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Project Summary

Investigation of Coal Mine Effluents—Regrade to Bond Release

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The objective of this fact-finding project was to characterize the effluents draining from surface-mined lands that are at various stages of reclamation preceding final release of bond. To produce the characterizations, water quality samples were collected from sedimentation pond inflow and outflow on a daily basis when flow was present, and hourly during runoff events at eight monitoring sites located in Ohio, West Virginia, Kentucky, Illinois, Kansas, Texas, North Dakota, and Montana. In addition, 50 sites located throughout the major U.S. coal mining regions were sampled once during or shortly after a storm event and/or evaluated with respect to water handling practices.

The water quality data show great variability in the concentrations of constituents affected by the physical and mining framework of each reclamation site. Water quality parameters analyzed include pH, acidity, alkalinity, specific conductance, total dissolved solids, total suspended solids, turbidity, settleable solids, total and dissolved iron, aluminum and manganese, and dissolved trace elements—antimony, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, thallium, and zinc.

The field data collection phase for this project was from August 1979 through October 1980. All water quality data were compiled into a data base and submitted to the U.S. Environmental Protection Agency, Industrial Environmental Research Laboratory in Cincinnati as a part of the unpublished project file.

The total suspended solids concentration limit of 70 mg/L was exceeded at each monitored site in 8 to 81 percent of the samples. The total iron concentrations are highly correlated with the total suspended solids concentrations and exceeded 7.0 mg/L at all but one monitored site in 4 to 75 percent of the samples. The total manganese concentration limit of 4.0 mg/L was exceeded at three sites in 3 to 38 percent of the samples. Upper or lower levels of pH (range 6 to 9) were exceeded in 68 percent of the samples at the West Virginia site and 4 percent of the samples from the Texas site. Settleable solids in excess of 0.5 ml/L/hr were found in 41 percent of the samples from the monitoring site in North Dakota.

The Mann-Whitney test of differences between the sedimentation pond inflow and outflow concentrations of total suspended solids was performed to test the impact of sediment ponds on the levels of particulate pollutants. The test results show that there was not a statistically significant difference between the inflow and outflow sets of total suspended solids data from four of seven monitoring sites or from the mine survey sites.

The concentrations of total suspended solids were reduced in 58 to 87 percent of the samples of daily pond inflow and outflow. The rest of the samples show increases in the total suspended solids in the pond outflow observed during base flow as well as during runoff events. The actual pond efficiency was found to be largely independent of precipitation levels.

The efficiency of other water control structures was observed to be highly variable, depending mainly on their design and maintenance.

The full report was submitted in fulfillment of Contract 68-03-2762 under sponsorship of the U.S. Environmental Protection Agency, Industrial Environmental Research Laboratory.

This Project Summary was developed by EPA's Industrial Environmental Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Project Scope and Logistics

The project was executed in two phases. Phase 1 consisted of preparing a research plan that outlined the technical approach to be employed by HRB-Singer, Inc. and by its subcontractor, Commercial Testing and Engineering, Inc. (CT&E), to perform research activities and sampling and analysis services related to the study. Phase 2 consisted of the actual implementation of the research plan in two tasks. The first task included a survey of 50 mine sites. Detailed water quality sampling of eight in-depth monitoring sites was performed in the second task.

Each of the in-depth monitoring sites was equipped with fiberglass Parshall flumes, automatic samplers, flow meters, and rain gauge/event recorders. Field laboratory technicians were stationed at each of the in-depth sites to maintain the equipment, to collect water samples, and to perform the required field analyses. Field laboratories were set up in close proximity to the monitoring sites and equipped for analysis of pH, acidity, alkalinity, specific conductance, total dissolved solids, total suspended solids, and settleable solids. All samples to be analyzed for total and dissolved metals and for particle size analysis were sent to CT&E laboratories in Golden, Colorado, and in New Holland, Illinois. Daily composite samples from each monitoring site were sent once a week to the Bituminous Coal Research, Inc. Laboratories in Monroeville, Pennsylvania, as part of the project's quality assurance program.

