

COAL REFUSE WEATHERING UNDER COLD DESERT CONDITIONS

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ABSTRACT

The presence and effects of acid generating materials associated with coal mine development are not well documented in the arid regions of Utah. A series of test plots were implemented on coal refuse at the J. B. King Mine in south central Utah to determine the effects of soil depth on changes in coal refuse, surface, and subsoil pH and electrical conductivity. This preliminary evaluation of the effects of soil depth over coal refuse and acid generation within the refuse material indicates that geologic strata high in pyritic sulfur will oxidize to form acidic conditions in arid environments. The rate of acidification is believed to be water related. This theory is currently being investigated.

INTRODUCTION

Many coal and hardrock mine sites throughout the western region of the United States are experiencing acid refuse problems parallel to those in the eastern states (Harvey and Dollhopf, 1985; Fisher and Munshower, 1984). Acid production from overburden and abandoned local carbonaceous refuse has been identified in Wyoming, New Mexico, Montana, Utah, Colorado, and Texas (Boon, 1986; Boon and Smith, 1985; Fisher and Munshower, 1984; and, Arora and others, 1980).

In Utah, coal and associated strata are considered to have a low pyrite content and therefore, a low probability of producing acidic conditions. However, while it is generally found that coal may be low in pyrites, the strata associated with coal beds do contain high levels of pyrite. Coal refuse (coal and associated strata) from the Emery Coal field in Utah had a pyrite content of 3.16 percent, 16 times higher than the regional average (Western States Minerals Corporation, 1985). There is a concern that coal refuse and other materials high in pyrite may be acid- and toxic-forming and could potentially degrade the hydrologic balance and environmental ecosystem if not properly managed.

In an attempt to evaluate the depth of soil cover necessary to reclaim coal refuse, a series of test plots have been established at the J. B. King mine site.

REGULATIONS AND BACKGROUND INFORMATION

The Surface Mine Control and Reclamation Act of 1977 (SMCRA) requires the identification and control of potential acid-or toxic-forming materials (PATFM) in permitting and reclamation of surface and underground coal mines. The finding of reclaimability, determination of adequacy, materials handling, cumulative hydrologic impact assessment, and bonding are directly related to the presence of PATFM. The SMCRA geologic description requires "chemical analysis...of those horizons which contain potential acid- or toxic-forming, or alkalinity producing materials." Specific sample and analytical methodologies accepted by the State of Utah have been outlined by Leatherwood and Duce (1987). PATFM are required by SMCRA to be disposed of in such a manner to render negligible environmental degradation to the hydrologic balance or vegetation communities.

Acid forming materials are associated with coal seams and adjoining strata that contain iron sulfides and organic sulfur. The oxidation of sulfide minerals causes the formation of acid soil and water, and is a source of dissolved sulfate and heavy metals in the aquatic environment.

In natural environments, the relative importance of physical, chemical, and microbiological factors may vary widely. Pyrite is initially oxidized by oxygen. Consequently, the pH decreases as sulfide oxidizes to sulfate. When the pH reaches 4.5, it is believed that ferric ions become more soluble and begin to act as an oxidizing agent, and below a pH of 3.0, they become the only primary pyrite oxidant (Brown, 1985).

Variables that control acid production from pyrite materials and organic sulfur compounds include: (1) surface area of the pyritic material; (2) ferric iron content; (3) partial pressure of oxygen; (4) forms of

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pyrite sulfur; (5) catalytic agents; (6) pH; (7) thiobacillis or ferrobacillus microorganisms; and, most importantly, (8) water (Brown, 1985; Brunynesteyn and Hackl, 1982; and Caruccio and Giedel, 1978). Acid-forming materials may remain stable for many years because of limited pyrite surface area exposure or other oxidation rate controlling factors such as water. Once oxidation begins, however, it becomes self generating, and all acid-producing mechanisms synergistically interact (Caruccio and Geidel, 1978).

