# Minefill Practices for Power Plant Wastes

An Initial Review and Assessment of the Pennsylvania System

May 18, 2003
Revised, July 4, 2003
Revised, July 30, 2003
Revised, August 29, 2003

Geo-Hydro, Inc.
1928 E. 14th Avenue
Denver CO 80206

(303) 322-3171

Charles H. Norris
Pennsylvania Licensed Professional Geologist
PG003994, Expires 9/30/03

## Preface

The following discussions are based upon the references cited as well as the review of relevant parts or summaries of the permits for the following operations in Pennsylvania: Laurel Land Development, Inc., **McDermott Mine Site**, SMP # 11950102; Amerikohl Mining, Inc., **Jacksonville Mine**, SMP # 102360-32980108; Kent Coal Company, **Lucerne No. 2**, SMP # 1387-32940105-05; Greenley Energy Holdings of PA, Inc., **Mine 40 Refuse Reprocessing**, # 1-02365-11833026-03; E. P. Bender Coal Company, **54 Job** - SGL 184, # 11930102; Cambria Reclamation Corporation, **Ernest**, # 32950201; and Maple Coal Company, **Rail Yard Site**, # 11970201. The selection of these permits was based on a desire to obtain an overview of the Pennsylvania program in terms of scale and type of operations where coal ash has been placed. In addition to these, the DPRA discussions of the four U. S. EPA MRAM Pennsylvania sites were reviewed; **Revloc Refuse Site**, **B-D Mine**, **Big Gorilla**, SMP # 54920201, and the previously mentioned Maple Coal facility. The MRAM discussion of the Big Gorilla site was supplemented by the information in Loop, *et al.* (2002).

## Introduction

There are high-volume materials associated in some areas with coal mining and reclamation that can cause severe environmental impacts. Improperly managed and controlled, they are a source of toxic levels of pH, strong mineralization of contact water and elevated concentrations of major, minor, and/or trace metals, anionic species, and/or other contaminants. The discharges from these materials can impair, and even eradicate, biota in affected streams and render ground water undrinkable and unusable. The effects of drainage from these materials can last for years or decades. By statute, these materials are precluded from being classified as hazardous wastes under RCRA. They are, however, recognized as potential “toxic forming material” under the surface mining law, SMCRA.

One such high-volume, potentially toxic forming material is sulfide-bearing waste rock, or spoil. Sulfide-rich spoil is naturally associated with some coal seams and is disturbed and moved when mining occurs. The key environmental reactant with this material is oxygen. When sulfide minerals and related minerals oxidize and weather, sulfuric acid forms. Water that contacts these minerals may become strongly acidic and characterized by toxic pH. Spoil leachate will often be highly mineralized and have elevated concentrations of major, minor, and/or trace metals, anionic species, and/or other contaminants. If disturbance by mining speeds the weathering and acid generation to rates beyond the rates that can be neutralized or absorbed by the environment, toxic drainage results. This drainage is commonly called acid mine drainage (AMD).

AMD is readily characterized and perceived as simply a discharge of acidic water that results from mining. However, the environmental damage and risks are not limited to the low pH of the water. These discharges are often toxic independent of the pH, due to other contaminants. Thus, neutralization of the AMD is only one element of a successful remediation effort. Damage from AMD may occur in many areas where coal is mined unless appropriate precautions are taken. It is a problem commonly found in areas of historical mining.

Another high-volume, potentially toxic forming material is power plant waste (PPW). PPW is generated from burning coal and implementing air pollution controls at power plants. Its placement in coal mines is becoming increasingly common. The key environmental reactant with PPW is water, with oxygen important to some. Water that contacts these materials may become strongly acidic or strongly basic and characterized at either extreme by toxic pH. At any pH, the leachate can be accompanied by strong mineralization and elevated concentrations of major, minor, and/or trace metals, anionic species, and/or other contaminants. If the reaction with water (and, in some cases, oxygen) and leachate generation occurs at rates beyond the rates than can be neutralized or absorbed by the environment, toxic drainage results.

Toxic drainage from PPW may be characterized by dangerous pH levels. However, the environmental damage and risks are not limited to low or high pH of the contact water. These discharges are often toxic independent of the pH, due to other contaminants. Power plant waste has contaminated both surface and ground water in virtually all environments across the country, including mine settings, as demonstrated in part by damage cases logged by the U. S. EPA. Leachate composition from combustion products often change with time. Similarly, the rate of leachate generation and speed of leachate migration are also often time-dependent. These changes are the result of changes in the mineralogy as the material ages.

## The Acid Mine Drainage Problem

### *SMCRA and Acid Mine Drainage*

The prevention of AMD through responsible mining and materials-handling procedures is a major goal, design, and success of SMCRA. Contemporary, SMCRA-permitted mines are required to prevent AMD in their design and operations. Pennsylvania is rightfully proud of its success, through SMCRA and extensive state-sponsored research, of preventing AMD. A measure of this success is the infrequency with which new SMCRA-permitted mines generate AMD. According to Pennsylvania Department of Environmental Protection (PADEP) statistics, AMD problems occurred in 15% of the mines between the years 1977 and 1985, and that rate had dropped to less than 3% for the period between 1985 and 1992 (Kania, in PADEP, undated(a), Chapter 18). A large part of the success in preventing AMD in new mines is the rigorous state program to develop a pre-mining prediction of post-mining water quality (PADEP, 2001). Based upon that prediction, permits are customized to prevent AMD formation or, in cases, denied when there is no apparent way to prevent it.

*Abandoned Mined Lands and Acid Mine Drainage*

AMD-producing conditions developed historically in many coal-mining areas, particularly in the Northeast, under the then-prevalent mining practices. Pennsylvania is at the center of the impacted area. According to the Pennsylvania Department of Environmental Protection:

> . . . as a result of a combination of unintentional environmental neglect as a result of the need and demand of industries in the early days of mining, and the inability of environmental technology to keep up with earlier coal mining practices, PA found itself in the unenviable position of being the most negatively environmentally impacted state in the union. (PADEP, 2001)

Although modern surface mining permitting decisions and operational practices have largely eliminated AMD as a problem in new mines, that does not remove the legacy of past practices remains. In Pennsylvania alone, there were hundreds of sites and at one time as much as a quarter of a million acres that were mined pre-SMCRA and constituted what are collectively called abandoned mined lands (AML). According to PADEP estimates, Pennsylvania's legacy represents as much as one-third of the total national AML (Seif, 2000). The numbers quantifying the problem are uncertain, however. Although the figure of 2,500 miles of streams is used as a current measure of the problem, Sheetz, *et al*, 1995, show that figure as dating to 1971 and, thus, not reflective of three decades of remediation. Similarly, the 1971 estimate of 175,000 acres of abandoned mined lands has through the years grown to over 250,000 acres in contemporary tradition (Seif, 2000).

