with Fly Ash." *Amer. Dyestuff Reptr.*, 62, 8, 21 (1973).
39. Stroka, P., and Reineke, J., "Effluent Treatment over Land, as Applied in Textile Finishing—For The Ecology of Inland Waters." *Textil-Praxis International* (Ger.), 28, 171, 208 (1973).
40. Laude, L., "Economy and Recycling of Water in the Bleaching and Dyeing Industry." *Teinture et Apprets* (Fr.), 133, 4, 49 (1973); *World Textile Abs.*, 5, 5940 (1973).
41. "Save A Stream and Yourself $85,000." *Textile World*, 123, 2, 70 (1973).
42. Porter, J. J., "Reusing Treated Wastewater: Will It Work in the Plant?" *Amer. Dyestuff Reptr.*, 62, 4, 79 (1973).
43. Porter, J. J., "Reuse of Treated Wastewater in the Textile Finishing Plant." Paper presented at the Amer. Chem. Soc., 165th Nat. Meeting, Dallas, Tex. (April 1973).
44. Brandon, C. A., *et al.*, "Complete Re-use of Textile Dyeing Wastes Processed with Dynamic Membrane Hyperfiltration." *Textile Chem. & Colorist*, 5, 7, 134 (1973).
45. Dettrich, V., "Processes for Effluent Treatment and Reuse in the Works." *Melliand Testilberichte International* (Ger.), 54, 9, 976 (1973).

Coal and coal mine drainage

JAMES F. BOYER, Bituminous Coal Research, Inc., Monroeville, Pa.

VIRGINIA E. GLEASON, Bituminous Coal Research, Inc., Monroeville, Pa.

For the ninth consecutive year, a bibliography of abstracts of published information on mine drainage was compiled.[1] Included in the 1972 supplement were abstracts of 53 articles written in 1972, 40 articles written in 1971, and 11 articles written in the period from 1955 through 1970. Two new biblographies on surface mining for coal were published. While both covered much of the same material and included sections on acid mine drainage, one bibliography [2] emphasized federal and state concerns and the other [3] highlighted environmental factors.

A series of reports has been prepared for the Appalachian Regional Commission (ARC) for the development of an overall environmental pollution abatement plan for the Monongahela River Basin. Based on water quality data and historical records, a mathematical modeling technique [4] was developed that could be used to rank the 30 sub-basins in the order in which they contribute to the total pollution load of the basin. The Lost Creek and Brown's Creek sub-basins in Harrison County, W. Va., were studied [5] to evaluate applicable pollution reduction methods and provide recommendations as to least cost and best overall solutions to mine drainage problems in the sub-basin. In order to provide data that will enable ARC to estimate costs of pollution abatement in the basin, a complete handbook [6] on pollution control costs and factors affecting these costs was prepared. The factors studied included backfilling, grading, revegetation of surface mines and refuse banks, mine sealing, stream diversion, treatment, and abatement procedures. Also in the Monongahela River Basin, a study [7] of active deep mines was conducted by EPA. This report provides data on 48 active mines that were producing discharges at the time of the survey. A geologic evaluation of the results that probably would occur because of mining of the Upper Freeport coal seam near Maple Run, Monongalia County, W. Va., was prepared by Overbey.[8] Factors studied included stratigraphy, overburden structure, and ground water and surface water hydrology. The Upper Freeport and 18 other West Virginia coals were studied by Renton *et al.*[9] to determine the relative acid-producing potential of coal. The technique devised to determine the acid-producing potential was described, and of the coals tested, the Upper Freeport, Pittsburgh, and Bakerstown seams were major acid producers, the other coals showed extremely low acid-production values.

