Wat. Sci. Tech. Vol. 28, No. 3-5, pp. 399–407, 1993.

0273–1223/93 $24·00

WATER QUALITY IMPACTS AT ABANDONED HARDROCK MINES

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ABSTRACT

Water quality pollution from abandoned mines is becoming an issue of growing awareness and concern. This concern is exacerbated by the fact that there are countless numbers of inoperative facilities with serious environmental, safety, and health problems. Abandoned tailings piles eroding heavy metals and sediment into watercourses, flooded tunnels and open pits filled with toxic water, unmarked open shafts and adits, and rotting timbers are some of the hazards facing unsuspecting humans and wildlife.

The purpose of this paper is to identify and characterize water quality sources at abandoned hardrock mine sites and best management practices (BMPs) used to control polluted runoff. There is a need to clearly define the best approach for controlling nonpoint pollution sources at abandoned mines. These are issues that could be addressed in reauthorization of the Clean Water Act.

KEYWORDS

Nonpoint source pollution; abandoned hardrock mines; section 319 program; storm water; acid mine drainage; heavy metals; erosion and sedimentation; best management practices.

INTRODUCTION

Water pollution at abandoned noncoal mines can result from access and haul roads, waste rock piles, old tailings, mills, leach pads, and the like. This potentially contaminated runoff and drainage is generally considered a point source when carried by storm water that enters into and is discharged from a discrete conveyance. These discharges, including storm waters that come in contact with onsite materials and wastes, are subject to the Clean Water Act's (CWA) permit requirements under the National Pollution Discharge Elimination System (NPDES) (EPA, 1990). In other situations (e.g., sheet flows, in-stream contamination, site area erosion) this runoff may best be characterized as a nonpoint source.

Because many abandoned mine sites are usually located in remote areas, they often are not perceived as posing a significant threat to the public health and are not considered to be high priority point or nonpoint sources. At individual sites, mine drainage and discharges may occur from both known and unknown sources, and the distinction between these categories is not clear in most cases. As a result, some States have categorized these types of discharges as nonpoint sources not subject to NPDES requirements even though such discretion is not permissible under the CWA. Some of these "nonpoint sources" may actually be point sources subject to NPDES permits, although some States to date have not regulated them as such.

There is a need to characterize nonpoint source problems found at abandoned hardrock mines and to recommend actions to define and clarify program roles. This paper is intended to describe some of the problems encountered and considerations for some solutions.

PROBLEMS

That discharges from mine sites can cause and have degraded waters of the United States is well documented. The States, in their nonpoint source assessment reports developed under section 319 of the CWA, have identifed mining activities, including abandoned mines, as being the second largest source of nonpoint pollution to the States' surface waters (8% in rivers, 7% in lakes) (EPA, 1992). The 1990 National Water Quality Inventory Report to Congress also identified resource extraction (mining operations) as being a significant cause of pollution to rivers (14%) and lakes (8.6%) (EPA, 1992a). Other publications also point out in some detail the damaging effects of pollution from mine related activity (GAO, 1988).

An adequate definition for an abandoned mine is generally not available. Often, mining operations that have ceased production are referred to as inactive and not abandoned. Due to changing economic conditions, some mining operations temporarily become inactive but with the intention to start up operations as the demand for the mineral becomes economically attractive. The differences of intent between inactive and truly abandoned mining sites needs to be defined to eliminate any confusion when determining reclamation needs.

Abandonment in the legal sense is related to ownership. For a mine to be abandoned, there must be a relinquishment of rights with the intent never to return. Several States define abandoned mines generally as those with no known operator, owner or other claimant (WIEB, 1991). Often where no legal owner can be identified, ownership of the land generally reverts back to the State. The States (and Federal land managers of public lands) are then left to deal with the pollution problems at truly abandoned mines if no responsible claimant exists.

Also included as problems are the real and potential hazards that abound at old abandoned mine sites that threaten the health and safety of animal and human life. Serious injury and death resulting from falls into unprotected deep shafts and open pits are reported in all mining States. Abandoned buildings, rotting equipment and infrastructure, old explosives, pits, ponds, dumps, open adits, tunnels and exploration holes lay dormant at uncharted locations. Many abandoned sites are flooded with foul air or contaminated water or both. In many mining districts, only a scarred landscape remains as testament to past abuse and neglect.