AMD in Pennsylvania is a problem almost entirely associated with AML. But, it is important to recognize that not all AML has AMD. AMD is only a subset of the environmental problems associated with AML. The environmental problems associated with these lands include subsidence and drainage problems, unreclaimed high walls, hazardous mine shaft and subsidence openings, mine fires, and abandoned structures, in addition to impacted ground and surface water. Further, not all AMD-impacted ground and surface water has low pH or is acidic. Some AMD has neutral pH but carries stored acidity in dissolved metals. Some has been neutralized by reaction with naturally occurring minerals (*e.g.*, calcite) and, although the drainage has chemical characteristics that allow its acid origin to be identified, the impact from the drainage is not due to its now being acidic (Rose and Cravotta III, in PADEP, undated (a), Chapter 1).

## Remediation of Acid Mine Drainage

### *Traditional Remediation of Acid Mine Drainage*

The remediation of AMD has been a major drive for Pennsylvania for decades. Hundreds of miles of Pennsylvania streams have been, and are being, improved and even cleaned to near-pristine conditions by these efforts. Two traditional approaches have proven effective during the years as experience has grown. The first is surface reclamation: regrading and revegetating a site.

Abandoned mined lands are often characterized by surface topography that encourages infiltration of surface water and precipitation and discourages vegetative growth. The result is an increased oxygen transport into spoil or coal waste, an increased rate of acid formation, and an increased rate of acid transport away from the site. Simply regrading some sites to eliminate internal drainage and promote a healthy vegetative cover can reduce oxygen transport, and substantially reducing AMD problems (BMR, 1997, and Murarka, 2002).

The second approach is to use one of a number of constructed features that passively treat the AMD from a site (PADEP, undated(b)). Passive treatment takes advantage of naturally occurring chemical and biological processes and reactions to abate acid mine drainage. Examples of passive treatment systems include constructed wetlands (aerobic and anaerobic), open limestone channels, and anoxic limestone drains. The successful application of passive treatment systems for AMD is highly site-specific. Experience clearly shows that a one-size-fits-all approach simply will not work. However, once site-specific design and performance-based adjustments are made, these techniques show virtually a 100% success rate based upon 19 existing and 8 in-progress sites (Milavec, undated).

### *Remining and Acid Mine Drainage Remediation*

Both of the above methods of treating AMD from abandoned mined lands require the expenditure of commonwealth funds. To increase the rate that AMD and AML problems are addressed, Pennsylvania has instituted mining regulations that specifically address remining areas that are impacted by AMD, either as stand-alone permits or as part of permits for new mining. Examples of remining would be the surface mining of old underground mines (daylighting) or the mining of coal refuse as a fuel resource. The regulations provide some regulatory relief and incentive if mining companies will reclaim problematic abandoned mined lands as part of new mining activities. Regulations for this program are found in 25 Pa Code Chapter 87 Subchapter F.

The success of remining as a means of remediating AMD is significantly less than the success of passive treatment or of preventing it at the permitting stage. As discussed above, prevention at the permitting stage shows a 97% success rate and passive remediation has a virtual 100% success rate of eliminating AMD. In contrast, an in-depth study of remining projects (Hawkins, 1995) showed a "success" rate of only 87% (21 of 24 sites evaluated).

However, even that lower success rate of the remining approach is overstated. Remining is not as good as it might appear because success in that program is defined with substantially lower criteria. In the case of remining, previously impacted water quality does not need to improve for successful reclamation and release of bond; it need only not worsen. Further, degradation is ranked only on a basis of contaminant loading, not contaminant concentration. Bond release, and hence success, under Subchapter F can occur with no more than an aesthetic improvement in the abatement area, provided the discharge water quality does not get worse, the area is stabilized, and the mining plan was followed (25 Pa Code Section 87.209 (b) (3) (ii)). The statistics cited above for the study by Hawkins were based only on the iron and acidity loads at the site and did not consider other contaminants. Only 8 (33%) of the sites demonstrated a significant decline in the acidity load (Kania, in PADEP, undated(a), Chapter 18), a measure of actual abatement.

*One Person's Success . . .* ***Laurel Land Dev. – McDermott Mine Site – SMP # 11950102***

There are interrelationships among the various remediation approaches and their statistics of success. In the discussion regarding examples of success in predicting AMD based upon pre-mining analysis, Kania's (PADEP, undated(a), Chapter 18) Site 2 in Cambria County is one that was projected to cause AMD, absent special efforts. The mining was permitted in part because alkaline addition was proposed in the form of importation and placement of ash from a fluidized-bed combustion (FBC) plant and placement of ash in a number of specific settings in the mine. In this case, the prediction – that the geology indicated likely acid mine drainage – was a success, but the prescription – alkaline addition using FBC ash – was a failure. Acid mine drainage appeared almost immediately at both a downgradient monitoring well and at a spring, both of which had previously had good water. Although it was speculated that the problem was an inadequate rate of alkaline addition, and more ash was sought, the final solution with respect to the spring discharge has been to install conventional AMD treatment.

Based upon the description of the mine, the site, and the performance, Kania's Site 2 is believed to be the same degraded site described by Mukherjee (2002). Mukherjee's assessment of the site and surrounding conditions was that the degraded spring water was not directly the result of the chemistry of the PPW. According to Mukherjee, the contamination of the spring was the result of rerouting of other contaminated water by the placement of the PPW on the mine floor as part of the new operations. The re-routed, contaminated water was attributed to a source other than the new operations. On that basis, the operator was apparently allowed to have his bond released, even though the PPW placement was the accepted cause of degraded spring flow. Presumably, if bond has been released, this site is among the examples of a success.

## Power Plant Waste Placement in Mines

*Power Plant Waste Management Practices, Historical and Today*

Coal combustion products are the subset of power plant wastes that consist of the non-carbon, mineral fraction of coal that is burned; any unburned or partially burned coal (products of incomplete combustion); combustion products from materials mixed or burned with the coal (co-burned fuel, or limestone in an FBC unit, *e.g.*); and materials stripped from the effluent gas as a means of controlling air pollution. Other power plant wastes are often mixed (co-managed) with these higher-volume combustion products. Some coal combustion products are recycled, but most have been and are disposed of as wastes.

Disposal of power plant waste has traditionally been near the point of generation with little or no isolation from the surrounding environments. Most commercial power generating sites are near major rivers or lakes and rely on the dilution of the leachate to minimize impacts. Where disposal does not have benefit of dilution, and where there is effective monitoring, these practices are documented to result commonly in contamination of ground and surface water, often severe contamination. This is partially documented by the expanding inventory of damage cases acknowledged by the U. S. EPA.

