Occurrence of Nitrate and Herbicides in Ground Water in the Upper Conestoga River Basin, Pennsylvania

Water-Quality Study of the Conestoga River Headwaters, Pennsylvania

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 85-4202

Prepared in cooperation with the
U.S. DEPARTMENT OF AGRICULTURE
and the
PENNSYLVANIA DEPARTMENT OF ENVIRONMENTAL RESOURCES

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ABSTRACT

Nitrate-nitrogen and herbicide ground-water data is being collected by the U.S. Geological Survey as part of the nationwide Rural Clean Water Program designed to determine the effects of agricultural-management practices on water quality. Data collected from September 1982 to October 1983 in the 188-square mile intensively farmed upper Conestoga River basin indicates high nitrate and detectable herbicide concentrations in ground water are closely associated with agricultural practices and carbonate geology. Maximum nitrate-nitrogen concentrations from 42 wells and one spring ranged from 37 to 40 milligrams per liter in the agricultural areas, and 12 to 19 milligrams per liter in the nonagricultural areas. Median concentrations of nitrate generally were three times higher in wells that penetrated carbonate rock than in wells that penetrated noncarbonate rocks. More than 40 percent of the wells in the carbonate and agricultural areas had dissolved-nitrate concentrations that exceeded 10 milligrams per liter as nitrogen, the criterion established by the U.S. Environmental Protection Agency as excessive for drinking water. Atrazine, simazine, alachlor, and metolachlor were found almost exclusively in the agricultural and carbonate areas.

Water-quality data collected before and after installation of terraces, manure storage, and nutrient and herbicide management practices is valuable in determining the effectiveness of these agricultural practices, and will provide useful information to protect agricultural land, local water supplies, the Conestoga and Susquehanna Rivers and ultimately the Chesapeake Bay.

INTRODUCTION

An intensive study is being conducted in the headwaters of the Conestoga River basin in south-central Pennsylvania to evaluate the effectiveness of agricultural best-management practices for improving water quality. This study, which began in 1981, is part of the nationwide Rural Clean Water Program designed to monitor the effects of agricultural-management practices on water quality. The upper Conestoga River basin area was chosen for study because it was designated as a watershed having the highest priority in Pennsylvania's Agricultural 208 Plan, a program designed to identify and control nonpoint-source discharges. Data collected early in the Pennsylvania Rural Clean Water Program indicate that high concentrations and large nonpoint-source discharges of nitrate and herbicides occur in the Conestoga River. These appear to be the most significant problems due to potential economic and health effects. Most of the drinking water in the upper Conestoga River basin is ground water obtained from domestic wells and springs. Local ground-water supplies contain high concentrations of nitrate that leave the Conestoga River basin as base flow that enters the Susquehanna River and eventually the Chesapeake Bay.

This report presents nitrate and herbicide data collected from ground-water sites throughout the Conestoga headwaters area from September 1982 to October 1983. The data are discussed in relation to land-use and geology. Data collection was concentrated in carbonate-rock areas of the basin, where agriculture is most intense.

FACTORS AFFECTING THE PRESENCE OF NITRATE AND HERBICIDES

The factors that can affect the presence of nitrate and herbicides in ground water include geology, land use, sources of nitrate and herbicides, and infiltration rates. Some of these factors, such as geology and infiltration rates, are inter-related, and are discussed further in this report.

The upper Conestoga River basin (fig. 1) comprises 188 square miles in Lancaster, Berks, Chester, and Lebanon Counties. The northern two-thirds of the study area is underlain by conglomerate, shale, sandstone, and diabase. The southern one-third is underlain primarily by carbonate rocks.

Land in the upper Conestoga basin area is intensively farmed; there is little other industry. The Lancaster County Conservation District (1982) reports that about 1,250 farms, averaging 52 acres, occupy 100 square miles, 54 percent, of the study area. Of this farmland, 53 percent is used for corn production, 26 percent for hay and pasture, and 14 percent for tobacco, small grains, and other row crops. The remaining 7 percent is classified as farmstead, woodlot, and other uses. The livestock and poultry density in the area is 2.0 units per acre (one unit equals 1,000 pounds of animal weight).

Sources of nitrates and herbicides in ground water are infiltration of agricultural chemicals, manure, waste water from septic tanks and sewage treatment plants, and atmospheric deposition. The primary factors that affect the rate of infiltration of the contaminating constituents are their solubility in water, the amount of precipitation, and the geology of the source area. Nitrate is highly soluble, and many of the herbicides applied to agricultural fields are partially soluble in water. Consequently, these constituents can be easily leached to the water table by rain or melting snow and ice. In carbonate areas, such as the upper Conestoga River basin, numerous sinkholes and solution-enlarged fractures in the rocks allow direct rapid transport of both soluble and insoluble compounds of nitrate and herbicides into ground water.