Data Summary and Conclusions

Statistical summaries of the water quality data indicating ranges of the concentrations and the variability of the individual constituents for each monitoring site and for the mine survey sites are given in the final report.

Trends in the concentrations of measured water quality parameters are influenced by the proportions of base flow and surface runoff in the discharge from each site. Variability of the data is also affected by physical and mining factors at each sampling site. Sources of the various pollutants are diffused throughout the reclamation sites, and fluctuations in the pollutant input also contribute to the data variability. Seasonal changes in precipitation and the mixing of the surface runoff, spoil leachate, and ground water that recharge the sedimentation pond contribute to the complexity of the hydrologic system. Leachate from the spoils can be flushed out during precipitation and temporarily affect the concentrations of water quality parameters such as acidity, pH, alkalinity, total dissolved solids, and dissolved metals.

Quite often it is difficult to define and describe the relationships among the site's physical characteristics, reclamation and water handling practices, and effluent water quality. Results of factor analysis indicate that the slope steepness, the length of the time period after regrading and topsoiling, and the pond sediment storage volume are the site-specific factors highly correlated with water quality parameters.

Water handling practices were observed to vary with the regional differences of the sites and were adjusted to the overall site morphology. Water samples collected during a storm event from diversion ditches at the monitoring sites show concentrations of total suspended solids mostly equivalent to those of the sediment pond inflow. The main function of the ditches is to collect the surface runoff and to divert the flow from problem areas to a sedimentation pond. The design, and especially the maintenance, of these structures are major factors determining their effectiveness.

Sediment traps used at the sites to reduce sediment loads in surface runoff before its entry into a sedimentation pond were observed to be effective in trapping only the coarser particles. Their effectiveness is highly variable and depends largely on site conditions and maintenance.

The evaluation of sedimentation pond efficiency in reducing total suspended solids concentrations was performed by calculating percent reduction in the concentrations of total suspended solids between the points of sedimentation pond inflow and outflow. The calculations were based on daily composite inflow and outflow samples and indicated an average daily pond effectiveness. The concentrations of total suspended solids were reduced in 58 to 87 percent of the samples taken at the monitoring sites. The rest of the samples showed increases in the total suspended solids load in the pond outflow. These increases were observed to occur during base flow periods as well as during runoff events. The observed efficiency of ponds in reducing the suspended solids was largely independent of precipitation levels and, in most cases, of the flow conditions as well.

The Mann-Whitney test was performed to determine if there is a statistically significant difference in the overall quality of sedimentation pond inflow and outflow data pairs. The NULL hypothesis, assuming no difference in the pollutant level of pond inflow and outflow, was rejected in approximately 38 percent of the tested samples. A significant difference in the concentrations of total suspended solids in the pond inflow and outflow was indicated for three monitoring sites. For the rest of the monitoring sites and the mine survey sites that were sampled mainly during storm events, the NULL hypothesis was not rejected, thus indicating that the ponds had no substantial quantitative effect on the total suspended solids levels.

Concentration levels of water quality parameters specified as potential pollutants associated with coal mining point source discharges were compared with EPA's effluent limitations guidelines specified in the *Federal Register*, Volume 48, January 13, 1981. The total suspended solids level of 70.0 mg/L was exceeded at each sampled site in 8 to 81 percent of the cases. The guideline levels for total iron concentrations were exceeded at all sites but one in 4 to 75 percent of the cases analyzed. Levels of pH in the range of 6.0 to 9.0 were exceeded in 68 percent of the samples from a West Virginia site and in 4 percent of the samples in Texas. The specified guidelines for total manganese were exceeded at three sites in 3 and 38 percent of the samples. The settleable solids level of 0.5 ml/L/hr was exceeded in 41 percent of the samples from North Dakota and in 1 and 2 percent of the samples from the mine survey sites and the monitoring site in Ohio, respectively.

