Minerals and Mine Drainage

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343. Linderoth, C. E., "Paper-mill Sludge as a Valuable Fuel." Tappi Energy Eng. Manage. Anthology, 89 (1991).
344. Barnes, J., and Rawlings, M., "Design and Start-up of a Pyroflow CFC (Circulating Fluidized Combustor) Firing Deinking Sludge." Tappi Energy Eng. Manage. Anthology, 322 (1991).
345. Henry, C. L., "Nitrogen Dynamics of Pulp and Paper Sludge Amendment to Forest Soils." *Water Sci. Technol.* (G. B.), **24**, 3, 417 (1991).
346. Almemark, M., *et al.*, "Treatment Technologies for Organochlorine-containing Sludges and Concentrates from External Treatment of Pulp and Paper Wastewaters." *Water Sci. Technol.* (G. B.), **24**, 3, 319 (1991).
347. Hoekstra, P. L., "Paper Recycling Creates Its Own Set of Environmental Problems." *Am. Papermaker,* **54**, 4, 30 (1991).
348. Pridham, N. F., and Yau, A. Y., "Sludge from Deinking as Fertilizer." *Papier (Darmstadt)* (Ger.), **45**, 3, 103 (1991).
349. Ettala, M. O., "Revegetating Industrial Waste Disposal Sites." *Waste Manage. Res.*, **9**, 1, 47 (1991).
350. Krouskop, D. J., *et al.*, "Multimedia Sampling for Dioxin at a Strip Mine Reclaimed with Sludge from Bleached Kraft Waste-water Treatment." *Tappi,* **74**, 4, 235 (1991).
351. Keenan, R. E., *et al.*, "Assessing Potential Risks to Wildlife and Sportsmen from Exposure to Dioxin in Pulp and Paper Mill Sludge Spread on Managed Woodlands." *Chemosphere* (G. B.), **20**, 1763 (1990).
352. Rabert, W., *et al.*, "Dioxins/Furans in Paper Pulp Sludges: Terrestrial and Aquatic Risk Assessment under TSCA." *First Symp. Environ. Tox. Risk Assess.*, Atlantic City, N. J. (1991).
353. Duraiswamy, K., *et al.*, "Indirect Steam Gasification of Paper Mill Sludge Waste." *Tappi,* **74**, 10, 137 (1991).
354. Modell, M., *et al.*, "Supercritical Water Oxidation of Pulp Mill Sludges." Tappi Eng. Conf., Nashville, Tenn. (1991).

Minerals and mine drainage

William R. Turney, Bruce M. Thomson

ENVIRONMENTAL IMPACTS AND REGULATIONS

During the 1990s, it was predicted that oil and gas recovery operations would have to change substantially the way they generate, handle, store, and dispose of hazardous wastes. Requirements established under the Resource Conservation and Recovery Act (RCRA) and the Hazardous and Solid Waste Amendments strongly discourage land disposal of hazardous wastes without treatment.[1] The U. S. oil and gas industry was modifying production activities to comply with the diverse nature of these environmental regulations.[2] New regulations established under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and Clean Water Act (CWA) were forcing U. S. drillers to change the methods for waste disposal or incorporate less-hazardous substances into drilling operations.[3] One recent focus in the U. S. was on regulations for handling and disposing of wastes generated during drilling operations. With newer and stricter regulations continually being established, the industry was pushed to develop more efficient low-cost technologies and processes to comply with regulations that will essentially eliminate landfarming of wastes.[4] Subtitle C of RCRA included exemptions for certain wastes associated with the exploration, development, and production of crude oil or natural gas. These exemptions, however, did not cover every material or waste generated at the rig site.[5] Polychlorinated biphenyl contamination resulting from natural gas recovery operations plagued the U. S. gas processing industry.[6] Some natural gas companies were taking actions in anticipation of tougher RCRA standards.[7]

