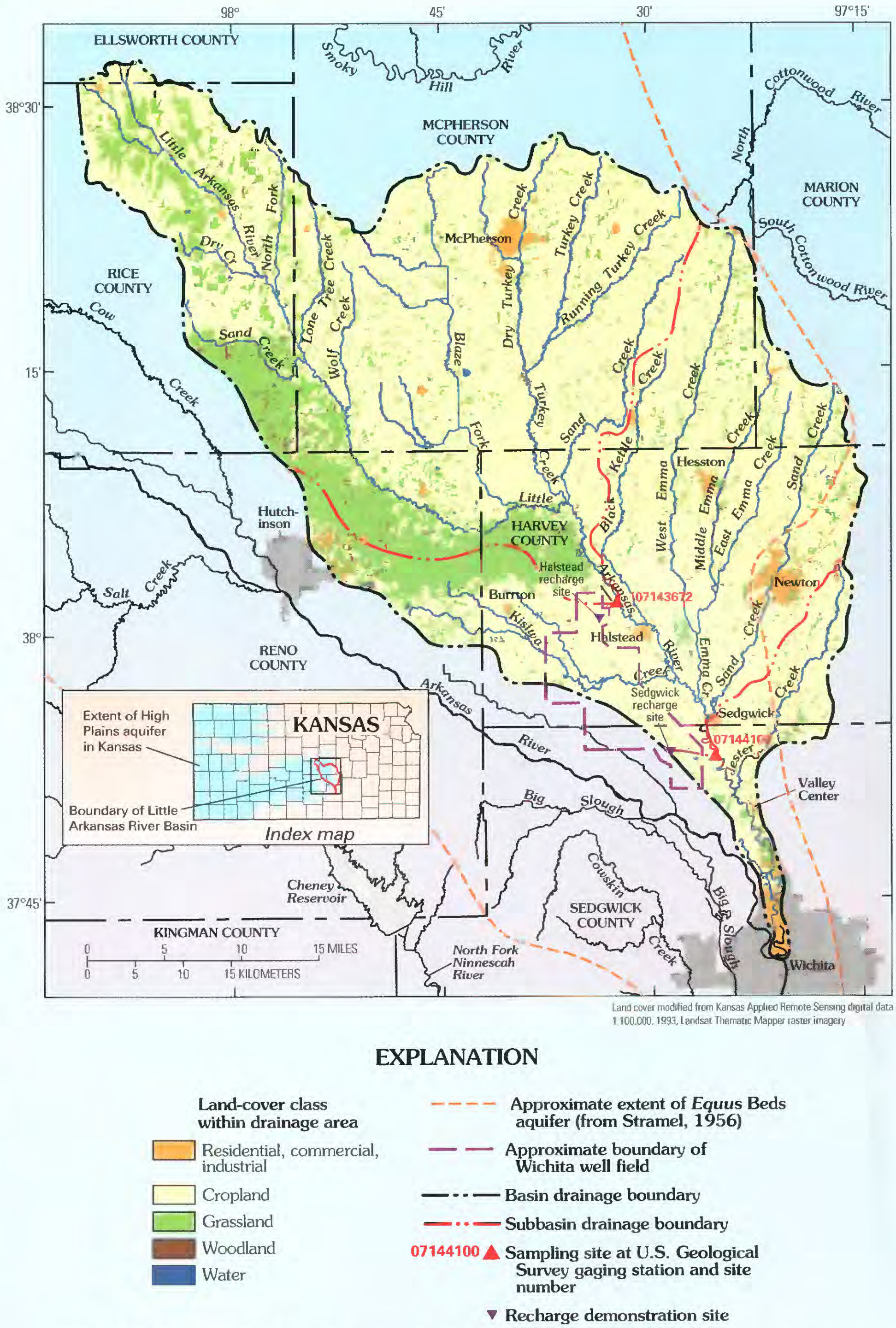


Figure 1. Land cover in the Little Arkansas River Basin and location of pertinent sites and boundaries.

December 1997. These data will be useful in determining the need for surface-water treatment to minimize the effects of atrazine before recharging the aquifer.

