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# AN ASSESSMENT OF THE COAL MINE DRAINAGE PROBLEM

By R. L. P. Kleinmann,[1] J. R. Jones,[2] and P. M. Erickson[3]

## Introduction

Acid mine drainage is one of the most persistent industrial pollution problems in the United States. Acidic water continues to flow from some underground mines and coal refuse piles that are already a century old. In 1967, the Federal Water Pollution Control Administration (FWPCA) estimated that inactive and abandoned mines and coal refuse piles were responsible for 78 pct of Appalachia's mine drainage problem (1,9). Since active operations now treat their discharge water, we calculate that the total number of stream miles affected has decreased, and that inactive and abandoned sites are currently responsible for about 99 pct of the problem that remains.

The 1967 FWPCA report stated that 10,500 miles of streams and rivers in the Appalachian Region were significantly degraded by coal mine drainage and that 5,740 miles of that total were acidic (9). In this paper, will update that study by looking at water quality in mined watersheds and providing a state-by-state analysis similar to the one compiled by the FWPCA two decades ago.

## Water Quality in Mined Watersheds

Comparison of current water quality in mine-affected watersheds with previous records indicate that indeed water quality has begun to improve. For example, in the eastern Pennsylvania Anthracite Field, the Askam, Buttonwood and South Wilkes-Barre outfalls drain a mine pool estimated to contain $6 \times 10^7$ $m^3$ ($1.6 \times 10^{10}$ gal) of mine water. The three outfalls together discharge about 2 $m^3/s$ (32,000 gal/min) of untreated acidic water into the Susquehanna River.

Data obtained from the PA Department of Environmental Resources indicate that as a result of inundation of most of the mine workings, acidity totals decreased 74 pct and sulfate concentrations decreased 49 pct during the period 1968 to 1979. (The decrease in sulfate indicates that the improvement is not simply caused by neutralization). The pH observed ranged from 3.3 to 5.6 in 1968; by 1979, this had improved to 5.8 to 6.2. Sampling of water in the flooded mines during the 1980's indicates that the water quality at the outfalls should continue to improve, for 93 pct of the mine shaft water samples collected were alkaline, with downhole pH's as high as 7.8 (12).

In western Pennsylvania, water samples collected at the McKeesport water treatment plant, located near the junction of the Monongahela and the Youghiogheny Rivers, show similar improvement. In 1934, records indicate that the Youghiogheny River had an acidity of 80 mg/L and that the Monongahela River averaged half that. By 1960, the acidity had decreased to about 18 mg/L in the Youghiogheny River and to about 22 mg/L in the Monongahela River, due apparently in part to the construction of reservoirs on both rivers (2). We recently analyzed water quality records for the Youghiogheny River, which indicate that acidity continued to decrease, averaging 12.2 from 1965 to 1967, 9.0 from 1976 to 1977, 6.5 from 1978 to 1984 and 1.8 from 1985 through 1987. Most of this improvement is probably due to enactment and enforcement of effluent limits for Pennsylvania's active mines.

On a larger scale, the USDA Forest Service conducted water quality analyses for streams draining selected small watersheds in the Appalachian region from 1977 through 1979 (3-8). Some of the watersheds were entirely unmined, while others had been mined only before or before and after passage of The Surface Mining Control and Reclamation Act (SMCRA). We used the Forest Service data to test for differences in water quality as a function of mining history. The

data were grouped to compare (1) unmined vs. mined and (2) mined before vs. mined after SMCRA using 1-tailed t-tests and pooled variances.

Comparison of unmined and mined watersheds showed degradation of water quality in mined watersheds in all states (Table 1). Concentrations of sulfate, iron, manganese and acidity were uniformly higher and pH was uniformly lower in each state's mined watersheds. The changes were statistically significant in only some states; mining increased sulfate in six states, increased manganese in three states, increased acidity and decreased pH in two states, and increased iron in one state.