Toxic materials most commonly associated with coal development are saline and sodic strata. Many of these strata were formed in saline marine environments. Saline materials become a problem when salt concentrates in the rooting medium increasing the soil osmotic potential and reducing available water to vegetation. In some cases, high concentrations of ions associated with salts such as sodium and boron may be toxic to vegetation. In sodic soils, sodium dominates the exchange phase of the clay mineral. This causes the clays to disperse and greatly reduce both the air and water that can enter into the soil (Donahue and others, 1977).

SMCRA dictates that coal waste banks are to be buried to a minimum depth of 4 feet with non-toxic material, unless it can be shown that the revegetation requirements will be met with less material. However, if too little cover is used over PATFM materials, the cover material may become contaminated due to the upward migration of salts or acid water from the underlying PATFM. The rate of this upward migration is dependent upon soil physical characteristics, such as: (1) the texture of the overlying soil; (2) the concentration gradients between the overlying soil and toxic material; (3) precipitation and evaporation regimes of the area; and, (4) the soil water flow (Hanks and Ashcroft, 1980). The precipitation and evapotranspiration regime is especially important since dissolved salts and/or acids formed in percolating soil water may be pulled toward the surface by differential water tensions caused by evapotranspiration.

LOCATION AND PHYSICAL SETTING

The J. B. King study area lies on the east central perimeter of the Emery coal field, located in southern Castle Valley between the Fish Lake Mountains on the west and the San Rafael Swell on the east. Vegetation in this area is typical of the salt desert shrubland. Land use consists of cattle grazing, recreation, and wildlife habitat.

The Early Cretaceous Ferron Sandstone Member of the Mancos Shale is the dominant rock cropping out in the study area. All coal beds are included in the Ferron Sandstone. Strata dips 1 to 2 degrees to the west and northwest. The structure of the area is controlled by the San Rafael Swell, a large anticline located east of the mining area.

Drainage is ephemeral and flows only in direct response to snowmelt or precipitation. The area is arid with precipitation ranging from 15 to 24 centimeters (cm) annually. Summer temperatures range from a low of -9°C to a high of 33°C while winter temperatures vary from -21°C to a high of 24°C. It is expected that potential evapotranspiration is higher than incoming precipitation; however, this has not been investigated to date.

The study-area soils consist primarily of borrow material removed from the Castle Valley soil series, extremely rocky, very fine sandy loam. These soils are taxonomically classified as loamy, mixed, mesic, lithic, Xerollic Haplargid. Natural undisturbed soil permeability is generally moderate. The soils are generally colluvium and residual derived from sandstone and shale (Western States Minerals Corporation, 1985).

TEST METHODS

The mining operation produced approximately 4.4 hectares of coal refuse from a coal washing operation located on the J.B. King mine site. The test area, approximately 0.4 hectares in size, was established on the uppermost portion of the waste pile during reclamation of the mine in 1985. The test area was divided into plots with varying soil cover depths of 0, 15, 30, and 60 cm (fig. 1). The plots were fertilized with 3 fertilizer rates of 100 percent, 50 percent and 0 percent of a full rate. The full rate was 150 pounds per acre of urea and 50 pounds per acre of triple super phosphate. The remainder of the refuse pile was buried under 120 cm of soil and fertilized at the full application rate.