Existing disposal volumes near the point of generation and sources of dilution are rapidly becoming filled. Newer technologies, such as FBC units, produce far more combustion wastes per ton of fuel than traditional burners. For example, in Pennsylvania, the ash production rates for FBC units were more than 60 percent of the tonnage of fuel burned (Sheetz, 1997). Normal disposal alternatives for industrial wastes, *i.e.*, landfills with engineered isolation from the environment, are significantly more expensive than historical practices. Electric utility generators increasingly look to placement in coal mines as an inexpensive alternative to disposal in landfills. Coal companies increasingly accept coal combustion waste placement on their permits as a cost of marketing their coal and/or reducing alternative reclamation costs.

The placement of coal combustion waste in coal mines is variously and increasingly allowed by the regulatory policies of individual states under the umbrella concepts of recycling and *beneficial use*. Depending upon the individual state regulations and regulators, placement under beneficial use can include the remediation of existing AMD sites, injection to prevent subsidence of old underground mines, alkaline addition for areas of potential acid generating problems from new mining, mine road construction, inexpensive fill to rebuild approximate original contour (AOC, a SMCRA concept and requirement), and dispersed- or monofill disposal at a mine. In effect, in one state or another, any form and purpose of placement is allowed under the guise and name of *beneficial use*, up to and including the simple dumping of coal combustion waste when, where, and in whatever volumes the generator, operator and regulator decide.

In an often-repeated, carefully-crafted overview statement, the federal Office of Surface Mining asserts that, "Currently, there are less than 2 percent of the CCBs that are produced in the U.S. that are placed back at the mine site where they originated." (Vories, 2002a) The statement creates the impression that PPW placement in mines is not substantial; perhaps a program in its infancy. Such an impression is erroneous. The misdirection is in the qualifying statement "are placed back at the mine site where they originated." Most PPW that is placed in mines is not part of a haul-back program, *i.e*., the placement is in some mine other than the source of the coal. In reality, where there is an active program for mine placement of PPW, far more than 2 percent of the waste stream is directed to mines. For example, in Pennsylvania alone in 1995, 6.75 million tons of ash were placed just on abandoned mined lands, from an estimated in-state generation of something less than 10 million tons (Sheetz, *et al*., 1997).

*The Appropriate Limitation of <u>Beneficial Use</u>*

Except for mining waste, power plant waste is the largest industrial solid waste stream in the United States. Although commonly discussed as though it is a single material, it is not. Various power plant wastes exhibit an incredible variety of chemical, physical, and mineralogical properties and make-up. Even when considering a subset of power plant wastes, such as desulfurization waste, that subset contains wide variation. There are no real comparisons chemically, physically or mineralogically among desulfurization products produced by dual alkali process, Wellman-Lord, and injected limestone, for example. Even a class of PPW, FBC ash, from a single state, Pennsylvania, has dramatically different characteristics, composition and mineralogy, depending upon whether it was derived from burning bituminous coal gob or anthracite coal culm (Sheetz, *et al*., 1997). As a result, there is little merit in even discussing a concept like *beneficial use* outside of a defining framework of which power plant waste in which potential use at which site.

Power plant waste has unquestionably demonstrated the capacity to contaminate ground and surface water. This is seen in dozens of sites across the country in a host of placement environments, an inventory that continues to expand as resources are available to document it. Its track record of water contamination is so transparent in non-mine settings that an Indiana administrative law judge determined it a potential toxic forming material under the surface mining laws, requiring special handling in the mine setting to protect ground and surface water.

The degree to which power plant wastes contaminate air by means of fugitive dust is largely unexplored. When the fugitive dust issue is discussed, the discussion is normally limited to concentrations of RCRA metals and similar metals, not the organic contaminants or major constituents, such as silica, aluminum and iron, that most likely to be of immediate health concern.

In the light of both its variability and its proven damage record when placed in the environment, any potential placement of power plant waste outside of disposal containment, including in mine settings, must carefully and uniquely measure the risks versus potential benefits at that particular site.

There is no reason to dispose of PPW in new, SMCRA-permitted mines unless that disposal has the same degree of isolation from the environment that would be required for any other disposal setting. SMCRA requires the minimization of damage to the hydrologic balance within the permit area and prohibits material damage to the hydrologic balance outside the permit area. In an otherwise properly permitted and operated SMCRA mine, there is no benefit derived that offsets the risk from the uncontained disposal of a non-mine industrial waste.

However, there may be some settings where specific power plant wastes can be appropriately used to assist in remediation or reclamation of abandoned mined lands that are an existing environmental problem. And, power plant wastes may sometimes be beneficially used for fill as part of abandoned minded lands reclamation, so long as comparable management and isolation from the environment is provided for the mine setting as for any other disposal setting.

Transient chemical and physical properties of some power plant wastes, in combination with their volume, may provide remediation benefits that offset their own potential to pollute. Two such properties exist in some, not all, power plant waste; some have substantial alkalinity and some are pozzuolanic.

The OSM approach to the transient characteristics of these wastes is to ignore them and consider only the first few months of reaction data (Vories, 2002b). However, the transient nature of the alkalinity and pozzuolanic properties of PPW must be emphasized as one considers using PPW in remediation schemes. If PPW is to be used appropriately in a reclamation project, it must be part of a total solution that will outlast its own interim contribution. A patch fix, even one that lasts a decade, may not be a rational use of these materials, if the final conditions are worse, or no better, than the original problem.

Alkalinity of PPW is lost by leaching and is consumed by reaction with acid materials and fluids. At best this means a finite functional life to the material as a source of alkalinity. At worst, its use can defer a problem now that becomes more severe in the future. The use of alkaline PPWs as a reaction barrier to continuing acid drainage is one example. While alkalinity remains, the acid drainage is neutralized and many metals will tend to precipitate, doubly abating the contamination problem. However, once the alkalinity is consumed, not only does the acid drainage problem recur, but the previously precipitated metals, as well as metals introduced with the PPW, are now subject to dissolution by the acid, producing higher levels of contamination than existed originally.

The transient pozzuolanic property of PPW must also be considered in any viable beneficial use scheme. This is the property of a material to "set up" as a solid mass when it is hydrated. The resulting solid can range from materials like concrete to materials like Plaster of Paris. The pozzuolanic characteristic is often relied upon to stabilize other industrial wastes, in a mine setting, to encapsulate acid forming materials, create blanket barriers between acid forming materials, redirect water flow, and/or reduce infiltration. As with alkalinity, the integrity of any feature or use that relies on pozzuolanic characteristics is temporary.