Eight federal reservoir projects of the Corps of Engineers in Kentucky and West Virginia were reviewed [10] to determine the problems associated with coal mining. Factors evaluated included sedimentation, acid mine drainage, and aesthetic aspects of mining. A comprehensive report[11] on the water quality conditions of the Kentucky River included available but limited data on mine water problems in the basin. Mackey[12] provided a preliminary report on the water quality of the South Fork of the Little Conemaugh River. Included are the locations and descriptions of the major mine acid discharges. Lake Hope, Ohio, has been selected as a site for a mine drainage abatement demonstration project. The feasibility study[13] described the mine water sources, stream quality, mine conditions, and the mine sealing abatement procedures recommended. A survey of the acid drainage problem in Illinois was conducted by Carter *et al.*[14] Acid mine drainage problems were limited to the Kaskasia, Big Muddy, and Saline rivers in southern Illinois.

Three reports were published on the effects of mine drainage on stream ecosystems. Butler *et al.*[15] determined the effect of different levels of acid mine drainage on the presence or absence of 116 species of fish in Pennsylvania watersheds. The median tolerance limits to low levels of pH of five selected aquatic insects were also determined. The stream ecosystem of the East Fork of the Obey River, Tenn., was studied by Nichols and Bulow.[16] The studies centered on water quality, microinvertebrates, fish, and aquatic flora. In an EPA study by McPhilliamy and Green,[17] biological sampling was conducted upstream and downstream from three mine drainage treatment plants to determine if the benthos in the receiving stream were affected by the treated mine effluent. Adverse effects were noted in each case; however, they were more noticeable below two of the plants where both acidity and iron concentrations were occasionally excessive.

The economics of mine drainage treatment was discussed by Bhatt.[18] All available treatment processes are described, sketched, or outlined, and the costs for each method are given. In a general article on the mine drainage problem, some of the same costs were reported by Aston.[19] An examination of the problem and the costs involved in abatement were also provided in a report[20] on the economic impact of public policy on the Appalachian coal industry. Projected treatment costs through 1980, based on expected proven technology, were also given. Dreese and Bryant[21] studied the economic implications of strip mining legislation on small firms. One of the costs examined was for water pollution control. Young *et al.*[22] reported on the development of a mathematical model having the capability of simulating the water quality and economic consequences of acid mine drainage abatement plants. A case study using the Tioga River Basin in Pennsylvania was included.

Long studies of strip mine lakes have shown that they become less acid over the years. King and Simmler[23] carried out laboratory studies to identify the chemical and biological processes involved in recovery of acid strip mine lakes and to show how organic wastes accelerate recovery.

The most difficult aspect of the mine drainage problem continues to be the formation of acidic mine water in underground mines. Robbins[24] reported on a study to determine the gas injection rates needed to develop and maintain slight pressures within a mine over ambient conditions during changes in the barometric pressure. The ultimate aim of the project was to determine the feasibility of blanketing an abandoned deep mine with an inert gas in order to prevent the formation of acid mine drainage. While pressurization tests conducted at a 50-acre (20.25-ha) test mine site were generally inconclusive, the final test results obtained at a 15-acre (6.08-ha) mine site were encouraging. Laboratory testing of commercially available chemical grouts was conducted by Chung[25] to evaluate their potential use, in conjunction with a cheap filler, for remote sealing of mine voids. A slurry mix consisting of an acrylamide grout with fly ash or mine refuse as a filler was found to produce a strong controllable gel that resisted chemical attack. The estimated cost of a mine seal using the gel material was not considered presently competitive. Foreman and McLean [26] evaluated various mine drainage pollution abatement techniques completed during the construction phase of Moraine State Park, Pa. As a result of underground mine hydraulic sealing and grouting work, the discharge flow rates were reduced from 146 to 57 gpm (from 9.2 to 3.6 l/sec) and the net acidity from 501 to 160 lb/day (227.5 to 72.6 kg/day). Prevention of surface water infiltration into underground mines is the objective of a demonstration project being conducted in the Dents Run Watershed, W. Va. The feasibility study for the project was presented by Zaval and Robbins.[27]

Coal mine refuse occasionally represents a source of acid drainage. Kosowski [28] reported that acid runoff from refuse piles can be controlled by covering the mineral wastes with soil, establishing a vegetative cover, and providing adequate drainage to minimize erosion. The average acid formation rate for the entire restored refuse pile was estimated at 16 lb (7.3 kg) acid as $CaCO_3$/day/acre, or a reduction of 91+ percent when compared to the original unrestored pile. Several different methods of sealing refuse piles to prevent infiltration were discussed by Scott.[29] Seals tested included sodium silicate, sodium silicate-sodium aluminate, carbonate bonding, surface sealing with clay, and surface sealing with a plastic sheet.