Environmental impacts from abandoned mines are major concerns. Acid mine drainage is common and continues to plague downstream surface and ground waters. Wind and water erosion eats away at forgotten waste dumps, tailings piles, and leach heaps which pollute receiving waters with contaminated sediments, toxic residues and heavy metals.

It is also difficult to determine, without a costly survey and inventory, the actual number, location, and condition of abandoned mines. In most cases, State and Federal land management agencies have no accurate estimate of old mines on lands under their jurisdiction. What data do exist have not been compiled, collated, and analyzed to present a clear and concise portrait of the extent of the problems posed by abandoned mine sites. Some authorities estimate that there are at least 200,000 abandoned noncoal mines scattered throughout the western States - many of which are located on Federal lands. While not all abandoned mines are problem sites, the combined area of land left disturbed by these dormant facilities is estimated at more than two million acres which contribute pollution impacts to more than 8,600 miles of surface streams. Costs to clean-up these lands and waters will easily exceed eleven billion dollars (Inspector General, 1991). From these limited data, numerous abandoned sites are known to exist which cause significant environmental, health and safety problems that will require substantial public and private expenditures for their remediation.

Abandoned mine problems are not always addressed or recognized. Several of the western States have some levels of management and involvement with inactive/abandoned mine remediation, much of which is limited due to a lack of resources. The few successfully completed mine clean-up projects were mainly accomplished with assistance from Federal agencies (EPA, BLM, USFS), and significant support from private and State sources.

Institutional Issues

Few States have any legislation or institutional arrangements that pertain directly to abandoned mines. Mining reclamation laws in the major mining States are mostly directed toward new and active mining operations. State mining programs have evolved only recently to satisfy the needs of each particular State. These State programs have specific conditions to assure that new and existing mining operations meet the State's objectives for operation and eventual closure. Abandoned facilities, however, may or may not be included in these requirements. Also, there is no consistent State definition as to what an abandoned mine is or when it becomes one.

EPA's storm water regulations provide that point source discharges from active and inactive mines are "associated with industrial activity", and therefore, subject to NPDES requirements. The storm water rule defines inactive mining sites as sites which are no longer actively mined, but have an identifiable owner/operator. The NPDES storm water regulations do not define or use the term "abandoned".

At the national level, mining related issues are being addressed by EPA under primarily sections of the CWA, sections 319 (addressing nonpoint sources) and 402 (addressing point sources); and to a large extent by the Department of the Interior's Surface Mining Control and Reclamation Act (SMCRA) which addresses coal mining. (EPA's Superfund, and the Resource Conservation and Recovery Act also address mining.) SMCRA is mentioned here to address the fact that this Act establishes an abandoned mine lands fund to reclaim and remediate abandoned coal mines, and to a very limited extent, abandoned noncoal mines. It also serves as a benchmark for State hardrock mining programs (Thompson, 1989).

Several States identify orphaned hardrock mines as abandoned if they were not actively mined prior to 1977, the adoption date of SMCRA. Some other States identify abandoned mines as those existing prior to the effective date of their State enabling legislation governing active mining operations. For example, Montana defines abandoned mines as those sites where there is no continuing reclamation responsibility by an owner or operator. These sites primarily include disturbances created prior to 1971 which is the effective date of the State's mining reclamation laws. In Idaho, the State has the power to reclaim on its own initiative, with landowner permission, any land which becomes or has become affected by mining operations either prior to or after the effective date (1971) of its reclamation program (WIEB, 1991).

Other than individual State efforts, there are no national environmental standards for abandoned hardrock mine clean-up and reclamation that are actively and aggressively promoted. The Mining Law of 1872 still serves as the mainstay legislation for hardrock mining in the U.S. but is silent on environmental issues (GAO, 1989). The law contains archaic provisions that are irrelevant to the needs of a modern mining industry, it requires no financial return such as royalties on the minerals extracted, and contains no environmental protection requirements (Aberswerth, 1991). Legislative changes have been proposed in Congress for amending the 1872 law (S.433, D. Bumpers [D-AR],1991; HR.322, N.J. Rahall [D-WV], 1993).