A pozzuolanic material is subject to attack and destruction its surrounding environment. Calcareous pozzuolans are subject to acid attack and concrete-like pozzuolans are subject to sulfate attack (Earle and Callaghan, in PADEP, undated(a), in Chapter 4). However, the properties of pozzuolans have temporal limitations independent of external chemical attack. Some PPWs react with water to form pozzuolans. The nature and strength of that reaction is more dependent upon the mineralogy of the ash than even its composition (Sheetz, *et al.*,1997). The initial minerals that form on hydration are metastable and the material continues to evolve chemically and mineralogically (*ibid*). Independent of the external environment, the initial mineralogy matures and, depending upon the specifics of chemistry and mineralogy, those changes can and do tear apart the fabric of the material and/or can release previously bound contaminants.

The unfortunately brief ability of pozzuolanic PPW to stabilize radioactive waste at the U. S. EPA Shattuck Site in Denver is but one example. The Shattuck Site is an in-city disposal site for uranium talings that dates back to the 1950s. Rather than exhuming and transporting these radioactive sediments to a landfill, the sediments were "stabilized" with pozzuolanic PPWs and reburied on-site. Standard index leaching tests were used to determine the efficacy of this remedial solution. Within months, the stabilized wastes were again leaching radioactive and non-radioactive metals and ultimately the original materials and added PPWs had to be exhumed and transported to an appropriate facility.

## Necessary Elements for Beneficial Use of PPW in Reclamation of Abandoned Mined Lands

### *Waste Characterization*

Prior to the consideration of any PPW for beneficial use, it must be characterized to determine that it is an appropriate material for the specific purpose and site at hand. This means that elemental and mineralogical composition of the raw material must be determined. It means the mineralogical and pore fluid composition of the PPW upon initial hydration or hydration at the site must be determined. It means the probable reactions of the waste with site water and site minerals must be determined to understand the combined evolution of the waste, of water in contact with it, and of water leaching from it.

The duration and ultimate fate of mineral phases must be considered. For example, in a material rich in gypsum, the sulfate concentrations in fluid will be high and will remain high until the gypsum is completely leached. One effect of high sulfate in solution is that many metals are bound by equilibrium in sulfate mineral phases. As sulfate levels drop, these minerals are subject to dissolution and the metals to mobilization. The remobilization of metals initially precipitated from neutralized acid drainage has been mentioned above, as another example. These reactions are not reactions typically that can be expected to occur in the early months or even years of a project. But they are reactions that can be systematically identified, and their results can be projected.

The implementation of this degree of characterization is not onerous, nor should it be difficult for either regulators or operators of mine sites. It is directly analogous to the characterization that is routinely required and performed for overburden spoil, the other toxic forming material at mines, as part of routine permitting for mining. It is also as fundamental to a successful beneficial use project as overburden analysis is to preventing acid mine drainage in contemporary mines.

Unfortunately, nothing close to this degree of characterization is required in Pennsylvania, or in other states. All that is generally required is an index leaching test, such as the TCLP or the

SPLP, with an arbitrary threshold for acceptance. Some states, including Pennsylvania, also require an elemental analysis. One or two such tests are frequently deemed adequate to characterize thousands of tons of PPW at sites covering dozens of acres and two or three distinct placement environments. The waste characterization is typically limited to such tests because the characterization is used primarily to determine whether a proposed ash will be accepted for mine placement by a state's program. It is not used as a tool to predictively assess the performance of the waste in the mine setting. For example, the Pennsylvania characterization program has pH limitations and allows an ash that shows TCLP or SPLP leachate concentrations up to 25x MCLs and 10x SMCLs to be certified for placement in mines (higher under some circumstances) (BMR, 1998a), but requires no further characterization toward understanding performance under conditions of disposal.

Such limited waste characterization programs for the unconfined placement of coal ash in any environment is undefendable. One can only imagine the response of mine-permitting staff in Pennsylvania, or at OSM, were a mine operator to submit a mining permit application with a random TCLP test of overburden for each 20 acres to be mined and perhaps paste pH. Such tests are simply not adequate to characterize natural materials for their toxic forming potential (Hornberger and Brady, in PADEP, undated(a), Chapter 7; and Kania, in PADEP, undated(a), Chapter 6). Yet, in spite of the recognition of, and need to understand, the complexity of spoil chemistry and its reactions, Pennsylvania shows no similar understanding of the complexity of PPWs and their reactions. Pennsylvania does not even require acid base accounting (ABA) for PPW that is being proposed for use as an alkaline addition (SAIC, 2003).

Unfortunately, OSM and DOE do not object to such minimal and ineffectual characterization. OSM uses the results of such ineffectual characterization to justify added placement strategies and even lower levels of testing, stating, "Research has shown that less than 1 percent of these materials have the potential to leach hazardous constituents based on laboratory testing with the TCLP method." (Vories, 2002b, citing DOE data)

The inadequacy of the characterization programs that are used for mine placement of these materials is not theoretical or hypothetical. The U. S. EPA Office of Solid Waste has requested a consultation by its Science Advisor Board on Improving Agency Leach Testing of Waste to address both the limitations of these tests and the misinterpretation of these tests, as well the need for better site-specific protocols. At site after site around the country, including mine placement sites (*e.g*., Murarka, *et al*., 2002), it is demonstrated that simple TCLP-like leaching tests do not characterize the leachates that form at a site, even initially, and frequently badly underestimate the concentrations of individual contaminates in the field. As an example in Pennsylvania, arsenic in water downgradient of coal ash placement at the **Ernest Mine** climbed to concentrations of several hundred ppb, but typically are below detection limits as low as 2 ppb in the leachate tests. The tests simply have no ability to shed light on what may occur at a site when ash is placed, much less a decade hence.

None of the sites reviewed in Pennsylvania had any chemical characterization of the PPW beyond the index leaching tests and/or elemental analyses except **Big Gorilla**, which also had mineralogical analyses of the ash and tested the ash for geotechnical properties (Proctor, penetrometer, and densitometer tests). The **Big Gorilla** site had some post-placement mineralogy discussed and pore water data were apparently collected although they have not yet been reviewed. This site also had *in situ* strength and permeability testing performed.

