

Effects of Surface Mining on Ground Water Quality

by Henry Rauch

Nature of Ground-water pollution by surface mining

Ground water is becoming a major concern with respect to surface mining of coal in both West Virginia and the nation's other coal fields. Two major concerns are ground-water quality and ground-water quantity, but only the quality aspects are addressed in this paper. Despite the new emphasis placed on ground water by regulatory authorities, the effects of coal mining on ground water are still poorly understood. It is my intention to elaborate on general aspects of ground water, and to share with you some results of research done in Monongalia and Preston counties in conjunction with colleagues and graduate students in geology at West Virginia University and the West Virginia Geological and Economic Survey.

Ground water occurs in a variety of ways, depending upon depth below land surface, rock type, and topography. Three important aspects of ground water related to the "hydrologic balance" are the storage capacity of rocks for ground water, the rate of movement of ground water and chemical quality. Rock units that have relatively high storage capacities and that allow relatively rapid movement of ground water are termed aquifers. A simple practical definition of an aquifer is a rock unit of other underground layer or zone that yields a sufficient quantity of water to a well or spring being used as a water supply source. This is generally at least one gallon per minute for domestic supplies for single families. Rock types that are usually considered aquifers, where they occur in thick enough units, are sandstone, limestone, and coal. Thick coal seams sometimes are the best yielding aquifers in certain localities, because of the coal cleats or fractures. Shales, mudstones, and clays are usually not aquifer units. Ground water can be classified by depth. Shallow ground water usually supplies springs and dug wells, whereas deeper ground water supplies mostly drilled wells. Shallow ground water is intersected beneath the water table, and deeper ground water (in drilled wells) commonly is artesian water under significant pressure. Deeper ground water is usually at least 30 feet deep, and has typically been in the ground longer and is flowing slower than shallow ground water. Ground water typically moves at rates ranging from a few feet per year to a few feet per day, which is much slower than stream flow.

Ground-water pollution can occur both directly and indirectly as a result of surface mining. Direct degradation can occur to ground water situated downhill or down gradient from a surface mine, by flow of contaminated drainage from the mine. This mine drainage can come from pits, ponds, or from rainfall infiltration and ground-water flow during mining and after reclamation. Ground-water pollution would result from the same toxic overburden and coal materials that cause surface water contamination.

Indirect degradation of ground water could result from blasting, which causes a temporary shaking of the rock and results in new rock fractures near working areas of the mine. Blasting can also cause old preexisting rock fractures to become more open or permeable, by loosening mineral debris or cement in these fractures; this could affect nearly vertical fractures located up to several hundred feet away from the surface mine, causing vertical leakage of ponded mine drainage from nearby abandoned deep mines to underlying aquifers. These deep mines could be situated in the same coal seam being surface mined or in a lower coal seam.

Acid mine drainage originates by geochemical reactions described by Harold Lovell in a companion paper of this symposium proceedings. Pyrite from exposed coal or associated rocks reacts with oxygen gas and water to yield dissolved iron and sulfuric acid. The iron then further oxidizes to yield more acid and precipitated iron mineral solids. Further, dissolved oxidized iron can react with more pyrite generating more sulfuric acid. Mine drainage may then be artificially or naturally neutralized. Most mine drainage becomes at least partially neutralized by natural exposure to alkaline rocks and minerals even without any treatment by the coal mine operator. The strong acid may become partially neutralized primarily by solution of carbonate minerals (such as calcite and dolomite). This happens in the reclaimed mine site as well as in rock strata underlying the mined coal seam.

Ground water contaminated by mine drainage often is different in chemistry from polluted surface water before chemical treatment. Polluted ground water typically has undergone a higher degree of natural neutralization than has polluted surface water, because of its greater contact with carbonate minerals and slower rates of movement. Typically, ground water contaminated by mine drainage in northern West Virginia has higher pH and total hardness, and lower acidity, total iron, manganese, aluminum, and suspended solids than untreated surface mine drainage. Ground water polluted by mine drainage is better in overall chemical quality. However, even after complete neutralization of acidity in mine drainage waters, residual pollution still exists in the form of dissolved sulfate. Sulfate is not normally precipitated, and mostly remains in solution following natural or artificial acid treatment. This sulfate is a good tracer or indicator of present and past mine drainage pollution.

Several factors affect the severity of mine drainage contamination of ground water. The acid-producing potentials of coal and overburden rock are a prime factor. In northern West Virginia my colleagues, students, and I have investigated the Pittsburgh, Sewickley, Upper Freeport, Bakerstown, and Waynesburg coals as mine drainage sources. With respect to ground water, we have found that the Pittsburgh coal is the worst mine drainage source (with poorest quality water), followed in order by the Upper Freeport, Waynesburg, Bakerstown, and Sewickley coals. Surface mines in the Sewickley coal usually do not significantly affect ground-water quality. Further, the quality of acid mine drainage appears to vary somewhat geographically within the same coal seam, for reasons not yet fully understood.