Until the 1987 amendments to the Clean Water Act that added sections 319, no specific or direct reference to the control of nonpoint source pollution from mining operations was made. Section 319(h)(5)(A) provides for the control of "particularly difficult or serious nonpoint source pollution problems, including but not limited to, problems resulting from mining activities." Earlier provisions under CWA sections 208 and 304(f) also authorize EPA to develop guidelines for evaluating nonpoint source pollution at mining facilities.

The overall 319 program initially called for the States to assess nonpoint source impacts and causes, and to develop management approaches and implementation plans to promote Statewide education, demonstration, and technical assistance for controlling nonpoint pollution. A key provision of section 319 is the issuance by EPA of grants to assist States in implementing their management programs and to achieve voluntary adoption of best management practices. This program has proven to be effective to demonstrate and implement successful remediation of nonpoint source impacts at abandoned mines.

Federal funding for all nonpoint activities (agriculture, silviculture, mining, and urban development) supported by the 319 program provided 191 million dollars from FY 1990 through FY 1993. The dollar amount directly used for abandoned mine remediation is not available since a mix of funding sources from CWA sections 201(g) and 319, and other Federal, State and private sources are combined. However, the total dollar amount is quite small, limited to a few western States plus a few eastern States addressing abandoned coal mines.

Under CWA section 402(p), EPA and authorized States are required to issue NPDES permits for point source discharges from mines including certain storm water discharges associated with mining. NPDES requirements also apply to non-storm water including contaminated groundwater from mine seepage. To implement these provisions, EPA has developed a storm water program that will require permits for storm water discharges from both active and inactive/abandoned mines. In general, NPDES requirements do not apply to in-stream contamination or to sources of pollution that cannot be attributed to a point source. Also, as a practicable matter, NPDES permits or enforcement actions are not taken where a person responsible for a discharge cannot be found.

The NPDES permitting program for mining and the section 319 nonpoint source control program have similar objectives; however, potential confusion may exist between these two programs. Both programs need to establish clear and complementary roles and objectives to best meet efficient pollution control at truly abandoned mines sites. To date, the States have chosen to issue permits for storm water pollution control under CWA section 402(p) for some sites, or to apply for project grants under section 319(h) to implement physical reclamation at other sites. (Some abandoned mining sites are under remediation by the Superfund program.) Usually the decisions made have depended on the State's resources and commitment to abandoned mine land clean-up. EPA's policy stipulates that section 319 demonstration project funds are not available for sites that have been issued an NPDES permit (EPA, 1991).

Environmental Issues

In the late 1980's, the Environmental Protection Agency asked the Western Governors' Association (WGA) to survey problems regarding mine wastes at active noncoal mining operations as a step toward developing an effective mine waste regulatory program. What the survey discovered was that serious environmental and health problems were found associated not only with active mining operations but even more so with inactive and abandoned mines. The survey also revealed that mining prior to 1970 was conducted with limited environmental awareness or regulation and that no reliable inventory of dormant mines and their condition existed (Mine Waste Task Force, 1990).

The remote location of many abandoned hardrock mines tends to obscure the pollution problems caused by runoff waters and fugitive dust from weathering mine wastes and residues which find their way into surface and ground water systems. The impact of nonpoint pollutants may not be realized until discovered in the watershed and aquifers many miles downstream.

Mining operations expose vast quantities of previously undisturbed land and material in the process of exploration, extraction, processing, and transportation. Before any mining controls were enforced, ceased mining operations were abandoned leaving behind the waste rock, tailings, and slag piles as well as the explosives, equipment, and structures used in the process. These wastes and discarded materials were most often dumped in stream valleys and along floodplains. Such remnants were left to the natural weathering process of oxidation and erosion to produce the major elements of nonpoint source pollution, including acid mine drainage and dissolved metals, heavy metals contamination in soils, and erosion and sedimentation (EPA, 1976).

