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UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
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CHEMICAL CHARACTER OF STREAMS IN THE DELAWARE RIVER BASIN

By Peter W. Anderson and Leo T. McCarthy, Jr.

1963
~~1972~~

U.S. GOVERNMENT PRINTING OFFICE: 1962—O-632210

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
BRANCH OF QUALITY OF WATER
P.O. BOX 133
TRENTON 1, NEW JERSEY

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U.S. Geological Survey Open-File Report

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Introduction: The water chemistry of streams in the Delaware River basin falls into eight general groups, when mapped according to the prevalent dissolved-solids content and the predominant ions normally found in the water. The approximate regions representing each of these iso-chemical quality groups are shown on the accompanying base map of the drainage basin. The prevalent chemical characteristics of the streams in each region are summarized in the following table:

Region	Dissolved solids (in parts per million)	pH	Predominant ions
1	10-70	6.0-7.5	calcium, bicarbonate, sulfate
2	100-500	< 5.5	calcium, sulfate
3	150-2,000	< 5.0	calcium, sulfate
4	100-250	6.5-8.5	calcium, magnesium, bicarbonate
5	70-150	6.0-8.0	calcium, sulfate, bicarbonate
6	40-150	5.5-6.5	calcium, sulfate
7	20-100	4.0-6.0	sodium, sulfate, chloride
8	100-25,000	6.5-7.5	sodium, chloride

The data in this table represent the majority of water-quality measurements in a region. A few streams in each region may not fall within these general limitations. Also, the main stems of the Delaware, Lehigh, and Schuylkill Rivers are affected by the water quality of tributary streams long after the rivers have crossed the regional boundaries. These effects are discussed generally under regions 2, 3 and 4.

Region 1, Upper basin: The headwaters of the Delaware River above the Delaware Water Gap and the headwaters and eastern tributaries of the Lehigh River above Lehigh Gap contain water of generally excellent quality for most uses. Water in most of the streams, lakes, and ponds has a dissolved-solids content in the range from 10 to 70 ppm (parts per million); slightly lower concentrations usually are found near headwaters of the tributaries. Surface waters are soft, usually ranging from 10 to 40 ppm in calcium and magnesium hardness. The pH of these waters usually ranges from 6.0 to 7.5 and the predominant ions are calcium, bicarbonate, and sulfate.

Streams in this region drain rough, mountainous, heavily-wooded lands of the Appalachian Plateaus and Appalachian Valley provinces. The region is underlain by shales, sandstones, and conglomerates mostly of Devonian age. Intense Pleistocene glaciation has left extensive drift deposits. The character and thickness of the glacial drift varies considerably from place to place, producing local variation in the quality of the ground water that issues from these deposits.

Although the topography and geology of this part of the Delaware River basin are similar to the adjacent Susquehanna River basin, the run-off per square mile is usually greater. A possible explanation of this phenomenon may be the higher average annual precipitation rates in the Delaware River basin compared to those in the Susquehanna River basin. Streams in the upper Delaware River basin usually have a low dissolved-solids content which is due to the brief duration of contact between the

solutes and the water. The rate of weathering or solute degradation in the basin above Easton is about half that in the basin between Easton and Trenton, in tons per square mile.

The Pleistocene drift deposits, a virtual lack of solutes, and the high runoff rates are dominant factors influencing the chemical quality of streams in this region.

Region 2, Western Tributaries Lehigh River: Although the headwaters of the Lehigh River and its eastern tributaries are low in dissolved-solids content, the chemical quality of the Lehigh River changes drastically below White Haven, Pa. Several of the river's western tributaries between Tannery and Jim Thorpe, Pa., receive drainage from the Middle-Anthracite coal fields. This mine drainage is usually acidic and very hard, and normally contains high concentrations of aluminum, iron, manganese, calcium, magnesium, sulfate, and free sulfuric acid. The chemical character of receiving streams is influenced greatly by this acid-mine drainage.

Hunter Run, Black Creek, Nesquehoning Creek and other western tributaries that drain the coal fields are usually acidic throughout their entire length, but progressive dilution and neutralization takes place downstream from the coal fields. Mine drainage and unaffected, naturally dilute surface waters produce the wide variation in prevalent dissolved-solids content of the region, 100-500 ppm.

Water from Lehigh River tributaries below Jim Thorpe contains high calcium bicarbonate concentrations, and this water tends to neutralize the effect of acid-mine drainage. Frequent analyses of water from the Lehigh River at Walnutport, Pa., between 1944 and 1952, usually indicated a pH between 4.5 and 5.5, whereas downstream, at Catasaqua, Pa., the pH was greater than 6.0 during 90 percent of the record. This change shows the neutralizing effect of the calcium bicarbonate waters in tributaries below Jim Thorpe.

Region 3, Headwaters Schuylkill River: The headwaters of the Schuylkill River are underlain by the once heavily mined Southern-Anthracite coal fields. The river above Berne, Pa., and its two main tributaries in this reach, the West Branch and Little Schuylkill River, carry a major part of the mine discharge from these fields. Some streams from these fields also drain into the Susquehanna and Lehigh River basins.

Acid-mine drainage is the principal factor influencing the chemical quality of the streams above Berne. Water in most of the streams above Berne has a pH less than 5.0, is very hard, and contains high concentrations of aluminum, iron, manganese, calcium, magnesium, sulfate, and free sulfuric acid. Dissolved-solids content of most streams in this region ranges from 150 to 2,000 ppm. Higher concentrations are produced from acid-mine drainage.