TABLE 1. - Mean water quality of mined and unmined watersheds in Appalachia (3-8). Statistically significant differences ($p = 0.05$) between mined (M) and unmined (U) watersheds in the same state are indicated by an asterisk.

| State | | pH | Concentration mg/L Sulfate | Iron | Manganese | Acidity |
|---|---|---|---|---|---|---|
| Alabama | (M) | 6.51 | 364.0 | 13.3 | 11.3 | 21.8 |
| | (U) | 6.91 | 9.2 | 0.26 | 0.12 | -12.2 |
| Kentucky | (M) | 6.59 | 341.0* | 3.44 | 4.32* | 76.9* |
| | (U) | 6.88 | 15.0 | 0.15 | 0.16 | 2.80 |
| Ohio | (M) | 6.66* | 519.0* | 1.84* | 6.22* | -30.0 |
| | (U) | 7.78 | 48.6 | 0.16 | 0.15 | -88.9 |
| Pennsylvania | (M) | 6.17 | 397.0* | 23.8 | 28.5 | -20.2 |
| | (U) | 6.71 | 23.3 | 0.18 | 0.34 | -23.2 |
| Tennessee | (M) | 5.16* | 262.0* | 15.3 | 7.21* | 69.9* |
| | (U) | 6.68 | 9.2 | 0.11 | 0.06 | -13.5 |
| Virginia | (M) | 6.90 | 73.5* | 0.30 | 0.41 | -19.2 |
| | (U) | 6.99 | 17.0 | 0.12 | 0.04 | -21.2 |
| West Virginia | (M) | 6.91 | 324.0* | 1.30 | 2.73 | -30.1 |
| | (U) | 7.02 | 20.5 | 0.09 | 0.04 | -28.5 |

The data are consistent with pyrite oxidation and neutralization processes. In most states, sulfate was at least an order of magnitude higher in mined watersheds. Sulfate is largely unaffected by factors other than dilution and is expected to persist in the stream. The production of 100 mg/L

of sulfate from pyrite oxidation is accompanied by production of 29 mg/L iron and 104 mg/L of acidity. The data in Table 1 show that iron and acidity concentrations in the mined watersheds are substantially lower than reaction stoichiometry would predict for the measured sulfate concentrations. Acidity is neutralized by alkalinity in the stream while iron precipitates as ferric hydroxide.

Water quality in watersheds where all mining was completed prior to passage of SMCRA in 1977 was compared to water quality in watersheds where mining continued after 1977 to determine if differences could be detected at the stream level (Table 2). Only a few differences were statistically significant. In two states, pH was greater for watersheds mined after 1977, probably attributable to water treatment. Sulfate was higher in watersheds mined after 1977 in Tennessee and lower in watersheds mined after 1977 in Ohio. Manganese and iron were higher in Pennsylvania for the group mined after 1977 owing to one watershed in Indiana County having these metals at concentrations an order of magnitude above most other sites in the data set. The mining history varied significantly across watersheds and states with respect to fraction of watershed mined, portion mined after SMCRA, and enforcement of state and federal regulations; these factors and the limited database could have masked the true effects of the water quality protection law.

## Overall Water Quality

An overall assessment of the acid mine drainage problem was last done for Appalachia in 1967, through it was partially updated in 1982 (1, 9-11). Both of these assessments relied heavily on estimates by field personnel and stream data that was already several years old. Nevertheless, these assessments provide a useful overview. In a similar vein, we have compiled stream mile

statistics for 12 of the coal mining states. The data were taken from 305-B reports, which each state submits to EPA every other year, based on actual stream water assessments (13). Although direct comparisons cannot be made, because of differences in the intensity of the sampling and variation of the criteria used to classify a stream as degraded, it is clear that water quality has improved but that mine drainage is still very much a problem.

Table 2. - Mean water quality of mined watersheds in Appalachia (3-8). Statistically significant differences (p = 0.05) between all mining before 1977 (B) and mining after 1977 (A) in the same state are indicated by an asterisk. Virginia was excluded because there was only one studied watershed with mining activity after 1977.

| | | Concentration, mg/L | | | |
|---|---|---|---|---|---|
| State | pH | Sulfate | Iron | Manganese | Acidity |
| Alabama (B) | 6.53 | 335.0 | 18.7 | 13.4 | 34.4 |
| (A) | 6.48 | 408.0 | 5.00 | 8.1 | 2.0 |
| Kentucky (B) | 6.32* | 288.0 | 4.55 | 5.42 | 93.0 |
| (A) | 7.16 | 182.0 | 0.90 | 1.94 | 38.8 |
| Ohio (B) | 6.27* | 624.0* | 2.16 | 7.89 | -6.41 |
| (A) | 7.32 | 342.0 | 1.29 | 3.40 | -71.8 |
| Pennsylvania (B) | 5.95 | 334.0 | 1.47 | 6.60 | -25.4 |
| (A) | 6.49 | 491.0 | 53.30*[1] | 13.80*[1] | -12.4 |
| Tennessee (B) | 5.24 | 203.0* | 10.9 | 4.28* | 51.6 |
| (A) | 4.96 | 403.0 | 24.8 | 14.2 | 106.0 |
| West Virginia (B) | 6.97 | 320.0 | 1.02 | 2.40 | -30.7 |
| (A) | 6.75 | 335.0 | 2.10 | 3.70 | -28.7 |

[1]These values are heavily influenced by one stream in Indiana County containing iron and manganese in excess of 1,000 mg/L and 200 mg/L, respectively.