Acid Mine Drainage. One of the most serious environmental problems arising from mining operations is acid mine drainage (also referred to as acid rock drainage) (Steffen, 1989). The potential for acid generation depends on site specific climatological and geological conditions. Acid formation results from the chemical reaction of sulfide minerals (principally pyrite) and air in the presence of water. The oxidation reactions that occur are often accelerated by biological activity which yields low pH water having the potential to mobilize any heavy metals contained in waste rock piles, tailings, and disturbed overburden materials. Dissolved metals in acid drainage may include lead, copper, iron, manganese, cadmium, and zinc. At various sites, these dissolved metals can become suspended in the low pH solution and then be introduced into and substantially degrade receiving waters and fish habitat.

Surface runon and runoff through waste rock piles and tailings, and the seepage from abandoned surface or underground mines, contain the products of the acid generating process. Moreover, acid mine drainage from abandoned mines will continue to be generated unless disturbed land and open pits are effectively reclaimed and that adits, shafts and tunnels are properly sealed. Unabated, acid mine drainage could have a chronic effect on surface and ground water quality many miles downstream.

Heavy Metals. Heavy metal contamination in soils is also associated with acid mine drainage and becomes an issue of concern where weathering conditions stimulate an interaction with acidic discharges (BLM, 1992). Geography and meteorology determine the weathering conditions and chemical interaction that may affect the metals toxicity in soils at a given site location. An example of this toxic effect is found in samples collected at abandoned copper smelting operations in Tennessee's copper basin which contain high concentrations of sulfur dioxide in the soils. The result is a lowering of pH in the soils causing reduced productivity of vegetative growth. Without vegetative cover, these acidic soils were open to both wind and water erosion readily transporting concentrations of toxic dust and heavy metals throughout the watershed (Bollinger, 1991).

Erosion and Sedimentation. Because of the vast acreages of land disturbed by historic mining activity and the large quantities of earthen materials often left exposed at abandoned sites, erosion induced sediment into receiving waters is a major water pollutant (EPA, 1985). Erosion can result from any of the past activities at old mining sites such as abandoned access and haul roads, tailings and spoil piles, waste rock, overburden and unvegetated slopes. Runoff from these wastes can cause significant loadings of sediments and any entrained metals to nearby streams during storm events.

Dry tailings piles are highly susceptible to water and wind erosion due to the material's flour-like consistency. Tailings include finely ground ore rock fragments and treatment residuals generated from the crushing, grinding, and other physical and chemical methods used to separate the metals of interest from the host rock. All of the substances naturally occurring in the ore and any additional substances such as reagents associated with extraction and processing operations can be found in tailings. Prior to site abandonment, these tailings were often pumped or dumped directly into streams and valleys where the stream waters generally flowed on and through the exposed materials. This practice severely impacted receiving waters with sediments and heavy metals. At abandoned mines, these problems often continue to degrade surface and ground water quality long after the mining operations have shut down.

In placer mining, tailings consist of spoil material remaining after gravity separation of gold-bearing material. Old placer mining operations significantly produced large quantities of sediment, most of which was dumped directly into the stream channel causing adverse changes in water quality, depressed aquatic populations, and a loss of fish habitat (Van Haveren, 1991).

Examples of Environmental Impacts at Abandoned Mines

Of the thousands of abandoned mines in the United States, a number of examples serve to illustrate the types of nonpoint sources from abandoned sites that impact surface waters. Of the more than one thousand sites on EPA's Superfund National Priorities List (NPL), at least forty-eight are mining related (EPA, 1992b). Two of the abandoned mining sites listed on the NPL are described below. A third site, French Gulch, is also described. French Gulch is not on the Superfund list but is currently under remediation with partial assistance of a section 319 grant. It is emphasized that these examples should not be taken as representative of historic mining operations in all regions of the country, or even of all abandoned facilities in a given region. Rather, they are presented to show the type of water pollution problems that may exist at individual sites.

Butte/Clark Fork River, Montana. Over 100 miles of river valley have been contaminated by mining, milling, and smelting operations dating from the 1880s. An estimated 229,000,000 cubic yards of mine wastes remain on the site, all of which are exposed to surface runoff with impacts to both surface and ground waters.

