

MANUFACTURE OF COAL MINE DRAINAGE

Harold L. Lovell

Professor of Mineral Engineering
The Pennsylvania State University
University Park, Pennsylvania

Presented

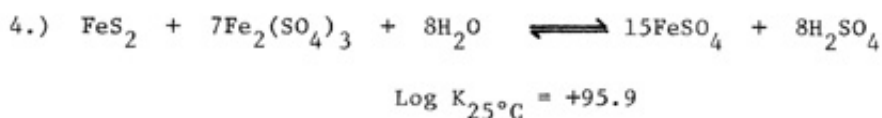
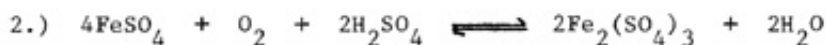
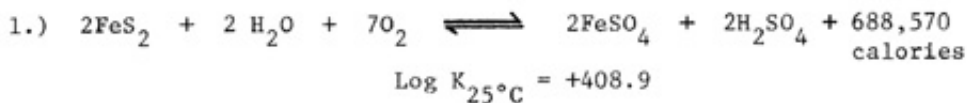
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SURFACE MINING FOR WATER QUALITY
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The unavoidable introduction of insoluble suspended solids (sediment) and soluble components into water form the basis for water quality degradation resulting from coal mining. The extremely complex and variable series of events leading to this degradation result from enhanced contact of surface and/or ground water with disturbed surface and/or near-surface solids. The disturbance causes a drastic change in the prevailing geological equilibria. Here we will consider only the water solubilization events and, of those, only the chemical species resulting from occurrences of iron sulfide minerals in coal-related strata.

There are actually five major occurrences involved:

1. The iron sulfide minerals
2. Water
3. Oxygen
4. The microbiological ecology
5. The environment in which the first four exist. These occurrences are inter responsive upon contact to the prevailing physical conditions which control a complex series of chemical reactions. These reactions are commonly generalized by four equations:



The first and fourth equations relate to oxidation of insoluble iron sulfides to soluble ferrous sulfate. Equation 2.) represents an oxidation of ferrous iron species (Fe II) to ferric iron species (Fe III). Thus, the increased availability of soluble ferric species as a product from equation 2.) obviously favors equation 4.) as a reactant, which is generally most responsive of these reactions. Reactions indicated by equations 1.) and 2.) are believed to occur by direct chemical reaction as well as being enhanced by specific microbiological activity.

The hydrolysis reaction described by equation 3.) fortunately removes iron from the soluble system as insoluble hydrous iron oxides, but unfortunately, also leaves soluble acidic ionic species as hydronium ions which further enhances water degradation. The extent of sulfide solubilization in a water of course controls species concentration. As such, a mine drainage which has the potential of contacting further strata including iron sulfides, may act as a lixiviant to further solubilize additional strata minerals such as clays. There has been little research into these phenomena.

The microbiological response toward equations 1.) and 2.) involves the acidophilic, chemolithotrophic bacteria Thiobacillus ferrooxidans. These bacteria are indigenous to coal strata environments and oxidize (as an energy source) reduced inorganic iron and sulfur compounds and fix carbon dioxide to the oxidation level of a carbohydrate. More recently, another bacterium Metallogenium (1) has been suggested as serving an environmental conditioning role prior to more prolonged, accelerated oxidation of iron sulfides by T. ferrooxidans. Further, it has been established (2) that numerous heterotrophs exist in the biomass that develops in natural T. ferrooxidans cultures.

The fifth occurrence involves the environmental conditions which may be conducive to, or more practically, retard the progression of these reactions.

Early attempts of the mining industry (1960's) to meet environmental regulations emphasized treatment of water effluents from mining sites as the reliable, positive control procedure. This capability exists. Subsequently, prevention-amelioration objectives have emphasized isolation of the reactants (pyrite-water-oxygen) to minimize reactions 1.) and 4.). Generally, such attempts have less effectiveness and reliability than treatment, but potentially result in reduced pollution loading and longer term control per unit of cost expended. Approaches to most existing state and federal regulations, including your own "Suggested Guidelines," are based upon reactant isolation premises but also provide for water treatment if necessary.

I propose the current and future objectives to control water quality degradation must extend beyond reactant isolation and water treatment and be incorporated into the system during premining planning. They must incorporate positive, long-term control of the physical and chemical conditions in the disturbed area to an extent approaching attaining those natural geological equilibria which existed prior to mining. These approaches will not be achieved without further effort and cost. To wit it is noted the existence of natural water outfalls, of less than acceptable quality, that occur where there has been no mining within miles.