DATA COLLECTION AND ANALYSES

The chemical quality and levels of ground water were measured four times to characterize existing conditions during periods of varying ground-water recharge. Data collected in September 1982 from measurements in 77 domestic wells and one spring were used to select a network including 42 wells and the

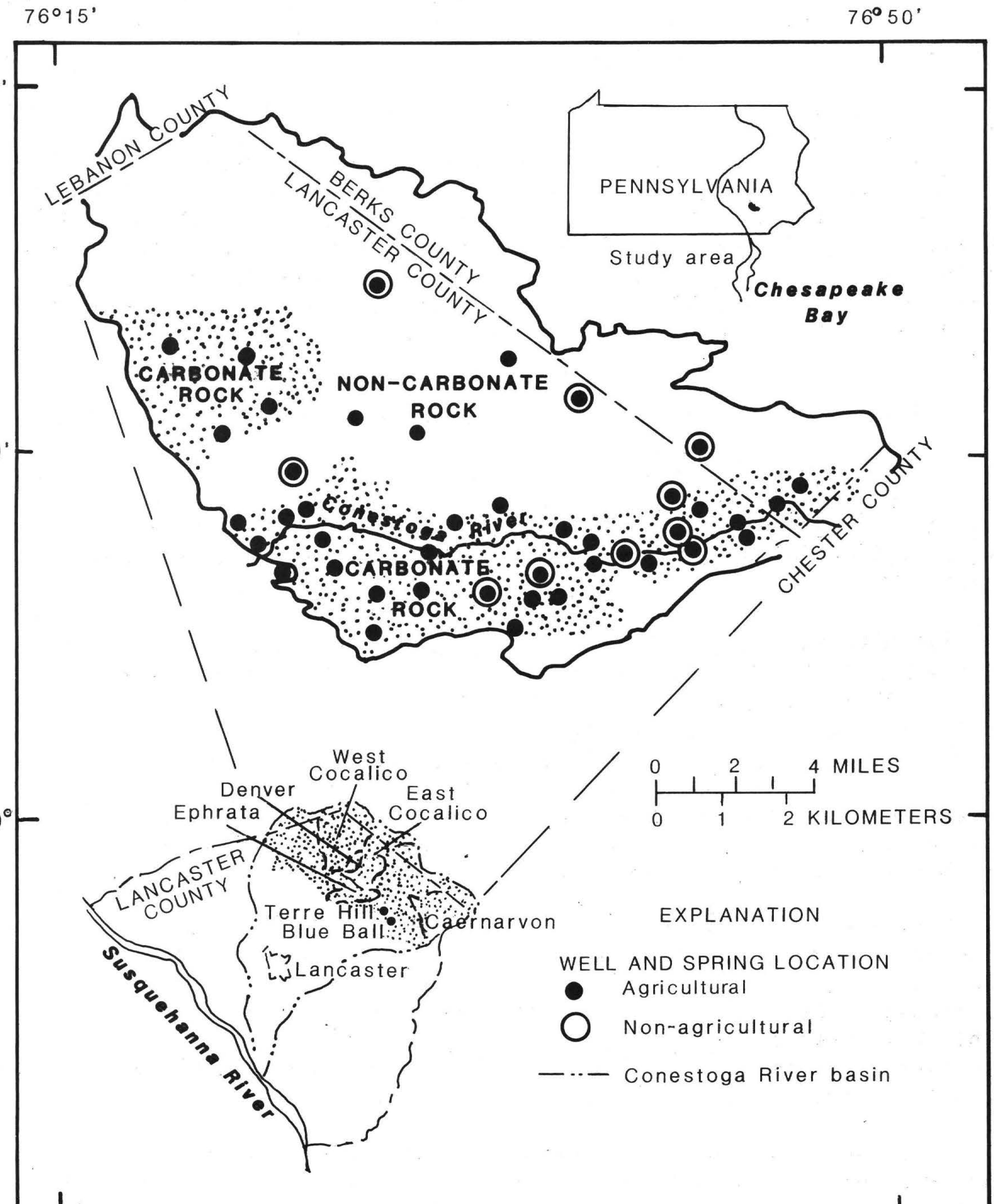

Figure 1.--Upper Conestoga River basin and ground-water sampling network.

spring (fig. 1) for continued monitoring of the shallow ground-water system (100-250 feet deep). The wells are generally cased to bedrock to prevent surface water and ground water in unconsolidated deposits overlying the bedrock from entering the water supply.

Water-quality samples were collected from domestic wells after pumping for a sufficient period to allow water temperature, specific conductance, and pH to come to equilibrium. Nutrient samples were preserved with mercuric chloride, and all samples were packed with ice and delivered within 24 hours of collection to the laboratory. Chemical analyses were performed by the Pennsylvania Department of Environmental Resources Bureau of Laboratories at Harrisburg. Nitrate analyses were determined by procedures given by Skougstad and others (1979, p. 437). Herbicide analysis were determined by methods described by Goerlitz and Brown (1972).