This site is divided into the Anaconda Smelter Site and the Silver Bow Creek/Butte Site. At the Anaconda Site, flue dust piles estimated at 316,000 tons have been found to be contaminated with arsenic, cadmium, copper, and lead. These dust piles are exposed to wind and water erosion, and the contaminated runoff flows into the Clark Fork River. Other wastes in the area include a 2.75 mile stretch of floodplain covered with smelter wastes; slurry wastes from a copper refining plant; beryllium from two pilot plants; slag piles; and 185 million cubic yards of tailings.

The Silver Bow Creek/Butte Site includes the towns of Butte and Walkerville. Over 450 acres of surface soils are contaminated with lead, zinc, copper, cadmium and arsenic. This site includes the Berkeley Pit, an open pit copper mine more than a mile deep and one and a half miles wide. The site also has over 3,500 miles of underground workings reaching as much as 5,000 feet below the surface. Prior to 1911, all mining, milling, and smelting wastes were discharged directly into Silver Bow Creek. Between 1911 and 1988, wastes were deposited in a series of dumps scattered all over the site; nineteen million cubic yards of sediments and tailings contaminated with heavy metals line the banks of Silver Bow Creek. Since dewatering ended in early 1980, the Berkeley Pit is now filling with water and it is expected that it will begin discharging highly contaminated and acidic waters to alluvial aquifers by the mid-1990s (EPA, 1991a).

Carson River, Nevada. This site covers a 50 mile stretch of river between Carson City and the Lahontan Reservoir. The river drains the historic Comstock Lode mining region in and around Virginia City which is contaminated with mill tailings piles and river sediments are contaminated with mercury. Historically, gold and silver were extracted by a process that used mercury to amalgamate the precious metals from the ore. A ratio of one part mercury to ten parts ore was needed to process the ore, and an average of 68 kilograms of mercury was lost for every ton of ore milled. An estimated 12 to 18 million pounds of mercury were lost in the milling process in this area, and the residual mercury is entrained in the tailings along, and the sediments in, the Carson River. These tailings are uncovered, unlined, and untreated. One tailings pile sampled contained 493 parts per million (ppm) of mercury (EPA, 1991a).

French Gulch, Colorado. Beginning in the early 1860s, the extraction of gold by placer and underground lode mining occurred with intensity along French Gulch until the late 1950s. Past mining along this valley left severe water quality and unsightly visual impacts. Most of the valley floor has been destroyed by gold dredges; in addition, several large lead/zinc/silver mines in the area continue to contaminate the stream with excessive loadings of toxic heavy metals in amounts several times larger than the State water quality standards. Below the Wellington/Oro mine and mill complex, aquatic life in French Gulch is non-existent. The stream has a bright reddish-orange color as it flows over and through old tailings strewn along its banks. The mine complex is located only 1.5 miles from the upscale ski town of Breckenridge where portions of the polluted stream waters flow through. Runoff from the mine complex into the Gulch has been identified as the most significant source of metals loadings to the Blue River, which empties into metro Denver's Dillion Reservoir drinking water storage facility six miles downriver. At the confluence of French Gulch and the Blue River, concentrations of zinc in the river ranged from 38 to 93 times the State chronic standards (Water Quality Control Division, 1992).

These examples of water pollution impacts caused by abandoned mines may be more severe than those found at other abandoned sites; however, they reflect the kinds of problems that can and do occur when the conditions at such facilities are allowed to deteriorate. Increased public awareness of similar problems or conditions will help get State and local officials' attention to promote environmental improvement and remediation action at abandoned sites. These efforts can be successful only if the conditions at abandoned mines are assessed and their locations are known.

Much progress is now being made through the cooperative efforts of Federal and State agencies, and the mining industry in developing effective treatment systems and reclamation techniques for enhancing water quality and site conditions at abandoned mines. The techniques to control abandoned mine pollution sources (which predominantly are adit drainage, long-term snowmelt runoff, and erosion) are through passive treatment systems and other techniques known as best management practices (BMPs).

BMPs are site specific measures. They are designed to achieve objectives and solve specific problems at individual sites. BMPs usually include combinations of measures for erosion prevention, soil stabilization, seeding and revegetation, runoff collection and dispersion, and sediment collection. BMPs must be carefully selected to meet specific site conditions including climate, geology, topography, soils, and type of mining and milling operations; such as, surface or underground mining, placer mining, and chemical leaching, smelting, etc. (Idaho Dept of Lands, 1991).