Existing attempts to predict mining impact for permit purposes'. as pyrite content or type (potential acidity), neutralization potential, paste pH, reaction rate evaluations, leaching tests, etc., as cited in your "Suggested Guidelines," are helpful but may become either unnecessary or grossly inadequate. At best, they are difficult to evaluate - especially complex is the short-term versus long-term water quality modification responses.

Control of Physical and Chemical Environmental Conditions to Avoid Water Degradation

Consider some of the variables of the five occurrences involved and the complex interactions between

them:

Pyrite: nature of occurrence, particle size, dissemination, morphology, crystalline format, purity, nature of its surface (degree of oxidation, etc.), solubility, and reactivity.

Water: chemical characteristics (dissolved gases - oxygen, carbon dioxide, hydrogen sulfide: dissolved salts - metallic sulfates, chlorides, and other minerals), pH, acidity-alkalinity, ionic strength, conductivity; flow rates, velocity, variation in flow, potential for pooling, temperature.

Oxygen: concentration - partial pressure, availability, water content, diffusion rates through strata and water.

Microbiological Ecology: the existence of responsive chemo-lithotrophic bacteria and/or symbiotic systems in rate responsive population levels. System Environment: conditions which limit the response of the other components ranging from water flow rates to quality.

Existing control concepts as segregation, and selective placement of readily identifiable toxic strata, strata composition analyses, use of impermeable membranes as a basis to isolate sulfides from water and oxygen sources (as illustrated in your "Guideline" Figure 5) are helpful measures. Further isolation approaches to control ground water recharge and to direct ground water movement (such as more extensive underground drainages (rock courses, pipe, etc.) from or around potentially soluble strata components must be constantly sought.

Perhaps the most uncertain practical area where further positive actions can be taken involves control of the "environmental system." One such specific measure is to maintain the strata-water system in a neutral to alkaline condition. The basis of this control is that the generalized chemical and microbiological responses cited to form solubilized components are constrained to significant and increasing extents in an environmental pH level above 6.0. This includes the microbiological activity as well as chemical. If such an environment can be achieved and maintained the solubilization of sulfides will be minimized - thus avoiding the need for treatment and maximizing the responses of isolation control measures.

In order to achieve and maintain a neutral or alkaline condition after mining, there must be further consideration of the economics involved, the establishment of a source of alkaline material, and development of processes or systems to use the alkaline materials effectively.

The sources of alkalinity in a surface coal mine include:

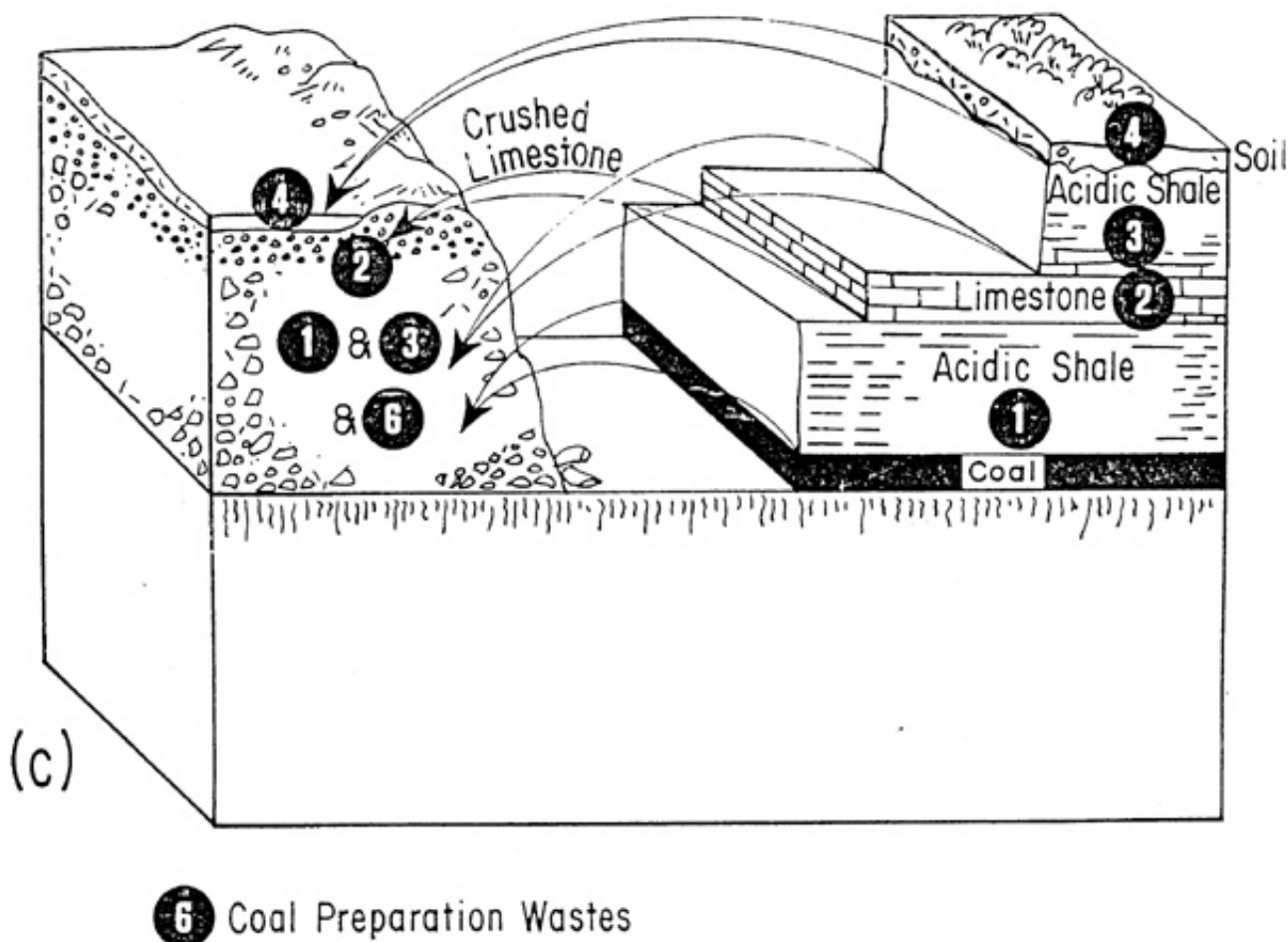
1. Calcareous and/or limestone strata within the overburden. This can be directed, stored, mixed, crushed to achieve maximum distribution during backfilling (see Parizek sketch).
2. Limestone from off site sources. This can include high quality commercial products or calcareous materials produced locally - for and/or by the coal mining organization.
3. Waste or by-product lime products as quarry fill, "bag house" lime, etc.