The coal refuse material had not been sampled before reclamation. The initial refuse and soil samples were collected during the summer of 1987. Electrical conductivity extract (ECe) and pH were evaluated to establish the physiochemical effects of the refuse material on the soil cover. Water soluble phosphorus and water soluble nitrogen were also evaluated, in addition to pH and ECe. Samples were taken from the upper 15 cm of soil, soil-refuse interface, and underlying refuse in each plot. Three samples of each material were analyzed from each plot to obtain average

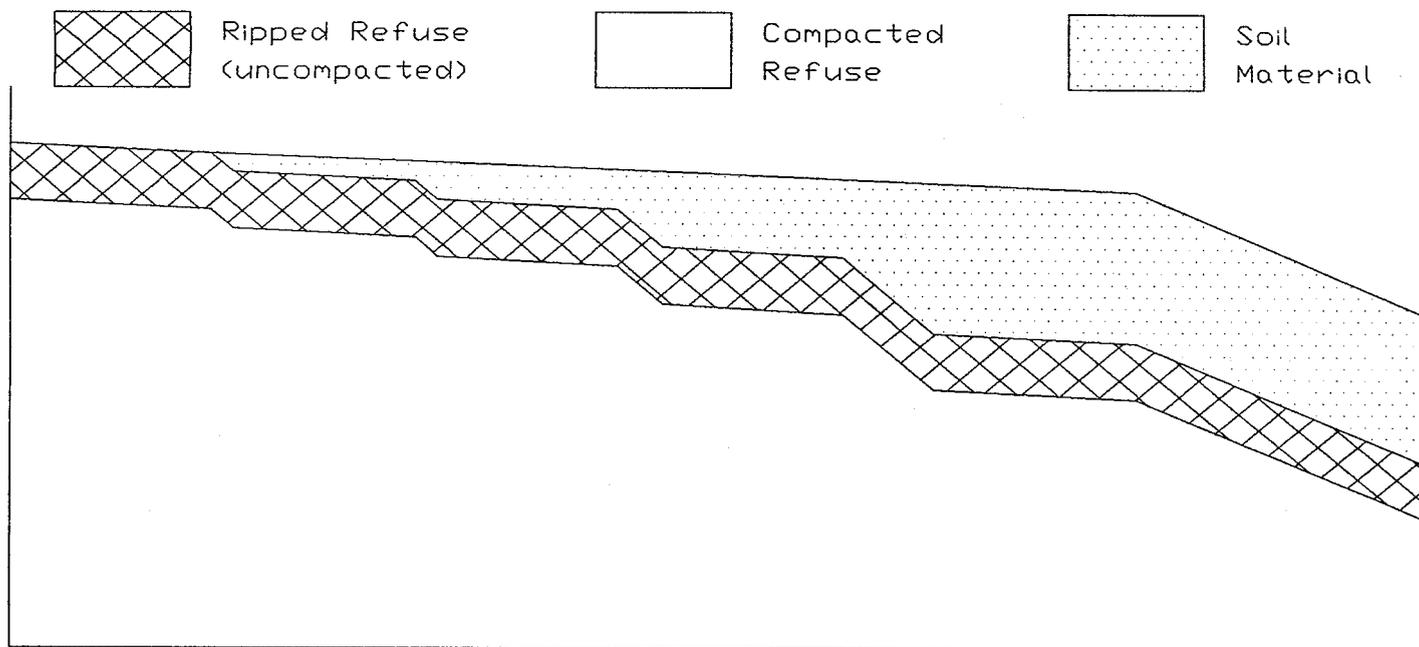


Figure 1.-Cross section of the refuse pile testplot

parameter values. ECe, pH, water-soluble phosphorus, and water-soluble nitrogen measurements were conducted on field samples using a Hach Field Soil Analyzer.

To determine if acidification or salinization is occurring in the coal refuse or soil cover, pH and ECe were monitored in 1987 on the 0 percent fertilizer plots. Monitoring did not take place on the fertilizer plots due to the potential of the fertilizer having an effect on pH and ECe values. The pH and ECe were monitored in all plots in 1988, and they will continue to be monitored in the future to establish the effects of fertilization on pH and ECe equilibrium with the coal refuse interface and soil cover.

