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pH in Streams Draining Small Mined and Unmined Watersheds in the Coal Region of Appalachia

Kenneth L. Dyer
Willie R. Curtis

Abstract

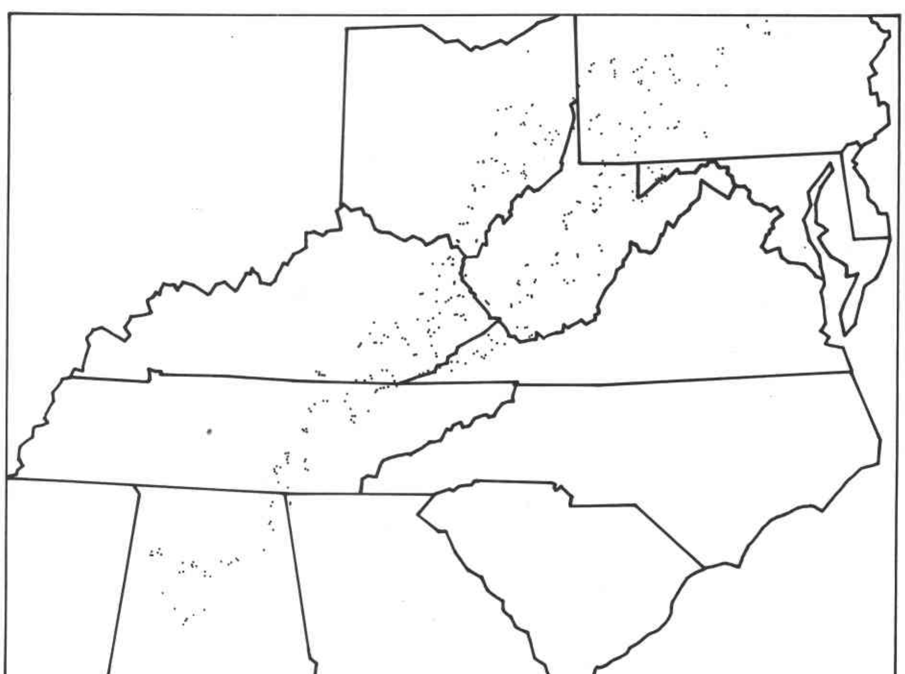
To better evaluate the effects of surface mining for coal in first-order watersheds in Appalachia, a network of 421 water-quality sampling stations was established in 136 counties in nine states in 1977 and sampled on approximately a monthly basis until August 1979. Three categories of watersheds were sampled: (1) unmined, (2) mined after January 1972, and (3) mined before January 1972. Mean pH values averaged 7.0, 6.7, and 6.3 for these three categories of watersheds, respectively.

Introduction

A network of sampling sites on small first-order surface-mined and unmined watersheds throughout Appalachia was needed so that water-quality data could be correlated with the type and date of surface mining, the type and date of reclamation, and the type of coal mined. It was intended that these small reference watersheds provide a data base for future studies to aid in determining differences in stream-water quality from mined and unmined watersheds, differences in the effects of various mining and reclamation techniques on water quality, and water-quality recovery rates in streams that have been affected by mining.

Such a network of 421 sampling sites was established in 1977 and maintained until August 1979 in 136 Appalachian counties in nine states where coal was surface mined (Fig. 1). Sites were selected in each county to represent three watershed conditions: (1) unmined, (2) surface mined before January 1972, and (3) surface mined after January 1972. Most watersheds mined before January 1972 were either not reclaimed or were reclaimed in accordance with desires of the mine company or land owner. Most watersheds mined after January 1972 were reclaimed in accordance with state and/or federal standards.

Figure 1. — Distribution of sampling sites in the Appalachian coal field.



The streams draining these watersheds were sampled on an approximate monthly basis and analyzed for common ions, trace elements, nutrients, suspended solids, settling volume, acidity, turbidity, and pH. All these data have been published in a series of seven state reports by Dyer (1982). To obtain a quick overview of the relative health of these streams, we need look at only one parameter, pH, because it is probably the best single indicator of water-quality problems associated with surface mining. If other conditions are suitable, a stream with a pH of 5 or above should be capable of supporting numerous life forms. A stream with a pH of about 4 or below is likely to be sterile except for acid-loving bacteria and algae; it is likely to contain appreciable concentrations of several toxic elements; and it will be corrosive to concrete and metals that it comes in contact with.