It was determined that federal laws, including RCRA, CERCLA, Title III of the Superfund Amendments and Reauthorization Act, CWA, Clean Air Act, Safe Drinking Water Act, and Toxic Substances Control Act, are applicable to all mining facilities, regardless of whether they are located on federal land.[8] Regulatory requirements continued to increase with passage of state and local laws that must be reviewed on a site-by-site basis. The Oregon Environmental Quality Commission adopted policies that will treat all mine operations using cyanide as if they were hazardous waste disposal facilities, even if the materials do not exhibit hazardous characteristics.[9]

Fraser[10] summarized the environmental assessment work conducted for a high-grade nickel/copper mine/mill operation where environmental work and approach were affected when a massive water problem was encountered in the mine. The paper described the tailings and water management practices of an environmentally acceptable procedure to dispose of a large volume of slightly saline water. Sedam[11] presented hydrologic data from selected drainage basins in the active coal-mining areas of Ohio. The data were collected as part of a second phase of a 7-year study to assess baseline water quality in Ohio's coal region. The effects of surface and deep coal mining on the hydrology of small stream basins in southern West Virginia were determined by Borchers *et al.*[12] The data did not support the theory that strip mining causes increased stream runoff but did contribute a large percentage of the dissolved chemical load in the outflow from mined basins. Impacts of mining and subsequent restoration of a near surface aquifer on the ground and surface water resources of a watershed affected by mining was described by Garlanger[13] in terms of groundwater recharge, groundwater levels, and base flow and runoff to the surface streams. Potential effects of coal mining included alteration of groundwater flow systems and changes in water quality and was addressed by Fogg *et al.*[14] Nonpoint source drainage results from stormwater runoff from mine facilities, such as haul roads, waste disposal sites, and ore bodies. Implementing nonpoint source drainage control plans that prevent impacts to water resources can be accomplished cost effectively with moderate labor requirements.[15]

Vast and increasing tonnages of gypsum ($CaSO_4 \cdot 2H_2O$) were generated by the flue gas desulfurization systems of coal-fired power stations.[16] Diminishing availability of landfills combined with rapidly escalating production underscored the need to use the gypsum as a resource rather than disposing it as a waste. Maintaining a water balance at milling operations may be difficult due to inconsistencies in precipitation, discharge slurry density, evaporation, recirculation to the mill, and the milling rate.[17] Efficient effluent management was achieved at one operation by minimizing the watershed and, therefore, minimizing runoff, use of large ponds to promote evaporation, ponding a high discharge slurry density to minimize the mill water discharge to the basin, and recycling much of the flow back to the mill. Grier and Karvinen[18] suggested that the dispersion of contaminants from existing and planned tailing sites are related to the local groundwater regime and not just to surface runoff. Impermeable tailings basins and good control on the movement of effluent would aid in preventing any contaminating solutions from entering the groundwater system or any interaction between groundwater and tailings. Impacts on plant growth were discussed by Guyette *et al.*,[19] where growth increments of eastern red cedar from sites in the iron-mining district of southeast Missouri were subjected to lead and cadmium analysis.

PREVENTION, TREATMENT, AND RECLAMATION

The complete elimination of acid mine drainage (AMD) is not normally a realistic goal for mine waste management. Treatment for AMD can include reduction of rate of oxidation, injection of tailings with relatively impervious materials, alkaline buffering of waste material, placement of reactive waste into mined-out pits, and biological treatment of wastes.[20] The use of surfactants in controlling the formation of AMD was evaluated by the U. S. Bureau of Mines.[21] Surfactants possessing high detergent activity were used in solution to wash off the protective wax coating formed by bacteria and caused them to be consumed by the same acid they produce. Scales[22] demonstrated that infiltration by precipitation could be reduced from 10 to 40% with a corresponding reduction in AMD. AMD effluent was collected and treated by pH adjustment. The solution was discharged to settling ponds where metals precipitate. Incorporation of cement kiln dust (CaO) and limestone ($CaCO_3$) neutralized coal waste acidity at a coal waste from a site in Montana.[23] Seeded vegetation was healthy and vigorous where lime was applied.