Despite attempts to control its formation, some acid mine water continues to be formed and must be treated before discharge. The only effective means of treatment is lime neutralization. Case histories demonstrating its use and effectiveness were presented by Lombardo [30] and others.[17, 31] A high-density sludge process, incorporating sludge recirculation into the lime treatment process, was described by Temmel [32] and Kostenbader.[33] Sodium hydroxide treatment was studied by Kennedy [34] who concluded that the process could be used effectively for treating small mine-drainage flows in remote locations. The cost for sodium hydroxide treatment was considerably higher than lime neutralization although this might not be a significant consideration because of the locations where it would be applied. The presence of ferrous iron in most acid mine waters prevents the use of limestone as the neutralizing agent. Ford and Boyer [35] conducted studies with activated carbon as a catalyst to achieve oxidation of ferrous iron. Iron was removed by this process by adsorption as well as oxidation, but the process cost is prohibitively high to consider its use in mine water treatment. An extremely thorough review of mine drainage treatment processes was prepared by O'Brien.[36] In addition to neutralization processes, the processes discussed included flash distillation, ion exchange, reverse osmosis, freezing, foam fractionation, bacterial sulfur reduction, and chemical sulfide treatment. Akers and Moss [37] studied the various conditioning methods and dewatering systems that could be applied to the sludges produced by lime and limestone neutralization. No single dewatering system was found best for all acid mine drainage sludges. However, on the basis of cost, the most promising acid mine drainage sludge dewatering techniques appeared to be centrifugation, conventional rotary vacuum filtration, and rotary precoat vacuum filtration.

Of general interest were review articles by Lovell [38] and Shackelford.[39] A thorough review of the effectiveness of government-sponsored mine drainage research was provided.[40] It was concluded that until significantly more federal and state funds are made available for the development of additional technology and for an action program to identify systematically and control acid drainage from abandoned mines, only limited progress can be made toward reducing pollution caused by such discharges.

REFERENCES

1. "Mine Drainage Abstracts—A Bibliography." Bituminous Coal Research, Inc., 1972 Supplement, Pa. Dept. Environ. Resources, Harrisburg (1973).
2. Tompkins, D. C., "Strip Mining for Coal." Public Bibliographies: 4, Inst. Governmental Studies, Univ. Calif., Berkeley (1973).