The pH value is the most common measure of acid in streams and is defined as the negative logarithm of the hydrogen ion activity. Table 1 illustrates the relationship of pH, hydrogen ion activity and pH values of several common substances. Mining for coal will generally cause a change in the pH of streams draining the mined area. These changes in pH are likely to have a major impact on the ability of drainage water to dissolve minerals from spoil materials, soils, sediment, and the stream bed. Acid mine drainage and streams affected by it can be expected to have higher than normal concentrations of elements such as iron, aluminum, manganese, nickel, and zinc. Water severely affected by acid mine drainage can be expected to be almost barren of life, not only because of the acid itself, but also because of the toxic elements dissolved from minerals by the acid.

Table 1. — The relationship of pH, hydrogen ion activity, and the pH of common substances

pH	Hydrogen ion activity		pH of common substances
	moles/1		
10	0.0000000001	1×10^{-10}	
9	0.000000001	1×10^{-9}	
8	0.00000001	1×10^{-8}	Baking soda in water (pH = 8.4)
7	0.0000001	1×10^{-7}	Pure water (pH = 7.0)
6	0.000001	1×10^{-6}	
			Pure rain water (pH = 5.65) (Saturated with carbon dioxide)
5	0.00001	1×10^{-5}	
			Zone of acid rain (pH = 2.4 to 5.6)
4	0.0001	1×10^{-4}	
			Zone of acid mine drainage (pH = 2.0 to 4.5)
3	0.001	1×10^{-3}	Vinegar (pH = 2.4 to 3.4)
			Lemon juice (pH = 2.3)
2	0.01	1×10^{-2}	

Observations and Discussion

Mean monthly pH values were compiled for sites with seven or more samples. Figures 2 to 4 show the means of the pH values for unmined, recently surface-mined, and old surface-mined watersheds. Mean pH values more nearly reflect stream conditions during the major part of the year than pH values computed from mean hydrogen ion concentrations.

The mean pH values for each site were grouped by watershed category and averaged again; the overall means obtained were 7.0 for 135 unmined watersheds, 6.7 for 152 recently mined watersheds, and 6.3 for 134 old mined watersheds. Standard deviations for these mean pH values were 0.8, 1.6, and 1.7 pH units, respectively.

Hydrogen ion concentrations were computed from each sample pH value and averaged for each site. Then they were converted to mean pH values that on the average were 0.19, 0.37, and 0.24 pH units lower; respectively, than the mean pH values given above. For most sites, especially the unmined sites, this difference was not very appreciable.

Individual-site pH values based on mean hydrogen ion concentrations were converted to mean hydrogen ion concentration, averaged by watershed category, and converted to pH again. These pH values were 5.79, 3.95, and 3.84 for the unmined, recently mined, and old mined watersheds, respectively. According to one school of thought, this computation should be representative of the larger streams, which show the composite effects of the smaller streams. Because of the buffering effect of several constituents normally found in stream water and not reflected in hydrogen ion concentrations, this set of pH values is appreciably lower than what we normally find in the larger streams draining watersheds in each mining status category in Appalachia. So, pH values computed from mean hydrogen ion concentrations appear to have little or no real validity or significance and are not discussed further.

In Table 2, the mean pH value from each site was categorized by pH range, state, and mining status. In all three mining status categories, the most common pH range was 7.0 to 7.9. Nearly half of the 421 sites evaluated had pH means in this range, and more than half of the re-

Figure 2. — pH levels in unmined watersheds.