AMD was recognized as an environmental and economic liability for the mining industry.[24] The U. S. Bureau of Mines, Colorado School of Mines, and the Tennessee Valley Authority treated AMD by constructing wetlands, with promising results. A low-maintenance system was developed by the U. S. Bureau of Mines research facility to remove heavy metals from AMD from small seeps of AMD at remote sites.[25] The system removed aluminum, arsenic, cadmium, chromium, cobalt, copper, gold, iron, lead, manganese, mercury, nickel, platinum, silver, thorium, uranium, vanadium, and zinc ions from water. The effluent water met or exceeded national standards for drinking water. The underlying principles and comparative effectiveness of three different approaches for treating AMD based on the addition of lime products, fertilizers, and bulk organic matter, such as wastewater sludge, were discussed by Davison.[26]

A relatively new technology, paste backfilling, enabled mine operators to use the total tailings (as opposed to just the deslimed portions) as underground backfill material.[27] The advantages for the mining industry included reduction in mine dewatering operations. Also, the size of surface tailing ponds can be cut approximately in half because the typical mine creates openings large enough for about half of the tailings produced in milling. Thomson[28] discussed underground disposal of wastes from uranium milling and coal mining, focusing on potential impacts on groundwater quality.

Waste stabilization pond systems were found to be suitable for treatment of high-strength industrial wastes.[29] The long retention times and high buffering capacity of such systems enables them to cope more readily with widely fluctuating organic loads and biologically toxic compounds. Natural degradation phenomena occurring in a tailings pond at the Lupin Mine 50 miles south of the Arctic Circle resulted in pH depression, photodecompostion of metal-cyanide complexes, oxidation of cyanide and gravity sedimentation of precipitated metals, and sparingly soluble cyanide complexes in the tailings pond.[30] A process for removing cyanide and base metal complexes from industrial waste streams used SO_2 (in liquid or gas form or solutions of sulfite salts) plus air that was dispersed in the effluent using a well-agitated vessel. Acid produced in the oxidation reaction was neutralized with lime at a pH of 7–10.[31] The process could be applied to detoxification of gold and silver mining waste streams, such as carbon-in-pulp tailing processes, barren solution bleeds, pond waters and heap leach rinse solutions, and also to plating shops' wastewaters. The functioning of the nitrogen cycle within mining wastes is necessary for revegetation and long-term stability of the disturbed ecosystem.[32] Monthly environmental audits and a search for ways to remove ammonia from mill effluent resulted in various research studies on the topic concerning ammonia removal.[33] Caldwell[34] summarized the waste pile stabilization technology developed in the Uranium Mill Tailings Remedial Action project with respect to cover technology, construction of radon barriers, and protection of groundwater resources.

MODELS

A three-dimensional computer model of the filling and drainage of backfilled open stopes was described by Traves and Isaacs.[35] The model is capable of describing irregular stope geometries and heterogeneous fill and predicting pressures and flows at specific locations within a stope. Hao *et al.*[36] discussed applications of a model for water treatment and AMD control for Mn(II) removal with chlorine. Anderson *et al.*[37] used mass-balance calculations and mineralogical and surface chemical analyses to identify important chemical processes and mineralogical alterations occurring during leaching. Trujillo[38] proposed a model of a treatment technique developed by the U. S. Bureau of Mines that used biomass and sphagnum peat moss to selectively remove zinc, cadmium, and other metals from a zinc mine wastewater to concentrations below the national drinking water standards. An extensive sampling program and the use of a numerical water flow model made it feasible to simulate and compare the dynamics of metal transport at different sites in the study area.[39] A hydrochemical model based on a fairly simple description of the mixing of water from different sources and a very simple pH dependence of the concentration of the metals, semiquantitatively, reproduced the dynamics of metal concentrations and mass transport of metals.

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REFERENCES

1. Corbett, R. A., "Refiners, Petrochem Plants Focus on New Waste Challenges." *Oil Gas J.*, **88,** 10 (1990).
2. Moritis, G., "Producers Modify Activities as Threat of New Rules Looms." *Oil Gas J.*, **89,** 50 (1991).

