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"Acid Mine Drainage
Present Impact and Alternate Future Strategies"

Submitted By

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Summary of Technical Progress

Efforts during the first phase of this study have followed the research activities schedule detailed in the original proposal and the following is a brief summary of the work accomplished to date under each of the proposed activities (Appendix A).

Activity 1. - Update of Study Plan

Initiation of the study was made by defining the specific region of interest for the investigation. Upon careful consideration of data availability, the scope of the study was defined to include the entire watershed of the West Fork and Tygart Rivers whose confluence forms the Monongahela River and terminated at the West Virginia - Pennsylvania border. This area was considered to be of sufficient magnitude so as to allow the discrimination of the effects of acid mine drainage (AMD) and neutralized AMD in the basin. Examining basin map No. 037-R40-3/1 for the Monongahela River Basin, prepared by the U.S. Army Corp of Engineers in November 1970, the total river, stream, and creek mileage to be studied and modeled was determined to be:

- West Fork River - 70 miles
- Tygart River - 65 miles
- Monongahela River - 37 miles
- Streams and Creeks off the Monongahela River - 117 miles
- Streams and Creeks off the West Fork River - 153 miles
- Streams and Creeks off the Tygart River - 129 miles

These 571 miles provide us with an extensive river basin area to view and study many varied water quality levels.

Activities 2 and 12. - Collect and Review Information on AMD Treatment Systems

A vast number of schemes have been proposed for the treatment of AMD and these cover a full range of practicality and cost. However, due to the fact

that lime neutralization appears to be the most widely used and cheapest procedure to date, most of the effort in this phase of the study was devoted to the accumulation of data for this system and the development of an adequate mathematical model to describe the behavior of the process. Although considerable work has been done in the area of AMD neutralization a review of the literature on this subject indicates that very little in the way of complete data has been published. In fact, most studies concentrate quite heavily on the removal of iron and acidity and tend to ignore the increase in hardness caused by lime neutralization, which could be a significant factor from the viewpoint of a secondary impact.

The primary objectives for the accomplishment of the work in this activity are:

1. the establishment of mathematical models to effectively predict the effluent concentrations from an AMD lime neutralization plant for the two cases where the influent data is complete or only partially available
2. the establishment of a suitable technique to determine the lime requirements of a neutralization system when influent data is complete or incomplete.

A description of the model can be visualized by realizing that a typical AMD is characterized by concentrations of calcium, magnesium, iron, aluminum, manganese and sodium usually in conjunction with sulfate anions and at a low pH. The basis of the model under development is to consider the reactor employed in the neutralization process to be completely mixed and to assume the aqueous reactions to occur very rapidly. In this manner it is reasonable to assume that all chemical species will attain an equilibrium state and thus the adoption of the name "Ionic Equilibrium Model"¹. In this model the Davies relationship has been used to compute the coefficient relating the molal concentration of the particular ion with its ionic reactive activity. It is also assumed in the model that the activity

coefficients for all the single valence ions are equal, the activity coefficients² for the non-ionized dissolved molecules are unity, and the lime (CaOH_2) is added dry to the process. A complete description of the reactions and relationships in this model will be provided in the final report.

To date, application of the model for the prediction of hardness levels in the effluent has met with some success when applied to data obtained from research units. One possible explanation for some of the inconsistencies in results potentially lies in the assumption of a completely mixed reactor as applied to the data published from small scale research systems. It is felt that in most cases complete mixing is not attained and in fact the application of a reactor bypass in the model seems to bring the results more in line with the measured parameters.

Some results of the model under development can be seen in the following table which illustrates measured and predicted calcium concentrations from published neutralization research plants.

Effluent Calcium Concentration (moles/l)		
	<u>Measured</u>	<u>Predicted</u>
Kefover Plant ³	0.75×10^{-2}	0.94×10^{-2}
Thompson Plant ³	1.95×10^{-2}	1.34×10^{-2}
Crown Plant ⁴	0.14×10^{-1}	0.67×10^{-2}

Prediction of effluent sulfate concentrations for these plants are in much better agreement with measured values and at present do not appear to present too much difficulty in future work while efforts are being made to improve the modeling of hardness in the discharged waters.