The type and degree of surface-mine reclamation also probably affect the severity of subsequent ground-water pollution, since it affects the degree of stream-water pollution. Although less pollution should occur with better reclamation, we have not yet evaluated this factor in our research.

The hydrogeologic setting can also influence the mine-drainage contamination of ground water. In northern West Virginia, shallow ground water (such as that in springs and dug wells) is more susceptible to pollution than deeper ground water. Springs near surface mines typically have lower pH, higher acidity and higher sulfate content than drilled wells near surface mines. In fact, almost all tested drilled wells exhibiting mine drainage pollution in northern West Virginia had pH values over 6.0, reflecting largely completed neutralization by natural solution of carbonate minerals. Furthermore, properly constructed drilled wells with casings over 30 feet deep usually have little or no problem with mine drainage pollution, even near surface mines; such wells tap deeper aquifers that are less likely to be contaminated by mine drainage.

The distance of a ground-water supply source from a surface mine is also critical in determining the severity of any pollution. In northern West Virginia, severe contamination appears to be mostly restricted to ground water located within about 200 feet horizontally of a mine drainage source. The eight most severely contaminated wells surveyed in Monongalia and Preston counties are near mines in the Pittsburgh, Waynesburg, Upper Freeport, or Bakerstown coal. These wells had sulfate contents of over 250 mg/l, iron contents of up to 11.0 mg/l, and manganese contents of up to 2.75 mg/l. A rule of thumb is that most wells and springs with more than 100 mg/l of sulfate are probably being

contaminated by mine drainage sources located within a few hundred feet uphill of these water supplies. However, wells and springs with less than 100 mg/1 sulfate are either not affected or are not significantly contaminated by mine drainage. Wells appear to be especially susceptible to contamination with mine drainage if they are located near an apparent rock fracture zone that also extends to a nearby mine. Such fracture zones would allow ground water to move more rapidly away from a mine, to create more severe mine-drainage pollution in their paths.

Some legal aspects of ground-water pollution by surface mining

Surface mine operators and companies are concerned about ground water with respect to their legal obligations for protection of groundwater quality and quantity. I interpret three types of legal obligations regarding ground-water quality. First, there are requirements for certain data and plans in the surface mining permit application. Second, there will be monitoring requirements during surface mining, and third, there are water quality standards which must not be violated. Only water quality standards will be reviewed in detail.

Concerning information needed for the mining permit, it is my judgment of Federal and State regulations that the following quality information is required or will soon probably be required of surface miners in West Virginia: (1) pre-mining surveys of ground water, including sampling of all water supply wells and springs within 1000 feet of the mine site, and chemical analyses of these waters for at least pH, total suspended solids, iron, and manganese; (2) characterization of water quality for each aquifer between land surface and the lowest mined coal (including the aquifer just beneath this coal), for pH, suspended solids, iron, and manganese. If wells or springs are not available for sampling and analysis to represent some aquifers, then new wells must be drilled; (3) description of how the potential for ground-water pollution will be minimized, and what pollution is likely to occur; (4) a plan for treatment of pond, pit, or stream waters before they infiltrate, to correct future ground-water pollution should it occur; (5) identification of alternate water-supply sources for ground-water users whose present supplies may become polluted; and (6) a plan for ground-water quality monitoring, involving wells, to be implemented where future pollution is judged probable for areas within 1000 feet of the mine site. It is likely that easily-pollutable ground water at springs and wells will have to be monitored at least once every three months, for at least pH, total suspended solids, iron, and manganese. Probably at least one new well will have to be drilled downhill from the mine site, if no other nearby wells are present.

Water quality standards that will likely soon be required in West Virginia fall under two major categories. First, we have chemical quality standards of the West Virginia Department of Natural Resources, U.S. Office of Surface Mining, and U.S. Environmental Protection Agency - NPDES program, which pertain to mine discharges. Such discharges also include ground water that is likely to be affected by infiltrating pit, pond, or stream waters at the mine. Monitored well and spring waters should not violate the following long-term water quality standards: pH - not less than 6.0 nor greater than 9.0; total suspended solids - not greater than 35 milligrams per liter (the same as 35 parts per million); iron - not greater than 3.5 milligrams per liter as total iron; manganese - not greater than 2.0 milligrams per liter as total manganese. Violations of these standards may result in criminal or civil prosecution, resulting in fines and additional required water treatment. However, most ground water polluted by mine drainage, especially deeper ground water, should be of acceptable quality according to the above standards. Research in northern West Virginia indicates the pH is usually above 6.0, and iron and manganese usually are less than 3.5 and 2.0 milligrams per liter respectively, at least for well waters. Total suspended solids would never be above 35 milligrams per liter in ground water, except perhaps in some underground mines. Shallow ground water that discharges at springs near surface mines will be especially susceptible to contamination by mining.