Land use in the Little Arkansas River Basin is extensively agricultural, with about 78 percent cropland and 19 percent grassland (fig. 1). The percentage of cropland in principal subbasins is about the same, as are the percentages of each crop type—about 63 percent wheat, 27 percent sorghum, 5 percent corn, and 5 percent soybeans. Crop data were estimated from county data compiled by the Kansas Department of Agriculture and U.S. Department of Agriculture (1997).

Methods of Study

Data were collected from 1995–97 to document the quality and quantity of water in the Little Arkansas River (Ziegler and Combs, 1997). Surface-water samples collected by the U.S. Geological Survey (USGS) used depth- and width-integrating techniques and automated samplers. The two surface-water sampling sites established for the study of atrazine are USGS gaging stations on the Little Arkansas River at Highway 50 near Halstead (site 07143672) and the Little Arkansas River near Sedgwick (site 07144100) (fig. 1). The Halstead gage has a contributing drainage area of about 686 mi^2 (square miles), and the gage near Sedgwick has a contributing drainage area of about 1,163 mi^2. Both sites are affected by ground-water withdrawals, surface-water diversions, and return flow from irrigated areas (Putnam and others, 1997, p. 288 and 290).

During the growing season, March through September, automated samplers collected two or more samples per day at the two sampling sites. During periods of low flow, October through February, fewer samples were collected, usually one per month. Although the automated sampler at the Halstead sampling site was discontinued in October 1996, manual samples were still collected periodically.

About 1,800 samples were analyzed for triazine herbicides by enzyme-linked immunosorbent assay (ELISA) (Thurman and others, 1990). The ELISA procedure is a cost-efficient and reliable indicator of atrazine. To confirm this, 191 samples also were analyzed by gas chromatography/mass spectrometry (GC/MS) to determine specific atrazine concentrations, which indicated that at least 80 percent of the triazine herbicide concentration determined by ELISA is atrazine. Therefore, the triazine herbicide concentrations determined by ELISA are referred to as atrazine in this fact sheet.

Daily mean atrazine concentrations are the average concentrations of samples collected that day. During the growing season, linear interpolation was used to estimate concentrations between days with samples collected. On days of low flow during October through February when no samples were collected, the daily mean atrazine concentration was arbitrarily assigned a value equal to the ELISA detection limit of 0.10 μg/L. Annual mean atrazine concentrations are the averages of the daily atrazine concentrations for each year.

Atrazine Concentrations, Loads, and Yields

Annual mean atrazine concentrations did not exceed the Maximum Contaminant Level (MCL) for atrazine for any year from 1995 to 1997 at either sampling site (table 1). However, daily mean atrazine concentrations in water samples from the two sampling sites were as large as 34 μg/L during spring and summer runoff (fig. 2). Concentrations larger than 3.0 μg/L did not occur at other times of the year.

The Sedgwick site had larger annual mean stream discharges than the Halstead site (table 1). The largest annual mean discharge for both sites occurred in 1995; however, that year had the smallest annual mean atrazine concentrations. Therefore, the largest atrazine concentrations did not necessarily correspond with the largest discharges. This indicates that one or more combinations of physical factors were affecting the concentration of atrazine detected in the surface-water samples. Possible physical factors include the timing of the runoff and atrazine application, crop or tillage type, method of application of atrazine, amount of atrazine applied, and other land-management techniques.

Atrazine loads were calculated to determine when large amounts of atrazine are transported in the Little Arkansas River (fig. 3). The computation of atrazine loads allow for an easier comparison between years because they account for hydrologic variability and allow for a mass-to-mass comparison. Daily atrazine loads (in pounds) were calculated by multiplying daily mean atrazine concentrations (in micrograms per liter) by daily mean discharge (in cubic feet per second) and by a unit-conversion factor of 0.00538.

Daily atrazine loads increase with an increase in either discharge or atrazine concentration. Atrazine is typically applied in early spring when crops are planted; however, this is also when rainfall generally is the most intense and likely to produce runoff. As a result, daily atrazine loads were largest during May through July when increases occurred in both discharge and atrazine concentration. In general, the Sedgwick sampling site had larger daily atrazine loads in 1995 and 1996 than the Halstead sampling site, resulting more from an increase in discharge at the downstream Sedgwick site than from an increase in atrazine concentration.