3. Munn, R. F., "Strip Mining—An Annotated Bibliography." W. Va. Univ. Library, Morgantown (1973).
4. "Determination of Estimated Mean Mine Water Quantity and Quality from Imperfect Data and Historical Records." Environ. Quality Systems, Inc., Rept. to Appalachian Regional Comm. (1973).
5. "Evaluation of Pollution Abatement Techniques Applicable to Lost Creek and Brown's Creek Watershed, West Virginia." Ackenheil & Associates Geo Systems, Inc., Rept. to Appalachian Regional Comm. (1973).
6. "Analysis of Pollution Control Costs." Michael Baker, Jr., Inc., Rept. to Appalachian Regional Comm. (1973).
7. "The Status of Active Deep Mines in the Monongahela River Basin." Wheeling Field Office, EPA, Wheeling, W. Va., Work Document No. 46 (1973).
8. Overbey, W. K., Jr., "Geologic Evaluation of Probable Results of Mining of Upper Freeport Coal Near Maple Run Monongalia County." Cheat Lake Area Environ. Conservancy (1973).
9. Renton, J. J., *et al.*, "Relative Acid-Producing Potential of Coal." W. Va. Geol. and Econ. Surv., Environ. Geol. Bull. No. 11 (1973).
10. "Problems Caused by Coal Mining Near Federal Reservoir Projects." Comptroller General of the United States, Rept. to Conservation and Natural Resources Subcommittee, Committee on Government Operations, U. S. House of Representatives, B-177092 (1973).
11. "Water Quality Management Element for the Kentucky River Area Development District—Comprehensive Water and Sewer Plan." Mayes, Sudderth & Etheredge, Inc., Rept. to Ky. River Area Develop. Dist. (1973).
12. Mackey, H. E., Jr., "Preliminary Report on the Water Quality of the South Fork of the Little Conemaugh River During 1972." Univ. Pittsburgh at Johnstown (1973).
13. "Feasibility Study Lake Hope Mine Drainage Demonstration Project." *Environ. Protection Technol. Ser.*, EPA-R2-73-151, EPA, Washington, D. C. (1973).
14. Carter, R. P., *et al.*, "Strip Mine Reclamation in Illinois." Argonne Natl. Lab., Energy and Environ. Studies Div., Rept. to Ill. Inst. for Environ. Qual. (1973).
15. Butler, R. L., *et al.*, "Fish and Food Organisms in Acid Mine Waters of Pennsylvania." *Ecological Res. Ser.*, EPA-R3-73-032, EPA, Washington, D. C. (1973).
16. Nichols, L. E., and Bulow, F. J., "Effects of Acid Mine Drainage on the Stream Ecosystem of the East Fork of the Obey River, Tennessee." *Jour Tenn. Acad. Sci.*, 48, 1, 30 (1973).
17. McPhilliamy, S. C., and Green, J., "A Chemical and Biological Evaluation of Three Mine Drainage Treatment Plants." Wheeling Field Office, EPA, Wheeling, W. Va., Work Document No. 47 (1973).
18. Bhatt, H. G., "Economics of Coal Mine Drainage Treatment." Presented at Seminar on Design of Coal Mine Drainage Treatment Facilities, Pa. State Univ., University Park (1973).
19. Aston, W. M., "The Problem, The Treatment, The Cost." *Green Lands*, 3, 3, 14 (1973).
20. "The Economic Impact of Public Policy on the Appalachian Coal Industry." Charles River Assoc. Inc., Rept. to Appalachian Regional Comm. (1973).
21. Dreese, G. R., and Bryant, H. L., "Economic Implications of Strip Mining Legislation: the Small Firms." Amer. Inst. of Mining Engr. Ann. Meeting, Chicago, Ill., Preprint 73-F-15 (1973).
22. Young, G. K., *et al.*, "Simulation and Optimization of Acid Mine Drainage Abatement Alternatives." Water Resources Engr., Inc., Rept. to U. S. Army Corps of Engr.; NTIS AD-757-782 (1973).
23. King, D. L., and Simmler, J. J., "Organic Wastes as a Means of Accelerating Recovery of Acid Strip-mine Lakes." Univ. Mo., Mo. Water Resource Center, Completion Rept. to Dept. Int., OWRR (1973).
24. Robbins, J. D., "Gas Requirements to Pressurize Abandoned Deep Mines." *Environ. Protection Technol. Ser.*, EPA-670/2-73-054, EPA, Washington, D. C. (1973).
25. Chung, N. K., "Investigation of Use of Gel Material for Mine Sealing." *Environ. Protection Technol. Ser.*, EPA-R2-73-135, EPA, Washington, D. C. (1973).
26. Foreman, J. W., and McLean, D. C., "Evaluaation of Pollution Abatement Procedures, Moraine State Park." *Environ. Protection Technol. Ser.*, EPA-R2-73-140, EPA, Washington, D. C. (1973).
27. Zaval, F. J., and Robins, J. D., "Water Infiltration Control to Achieve Mine Water Pollution Control—A Feasibility Study." *Environ. Protection Technol. Ser.*, EPA-R2-73-142, EPA, Washington, D. C. (1973).
28. Kosowski, Z. V., "Control of Mine Drainage from Coal Mine Mineral Wastes—Phase II—Pollution Abatement and Monitoring." *Environ. Protection Technol. Series*, EPA-R2-73-230, EPA, Washington, D. C. (1973).
29. Scott, R. B., "Sealing of Coal Refuse Piles." EPA, Natl. Environ. Res. Center, Cincinnati, Ohio (1973).
30. Lombardo, J. L., "State of the Art—Acid Mine Drainage Control." Amer. Mining Congr. Convention, Denver, Colo. (1973).
31. "Reclamation: Restoring Beauty and Balance