The acid-mine drainage affects the chemical quality of the main stem Schuylkill River throughout its length (through Regions 4 and 5). However, below Berne calcium bicarbonate water from tributaries dilutes and neutralizes the acidic Schuylkill River water. As a result, the bicarbonate ion concentration usually exceeds 25 ppm at Pottstown, Pa., in contrast to the negligible amount at Berne. The affects of dilution also are reflected in a reduction in dissolved-solids content. The dissolved-solids content exceeded 400 ppm at Berne, 250 ppm at Pottstown, and 210 ppm at Philadelphia, Pa., less than 50 percent of the time.

Region 4, Middle basin: Streams in this region drain the Appalachian Valley and New England provinces. The topography varies from low, well-rounded hills and valleys in the south to the ridge of mountains along the northern boundary, which are the foothills of the Appalachian Mountains. Except for small forested areas, most of this region is farm land.

The geology of this region is complex. Extensive beds of Cambrian and Ordovician limestones and dolomites are present throughout this region. These deposits greatly influence the chemical quality of surface waters. Water issuing from these deposits contains high concentrations of calcium magnesium, and bicarbonate. These ions predominate in streams that traverse these deposits. The pH of most surface water ranges from 6.5 to 8.5 and the dissolved-solids content from 100 to 250 ppm.

The chemical quality of several streams in the lower basin is influenced by industrial and domestic wastes from the highly populated and industrial Philadelphia-Chester area along the Delaware estuary. The water quality in lower reaches of tributary streams below Trenton, N. J., is affected also by tidal influences. These effects are described in region 8.

Region 6, Inner Coastal Plain: Streams in this region drain small areas and discharges are normally low. The lower reaches of these small streams are affected by tides (see region 8). The land is fertile and highly cultivated.

The boundaries of the inner Coastal Plain approximately coincide with the boundaries of the Mesozoic glauconitic sandstones. Rocks along the southern border are youngest, approaching in age the time-unit boundary between Mesozoic and Cenozoic.

Dissolved-solids content of surface water above tidal influence usually ranges from 40 to 150 and pH from 5.5 to 6.5, and the predominate ions are calcium and sulfate. The chemical quality of streams in the Camden, N. J., area is affected by industrial and domestic wastes.

Region 7, Outer Coastal Plain: Streams in this region flow through shallow, open valleys characteristic of the Atlantic Coastal Plain province. The lower reaches of these streams are affected by tides in the Delaware estuary (see region 8). Rock materials are largely Cenozoic unconsolidated sands, gravels, silts, and clays.

Dissolved-solids content of the streams above tidal influence usually ranges from 20 to 100 ppm and pH from 4.0 to 6.0, and the predominate ions are sodium, sulfate, and chloride.

Region 8, Delaware Estuary: Below Trenton, N. J., the chemical quality of the Delaware River and the lower reaches of tributaries entering the tidal basin is influenced in varying degrees by saline water from the Delaware Bay and the Atlantic Ocean. The salinity or salt content in the water increases in the seaward direction. Salinity also increases when streamflow is reduced, for when low streamflow persists the saline water encroaches progressively upstream. The saltiness of the water in the estuary at any location is dependent upon the distance from the ocean, the net fresh-water salt-water outflow, the stage and range of tide, and the climatic conditions.

The effect of fresh-water inflow on the salinity of the Delaware estuary is illustrated by comparing salinities in 1957, a year of extended summer drought and below average streamflow, with 1960, a year having greater than average streamflow. The average fresh-water discharge at Trenton was 8,957 cfs in 1957 and 14,230 cfs in 1960. During 1957, the chloride concentration at Marcus Hook and Chester equalled or exceeded 400 ppm on 144 and 99 days, respectively, during the year; and at Bridesburg (a section in northeast Philadelphia) exceeded 50 ppm on 86 days. In 1960, there were no days on which the chloride concentration exceeded 400 ppm at Marcus Hook or Chester, or exceeded 50 ppm at Bridesburg.

Water in the Delaware estuary can be divided into a fresh-water zone containing less than 0.3 percent sea water, an intermediate zone containing 0.3-67 percent sea water, and a saline zone containing 67 to 90 percent or more sea water. During the winter and spring months, the fresh-water zone extends from Trenton to New Castle, Del. When the Delaware River and its tributaries are at flood stage, the fresh-water zone extends below Delaware City, Del. However, during periods of low river flow, saline water from Delaware Bay advances upstream. The most prolonged upstream advance of the intermediate zone usually occurs in the summer and fall months. At these times, the front of the intermediate zone is generally in the vicinity of Chester, Pa.

Selected References: Additional information pertaining to the chemical quality of streams in the Delaware River basin may be obtained at the District Office of the U.S. Geological Survey, Rm. 1302 Custom House, Philadelphia, Pa. Several reports describing the chemical characteristics of portions of the basin are listed below.

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76°
42°
NEW YORK
PENNSYLVANIA
74°
42°
N
West Branch Delaware River
Cannonsville Res.
East Branch Delaware River
Pepacton Res
Hancock
Neversink Res
DELAWARE RIVER
Lyberry Res
Prompton Res
Swinging Bridge Res
Lake Wallenpaupack
Port Jervis
NEW YORK
NEW JERSEY
1
2
3
4
4
5
5
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6
7
7
Delaware Water Gap
Easton
Pottstown
Camden
Chester
Wilmington
New Castle
PENNSYLVANIA
MARYLAND
Chesapeake Bay
MD.
DEL.
DELAWARE BAY
39°
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74°
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5 0 5 10 15 20 25 Miles