Other treatment systems for AMD such as soda ash neutralization, ion exchange, and reverse osmosis will be examined and modeled in detail during the second phase of this study.

Activity 3. - Collect and Review Information on the Monongahela River Basin

Due to the nature of the study it has been necessary to gather specific information on water quality and flow characteristics for all rivers, streams and creeks in the study basin. This information along with items to be discussed in activities 4 and 5 will be included in a computerized data base that can be accessed in part or total to accomplish the overall goals of the project. Basic logic for developing and using the data base is presented below:

Following accepted data processing techniques the many varied pieces of data are gathered, key punched on IBM cards, checked for errors before being recorded in the data base, statistically summarized for the user and finally used within the simulation model to aid the decision maker in determining the effects of various AMD treatment alternatives.

Specific pieces of information obtained for each river-segment (format to be discussed later) include:

- a) position element for the river-segment (latitude and longitude)
- b) river name
- c) county
- d) presence or absence of a USGS recording station
- e) presence or absence of locks
- f) presence or absence of dams
- g) average river flow
- h) 7Q10 river flow
- i) average river depth
- j) 7Q10 river depth
- k) average river width
- l) 7Q10 river width
- m) river flow slope
- n) Manning's coefficient
- o) drainage area
- p) data source

With this information along with water quality information obtained for wasteloads (active and inactive mines as discussed in Activity 4 and 5) in the study basin, required data is supplied to a simulation model (Qual II⁵ as discussed in Activity 7) to predict water quality levels as a function of various treatments for AMD (as discussed in Activity 2).

Sources of information for the Monongahela River Basin include numerous government agencies particularly the DNR, USGS, U.S. Army Corp of Engineers as well as previous studies on water pollution in the study area. However, no single source is able to provide extensive data needs nor provide consistently up to date information. In most cases data has been collected in various formats and then rearranged and reformatted to create data files needed in this work. Information such as hydraulic data, river mile identification (latitude and longitude), and source of data (USGS, DNR, etc) are being collected much more easily since they can be drawn from maps, charts, and tables. Approximately 60% of the needed data is on hand now.

Activities 4 and 5. - Identify Active and Inactive Mine Drainages into the Monongahela River

The wasteload information which will be included with the river segment information is also being gathered and processed.

Specific information collected on all wasteloads, whether it be an active mine, inactive mine, municipal discharge, coal preparation plant, refuse pile, or industrial discharge, include the following:

- a) wasteload name
- b) wasteload element location (latitude and longitude)
- c) flow rate
- d) pH level
- e) alkalinity
- f) acidity
- g) total hardness
- h) calcium
- i) magnesium
- j) manganese
- k) sodium
- l) aluminum
- m) total iron
- n) SO_4
- o) PO_4
- p) chlorides
- q) NH_3
- r) TKN
- s) BOD_5
- t) total dissolved solids
- u) suspended solids
- v) fecal coliforms

Primary sources for this information are the EPA, USGS and previous related studies. However, as before, no one source has extensive records and that which is available does not match the format of data from other sources. Due to this reason, rearranging and reformatting is being performed to allow for a large data file to be developed. For approximately one half of the twenty-two elements 60-70% of the information needed to describe the wasteloads has been gathered but is just now being coded and keypunched for checking in the edit program. For the remaining data needs as little as 10-30% is in hand but can be obtained.

Figures now indicate the number of wasteloads in the study area are as shown below:

<u>Abandoned Mines</u>	<u>Active Mines</u>	<u>Municipal Discharges</u>	<u>Industrial Discharges</u>	<u>Refuse Piles</u>	<u>Preparation Plants</u>
1557	50	92	1	18	1

Due to the flexibility of the computer data base which "feeds" the simulation model these figures are continually being updated within the data base.