CONCENTRATIONS OF NITRATE AND HERBICIDES FOUND IN GROUND WATER

Of the 43 wells sampled for nitrates and herbicides, 33 wells are in carbonate rocks and 10 are in noncarbonate rocks (fig. 1). Thirty-two of the wells are in agricultural areas, and 11 are in nonagricultural areas, primarily residential neighborhoods or small towns surrounded by agricultural fields.

The nitrate concentrations are substantially higher in the agricultural areas than in the residential areas (table 1). The maximum nitrate concentrations as nitrogen, during the study ranged from 37 to 40 mg/L (milligrams per liter) in the agricultural areas and from 12 to 19 mg/L in the nonagricultural areas. Median concentrations of nitrate ranged from 8.6 to 12 mg/L and from 3.4 to 3.8 mg/L in the agricultural and nonagricultural areas, respectively. However, median concentrations of nitrate generally were three times higher in wells that penetrated carbonate rock than in wells that penetrated noncarbonate rocks.

Throughout the year, more than 40 percent of the wells sampled in the carbonate and agricultural areas had dissolved-nitrate concentrations that exceeded 10 mg/L as nitrogen, the criterion established by the U.S. Environmental Protection Agency (1980) as excessive for drinking water (table 2). Even though 5 of the 11 nonagricultural wells were outside the carbonate area, as much as 27 percent of the samples from the 11 wells had excessive nitrate concentrations.

Atrazine, simazine, alachlor, and metolachlor, the herbicides detected most frequently, were found almost exclusively in the agricultural and carbonate areas (fig. 1 and table 1). In the agricultural area, maximum concentrations of these herbicides were found in the spring, summer, fall, and spring, respectively, although all were applied as pre-emergent herbicides in May and June. The number of wells in which herbicides were detected was about constant throughout the year. This appears to indicate that a significant amount of herbicide remains in the soils and is leached to the ground-water system after the growing season. In the nonagricultural area, atrazine and simazine were each found in only one analysis, and the concentrations were traces slightly above the detection limit.

Table 1.—Number of observations (n), ranges, and medians of nitrate and herbicide concentrations in wells in the upper Conestoga River basin

	Agricultural	Non-agricultural	Carbonate	Non-carbonate
Nitrate, dissolved as N (mg/L)				
FALL 1982				
n	32	11	33	10
maximum–minimum	40 - 0.40	12 - 0.82	40 - 0.40	8.2 - 0.82
median	8.6	3.4	9.2	3.2
SPRING 1983				
n	31	11	32	10
maximum–minimum	39 - 1.1	15 - .98	39 - 1.1	10 - .98
median	9.0	3.5	9.4	3.0
SUMMER 1983				
n	32	11	33	10
maximum–minimum	40 - .53	19 - 1.2	40 - .53	19 - 1.2
median	12	3.8	12	5.8
FALL 1983				
n	32	11	33	10
maximum–minimum	37 - .3	12 - 1.2	37 - .30	8.8 - 1.2
median	8.7	3.4	9.1	3.2
Atrazine, total (µg/L)				
SPRING 1983				
n	32	11	33	10
maximum–minimum	3.0 - <.2	<.2 - <.2	3.0 - <.2	<.2 - <.2
# observations > 0.2 (µg/L)[1]	11	0	11	0
SUMMER 1983				
n	32	11	33	10
maximum–minimum	1.3 - <.2	<.2 - <.2	1.3 - <.2	<.2 - <.2
# observations > 0.2 (µg/L)[1]	13	0	13	0
FALL 1983				
n	32	11	33	10
maximum–minimum	1.2 - <.2	.2 - <.2	1.2 - <.2	<.2 - <.2
# observations > 0.2 (µg/L)[1]	10	1	12	0
Simazine, total (µg/L)				
SPRING 1983				
n	32	11	33	10
maximum–minimum	1.6 - <.2	<.2 - <.2	1.6 - <.2	<.2 - <.2
# observations > 0.2 (µg/L)[1]	3	0	3	0
SUMMER 1983				
n	32	11	33	10
maximum–minimum	3.4 - <.2	<.2 - <.2	3.4 - <.2	<.2 - <.2
# observations > 0.2 (µg/L)[1]	4	0	4	0
FALL 1983				
n	32	11	33	10
maximum–minimum	0.7 - <.2	<.4 - <.2	0.7 - <.2	<.2 - <.2
# observations > 0.2 (µg/L)[1]	7	1	8	0
Alachlor, total (µg/L)				
SPRING 1983				
n	32	11	33	10
maximum–minimum	1.0 - <.05	<.05 - <.05	1.0 - <.05	<.05 - <.05
# observations > 0.05 (µg/L)[1]	5	0	5	0
SUMMER 1983				
n	32	11	33	10
maximum–minimum	1.8 - <.05	<.05 - <.05	1.8 - <.05	<.05 - <.05
# observations > 0.05 (µg/L)[1]	2	0	2	0
FALL 1983				
n	32	11	33	10
maximum–minimum	3.0 - <.05	<.05 - <.05	3.0 - <.05	<.05 - <.05
# observations > 0.05 (µg/L)[1]	3	0	3	0
Metolachlor, total (µg/L)				
SPRING 1983				
n	32	11	33	10
maximum–minimum	0.4 - <.1	<.1 - <.1	.4 - <.1	<.1 - <.1
# observations > 0.1 (µg/L)[1]	3	0	3	0
SUMMER 1983				
n	32	11	33	10
maximum–minimum	0.2 - <.1	<.1 - <.1	.2 - <.1	<.1 - <.1
# observations > 0.1 (µg/L)[1]	2	0	2	0
FALL 1983				
n	32	11	33	10
maximum–minimum	0.1 - <.1	<.1 - <.1	.1 - <.1	<.1 - <.1
# observations > 0.1 (µg/L)[1]	1	0	1	0