Table 3 summarizes the stream data for all three assessments. With respect to the recently-compiled data, it should be noted that only a few states now record acid mine drainage as distinct from mine water in general, since the acidity may be transient and somewhat affected by other causes, such as rainfall quality. Indeed, several states use the industry category of resource extraction, rather than coal mining, making it difficult to discern the

specific pollution source. Futhermore, it should be noted that, as in previous studies, there is no consistency with respect to how stream miles are calculated. For example, Maryland continues to tabulate only "main-stem miles", restricting analysis to higher order streams (eg. the Potomac River and George's Creek, but not the tributaries of George's Creek). Other states, recognizing that pollution sources that only slightly affect a high-volume flow can devastate a smaller watershed, have put a great deal of effort into documenting the effects of pollution on all streams. Also, states generalize their sampling efforts in disparate ways: some include the entire length of affected streams, others use the length of stream below know AML sites, while others, such as Pennsylvania, divide the stream into segments and sample accordingly. In general, a decrease over time in affected stream miles probably represents actual improvement, but increases probably indicate a more intense sampling effort rather than an increased level of pollution.

TABLE 3. - Total miles of streams in coal mining states affected adversely by coal mine drainage. Where a breakdown was provided, bracketed numbers represent the number of stream miles known to be adversely affected by acid mine drainage.

| State | Year of Study | | |
|---|---|---|---|
| | 1969 | 1982 | 1988 |
| Alabama | 50 [30] | NA* | 76 |
| Kentucky | 1,140 [50] | 2,100 [77] | 1,085 [185] |
| Kansas | NA | NA | 242** |
| Illinois | NA | NA | 453** |
| Indiana | NA | NA | 145 |
| Maryland | 200 [200] | 450 | 113 |
| Missouri | NA | NA | 190 [104]** |
| Ohio | 1,750 [560] | 1,075 | 468 |
| Pennsylvania | 3,900 [3,430] | 1,960 | 1,701 |
| Tennessee | 280 [60] | 994 | 350** |
| Virginia | 70 [20] | NA | Negligible |
| West Virginia | 3,130 [1,390] | NA | 2,427 [2,341] |
| Total | 10,520 [5,740] | | 7,250 |

*NA--Not available.

**Mileage adversely affected by "resource extraction" with no breakdown for coal mining specifically.

Given that caveat, it is apparent that significant improvement has occurred but that water pollution from abandoned mines continues to be a very serious problem. For example, in Pennsylvania, affected stream mileage has decreased over 50 pct, yet mine drainage remains the state's single largest pollutant. This improvement is largely due to the chemical treatment of mine drainage by active mines and by The Pennsylvania Department of Environmental Resources, as part of Operation Scarlift, which targeted $120 million at Pennsylvania's mine drainage problem.

However, as pollution sources in general are eliminated through regulation and site cleanup efforts, the adverse effects of abandoned mine sites continues, since AML reclamation for water quality improvement has not been a high priority. The improvement that has occurred is due to regulation of active mines and some reclamation efforts, but without increased expenditure of AML funds on priority III problems, it is likely that there will be very little further improvement. Indeed, it is possible that long-term water treatment requirements will eventually drive smaller companies into bankruptcy, creating additional sources of contamination in the future.

## Discussion

Despite the fact that the mining industry spends an estimated million dollars a day to treat effluent water, mine drainage continues to have a major effect on stream water. In Kentucky, Pennsylvania and West Virginia alone, over 5,000 miles of streams and rivers are affected. In addition, at least eight other states suffer significant degradation in watersheds affected by inactive or abandoned mines. Despite these facts, stream water quality is significantly improved over what it was before passage of effluent-limiting regulations.

Most of this improvement is probably due to the effects of chemical water treatment. Recently-developed techniques, such as the use of anionic surfactants to inhibit iron-oxidizing bacteria and the construction of wetlands to treat small flows of mine water do not address the major sources: abandoned underground mines that continue to discharge enormous quantities of acidic water. Control measures that can be used in abandoned underground mines must be developed before much further improvement is likely.