Activity 7. - Evaluate the Format of the Data to Facilitate Ease of Using the Data

The format for recording wasteload information and river quality and hydraulic data on cards has been structured to insure ease of preparation by the user along with efficiency in creating the computerized data base. Field widths have in all cases where possible been kept constant and large enough to allow the user to place decimal points where needed. This has been done to reduce chances of error in keypunching. The data taken from these card field widths has been stored in formats large enough on tape to prevent possible overflow or elimination of significant digits. The setting of the field widths also took into consideration the largest possible numbers expected from a review of available past data to prevent wasting of space where possible.

Programs have already been written to compile different sources of information onto cards in our required format. Editing programs to check these input cards, programs to build separate river segment and wasteload files are written, and the program to merge these two files into the data base has been completed. Much of the data, particularly on the hydraulics for the river segments, has yet to be coded and placed on cards to be run through the edit, file, and merge programs.

A mass balancing program to enable the data base to be used in Qual II is being developed. The user program allowing several options (such as up dating, summaries, and Qual II use) with the data base input is also in progress.

A summary of the programs completed:

- 1) Editing programs for wasteload data cards and river segment data cards
- 2) Programs to build files on tape or disk from these two input sets of cards
- 3) Programs to list these data files
- 4) Program to merge these two files into the data base, (placing wasteload location) and give a printout of the information by river segment with its associated wasteloads.
- 5) Program to list the information on the data base (no merge or input option)

Programs still in progress:

- 1) User program for making use of the data base
- 2) Mass balancing program for converting multiple wasteloads in a river segment into a single point source wasteload to be used in Qual II.

Besides the normal time required for programming that was involved in writing these programs, time was used to research JCL (Job Control Language) and available user's programs already written and catalogued in the WVU computer library. The use of the EUUTIL library programming package enhanced actual computer usage time and correspondingly dropped costs by approximately two-thirds over regular FORTRAN or SAS programs written to perform the same function.

The two disadvantages of relying solely on EUUTIL were:

- 1) the availability of the program package at various computer sites.
- 2) very little control over the format of the printed output.

It was for these two reasons that FORTRAN or SAS backup programs were written that will accomplish the same tasks with our data.

With EUUTIL, the user needs only about 7 control cards, on the average, plus his data, to build the two files necessary to merge into the data base. These cards will be documented in the final report.

At present the work proposed is completely in phase with the time schedule for research activities illustrated in Appendix A. It is anticipated that the projection of future hardness levels resulting from lime neutralization of active and inactive mines (Activities 8, 9 and 10) will also adhere to the original research plan.

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APPENDIX A

(copied from the original proposal)

ACTIVITIES

1. Update study plan.
2. Collect and review information on AMD treatment systems.
3. Collect and review information on Monongahela River basin.
4. Identify active mine drainages into Monongahela River.
5. Identify inactive mine drainages into Monongahela River.
6. Review and evaluate progress to date.
7. Evaluate the format of the data to facilitate ease of using data.
8. Project future hardness levels of active mine discharges due to lime-limestone neutralization.
9. Project future hardness levels of in-active mine discharges due to lime-limestone neutralization.
10. Assess projected quantitative and qualitative effects on various regions due to lime-limestone neutralization.
11. Identify regions in which the projected secondary economic impacts from lime-limestone neutralized discharges warrant the application of other abatement technologies.
12. Determine various strategies available (at present or in the future) for treating AMD, other than lime-limestone.
13. Identify the levels of hardness from various combinations of the treatment processes as proposed in (12) above.
14. For the regions identified in (11), determine the projected secondary impacts from the treatment processes set forth in (12).
15. For the regions identified in (11) analyze and compare the hardness levels and projected secondary economic impacts for each process strategy combination.
16. From results obtained in (15) make conclusions.
17. Write up of report.

Figure 2. Time Schedule for Research Activities

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