*Site Characterization*

There is probably no way to overestimate the importance of pre-placement characterization of the site. With respect to the characterization of the ground water, one element of site characterization, Callaghan, *et al*., stated,

> An understanding of the groundwater flow regime is essential to the design of site-specific monitoring plans to determine the impact of mining on groundwater quality and the hydrologic balance. The more thorough the understanding of this system, the more efficient this plan can be, maximizing the information which can be obtained and minimizing the costs of monitoring. This knowledge also gives the groundwater chemistry of the site meaning by providing a frame of reference regarding a given monitoring point's location and relative importance within the groundwater flow system. Absent this understanding, considerable time and money can be wasted by the poor placement of groundwater monitoring wells and the subsequent collection of meaningless water quality data. Although groundwater chemistry can be used to help characterize the flow system, it must be integrated within a broader effort intended to define groundwater potential and hydraulic gradient. The importance of understanding groundwater flow at a site is emphasized by Earl (1986) who suggested that for groundwater investigations, 90% of the budget should be used to define the flow system, and the remainder

for water chemistry analysis. (PADEP, undated (a), Chapter 2)

The above discussion is couched in terms of the pre-operational ground water characterization. However, it is important to recognize that a pre-operational prediction of the post-operational ground water system is equally important, with respect to both flow systems and chemistry. One of the major lessons that has been gained from the experiences in passive remediation programs is that recharacterization of the site is often necessary, partially in response to induced changes by remediation activities (Milavec, undated). Nothing less should be expected from abatement efforts using PPWs.

Any remediation scheme involving placement of PPW will change the pre-operation system, just as mining will. Sometimes such changes are deliberate, such as plugging a mine discharge or daylighting an old mine, and sometimes they are inadvertent. Pre-operational monitoring locations may become meaningless as a result of operations, and points unnecessary to monitor before operations may become important in evaluating the post-operations conditions. Further, deviations of observations from projected results offer a strong clue that the post-operation site may require additional characterization.

Parallel discussions for the characterization of the surface water at a site and for the modified geology can be made. For all site elements, the conditions pre-operations should be described, and the conditions post-operations should be projected. The post-operations conditions should be measured against projections, and the site characterization should be updated as needed. Then, the performance should again projected into the future. Because beneficial use creates an inherently transient system, site characterization is a dynamic process that continues indefinitely.

In general, the permits that were reviewed show little in the way of detailed pre-operations site characterization. Most are remining sites that presume that the pre-existing mining characterization is still adequate. As discussed by Milavec (undated), however, one of the lessons learned from passive system treatment is that characterization deemed adequate for mining purposes often does not contain the detail needed for effective abatement of AMD.

As a rule, there is little attempt to predict a post-operations site characterization. Under Subchapter F permits, the only required projection by the permit is for the type and success of post-mining vegetative cover. Without performance projections, there is no way to measure performance and determine the need for additional, new characterization. An exception to this is when coal ash operations have created actionable contamination. There is an implied projection that the operation will not worsen existing pollution. Using the **McDermott Mine Site** and **54 Job** as examples, additional characterizations were undertaken because unacceptable degradation did occur. However, other responses should also trigger new characterization. Expected abatement that doesn't occur and unanticipated abatement that does are two such situations. Either demonstrates that the original characterization is in some way flawed.

One exception to the lack of initial and lack of dynamic characterization among the sites reviewed is the **Big Gorilla** site. Throughout the disposal of ash into the lake there has been geotechnical testing of the surface ash, as described above. In addition, there has been limited subsurface sampling of disposed ash for mineralogical comparison and a single permeability test is reported. However, there are major elements of characterization that remain incomplete. For example, evidence indicates that the lake has a ground water drain system that has not yet been identified (Loop, *et al*., 2002), a major and significant inadequacy of the initial and existing site characterization.

*Site Monitoring*

The monitoring of a site of PPW placement theoretically will verify the performance of the material that has been used and the success or failure of that use to meet the objectives or requirements. The action of monitoring alone confers no protection from a given operation, nor is it necessarily meaningful. Protection is conferred by monitoring only if (a) each relevant location is monitored at (b) its relevant times for (c) all relevant contaminants, and there are (d) protective standards for monitoring results that trigger (e) enforced remediation actions.

In order to meet all five of the above requirements for a meaningful and protective monitoring system, it is clear that both waste characterization and site characterization must be adequate, particularly site characterization. Absent a complete and adequate site characterization, the construction of a meaningful and protective monitoring system relies on random chance and serendipity. As quoted above in Callaghan, *et al*. (PADEP, undated (a), Chapter 2), "Absent this understanding, considerable time and money can be wasted by the poor placement of groundwater monitoring wells and the subsequent collection of meaningless water quality data."

If waste characterization is inadequate, one doesn't know what to look for, in what sequences, to determine whether the placement program at the site is working.

The review of the 10 permits listed above showed not one of the permits achieved all five criteria. Whether each relevant location (element (a)) is being monitored at each of the 10 permits cannot be independently verifed from the data in the permit. As discussed above in the section on site characterization, the ash-use permits generally do not independently demonstrate the validity of the monitoring points; they are accepted as appropriate based upon their prior use for earlier mining. Similarly, the waste is not characterized sufficiently to know what constituents (element (c)) are key at what stage of evolution at any site.

There are two components for element (b), time of monitoring. One component is the result of the temporal variation in the site due to evolution of the PPW itself. None of the sites address this aspect at all. The importance of this component cannot be overestimated. At sites across the country, damage from PPW placement or use may not begin until a decade or more after placement. Similarly, there are sites where contamination, left unchecked, continues to worsen 20 and 30 years after it begins.

The other component of element (b) considers simply travel time between placement location and the monitoring point. At no monitoring location in any of the ten permits is there even an estimate of contaminant travel time to the point of monitoring, once that contaminant is released. While migration through a double-porosity or pseudo-karstic system like spoil (Hawkins, in PADEP undated(a), Chapter 3) is difficult to quantify, failure to even estimate travel times severely reduces the ability to interpret the monitoring data. If monitoring stops after two or three years, as it does at some of the examined permits, and if the migration period to that location is 4 years, the monitoring is meaningless for detecting even existing problems, let alone evolving problems. Similarly, if the travel time to a monitoring location is only one year, but it will take 4 years to re-establish the post-placement flow system, monitoring for anything less than five years means nothing. The latter case does not appear relevant to any of the 10 Pennsylvania sites reviewed, except perhaps for **Big Gorilla**, but it certainly is a factor in many mines in the Midwest, for example.

Monitoring in the absence of trigger levels and enforceable remediation confers no protection. It is an exercise in science – perhaps valuable and important science – but only science. Protection is afforded only if an unacceptable condition is defined and only if a corrective action is required. Some of the reviewed permits referenced trigger levels for the monitoring program. However, the trigger levels were not specified or it is unclear that they are in effect. For example, the permit for **Job 54** states that the "trigger levels will be the higher of either drinking water standards or the highest background concentration." These would appear to be protective. But, the permit goes on to say that the triggers will be shown on data sheets in Module 25A, and these sheets do not list any trigger levels.

PADEP staff has indicated on several occasions that Pennsylvania has eliminated trigger levels as a management tool several years ago. They have indicated that while concentrations above the levels specified for ash certification would cause concern, even these levels (25x MCLs and 10x SMCLS) are not triggers and any action or remediation would be discretionary on the part of the Department. This interpretation appears to be confirmed by Loop, *et al*. (2002) in the discussion of **Big Gorilla**. In that paper, most water quality considerations are dismissed with the simple observation that concentrations are below the 25x standard of Module 25 of the permit.