3. Moritis, G., "Drilling Production Meet Environmental Challenge." *Oil Gas J.*, **88**, 10 (1990).
4. Rhodes, A. K., "Recent and Pending Regulations Push Refiners to the Limit." *Oil Gas J.*, **89**, 50 (1991).
5. Rappold, K., "Drilling Wastes Require Extra Attention." *Oil Gas J.*, **89**, 50 (1991).
6. True, W. R., "Clean Air Act and PCB Cleanup Hold Attention of Processors, Pipelines." *Oil Gas J.*, **88**, 10 (1990).
7. True, W. R., "Pipeliners and Gas Processors Target." *Oil Gas J.*, **89**, 50 (1991).
8. Philbrook, J. N., "Environmental Audits: Determining the Need at Mining Facilities." *Min. Eng.* (N. Y.), **44**, 207 (1991).
9. Anonymous, "Oregon Policy Will Treat All Cyanide Use at Mines as Hazardous." *Min. Eng.* (N. Y.), **44**, 1393 (1991).
10. Fraser, W. W., "Environmental Management at Namew Lake." *Can. Mining Metall. Bull.*, **84**, 949 (1991).
11. Sedam, A. C., "Geologic Setting and Water Quality of Selected Basins in the Active Coal-mining Areas of Ohio, 1987–1988." Rep. 90-4109, U. S. Geol. Surv., Columbus, Ohio (1991).
12. Borchers, J. W., *et al.*, "The Effects of Coal Mining on the Hydrologic Environment of Selected Stream Basins in Southern West Virginia." Rep. 84-4300, U. S. Geol. Surv., Charleston, W. V. (1991).
13. Garlanger, J. E., and Shrestha, R. K., "Groundwater Engineering Restoration in Mined Areas." *Min. Eng.* (N. Y.), **44**, 1159 (1991).
14. Fogg, J. L., *et al.*, "Geohydrology and Potential Effects of Coal Mining in 12 Coal-lease Areas, Powder River Structural Basin, Northeastern Wyoming." Rep. 87-4102, U. S. Geol. Surv., Cheyenne, Wyo. (1991).
15. Mohr, R., "Control of Surface Mine Drainage at Coeur d'Alene's Thunder Mountain." *Min. Eng.* (N. Y.), **44**, 210 (1991).
16. Harben, P., "FGD and Chemical Gypsum: Waste Product or Commercial Resource?" *Ind. Miner.*, **47**, 7 (1991).
17. Welch, C. E., "Water Accounting." *Can. Mining J.*, **112**, 2, 29 (1991).
18. Grier, M. E., and Karvinen, W. O., "How to Guard Against Contaminating Groundwater." *Can. Mining J.*, **112**, 3, 3 (1991).
19. Guyette, *et al.*, "Lead and Cadmium in Tree-rings of Easter Red-Cedar." *J. Environ. Qual.*, **20**, 146 (1991).
20. Knapp, R., and Welch, D., "No Simple Solution." *Can. Mining J.*, **112**, 6, 63 (1991).
21. Foley, J. T., "Surfactant Chemical Technology Works for Environmental Jobs." *Min. Eng.* (N. Y.), **44**, 1329 (1991).
22. Scales, M., "Departing With Dignity." *Can. Mining J.*, **112**, 5, 33 (1991).
23. Gitt, M. J., and Dollhopf, D. J., "Coal Waste Reclamation Using Automated Weathering to Predict Lime Requirement." *J. Environ. Qual.*, **20**, 285 (1991).
24. Kalin, M., "In Search of a Solution." *Can. Mining J.*, **112**, 7, 76 (1991).
25. "New Hanson Division Offers Mine Waste Water Treatment Services." *Min. Eng.* (N. Y.), **44**, 584 (1991).
26. Davison, W., "Treatment of Acid Waters by Inorganic Bases, Fertilizers and Organic Material." *Trans. Inst. Mining Metall.*, **99**, 4, A153 (1990).
27. Brummer, R., and Moss, A., "Paste: The Fill of the Future?" *Can. Mining J.*, **112**, 8, 31 (1991).
28. Thomson, B. M., "Engineering Perspectives for Deep Geologic Disposal of Wastes." In "Deserts as Dumps?" C. C. Reith and B. M. Thomson (Eds.), Univ. of New Mexico Press, Albuquerque, N. Mex. (1991).
29. Alabaster, G. P., *et al.*, "Combined Treatment of Domestic and Industrial Wastewater in Waste Stabilization Pond Systems in Kenya." *Water Sci. Technol.*, (G. B.) **24**, 1, 43 (1991).
30. Wilson, H. R., "Tailings Management in the Canadian Arctic: Echo Bay's Lupin Mine." *Min. Eng.* (N. Y.), **44**, 213 (1991).
31. Devuyst, G., *et al.*, "Inco's Cyanide Removal Technology Working Well." *Min. Eng.* (N. Y.), **44**, 205 (1991).
32. Sorensen, D. L., and Fresquez, P. R., "Nitrification Potential in Reclaimed Coal Mine Spoils and Soils in the Semiarid Southwest." *J. Environ. Qual.*, **20**, 146 (1991).
33. Anderson, S., "Greening of a Giant." *Can. Mining J.*, **112**, 5, 24 (1991).
34. Caldwell, J. A., "Engineering Perspectives for Near-surface Disposal." In "Deserts as Dumps?" C. C. Reith and B. M. Thomson (Eds.), Univ. of New Mexico Press, Albuquerque, N. Mex. (1991).
35. Traves, W. H., and Isaacs, L. T., "Three-Dimensional Modeling of Fill Drainage in Mine Slopes." *Trans. Inst. Mining Metall.*, **100**, 2, A66 (1991).
36. Hao, O. J., *et al.*, "Kinetics of Manganese (II) Oxidation with Chlorine." *J. Environ. Eng.*, **117**, 359 (1991).
37. Anderson, M. A., *et al.*, "Interactions of Acidic Metal-rich Coal Pile Runoff with a Subsoil." *J. Environ. Eng.*, **25**, 2038 (1991).
38. Trujillo, E. M., "Mathematically Modeling the Removal of Heavy Metals from Wastewater Using Immobilized Biomass." *Environ. Sci. Technol.*, **25**, 1559 (1991).
39. Sandén, P., "Estimation and Simulation of Metal Mass Transport in an Old Mining Area." *Water, Air, Soil Pollut.* (Neth.), **57**, 387 (1991).