Thirty-day moving averages calculated for daily values of total suspended solids, total iron, and total manganese were compared to the limitations guidelines given for average daily values for 30 consecutive days. The 30-day average for total suspended solids of 35 mg/L was exceeded at each monitoring site in 38 to

100 percent of the samples. The high percentages of total suspended solids identified for the in-depth sites in Illinois, Kansas, Texas, and North Dakota that exceeded 35 mg/L correspond to the high number of cases where the guidelines of 3.5 mg/L for total iron were also exceeded. The total manganese level of 2.0 mg/L was exceeded at the in-depth sites in West Virginia, Kentucky, and North Dakota.

Trace element concentrations were determined for samples taken from sedimentation pond outflow at the in-depth monitoring sites and the mine survey sites. Most of the elements were below or close to the detection limits.

Total suspended solids and turbidity were found to be highly correlated in the majority of the measurements. However, the quality assurance program indicated a progressive error in the turbidity determinations for samples with high concentrations of suspended solids.

The total suspended solids concentrations are also very highly correlated with those of total iron and total aluminum. The three constituents were found to be redundant, indicating high interdependence and a high correlation in the variability of their values. The same is true about occurrences of total and dissolved manganese. Total and dissolved occurrences of iron and aluminum are not strongly correlated, since each of the parameters measures slightly different water quality properties. Concentrations of total iron and total aluminum reflect changes in the concentration of the total suspended solids as well as the composition of the particles in suspension. The analytical method for determining total metals calls for vigorous digestion of an unfiltered sample and indicates the sum of the concentrations of metals in both the dissolved and suspended fraction. Metals are extracted from silts and clays that, under ambient conditions, are not easily released into solution.

Approximately 98 percent of the samples collected during the project and analyzed for settleable solids yielded values below 1 ml/L/hr. The detected values ranged from 1.0 ml/L/hr to 290 ml/L/hr. The values are well correlated with concentrations of total suspended solids and in the majority of cases were detectable only when the total suspended solids reached concentrations of hundreds or thousands of mg/L. All of the sedimentation pond discharges characterized by such high concentrations of suspended solids occurred during runoff events.

Twelve surface mines selected to represent the prevailing mining and physical conditions in western mining areas were visited to evaluate the water handling practices used in reclaiming semiarid and arid lands. The overall erosional regime of the western reclamation sites is influenced by short duration, high intensity precipitation events that produce surface water runoff with high erosive capacity.

Management and water control practices used at the western mines are basic agricultural soil and water conservation practices. Most of these practices are fairly standard and result in good erosion and sediment control. About 20 percent of the mines visited used irrigation to reestablish vegetative cover during unusually dry periods. Overgrazing of some recently revegetated sites appears to be one of the major causes of erosion during the final stages of reclamation.

Revegetation using native species sometimes presents problems because of the species' slow establishment rates. Poor erosion control often results during the first season after reseeding. In order to control erosion, a quick cover annual or a biannual species is used as a "nurse crop." This practice was observed to produce very good results.

Utilization and design of various diversion and conveyance structures vary with the local conditions determined by the site's physical and mining framework. Restoring the premining drainage patterns—particularly stabilizing new drainage channels—is one of the difficult tasks that affects the overall erosional regime of the reclaimed area.

The majority of the surveyed mines have constructed sedimentation ponds to collect water draining from the reclaimed areas, pit pumpage, and other drainage from active mining areas, including haulage roads. Because of the scarcity of water in the dry regions, total containment practices are often implemented for the sake of water conservation.

There is no conclusive information on the effectiveness of ponds in removing suspended solids during runoff events, even when the ponds are designed according to the criteria set forth by the Office of Surface Mining. Concentrations of suspended solids during runoff events in dry regions are extremely high and often contain large proportions of very fine particles.

Concern has been expressed over the sediment removal below baseline levels and the effects of sedimentation ponds on the downstream erosional and depositional conditions. These effects may be especially pronounced when associated with sediment retention structures of relatively long lifespans.

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***J. F. Martin** is the EPA Project Officer (see below).*
The complete report, entitled "Investigation of Coal Mine Effluents—Regrade to Bond Release," (Order No. PB 84-177 906; Cost: $14.50, subject to change) will be available only from:
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