The Pennsylvania program is also ambiguous with respect to corrective actions that must be taken if contamination occurs. In responding to U. S. EPA queries about the program (SAIC, 2003), Pennsylvania indicates that corrective actions “can occur” (not "will occur”) when quarterly and/or annual monitoring parameters exceed background values. However, as discussed above, for at least annual parameters (trace metals, heavy metals, etc.), there is no performance requirement or trigger reflective of background or drinking water quality standards or stream standards. The corrective action responses to contamination are apparently (a) possibly no more placement if it is proven ash is the cause (how the proof would be obtained is not addressed), and/or (b) remedies afforded under SMCRA if the contamination constitutes a permit violation. Absent trigger levels for most constituents, it is unclear that there could be a violation of the permit for contamination from most constituents.

Finally, it is important to note that discussions of corrective action described under the Pennsylvania program apply to definable discharges of ground water at a site, not ground water on the site or migrating from the site as ground water. Degradation of ground water that is demonstrated by monitoring wells does not result in corrective actions. This is reflected in the performance requirements for AMD abatement permits. These permits, for sites with prior contamination from pre-law activities, have a non-degradation standard only for existing pollutant loads in discharges, not contaminant concentrations, as discussed in more detail below.

**Pennsylvania’s Beneficial Uses Program for Coal Ash in Mines: Performance, Objectives and Policies.**

> X 3. Does the state have any damage cases? **We have no damage cases where coal ash on mine sites has caused water quality degradation related to coal ash placement.** (SAIC, 2003)
>
> All of the scientific evidence to date shows that placement of these materials at SMCRA mine sites has either been environmentally beneficial or has had no negative effect. (Vories, 2002b)

The first citation is the PADEP response to a U. S. EPA question regarding Pennsylvania’s mine placement program for PPW. The second is the response of the U. S. Department of the Interior Office of Surface Mining to concerns raised by citizens about the adequacy of SMCRA to manage PPW. These are two powerful statements. They are both wrong. They are individually, demonstrably and multiply wrong.

*Review of Pennsylvania Sites*

Two of the 10 facilities examined unquestionably demonstrate “coal ash on mine sites has caused water quality degradation related to coal ash placement.” Those sites are the **McDermott Mine Site** and **Big Gorilla**.

> At a minimum, the coal ash placement at **McDermott Mine Site** caused the water quality degradation at a spring. The Department of Environmental Protection has required corrective action as a result of the degradation, so there can be no doubt of the Department’s understanding and awareness of this case. The current interpretation of the degradation of the spring is that the location and placement method for the FBC ash caused the flow of contaminated water on the site to be deflected to the location of the previously uncontaminated spring.

> At a minimum, the coal ash placement at **Big Gorilla** caused the water quality degradation that is observed in the mine lake. A staff member of the Pennsylvania Department of Environmental Protection has co-authored a publication on the site (Loop, *et al*., 2002), so there can be no doubt of the Department’s understanding and awareness of this case. Coal ash placement at this site caused the pH of a rain-recharged mine lake to increase from about 3.6 s.u. (not unlike that of acid rain), to a pH consistently above 12.0 s.u. The former pH can be tolerated by some biota, although not fish (Earle and Callaghan, in PADEP, undated, Chapter 4), and the latter is lethal to all life. Other degradation may be present but data are not reported. The lake discharges as ground water but the path of migration has not yet been identified (Loop, *et al*., 2002), so ground water impacts remain unknown.

One of the 10 facilities with coal ash placement in an AMD abatement project shows water quality degradation of discharging water. The contamination is severe enough to require corrective action.

> Two discharge points at the **54 Job** exceeded baseline limits for acidity and manganese and now need treatment prior to discharge.

One of the 10 facilities with coal ash placement in an AMD abatement project showed strong trends of improving ground water quality prior to coal ash placement and the trends declined or stopped after placement began.

> The **Coal Yard Site** (Maple Coal Site of MRAM) showed pre-placement declines over the four year period of record for at least TDS, sulfate, arsenic, cadmium, manganese, and iron at two downgradient wells, with all parameters still above MCLs or other standards at initiation of placement. Pre-placement, chromium was increasing at one downgradient well. The pH downgradient was stable and between 2.5 and 4.5 s.u.

> Within one year of the start of placement, pre-placement declines stopped, or the rate of decline reduced, for at least TDS, sulfate, arsenic, and cadmium. Stabilized concentrations for these were above respective MCLs, except for cadmium. Declines for iron and manganese stopped for a period of years at levels above their respective MCL but may recently have seen a further decrease in the most recent year of record. Chromium has declined since pre-placement, to a concentration near its MCL. The pHs observed in the downgradient wells have not changed.

Two of the 10 facilities with coal ash placement in an AMD abatement project showed no discernable water quality degradation during the short periods of monitoring and no discernable water quality improvement during the short periods of monitoring.

> The **Jacksonville Mine** showed no evidence of either degradation or improvement in water quality during the 3-year period of monitoring after coal ash placement. The site was projected to have improved water quality due to coal ash placement, a change that was not observed.
>
> The **Lucerne No. 2** site showed no evidence of either degradation or improvement in water quality during the 7-quarter period before monitoring was discontinued. The monitoring wells that were installed to track the performance of the placement were dry during the placement monitoring period. The site was projected to have improved water quality due to coal ash placement, a change that was not observed. On both these counts it is apparent that the post-placement monitoring conditions are not understood and there was never effective monitoring of groundwater by the wells.

Two of the 10 facilities with coal ash placement in AMD abatement projects showed ground water quality changes during the period of monitoring, but the changes are inconsistent with the site characterization.

> The **B-D Mine** has a substantial pre-placement record of data from monitoring wells and four years of data since placement started. Water quality improvement for manganese and iron are observed since placement began, but these occurred in the <u>upgradient</u> well, not the downgradient well. This suggests either or both an inadequate initial characterization and a significantly modified site as a result of placement.
>
> Severe ground water quality degradation occurs between the <u>designated</u> upgradient and downgradient wells at the **Mine 40 Refuse Reprocessing Site**. Since placement began, the <u>designated</u> downgradient wells have shown minor improvement in some

> contaminants and the <u>designated</u> upgradient well has seen degradation. Review of the data show that the designated upgradient well has the lowest head elevations, and one of the designated downgradient wells has the highest head elevations. This demonstrates a fundamentally flawed initial site characterization that has apparently been accepted unquestioned by PADEP throughout 12 years of regulatory oversight. The import of the error renders interpretation of site data impossible at this point. However, the site was projected to show improved water quality due to coal ash placement, and the effect has been degradation in one relatively uncontaminated well and little or no change in two contaminated wells.