Annual mean atrazine loads were calculated by summing the daily loads. The largest annual mean atrazine loads of 2,100 and 4,100 lb (pounds) at the Halstead and Sedgwick sampling sites,

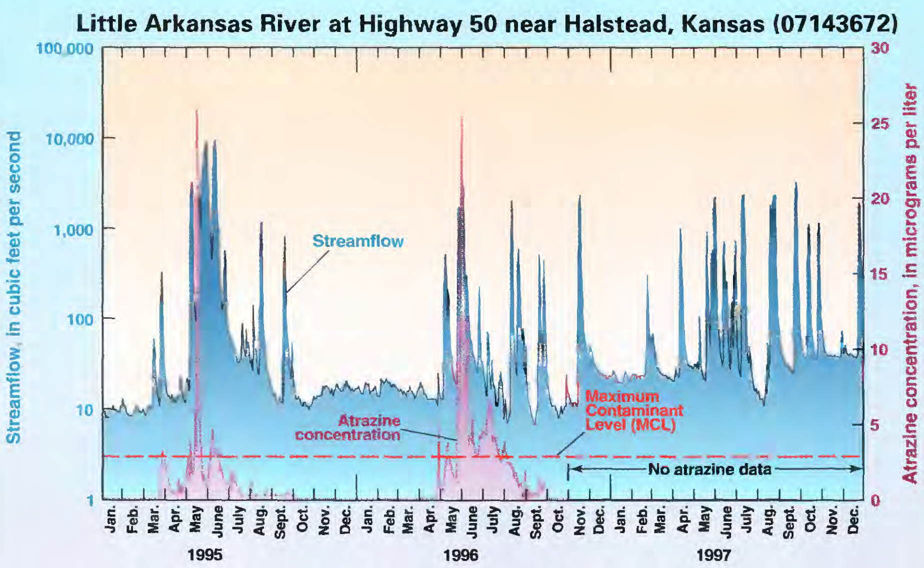
Atrazine, a Triazine Herbicide

Atrazine, one of the triazine herbicides, helps control the growth of weeds through inhibition of photosynthetic reactions. It is used extensively because it is economical and effective in reducing crop losses due to weed interference. Atrazine has gained much attention because of its frequent detection in surface- and ground-water supplies. Atrazine has a half-life in topsoil of about 60 days, but its half-life is significantly longer in subsurface soils or in ground water (U.S. Environmental Protection Agency, 1988). Atrazine is used alone or in combination with other herbicides such as alachlor and metolachlor, or it is sometimes included in a premix (Regehr and others, 1994).

The State of Kansas has adopted the U.S. Environmental Protection Agency's Maximum Contaminant Level (MCL) of 3 μg/L (micrograms per liter) for atrazine in drinking water (Kansas Department of Health and Environment, 1994). The annual mean atrazine concentration to determine compliance for public-water systems is determined by quarterly samples. Drinking water with an annual mean atrazine concentration equal to or less than the MCL is safe to drink over the course of a lifetime (Regehr and others, 1993).

Table 1. Stream discharges and atrazine concentrations, loads, and yields

	Little Arkansas River at Highway 50 near Halstead, Kansas			Little Arkansas River near Sedgwick, Kansas		
	1995	1996	1997	1995	1996	1997
Annual mean stream discharge (cubic feet per second)	401	112	208	697	205	329
Annual mean atrazine concentration (micrograms per liter)	0.9	1.6	--	1.4	2.2	2.6
Annual atrazine load (pounds per year)	2,100	1,500	--	4,100	2,200	3,200
Annual atrazine yield (pounds per square mile)	3.0	2.2	--	3.5	1.9	2.8
Daily mean stream discharge (cubic feet per second) during 90 percent of annual load	4,770	1,260	--	5,830	1,180	1,270
Mean atrazine concentration (micrograms per liter) during 90 percent of annual load	5.2	13	--	3.7	14	11