RESULTS AND DISCUSSION

Comparison of pH by treatment depth for both 1987 and 1988 indicates a decreasing trend from the soil to interface to refuse profiles. The average pH values for the 1987 pH soil, interface, and refuse samples were 7.2, 6.7 and 6.6; and in 1988 the same averages were 7.4, 6.7, and 5.9, respectively. The pH values for soil remained relatively constant from 1987 to 1988 for all treatments. The interface exhibited a slight increase in pH at the 15 and 30 cm depths, and a large decrease in pH from 6.7 to 5.9 at the 60 cm depth (fig. 2). Refuse with no cover

had increased pH values from 1987 to 1988. The increase in pH for the refuse with no cover may possibly be from the depletion of pyrite generated acids and neutralization by contaminants from surrounding soils via runoff and/or wind erosion.

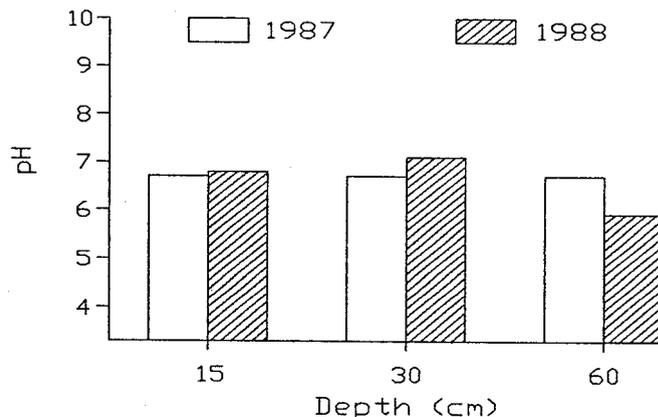


Figure 2.-Comparison of interface pH and treatment depth in coal refuse, 1987-1988.

The pH of all refuse beneath the 15, 30 and 60 cm treatment decreased in pH from 1987 to 1988 (fig. 3). The refuse in the 15 cm treatment decreased from 6.9 in 1987 to 5.6 in 1988. The refuse in the 30 cm treatment decreased from 7.0 in 1987 to 5.7

in 1988. The pH value from the 60 cm treatment changed the most with an average pH change from 7.1 to 5.1 for 1987 and 1988, respectively. The overall 1988 refuse pH can be seen in figure 4.

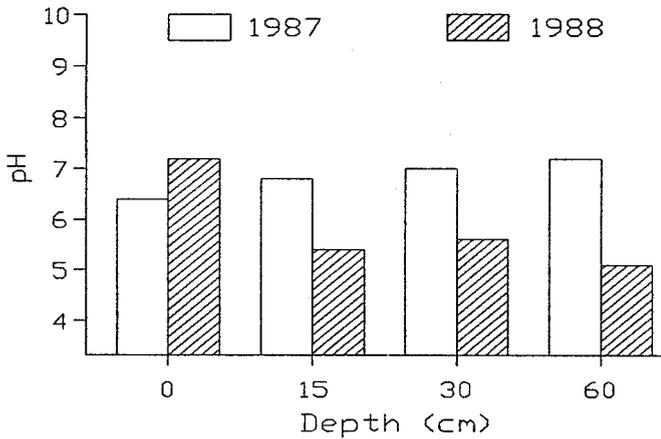


Figure 3.-Comparison of coal refuse pH and treatment depth, 1987-1988.