One of the 10 facilities with coal ash placement in an AMD abatement project showed initial ground water quality degradation within a year of coal ash placement at a downgradient gradient monitoring well.

> The **Revloc Mine** showed ground water degradation from at least TDS, iron, and arsenic at a downgradient monitoring well within the first two years after initial placement of coal ash. All have declined over 12 years of monitoring since placement started, but TDS and iron still exceed their concentrations in the upgradient well. There has been no improvement in ground water pH (3-4 s.u.), which remains below the background.

One of the 10 facilities with coal ash placement in an AMD abatement project shows water quality degradation of discharge water relative to pre-disposal background water quality and degradation of well water quality relative to background well water quality.

> One defined hydrologic unit at the **Ernest Mine** shows discharge water quality degradation, expressed as load, for SMCRA parameters: a 3.3-fold increase in the median acidity load, a 2.0-fold increase for iron, a 1.6-fold increase for manganese and a 4.0-fold increase for aluminum. Degradation expressed as concentration is more severe. For ash placement monitoring points, components including arsenic, lead, and nickel also exceeded trigger levels, and the pH at the ash monitoring points did not improve. The site was projected to have improved water quality due to coal ash placement, a change that was not observed.

*Problematic Elements of the Pennsylvania AMD Abatement Program*

One somewhat problematic aspect of the Pennsylvania program for using coal ash in projects for AMD abatement is that AMD abatement is not a required result. The projects that are undertaken under Subchapter F need only show no-change with respect to the discharge loads of major metals and acidity. Thus, an incentive program to industry that has the expressed objective of cleaning up Commonwealth streams that were damaged by historical mining practices does require that there be any clean up of the affected streams. When alkaline addition is the abatement mechanism being proposed in the permit (often the case in coal ash placement), AMD abatement projects require the lowest rate of addition of any mine setting (BMR, 1997). Further, acid base accounting of the placed ash is not required (SAIC, 2003). Acid base accounting of a material is the only way to determine the magnitude of alkaline addition.

Another problematic element of the Pennsylvania AMD abatement program is the choice of loading as an abatement criterion, rather than concentration. Loading is the product of concentration and flow rate. When a pollution discharge is small relative to the receiving water body and the receiving body has a capacity to mix the discharge, loading can be an appropriate criterion. An example would be a discharge of acid drainage into a large, flowing river. Even if the discharge concentration increases, if the volume of discharge is reduced proportionately more, the end effect on the receiving body is an overall lowered concentration after thorough mixing. However, the underlying premise to this approach, that the discharge volume is insignificant to the receiving volume, is invalid in many mining areas in Appalachia. Mines are frequently at or near the headwaters of streams and discharges from the mines constitute a substantial portion of stream flow, or even its entirety. Under such conditions, discharge at a higher concentration, even though the total load may be reduced, can be lethal to an impaired stream.

The mass of coal ash placement does not seem to be scaled in any way to severity of the AMD problem at sites. At the one extreme, as discussed above, there is no requirement that alkaline addition in AMD abatement projects be sufficient to reduce acidity of discharges at all. At the other extreme, placement mass in the millions of tons are approved for sites that do not appear to be significant producers of AMD. The **Cambria Ernest Mine** serves as an example. McKee Run is the stream that receives drainage from the AMD abatement area. Background data in the permit shows upstream pH in McKee Run distributed around a median value of 6.5 s.u. over a 19 month period in 1994 and 1995. Downstream of the AMD area, the median pH for the same period of record was 6.0 s.u. The median decline in pH was 0.6 s.u. during this period of record, and on two occasions, the downstream pH was higher than the upstream pH. The minor degradation of the stream is a reflection of the measured AMD discharge. Although 12 points representing several dozen individual seeps were identified for purposes of delineating the proposed abatement area, the cumulative median flow of these discharges is less than 11 gpm. The plan that is being implemented to abate 11 gpm is to place millions of tons of coal ash on the site; a cure that seems somewhat out of scale with the disease. It increases the irony that this site is among those where the discharges have gotten worse, not better, since placement started.

Finally, it is clear that customized abatement programs, designed to address the specific problems and conditions at an individual site are neither the goal nor the result of the Pennsylvania program. The following excerpts from three of the permits reviewed illustrate this point.

> Following the removal of coal and all associated pit cleanings from each block, CFB ash will be spread over the entire pit floor. Following the blasting of material on a block of overburden to be stripped, CFB ash will be spread on the blasted material in order to incorporate it into the spoil as it is mined. In accordance with the procedures outlined in Module 10.9, CFB ash will be added to the "pods" of material that are special handled. – from **54 Job** permit

> Following the removal of coal and all associated pit cleanings from each block *[reference to a particular coal seem]*, CFB ash will be spread over the entire pit floor. Following the blasting of material on a block of *[reference to a particular coal seem]* overburden to be stripped, CFB ash will be spread on the blasted material in order to incorporate it into the spoil as it is mined. In accordance with the procedures outlined in Module 10.*8*, CFB ash will be added to the "pods" of material *[reference to a particular coal seem]* that are to be special handled. – from **Lucerne No. 2** permit
>
> Following the removal of coal and all associated pit cleanings from *[reference to a particular coal seem]*, CFB ash will be *trucked directly into the pit and* spread over the entire pit floor. Following the blasting of material on a block of overburden to be stripped, CFB ash will be *trucked in and* spread on the blasted material in order to incorporate it into the spoil as it is mined. [Details "pod" placement that are in Modules 10.9 and 10.8 of above examples] – from **McDermott Mine** permit

The use of boilerplate design and language is not coincidental; it is a stated policy by the PADEP. Under the Reclaim PA program, the Remining Permitting Improvements initiative explicitly calls for the development of standard plans "in place of site-specific designs" to reduce the cost and time of permitting for operators (Seif, 2000). It is almost certainly significant that two of the three examples cited above, the **McDermott Mine** and **Job 54,** are similar not only in their coal ash placement designs, but also in the similar contamination problems that required similar treatment of discharge as a corrective action. Further, when a regulatory agency writes standard permit plans for permit applicants, the role as overseer has been destroyed.

**PPW Placement outside of Minefilling - the Expanding General Permit Program**

Pennsylvania now implements programs for the placement of PPWs in a virtually unlimited variety of settings outside of minefilling or AML reclamation. The permitting process with respect to the PPW is essentially parallel to that for mine-associated placement. A particular PPW is tested using an index leaching test and elemental analysis. Based upon the leaching test, the waste stream can receive certification for use in a statewide General Permit for "beneficial use". As with placement in the mining program, *beneficial use* is most often synonymous with *fill*. If the use has permeability or strength requirements, other appropriate testing of physical parameters may be required; *e.g.*, geotechnical parameters if used as embankment fill for roads.