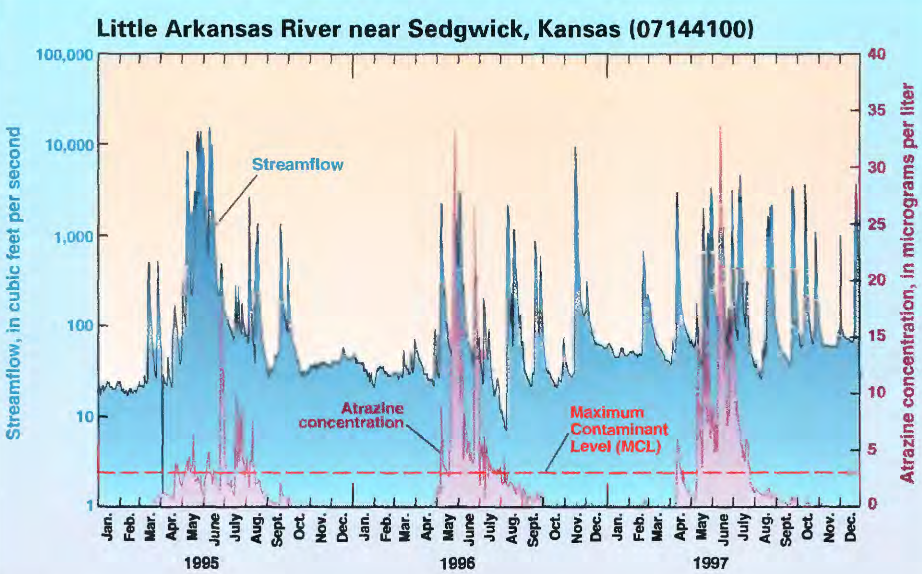


Figure 2. Daily mean stream discharges and atrazine concentrations, 1995–97, for two surface-water sampling sites in the Little Arkansas River Basin.

respectively, occurred in 1995. The smallest loads of 1,500 and 2,200 lb occurred in 1996 (table 1). For the years in which data were available, the largest annual mean atrazine loads occurred in years of largest discharge, whereas the smallest loads occurred in years of smallest discharge.

Annual atrazine yield was determined by dividing the annual load by the drainage area. Annual yield was calculated to account for the difference between the two drainage areas. If the annual yields were substantially different between the two sampling sites, this could reflect a difference in land use or land-management practices. In 1995 the larger annual yield of 3.5 lb/mi^2 (pounds per square mile) occurred at the Sedgwick site, whereas in 1996 the larger annual yield of 2.2 lb/mi^2 occurred at the Halstead site. Because the downstream Sedgwick site had larger discharges both years, the larger annual yield at the Halstead site in 1996 is probably not due to hydrologic conditions but rather a combination of other physical factors. These physical factors would be the same as those that affect the atrazine concentration, such as method of application and crop or tillage type.

Conclusions and Implications

Neither sampling site on the Little Arkansas River had an annual mean atrazine concentration greater than the MCL of 3.0 μg/L (annual mean) for atrazine during the timeframe of this study (table 1). On the basis of an estimated application rate of 1.4 lb/acre (pounds per acre) and about 25 percent of the basin in sorghum and corn, it was calculated that about 260,000 lb of atrazine were applied to crops in the Little Arkansas River Basin upstream from Sedgwick during 1995, 1996, and 1997. Of this 260,000 lb, about 1 percent or 2,600 lb were transported annually in surface runoff to the Little Arkansas River. Ninety percent of this runoff load occurred during a short period of time, generally from May through July, following application of herbicides. In fact, at the Halstead site, 90 percent of the atrazine load occurred during about 15 days each year. Similarly, at the Sedgwick site, 90 percent of the atrazine load occurred during about 40 days each year.

