Surface Mine Hydrology

by

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Introduction

During the past several years major advances have been made toward minimizing the pollution of lakes, rivers and streams from coal mining. The combination of conscientious mine operators and more stringent laws have led to a decrease in stream sediment loads as well as minimizing the acid pollution potential. The advances in decreasing the acid problems have been made as a result of modifying the material handling techniques and by the prediction of the potential toxic or acid zones in advance of mining. However, not all of the acid discharge problems have been solved and areas using the most up to date technology still experience acid problems. There are several methods available which are being used to predict the drainage quality from specific mine sites. Some of these methods, such as acid-base accounting, take into consideration only the properties of the individual rock types while others consider the individual rock characteristics as well as the manner in which rocks react in water. However, before the merits or deficiencies of any of these predictive methods can be adequately determined, a more important question must be resolved and that is the hydrology or the manner in which the water actually migrates through the surface mine backfill system. The best water quality predictive methods cannot be accurately defined until the extent and manner of rock-water interactions is determined.

Hydrologic Factors Affecting Drainage Quality

The hydrology of a backfill mine site is dependent on a variety of factors which include the source of the water, the rock type and permeability of the backfill material, the nature of the underclay, and the mining plan and technique.

The three main sources of water are from highwall bleed, the infiltration of precipitation and the upward movement of water through cracks in the underclay. In many areas of the Appalachian coal fields, the latter is rarely the primary source of water because 1) care is taken to preserve the integrity of the underclay and 2) if the pavement is broken, rarely are the horizons immediately below the pavement artesian systems. The primary sources of water in surface mines within the eastern bituminous fields are either highwall seepage or precipitation infiltration and the percentage contribution of each source will depend on the individual site conditions. Areas which are mined primarily as contour operations and which have relatively steep slopes and large highwall faces tend to have reduced surface infiltration and increased highwall seepage. Alternatively, in contour mines with low slopes or mountain top removal operations, the groundwater will be primarily recharged by precipitation infiltration. Naturally, between these two extreme topographic examples the percentage contribution of both sources will vary greatly.

The source of the water determines how the water will enter the mine but the primary concern is the manner in which it migrates through the backfill and where the resulting groundwater table will be reestablished. These conditions will be affected by the mine plan and material handling techniques. In operations where a layer of large blocks or boulders are placed immediately above the pavement to provide a zone of high permeability, water seeping out of the highwall will flow down the highwall face to the underclay and will fill the voids. The extent to which the water level will rise in the backfill will depend on the dip of pavement and whether an undisturbed toe has been left at the coal outcrop. The porosity will determine the actual volume of water retained in this portion of the backfill.

Infiltrating precipitation will also eventually accumulate in this zone of high permeability. However, water from infiltration will normally have a greater rock-water interaction and the flow paths of the infiltrating water will be greatly affected by the mine plan and backfill composition.

Mine plans vary in the degree of compaction of the backfill primarily due to the type of mining equipment used. Operations which primarily utilize a shovel or dragline for overburden removal, usually have relatively uncompacted spoil, coupled with high infiltration rates. A site in east-central Ohio mined by a large shovel operation had a backfill with infiltration rates which varied from 0.3 to 1.5 inches per hour.

Other mining techniques utilizing large trucks, front-end loaders and earth scrapers will usually have lower infiltration rates due to increased compaction caused by the equipment traversing the area. In southwestern Pennsylvania, an operation using this type of equipment to move overburden, had very low infiltration rates; less than 1/16 of an inch per hour. These two mines may represent the greatest and least infiltration rates because, coupled with the various mining methods, were varying rock types.

The composition of the backfill is an important facto in determining the hydrology because of the effect of rock type on the permeability of the system. In mines where sandstones comprise the majority of the overburden, the backfill is generally more permeable than in those areas where most of the overburden is shale. Shales are more friable than sandstones and decompose with time in the backfill. The resulting small particle sizes decrease the permeability. Sandstones, however, generally decompose at a slower rate than shales and even after weathering still have a larger grain size and normally a greater permeability.

Methodology for Hydrologic Study

The study of backfill hydrology is very complex due to the unconsolidated nature of the material, the extreme range in particle sizes, the mixing of rock types and the source of the water. In addition to the complexities surrounding the hydrology are another set of difficulties including the methodology which can be used to complete hydrologic studies of the backfill. Very little field data have been collected due to the extreme problems in drilling through unconsolidated non-uniform particle size material and in being able to drill wells of sufficient diameter to be able to lower pumps into a backfill well. A second approach which has been used is computer modeling of the hydrology. However, without field data to check a ground water flow models it is difficult to determine the accuracy of such computer models.

One portion of the AMDTAC project is to study the hydrology of a backfilled site. However, the approach which is to be used will be to follow the path of the water through the backfill until it emerges as a seep. This will be accomplished by using tracers at various stages of the backfilling process and then monitoring seeps to determine how the water has traveled through the material.