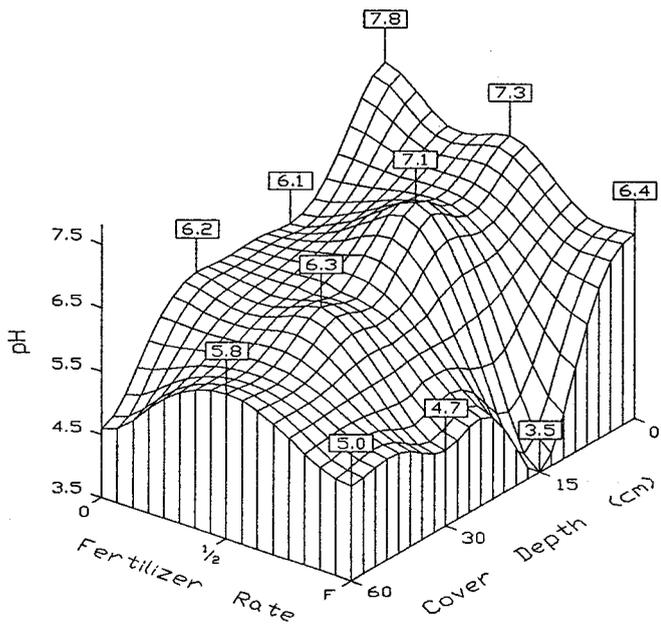


Figure 4.-pH of coal refuse, 1988.

The soil, interface, and refuse had Ece values greater than 4 millimhos per centimeter (figs. 5, 6, and 7) and are considered saline. The Ece of the soil was relatively less than that of the interface zone and the refuse. Refuse Ece values increased (fig. 6) in all treatments, and decreased in the non-cover treatment for 1987 and 1988.

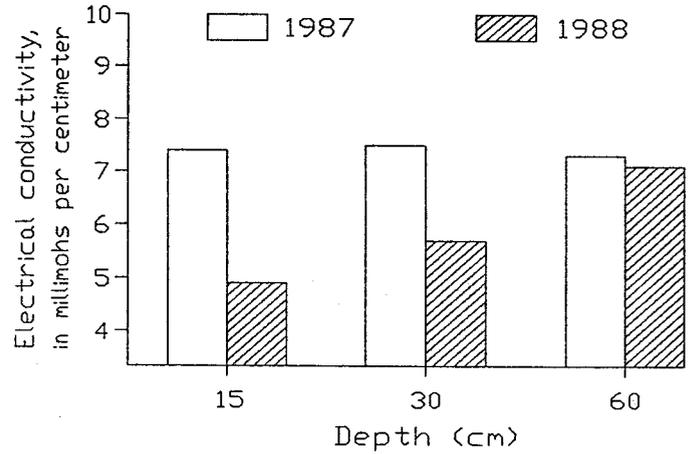


Figure 5.-Comparison of soil electrical conductivity and treatment depth in coal refuse, 1987-1988.

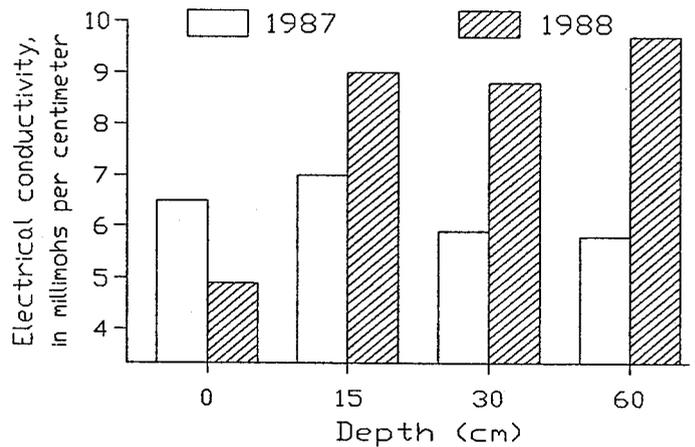


Figure 6.-Comparison of refuse electrical conductivity and treatment depth in refuse, 1987-1988.