There appears to be four basic keys to the effective utilization of such material:

1. The amount of alkaline material necessary. It is proposed this value is determined more by the alkalinity present in the strata (neutralization potential) and by existing acidity (net available acidity and pH paste) than by pyrite concentration- distribution levels. Obviously the long range aspect of alkaline material solubilization involves rates of water flow.
2. Proper placement and adequate mixing of the calcareous materials throughout the strata to be handled.
3. Controlling the effectiveness of the material utilized to maintain alkaline conditions. Considerations include the characteristics of the material as composition and particle size as well as short-long term responses.
4. Insure that any waters contacting acid-producing materials are neutral to alkaline. Therefore, the alkaline strata should be available near the surface of major recharge areas and upstream from locations where acid-producing materials are selectively stored.

Basis of alkali utilization and locations recommendations:

1. If an available alkalinity environment is maintained, including any water contacting overburden strata, the chemical reaction rates involved in equations 1.) and 4.) will be low to negligible.



(Parizek, 1979)

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2. Under alkaline conditions, the ecology of chemolithotrophic bacteria will be constrained and their acid-forming responses stopped or limited. Other "field disinfection" measures suggested may have unacceptable side effects, be too expensive, be fleeting in response, or be totally impractical. A current study by Furry and Klingensmith (4) at Barnes and Tucker Coal Company is evaluating the use of a fatty acid sulfate as a disinfectant to control acid formation in coal preparation refuse disposal. The results are encouraging.
3. Should some small level of acidity form, the excess available alkalinity should be able to neutralize it, however, this response is secondary - the main objective is to limit the solubilization reactions.

In summary, a concept coal mine drainage control is advocated to maintain environmental conditions which minimize the capability of iron sulfide oxidation reactions from proceeding. Inherent in the approach is the concept that greater costs may be incurred in the short term control to prevent coal mine drainage formation in contrast to the costs of long term treatment, reexcavation to correct reoccurring outfalls, and problems associated with release of bonding or other legal or regulatory considerations.

This approach, combined with reactant isolation as required by regulation, and water treatment as a last resort, provides a positive control on water quality degradation during mining.

References Cited

1. Walsh, F. and R. Mitchell. A pH-dependent succession of iron bacteria. Environ. Sci. Tech. 6: 809-812, 1972.
2. Unz, R. F., H. Olem, and P. L. Wichlacz. Microbiological Ferrous Iron Oxidation in Acid Mine Drainage. Process Biochemistry 14, 6, 1979.
3. Ramani, R., L. Saperstein, H. Lovell, and R. Parizek. User's Manual for Premining Planning of Eastern Surface Coal Mining. Vol. I, Executive Summary, EPA 600/7-78-180. Vol. #2 through 5 - in Press. The Pennsylvania State University.