Petroleum processing and synthetic fuels

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PETROLEUM PROCESSING

Environmental issues facing the exploration, drilling, production, transportation, refining, marketing, petrochemicals, and gas processing sectors of the petroleum industry were discussed by Williams.[1] The sources and characteristics of hazardous and solid wastes in a refinery were summarized by Bryant and Moore,[2] along with disposal alternatives for current and proposed regulations. A critical need was seen for exploration and production operations to keep waste generation to a minimum, to prevent classification of wastes as being hazardous under the Resource Conservation and Recovery Act and to find new ways to treat and dispose of wastes.[3] Waste minimization at BP Oil's Alliance refinery in Louisiana includes waste stream inventories, identification of waste management opportunities and practices, facility specific annual waste management goals, and an annual review of achievements.[4] Activities and programs in the petroleum industry that protect the environment from pollution and degradation were described in a series of articles on individual companies and their specific accomplishments.[5] A bibliography containing citations of techniques and equipment used for pollution control in the chemical and petrochemical industries was prepared by the National Technical Information Service.[6] Pictorial simulation models considering pictorial entities (defined by shape, size, color, and position) and operations parameters were proposed for two water quality management problems: oil spill accidents and waste stabilization ponds ecology.[7] Thirteen papers presented in the American Society of Mechanical Engi-