Examples of completed abandoned mine remediation projects using BMP technology are described below. The BMPs installed at these sites include passive treatment systems for neutralizing acid drainage, site grading to restore natural contours, and planting of vegetation to stabilize disturbed land masses. These projects were developed with EPA nonpoint source program grant assistance and local support.

Chalk Creek/St.Elmo Project. Past mining activity above Chalk Creek near St. Elmo, Colorado, left scattered piles of tailings, waste rock, and disturbed land areas to the forces of wind and water erosion. In addition, a steady flow of acid mine drainage from the Golf Tunnel reached its way into Chalk Creek. With a combination of funding sources, the Colorado Mine Land Reclamation Division initiated the Chalk Creek Project in 1989 along with 12 participating public and mining industry volunteers. Mine tailings were removed, consolidated, regraded, and revegetated. Wetland ponds were created to receive and treat the acid drainage prior to being discharged into the Creek; a gate was installed at the tunnel opening for security. Special plant sedges and wetland grasses were planted to stabilize the site and to create a riparian habitat. The project cost $189,000 and was finalized in the Fall, 1991 (Water Quality Control Division, 1992).

Demonstration Program Sites. By mid-1991, the State of Colorado had spent over $600,000 of EPA nonpoint source 319(h) program and State matching funds to support remediation efforts at several abandoned mine sites. The State's first project gaining relative success was at Gamble Gulch where a series of wetland ponds collected acid drainage from an adit at the Tip Top Mine to neutralize heavy metals loading to the Gulch and South Boulder Creek. At the Peru Creek Pennsylvania Mine project, a limestone feed system was added to the mine drainage, settling pond, and zeolite polishing unit for metals reduction. From this project, the State learned that the system as designed needed improvement to deal with the high acidity of the drainage and winter accessibility of the site. This project was expanded to study other neutralizing agents and field applications (Water Quality Control Division, 1992).

Abandoned mine land and water reclamation is evolving as a significant new field. In the near term, new techniques and innovative practices will be needed to advance the science of best management practices as well as other economically achievable measures which will be needed to achieve the greatest degree of pollutant reduction at abandoned mine sites.

KEY ISSUES

A key issue under existing law is what constitutes abandonment at noncoal/hardrock mines. This issue is significant for the nonpoint source program because it can determine how the management of pollution sources at abandoned mines will be handled and under what responsibility.

Appropriate changes to current section 319 to clarify nonpoint source program objectives could be by legislation, regulation, or by formal or informal policy; although, any change other than legislative would have to be carefully considered and crafted. The pending reauthorization of the Clean Water Act provides the opportunity to clarify the use of nonpoint source controls at abandoned mine sites. States should have alternatives to allow Federal funding to be used for treatment of abandoned mine runoff regardless of how point and nonpoint sources are defined.

Also, a national inventory is necessary to identify the locations and to assess site conditions of abandoned mines. This is a key step to set priorities for site reclamation and water quality enhancement. Currently, BLM, USFS, USPS, and USGS, are involved in conducting inventories of mining districts. EPA could join and assist these agencies in developing a program with specific responsibilities for abandoned mine site remediation.

Future considerations could include the following:

develop a clear definition and national policy direction for the remediation of pollution at abandoned noncoal/hardrock mines.

develop a national inventory and assessment of abandoned mine sites to determine the number, location and condition of these sites and to set remediation targets for priority problem sites.

develop a better understanding of mine site pollution discharges and define a clear line of program responsibility for achieving nonpoint source controls at abandoned mine sites.

evaluate the possibility of combining existing program resources to achieve the greatest pollution reduction benefit.

encourage mining States to actively use section 319 program grants as a means for implementing abandoned mine land and water remediation projects.

Hopefully, some of the issues described above will be clarified by EPA and/or addressed in reauthorization of the Clean Water Act.

DISCLAIMER: The views and opinions expressed in this paper are those of the author and do not necessarily reflect the policies of the U.S. Environmental Protection Agency.

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