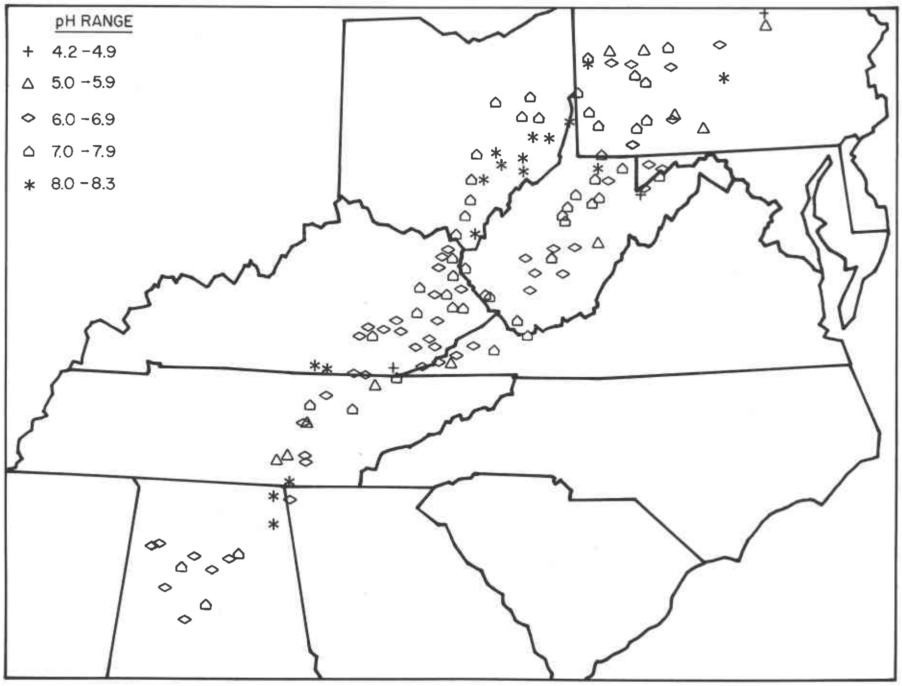
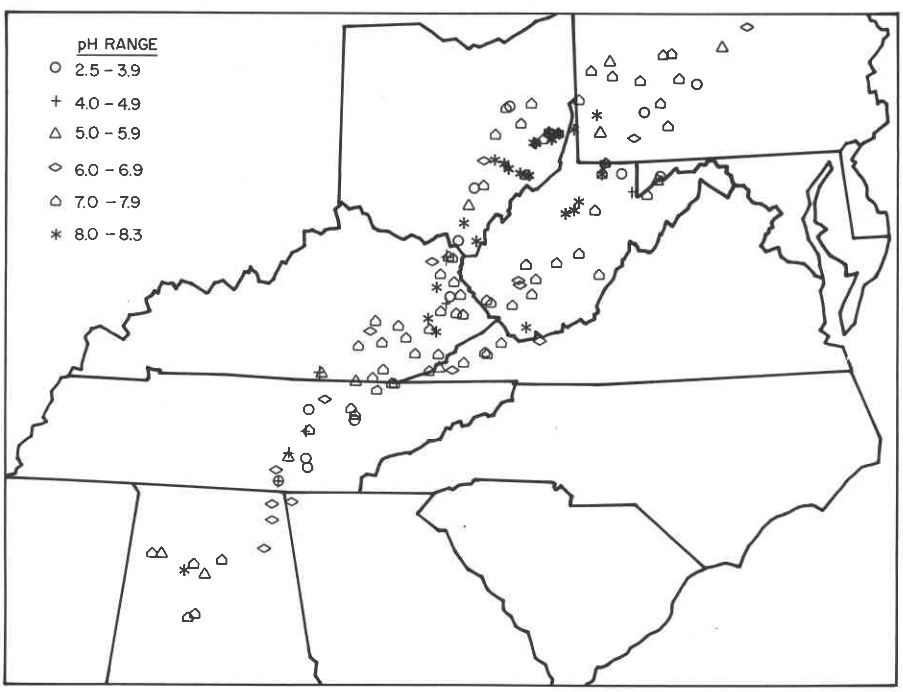


Figure 3. — pH levels in watersheds mined after January 1972.



mainder had pH means of 6.0 to 6.9 and 8.0 to 8.9. Only 22 percent of all watersheds had a mean pH value of less than 6.0: 10 percent of the unmined watersheds, 24 percent of the recently mined watersheds, and 33 percent of the old mined watersheds. In general, it seems that acid mine drainage is more likely to occur in the old mined watersheds than in the newly mined ones. This trend is apparent in the three lowest pH ranges in Table 2 and can probably be attributed to both improved mining and reclamation procedures and to deliberate neutralization of acid mine drainage on the recent surface mines. Recent restrictions on the use of high sulfur coal and requirements for neutralizing acid mine drainage have tended to reduce mining activities in areas most likely to produce acid mine drainage.

Figure 2 shows that while the more alkaline streams (pH value of 7.0 or higher) on unmined watersheds are scattered throughout Appalachia most are concentrated in Ohio, north-central West Virginia, southwestern Pennsylvania, and along the Kentucky-West Virginia border. We believe that the generally alkaline status of these streams usually can be attributed to limestone or calcareous strata on the watersheds.

Streams draining the recently mined watersheds are more frequently alkaline than those draining unmined watersheds (Figs. 2 and 3). The only readily observable concentration of severely acid streams in the recently mined watersheds (pH values averaging less than 5.0) is in Tennessee.

Figure 4 displays pH levels for streams draining the old mined watersheds and shows a belt of streams with relatively low pH values along the northwest margin of the sampled area. Much of this belt, particularly in Ohio, corresponds to a similar belt of high pH streams draining the unmined watersheds (Fig. 2). The high pH and high alkalinity of streams draining these unmined watersheds seem to indicate the presence of calcareous sedimentary strata over most of this belt. Careful placement of the calcareous material with and below the acid-producing spoil might largely ameliorate the production of acid from mines in this area.

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Kenneth L. Dyer is a hydrologist and Willie R. Curtis is a research forester, Northeastern Forest Experiment Station, Berea, Kentucky.