1/ Indicated concentration is minimum detection limit.

Table 2.--Percentages of wells that exceeded the U.S. Environmental Protection Agency maximum-allowance criterion for nitrate in drinking water [10 milligrams per liter as N]

	Carbonate	Non-carbonate	Agricultural	Non-agricultural
Fall 1982	42	0	41	9
Spring 1983	44	0	42	18
Summer 1983	67	20	66	27
Fall 1983	45	0	41	18

SIGNIFICANCE OF NITRATE AND HERBICIDE LEVELS FOUND

Nitrate concentrations higher than 10 mg/L as nitrogen may adversely affect humans and livestock (Mancl, 1983, p. 1); newborns, in particular, are sensitive to high concentrations. Infants ingesting excessive quantities of nitrate in their first several months may suffer from methemoglobinemia, or blue-baby disease. This is because newborns have a higher gastric pH, that permits bacteria to convert nitrate to nitrite; the nitrite then blocks the blood's ability to carry oxygen.

Criteria have not been established for the detected herbicides in drinking water. Although low levels of triazine herbicides (atrazine and simazine) are being found in drinking-water supplies in various parts of the country (National Academy of Sciences, 1977, p. 533), little has been reported on the long-term effects of low levels of the detected herbicides on animal life. This may be because these herbicides have been used on a widespread scale only for the past 15-20 years. However, recent reports have indicated that alachlor is suspected of having carcinogenic properties (Dr. Gerard Florentine, Pennsylvania Department of Agriculture, oral commun., 1984).

Nitrate and herbicides enter streams with ground-water discharges (referred to as surface water base flow) and may affect downstream water users and aquatic life. Ground water and treated surface water from the Conestoga River and its tributaries is used for drinking by communities in and downstream from the study area. These communities include Lancaster, Ephrata, Blue Ball, Caernarvon, Denver, East and West Cocalico, and Terre Hill. Conventional treatment techniques used in the study area do not remove nitrates from the water and are not designed to remove herbicides.

Ultimately, surface water from the Conestoga River, and other streams draining intense agricultural areas, flows into the Chesapeake Bay. Many areas outside the study area in Blair, Center, Cumberland, Franklin, Lehigh, Northampton, and York counties in Pensylvania also are highly agricultural and underlain by carbonate rocks; therefore, they too may have similar water quality. The U.S. Environmental Protection Agency (1982, p. i-vi) reports that nitrate and herbicides contribute to the degradation of the Bay. High nitrate concentrations contribute to eutrophication, a nutrient-rich condition characterized by algal blooms, that prohibits light from reaching submerged aquatic vegetation, causing depletion of oxygen supplies. High concentration of herbicides in the water or the bottom material may cause further reduction of the bay-grass population. Insufficient aquatic vegetation, deficient oxygen supplies, and bio-accumulation of herbicides will continue to be detrimental to the aquatic life in the Bay, including organisms such as diatoms, shellfish, and fin-fish.

SUMMARY

Data collected during an intensive study in the upper Conestoga River basin indicates the occurrence of high nitrate and herbicide concentrations in drinking water is closely associated with agricultural practices and geology. Transport of nitrate and herbicides through ground water in areas underlain by carbonate rocks is rapid; therefore, proper management of soluble nutrients and herbicides is especially important in these areas. Monitoring of water quality before and after the installation of terraces, manure storage, and nutrient and herbicide management practices will provide valuable information that is necessary to determine the effectiveness of these practices. Such information will help in making proper management decisions that will protect agricultural land, local water supplies, the Conestoga River, Susquehanna River, and ultimately the Chesapeake Bay.

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