The concerns with the General Permit program for PPW placement are essentially those that are described in this report for the mine-placement program. The acceptance of an index leaching test as the criterion for the safety of the material for unconfined placement in the environment is unwarranted and counter to a vast body of observational data. Site characterization of the placement area is inadequate, if it is even required. There is typically no monitoring required in the General Permit to determine if, when, or where there are impacts from the placed material. There are no trigger levels, no stipulated corrective actions and there is no financial assurance related to environmental performance.

The inadequacy of this approach is driven home by consideration of the first PPW to receive certification under the General Permit program. This certification was based upon the benign appearance of the leaching test for the PPWs from the Elrama plant south of Pittsburgh. PPW from the Elrama plant that is not placed under the General Permit system is disposed in a permitted, unlined landfill called Fern Valley. Leachate from this landfill has severely degraded both ground and surface water in Fern Valley and has impacted biota in the draining stream. This contamination occurs where there are no receptors of the ground and surface water contamination except the Monongahela River, which offers a perceived acceptable dilution factor. This same waste can now be used across the State at environmentally healthy sites that undergo no characterization, have no monitoring systems, and usually have no diluting river to reduce the dangers.

The justification for this program is the declared "success" of the mine placement program. It relies on the unjustified, but oft-repeated, assertion that PPW placement in mines is universally an improvement for the mining environment or neutral to the mining environment. In simplest terms, the General Permit system allows unconfined land-disposal of PPWs away from the point of generation with no management or regulatory protections. These are exactly the same settings that have become the nation-wide damage cases, from exactly the same wastes.

Yet another thread to this burgeoning Pennsylvania program is that non-mining and mining sites that are targeted for placement of PPWs are now also being targeted for placement of other high-volume wastes under General Permits. These include cement kiln and lime kiln dusts and harbor and river dredgings. In some cases, previously defined contaminant concentration limits for these wastes are being waived, based on the results of the same inappropriate index leaching tests and the “success” of the mine placement program.

## References

BMR, 1997, "Alkaline Addition for Surface Coal Mines", Document Number 563-2112-217, Pennsylvanian Department of Environmental Protection, Bureau of Mining and Reclamation, Effective Date June 30, 1997.

BMR, 1998a, "Certification Guidelines for Beneficial Uses of Coal Ash", Document Number 563-2112-224, Pennsylvanian Department of Environmental Protection, Bureau of Mining and Reclamation, Effective Date April 30, 1998.

BMR, 1998b, "Technical Guidance Document for Beneficial Uses of Coal Ash", Document Number 563-2112-225, Pennsylvanian Department of Environmental Protection, Bureau of Mining and Reclamation, Effective Date April 30, 1998.

Hawkins, Jay W., 1995. Characterization and Effectiveness of Remining Abandoned Coal Mines in Pennsylvania. Report of investigations 9562, U. S. Department of Interior, 37 p.

Loop, Caroline M, B. E. Sheetz, and W. B. White, 2002, "Surface Mine Pool Reclamation with Direct Ash Placement", in 2002 National Meeting of the American Society of Mining and Reclamation, ASMR, Lexington KY, June 9-13, 2002.

Milavec, Pamela J., undated, "Abandoned Mine Drainage Abatement Projects: Successes, Problems and Lessons Learned", Bureau of Abandoned Mine Reclamation, on PADEP website at http://www.dep.state.pa.us/dep/deputate/minres/bamr/bamr.htm, last revised 1/17/03.

Mukherjee, Ajoy K., 2002, "Coal Combustion Ash (CCA) Disposal in a Pennsylvania Surface Mine Site And Its Non-beneficial Impacts on Ground Water Flow Regime: a Degradation Experience", in Proceedings of Coal Combustion By-Products and Western Coal Mines: An Interactive Forum, Appendix II, USDI OSM and Coal Research Center, Southern Illinois University - Carbondale, Denver Colorado, April 16-18, 2002.

Murarka, Ishwar P., T. E. Bailey and J. R. Meiers, 2002, "Water Quality at a Coal Ash Filled Surface Coal Mine Pit in Indiana", in Proceedings of Coal Combustion By-Products and Western Coal Mines: An Interactive Forum, USDI OSM and Coal Research Center, Southern Illinois University - Carbondale, held in Denver Colorado, April 16-18, 2002.

PADEP, undated(a), Coal Mine Drainage Prediction and Pollution Prevention in Pennsylvania, website at http://www.dep.state.pa.us/dep/deputate/minres/districts/cmdp/main.htm, last revised 7/30/2002.

PADEP, undated(b), "The Science of Acid Mine Drainage and Passive Treatment", website at http://www.dep.state.pa.us/dep/deputate/minres/bamr/amd/science_of_amd.htm, last revised 4/5/2002.

PADEP, 2001, “New Remining and Reclamation Technologies”, website at http://www.dep.state.pa.us/dep/deputate/minres/reclaimpa/newtech.html, last revised 4/16/2001.

SAIC, 2003, “Site Visit Report, Coal Combustion Waste Minefill Management Practices – Pennsylvania –, Draft Report, March 19, 2003.

Scheetz, Barry E., M.J. Menghini, R.J. Hornberger, T.D. Owen and J.H. Schueck, 1997, “Beneficial use of coal ash in anthracite and bituminous mine reclamation and mine drainage pollution abatement in Pennsylvania”, in: Proceedings, Air and Waste Management Association’s 90th Annual Meeting and Exhibition, June 8-13, Toronto, Ontario, Canada.

Seif, James M., 2000, “Pennsylvania’s Abandoned Mine Reclamation and Well Plugging Program Status Report”, April 2000, on PADEP website at http://www.dep.state.pa.us/dep/deputate/minres/reclaimpa/Status_files/status.pdf, last revised 4/23/2003.

Vories, Kimerly, 2002a, “Coal Mining and Reclamation with Coal Combustion By-Products: An Overview”, in Proceedings of Coal Combustion By-Products and Western Coal Mines: An Interactive Forum, USDI OSM and Coal Research Center, Southern Illinois University - Carbondale, held in Denver Colorado, April 16-18, 2002.

Vories, Kimerly, 2002b, “The Surface Mining Control and Reclamation Act: A Response to Concerns About Placement of Coal Combustion By-products at Coal Mines”, in Mine Placement of Coal Combustion Waste Meeting #4, Williamsburg VA, October, 2002, on U. S. EPA website at http://www.epa.gov/epaoswer/other/fossil/meeting4/osm-resp.pdf, last revised 4.17.2003.