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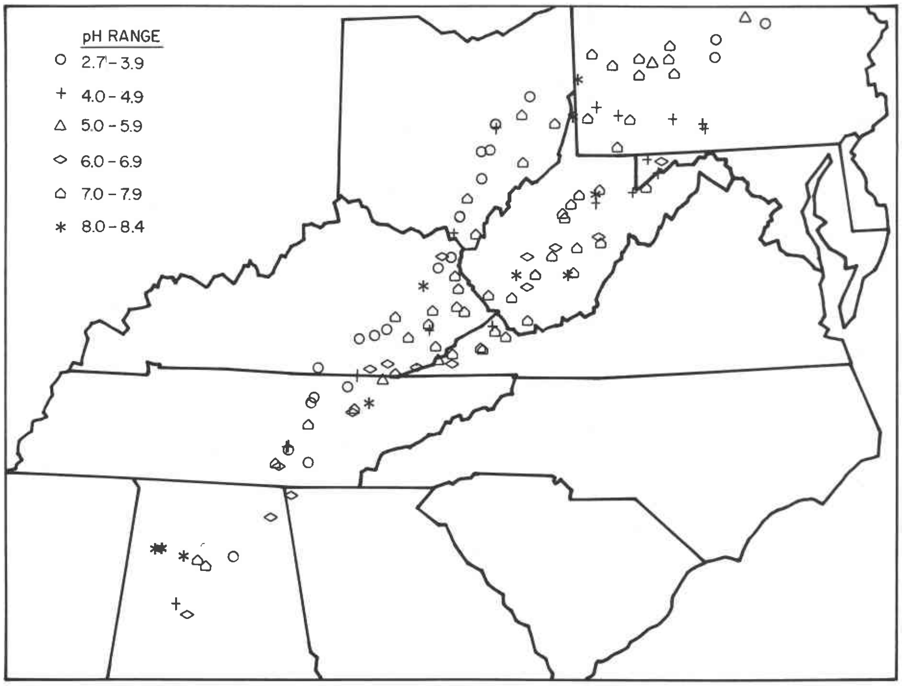
Figure 4. — pH levels in watersheds mined before January 1972.



Figures 3 and 4 indicate that acid mine drainage was a greater problem from the old pre-1972 surface mining than from more recent mining. The better placement of spoil associated with modern mining methods may have been the main factor in keeping acid mine drainage under control. Also, runoff from some recently mined watersheds has been chemically treated to neutralize acid. However, it is not known how much of the observed improvement was due to chemical treatment and how much was due to better mining and reclamation techniques. By using information gained from careful examination of the overburden strata, future surface mining operations in Appalachia could result in less acid mine drainage, and normal acidity in most streams could be maintained.

Table 2. — Number of watersheds categorized by mining status, state, and pH range

State	pH Range						
	2.49-2.99	3.00-3.99	4.00-4.99	5.00-5.99	6.00-6.99	7.00-7.99	8.00-8.40
Unmined Watersheds:							
Alabama	—	—	—	—	8	2	2
Georgia	—	—	—	—	1	—	—
Kentucky	—	—	1	—	16	11	2
Maryland	—	—	—	—	2	—	—
Ohio	—	—	—	—	—	9	8
Pennsylvania	—	—	1	5	7	10	1
Tennessee	—	—	—	3	6	4	—
Virginia	—	—	—	1	3	2	—
West Virginia	—	—	1	1	11	15	2
Total Unmined	—	—	3	10	54	53	15
Mined after Jan. 1972:							
Alabama	1	—	—	2	3	7	1
Georgia	—	—	—	—	1	—	—
Kentucky	—	1	3	2	2	24	1
Maryland	1	—	—	—	—	2	—
Ohio	—	3	1	1	1	13	10
Pennsylvania	1	3	—	3	3	10	2
Tennessee	1	4	4	2	3	4	—
Virginia	—	—	—	—	3	4	—
West Virginia	1	1	1	1	2	13	6
Total Recently Mined	5	12	9	11	18	77	20
Mined before Jan. 1972:							
Alabama	—	1	1	—	2	5	2
Georgia	—	—	—	—	1	—	—
Kentucky	1	5	3	—	3	14	1
Maryland	—	—	1	—	1	—	—
Ohio	—	6	2	—	1	5	—
Pennsylvania	—	3	5	2	1	12	1
Tennessee	2	3	2	1	3	5	1
Virginia	—	—	1	1	1	5	—
West Virginia	—	—	2	2	5	19	2
Total Old Mined	3	18	17	6	18	65	7
Total	8	30	29	27	90	195	42

Note: Data summarized in this table do not coincide exactly with those shown in figures 2, 3, and 4 for three reasons: (1) the figures show only those sites for which 9 or more samples were collected, (2) data were rounded differently, and (3) many sites on the figures were so close that symbols were superimposed.