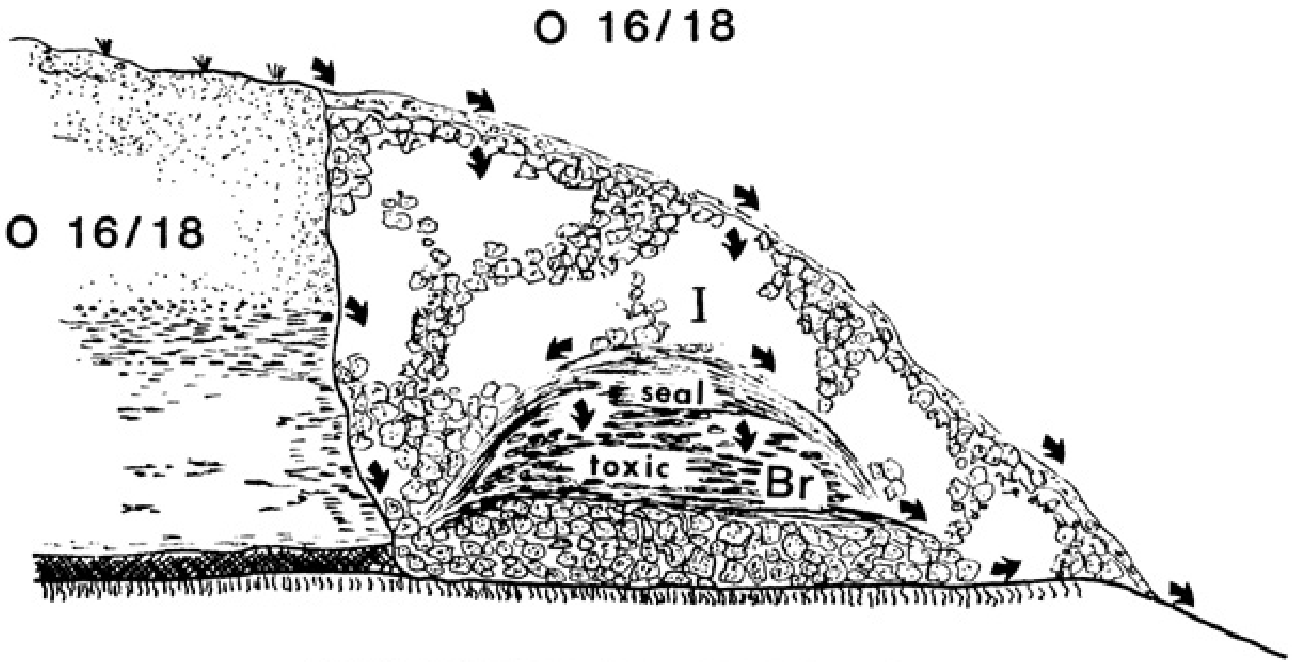
First, two tracers (iodide and bromide salts) will be placed in the backfill material. Because one of the objectives of this study will be to determine if a clay layer placed over toxic material is an effective means of eliminating infiltration into the toxic material, the bromide tracer will be placed in the toxic zone and the iodide will be placed above the clay seal in the inert or alkaline material.

Secondly, because it is important to know the source of the backfill ground water, we will monitor natural tracers in the precipitation and in the water emanating from the highwall face. During each rainfall or precipitation event, the water will have a unique ratio of oxygen with an atomic weight of sixteen (16O) to oxygen with an atomic weight of eighteen (18O). By monitoring the rainfall and measuring this ratio, and by monitoring the seeps from the backfill for the ratio, the length of time required for water to migrate through the backfill can be determined. The water seeping out of the highwall will also be measured for this ratio. However, the ratio in the ground water bleeding from the highwall is much different than that found in the rainfall, and therefore it acts as a tracer distinct from the rainfall. The placement and possible flow paths are shown in Figure 1.

Monitoring seeps from the backfill for all of the tracers will enable the hydrology of the site to be determined. Some of the possible results of the monitoring phase and their interpretation are presented below.

Example 1) During the monitoring phase, neither iodide nor bromide are detected, and the oxygen ratio is similar to that of the rainfall. Given these results, the source of the water in the seep will be from surface runoff.

Example 2) Iodide is detected and there is a lag time in the oxygen ratio measured in the rainfall until that same ratio is measured in the seep. In this case, precipitation is infiltrating into the backfill,



DISTRIBUTION OF TRACERS

WITHIN THE MINE BACKFILL

contacting the non-acid material but is not infiltrating through the clay layer into the toxic material. If the water does not show evidence of acidity, then it is also probable that the pavement is non-acid. However, if there is a high sulfate content in the seep but the seep is alkaline or if the seep is acid, also with high sulfate, it is probable that the pavement is acid. In the case of high sulfate, non-acid conditions, the water was neutralized in the backfill whereas in the latter case, the acidity was not neutralized.

Example 3) When iodide, bromide, and a lag time in oxygen ratios between rainfall and the seep occurs, then the primary water source is rainfall infiltration and the clay seal is allowing infiltration of water into the toxic material. In this case, either acid conditions, or high sulfate would be expected.

Example 4) Finally, if neither iodide nor bromide were detected, and the oxygen ratio were similar to that in the highwall bleed, then the primary source of water in the backfill would be from highwall groundwater discharge.

Naturally there are many other combinations of tracers which could be measured and this only represents a few select examples. At the conclusion of this study, the results should provide the necessary information on the movement of water through the backfill to predict the water quality from a surface mine backfill.