The mean atrazine concentration during this period of 15 or 40 days was between 5.2 and 13 μg/L at the Halstead

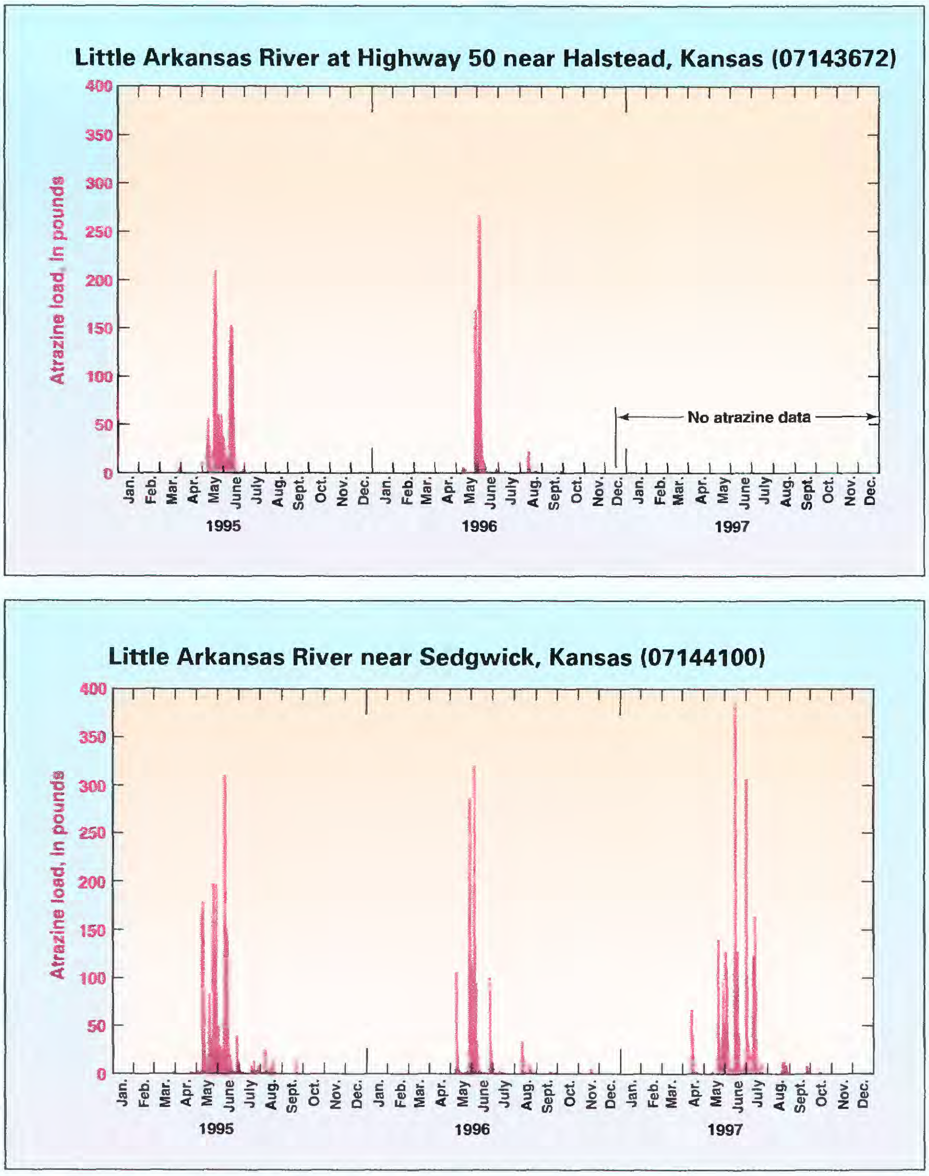


Figure 3. Daily atrazine loads in the Little Arkansas River at Highway 50 near Halstead and the Little Arkansas River at Sedgwick, 1995–97.

site and between 3.7 and 14 µg/L at the Sedgwick site. The large discharge during 90 percent of the annual load transport possibly may be used as an indicator of when treatment for atrazine is necessary.

Data from this study have defined seasonal distribution of atrazine in the Little Arkansas River and have provided information related to timing and requirements for treatment of water withdrawn from the river for artificial recharge. During the growing season when discharge generally is large and water is available for artificial recharge, atrazine concentrations are also typically large. Therefore, water treatment prior to recharge may be important to prevent degradation of the *Equus* Beds aquifer by atrazine. Water from the Little Arkansas River is suitable, with regard to atrazine, for recharge during most of the year; however, this study indicates the value of daily monitoring for atrazine during the growing season.

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