The second set of chemical quality standards apply only indirectly, but are much more significant and

comprehensive for ground water. If a spring or well owner can reasonably show that his water supply has significantly worsened in quality and that a nearby surface mine is probably to blame, then the mine owner is obligated to replace the contaminated supply with another potable one. What water quality parameters are considered are not indicated in detail by any regulations pertaining directly to mining. Regulations of the West Virginia Department of Natural Resources (chapter 20, article 5A, section 3) may be interpreted to include ground-water supplies affected by pollution sources. Pollution sources, including mines, should not cause or significantly worsen objectionable taste, odor, or color of water supplies, and should not require an unreasonable degree of treatment for potable water.

Furthermore, if a water-supply owner can show from quantitative measurements that significant adverse changes have occurred in chemical concentrations for his water, he will probably have a stronger legal case. Adverse changes probably indicate pollution and pollution may be aesthetic or physiologic in character. Aesthetic pollution causes bad tastes, smells or appearance, whereas physiologic pollution is more serious and commonly causes a disease or illness following water consumption. Fortunately, physiologic pollution of ground water by coal mining is not likely to occur, but research on toxic trace elements in polluted ground water has not yet been done to prove this assumption. However, aesthetic ground-water pollution is likely to occur because of mine drainage, at least with respect to iron, manganese, and sulfate. According to standards of the U.S. Environmental Protection Agency -Safe Drinking Water Act of 1974, iron and manganese become objectionable in water if their total concentrations exceed 0.3 and 0.05 milligrams per liter respectively. When this occurs, they cause brown or black mineral stains on laundry, cooking utensils, and bathroom fixtures, and the water also commonly looks and tastes bad. Most tested ground waters of northern West Virginia exceeded these standards, where mine drainage pollution was apparent. Note that these standards are much more stringent than those Office of Surface Mining Standards mentioned above for mine discharges. Some ground-water supplies are naturally high in iron and manganese and even exceed the Environmental Protection Agency standards without mine drainage pollution, but these elements become even higher in concentration if mine drainage pollution results.

Just as serious as iron and manganese is sulfate. Water with sulfate over 250 milligrams per liter is considered to be unfit to drink by guidelines issued by the U.S. Environmental Protection Agency -Safe Drinking Water Act. High sulfate contents cause diarrhea and poor-tasting water. Water supplies serving 200 or more customers should not exceed 250 milligrams per liter, by U.S. Environmental Protection Agency and West Virginia State Board of Health standards. However, if a well or spring owner can show that his water's sulfate content has significantly increased because of coal mining, he may institute a civil suit for polluted water. Such a person would have an especially strong case, if he can demonstrate that sulfate was previously less than 100 milligrams per liter, but then increased to greater than 250 milligrams per liter during nearby surface mining. All wells and springs tested to date in northern West Virginia, with sulfate contents of over 250 milligrams per liter are located near sources of mine drainage.

Preventive and corrective measures for mine drainage pollution

Several actions can be taken to lessen the chances of ground-water pollution occurring because of surface mining. Ground water should be directed away from the mine site both during and after mining, where possible. This objective should be easier to achieve for contour mines than for area mines. In contour mines, drainage pipes can be installed in ditches dug at the foot of the high walls just prior to reclamation. This will result in lower water tables after reclamation, and less ground-water contact with fill material. Ground-water drainage could then be directed in pipes towards a nearby stream channel. Another approach would be to install an impermeable barrier in the backfill material, a few feet below the surface. This would have the effect of directing infiltrating rainfall downslope away from the mine and buried toxic overburden. Where possible, surface mining should be kept at least 200 feet away from any well or spring water supply, especially those supplies located

downhill from the mine. Also, all bore holes created by coring operations and all old abandoned wells should be filled with concrete grout at the mine site during mining. Otherwise, polluted mine drainage may recharge aquifers underlying the mine. Likewise, wells drilled near the mine to monitor ground water should be grouted following mine reclamation.

Certain corrective measures can be taken after ground-water pollution is detected. One should first locate and stop discharges from specific pollution sources on the surface mine site, if possible, before reclamation is completed. This could include channeling mine surface water into treatment ponds that are lined with impermeable bottoms. Second, new water supplies should be located for persons whose wells or springs have become polluted. The most dependable water supply would be piped water from a water service district. If piped water is too far away to be economically feasible, then the choices would be a new well, a cistern or a nearby spring. Of these, a new well is definitely preferable. It should be located as far away from the mine as possible and away from other potential pollution sources such as septic tanks, acid streams and other mines; it should also be properly constructed and sealed, and have enough casing to seal off the upper shallow ground-water zone. If possible, a deeper aquifer with potable ground water should be tapped for a water supply. New well drilling and construction should be handled by an experienced water-well driller.