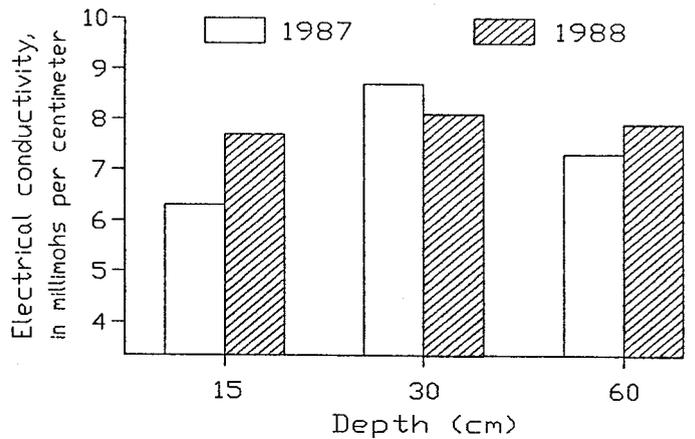


Figure 7.-Comparison of interface electrical conductivity and treatment depth in coal refuse, 1987-1988.

The authors hypothesize that the change in pH and the Ece values are directly related to the water flow characteristics

and amount of water available for the oxidation processes. Recharge at the J. B. King study area consists primarily of snowmelt and SCS type II storm events. Precipitation may fall at a rate greater than the infiltration rate of the soil, allowing precipitation to run off the test plots. The refuse material probably has a higher infiltration rate than the soil, allowing more water to infiltrate into the refuse.

During reclamation of the mine site, the refuse material was broken up at the surface to increase the contact with the cover material. This operation may have produced a lense of less dense material. During large precipitation events, the infiltrating water would move through the uncovered refuse, into and within this lense. During the more prevalent dry spells, the soil becomes dried out, impeding the upward migration of water (Donahue and others, 1977). The test plot slope, decreasing from the no cover to the 60 cm depth, allows water to be transported from the no cover and possibly 15 cm treatment by either saturated or most likely unsaturated flow to the 60 cm treatment, where the water is used in evapotranspiration by existing vegetation. This hypothesis is supported by the decreasing refuse pH values from 1987 to 1988 for the 15, 30, and 60 cm treatments. If this hypothesis were to occur, dissolved-solids movement would be associated with the water movement, decreasing as water infiltrated and increasing where water was lost to evapotranspiration.

The hypothesized relationship of pH and water movement and availability supports Snyder and Caruccio's (1988) conclusion that water and its pathways play a critical role in the acidification process through mass transfer and production of acidity and alkalinity. The hydrology (event recharge, pore distribution, porosity, acid base potential, residence time and outflow) of the backfilled refuse and soil cover will be the keystone for effective management of all potential acid- or toxic-forming materials. Infiltration rates, permeability, and vadose zone monitoring have not been established at the test site to date. Monitoring of these hydrologic parameters is recommended for future analyses.

SUMMARY AND CONCLUSIONS

Two years of sampling indicate that geologic strata high in pyritic sulfur associated with the coal fields in the arid regions of Utah will oxidize to form acidic conditions. A decrease in pH values were associated with an increase in

electrical conductivity in all treatments except the treatment with no cover material where precipitation leached the dissolved solids out of the sample zone.

The refuse pH decreased over time and is expected to do so in the future until physiochemical equilibrium is established with the system. The 1988 refuse pH values generally decreased as the depth of cover increased from no cover to 60 cm of cover. This pH relationship is assumed to be hydrologically related. Poor infiltration rate of the soil and a high refuse infiltration rate cause the incoming water to diffuse through the refuse plot allowing the acidification and transportation of the dissolved solids to occur. At the 60 cm treatment, the deficit water caused by a postulated higher rate of evapotranspiration than the other treatments pulls the water and associated dissolved salts out of the refuse, into the soil. The rate of pyrite oxidation occurring at the 15 and 30 cm treatments is slower than the no cover or 60 cm treatments due to water availability.

An understanding of refuse backfill hydrology will be instrumental in developing effective and efficient disposal management of potential acid- or toxic-forming materials. Regulatory authorities and mining personnel have commonly approached this problem under the assumption of a uniform wetting front, when in fact, the majority of the water flow, and associated physiochemical reactions, are possibly occurring along more permeable zones. Further research into soil and refuse hydrologic dynamics and physiochemical interactions are required.

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