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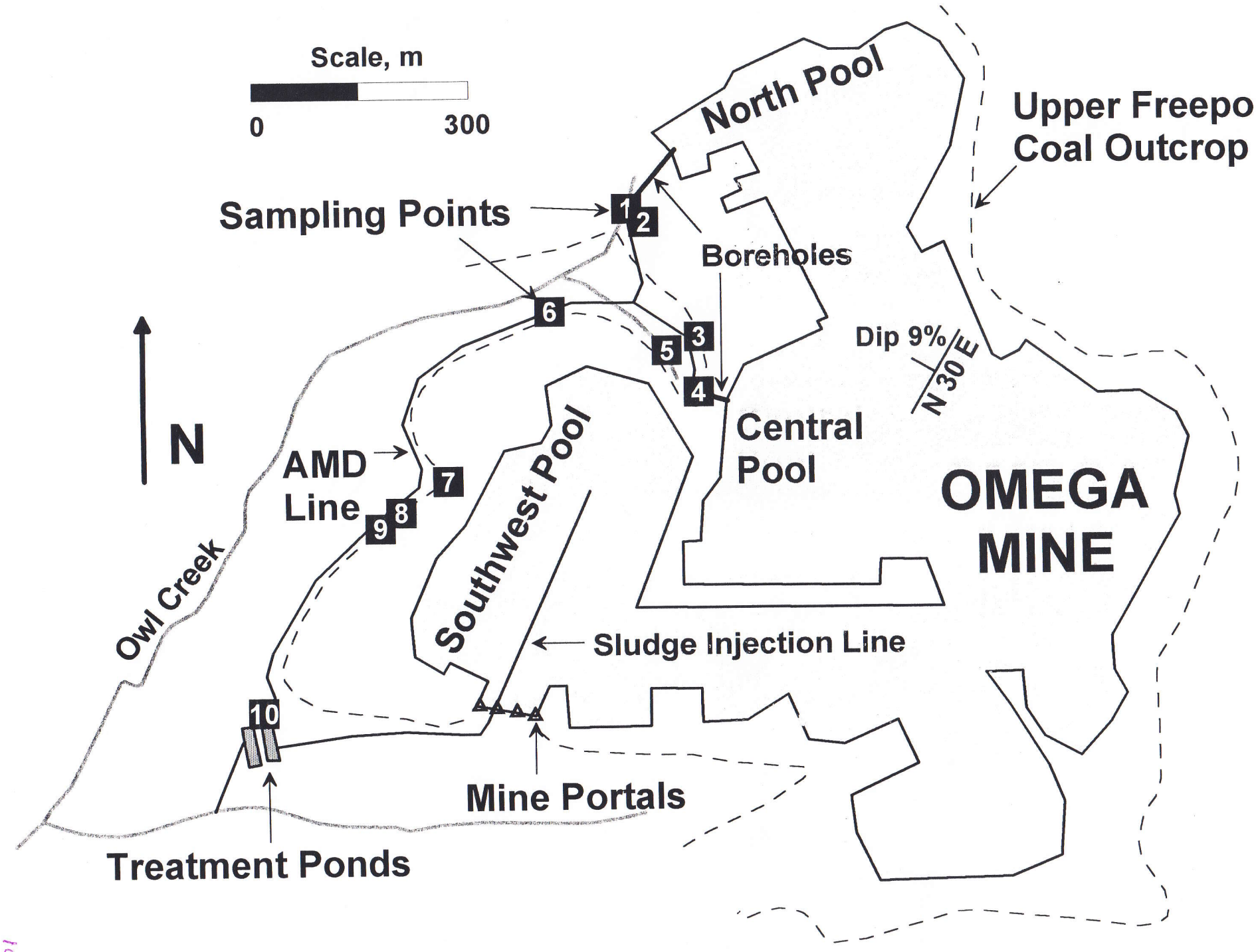
13. In addition, 305-B reports and assistance were obtained from the following state agencies: Alabama Dept. of Environmental Management, Arkansas Dept. of Pollution Control and Ecology, Kansas Dept. of Health and Environment, Kentucky Dept. for Environmental Protection, Illinois Environmental Protection Agency, Indiana Dept. of Environmental Management, Maryland Dept. of Environment, Missouri Dept. of Natural Resources, Ohio Environmental Protection Agency, Oklahoma Dept. of Pollution Control, Pennsylvania Dept. of Environmental Resources, Tennessee Dept. of Health and Environment, Virginia Water Control Board, and West Virginia Department of Natural Resources.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