is US Steel's Goal." *Coal Age,* **78**, 11, 100 (1973).
32. Temmel, F. M., "Case History on Acid Mine Drainage Control." Amer. Mining Congr. Convention, Denver, Colo. (1973).
33. Kostenbader, P. D., "Method for Treating Acid Water Containing Metallic Values." U. S. Patent 3,738,932 (1973).
34. Kennedy, J. L., "Sodium Hydroxide Treatment of Acid Mine Drainage." EPA, Natl. Environ. Res. Center, Cincinnati, Ohio (1973).
35. Ford, C. T., and Boyer, J. F., Jr., "Treatment of Ferrous Acid Mine Drainage with Activated Carbon." *Environ. Protection Technol. Ser.,* EPA-R2-73-150, EPA, Washington, D. C. (1973).
36. O'Brien, W., "Treatment of Acid Mine Drainage." Ph.D. thesis, W. Va. Univ. (1972); University Microfilms, Ann Arbor, Mich., 72-26, 887 (1973).
37. Akers, D. J., Jr., and Moss, E. A., "Dewatering of Mine Drainage Sludge." *Environ. Protection Technol. Ser.,* EPA-R2-73-169, EPA, Washington, D. C. (1973).
38. Lovell, H. L., "Coal Mine Drainage Pollution —1973." *Earth & Mineral Sciences,* **42**, 54 (1973).
39. Shackelford, J. M., "Water Reuse in Industry —Part 3—Mine Water." *Mech. Eng.,* **95**, 6, 32 (1973).
40. "Federal and State Efforts to Control Water Pollution Caused by Acid Drainage from Mines." Comptroller General of the U. S., Rept. to Conservation and Natural Resources Subcommittee, Committee on Government Operations, U. S. House of Representatives, B-177011 (1973).

Steel industry wastes

J. W. PATTERSON, Department of Environmental Engineering, Illinois Institute of Technology, Chicago, Ill.

M. H. CHENG, John R. Snell Engineering, Inc., Lansing, Mich.

The recent literature on steel industry wastewater pollution abatement is largely concerned with recirculation of water, treatment of coking and blast furnace gas washwaters, and recovery and reuse of wastewater constituents. Among the latter, a large segment of the literature relates to the treatment and reclamation of sulfuric and hydrochloric acid pickle liquors. Much of the information on pickle liquor treatment and reclamation is contained in the patent literature.

GENERAL

Several general papers on pollution abatement programs within the steel industry have been published. Stoner [1] described waste treatment facilities at a plant in operation for three years, which produces cold rolled and galvanized sheet steel. The pollution abatement program includes deep well disposal of waste pickle liquor, lagoon thickening of water, and wastewater treatment sludge with final disposal to land, incineration of waste oil, and recycle of treated wastewater.

Theegarten and von Hartman [2] described the use of a recycle cooling water system in operation at a West German hot strip mill. Because of the high cost of raw water, the need to meet stringent effluent standards, and a high effluent discharge surcharge, the company elected to implement a recirculating system. Each of the four recirculating lines of the mill is described, and important criteria of design and operation are discussed. Nauratil [3] provided a similar discussion of a recirculating water system for a Czechoslovakian steel mill. Treatment of phenolic wastewaters to 98 percent efficiency, followed by discharge to a municipal treatment facility, was described.

Centi [4] surveyed wastewater treatment techniques for steel mill wastewaters including treatment of coking, scale and oily wastes, and treatment and disposal of pickle liquor. Two articles described steel industry pollution abatement programs in Japan. Mizuno [5] stated that over 90 percent of the water used in many Japanese steel mills is recirculating water. The high level of recycle was made possible by improved ss removal techniques. Nagasaki [6] described a range of pollution control measures and cited working processes within the industry.

Spright [7] listed methods of air pollution control in the steel industry, characterized air pollutants according to process sources, and described those quenching and gas washing methods which generate waste-