THE BENEFICIAL USE AND DISPOSAL OF COAL ASH ON ACTIVE MINE SITES IN PENNSYLVANIA[1]

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Abstract.--Recent statutory and regulation changes of the Department of Environmental Resources have affected the disposal or beneficial reuse of fly ash in Pennsylvania. Act 168, which became effective February 12, 1987, partially deregulates the beneficial reuse of fly ash. While Department approval is still required for a beneficial reuse, the formal permitting procedure has been eliminated. Through changes in Departmental Policy, the permitting procedure for fly ash disposal on mine sites has also changed. When the fly ash disposal site is located on an active mining permit, the responsibility for permitting and inspecting the site has been transferred to the Bureau of Mining and Reclamation (BMR). Surface mining sites, coal refuse disposal sites, and coal refuse reprocessing sites are the three types of mining sites where ash disposal or beneficial use can take place. As of December 1987 the BMR had issued 12 fly ash disposal permits and 2 beneficial use approvals. The number of sites permitted is expected to increase substantially in the future.

INTRODUCTION

Pennsylvania produces approximately 6 million tons of fly ash annually from coal-burning power plants. In addition, the "haul back" of fly ash from out-of-state power plants has the potential for further increasing the total volume of ash that must be disposed of in Pennsylvania. Pennsylvania also has over 17,000 acres of refuse banks left over from previous deep mining and preparation plant operations. This coal waste is suitable for burning in modern fluidized bed combustion (FBC) boilers. Recent changes in the Public Utility Regulatory Policy Act, favorable tax advantages for waste to energy plants, along with improved technology for coal waste-fired energy projects, have made these unsightly coal waste piles an important source of energy and economic development for the coal regions of Pennsylvania. Fly ash disposal has created environmental questions regarding the location and method of fly ash/bottom ash disposal or beneficial reuse. Active mine sites have been shown to be acceptable locations for both beneficial reuse and disposal (Capp, 1978). The Department's permitting process makes a distinction between beneficial reuse of fly ash, which requires Departmental approval, and fly ash disposal, which requires a formal permit. Permitting and approval of fly ash disposal sites and beneficial reuse of fly ash is the responsibility of the Pennsylvania Department of Environmental Resources (D.E.R.).

FLY ASH DISPOSAL

The Bureau of Mining and Reclamation has been delegated authority for the permitting and inspecting of fly ash disposal sites, when the disposal takes place at an active permitted mine site. The program is administered using the Solid Waste Management Act and corresponding rules and regulations (Chapter 75). This program applies to active surface mine sites, coal refuse disposal sites, and coal refuse reprocessing sites (Program Guidance Manual).

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Disposal is incidental to the mining operation, and the following restrictions apply to surface mine sites: 1) maintaining the approximate original contour in final reclamation; 2) the volume of ash being disposed of cannot exceed the volume of coal removed; 3) the operator must maintain concurrent backfilling; 4) the ash must be non-polluting; and 5) disposal is prohibited from sites that could be potentially sensitive to ash disposal. Sites on public water supply recharge areas, high quality watersheds, and sites with acidic overburden or underlying deep mine discharges generally are not acceptable for disposal. Abandoned pits can be permitted for ash disposal if the area is included on the active surface mine permit area and it can be shown that adequate reclamation of the affected area, including existing spoil ridges, can be achieved. The use of abandoned pits allows for both environmentally acceptable disposal and reclamation of these unsightly areas.

The disposal of fly ash on coal refuse disposal sites is limited to sites where fly ash is less than 50% of the total disposal volume. Fly ash disposal may be permitted at coal refuse disposal sites with collection and treatment of leachate or sites utilizing natural soil attenuation. Sites utilizing soil attenuation depend on the cation exchange capacity of the soil to tie up any metals in the leachate.

The disposal of fly ash on coal refuse reprocessing sites is limited to sites where there will be no increase in the total volume of material on site, and no reconstruction of large surface piles. The ash and the disposal location must also be environmentally acceptable.

PERMITTING PROCESS

The permitting process that is followed for fly ash disposal is an extension of the mining permit application procedure. An additional module (number 25), to be completed along with the mining permit application, has been developed and includes information on the chemical characteristics of the ash, its leachability, an operation plan for the disposal area, and ground water hydrology and quality information. Table 1 lists the required solids analysis and typical bituminous fly ash values. The EP Toxicity Extraction Procedure, which simulates an acid environment, is used to analyze the leaching potential of a particular waste stream. While no laboratory test procedure can exactly duplicate field conditions, the EP Toxicity Test simulates disposal that would occur in an acid environment possible on mine sites. Actual field conditions could produce leachate at higher or lower concentrations (L.L. Labuz, 1986). Table 2 lists the required leachate analysis parameters for the EP Extraction Procedure.

Table 1

Table 1.--Listing of parameters to be included in the ash chemical analysis of solids, with typical bituminous fly ash values.*

Parameter	mg/kg
Aluminum	140,000
Arsenic	175
Barium	900
Boron	300
Cadmium	10
Chromium	225
Iron	125,000
Lead	200
Manganese	350
Mercury	0.5
Nickel	250
Selenium	145
Copper	200
Molybdenum	50
Zinc	300

*adapted from Adriano, et al. 1980., L. L. Labuz, et al. 1986., and D. W. Weeter and M. P. Bahor 1979.

Table 2.--Listing of parameters to be included in ash leachate analysis (mg/l).

pH	Iron
Cyanide	Lead
Sulfate	Manganese
Phenolics	Mercury
Aluminum	Nickel
Antimony	Selenium
Arsenic	Silver
Barium	Copper
Boron	Molybdenum
Cadmium	Zinc
Chromium	

Total Organic Halogen
Chemical Oxygen Demand
Total Organic Carbon

The ground water at a fly ash disposal site is monitored before and during the disposal operation to insure that the site is suitable for fly ash disposal, to provide for early detection of potential ground water pollution, and to insure that ground water pollution does not occur. The background water quality monitoring submitted with the permit application must include up and down gradient monitoring points with a minimum of six samples analyzed at monthly intervals for each point. All six samples are analyzed for mine drainage parameters (table 3), and at least one of the six samples must include analysis of the additional parameters (table 4). Fly ash disposal is not permitted at sites with polluted ground water, unless disposal would have a positive affect on water quality. This could apply on abandoned sites, where backfilling with fly ash could reduce surface water contributions to underlaying acid producing deep mine discharges.

Table 3.--Listing of basic mine drainage parameters required for ground water monitoring.

pH	Manganese
Specific Conductance	Aluminum
Alkalinity	Sulfate
Acidity	Suspended Solids
Iron	Total Dissolved Solids

Table 4.--Listing of additional ground water quality parameters required for ground water monitoring.

Arsenic	Calcium
Barium	Magnesium
Cadmium	Chloride
Chromium	Phenol
Fluoride	Sodium
Lead	Ammonical Nitrogen
Mercury	Potassium
Nitrate Nitrogen	Copper
Selenium	Zinc
Silver	

The operational plan for the disposal site must be designed to minimize the potential for environmental degradation. Upslope runoff must be diverted away from the disposal area and site runoff must be controlled and treated, where necessary. The disposal area must be a minimum of 8 ft away from the permanent ground water table, the pit floor, highwall, and low wall. A suitable fine grained renovating material, other than topsoil or subsoil, is to be reserved or stockpiled for the area beneath the waste material, to attenuate any leachate that is formed. This material shall be a minimum of 8 ft in thickness.

The fly ash must be compacted to 90% of the Modified Proctor Test density to reduce the leaching potential at the site. The permeability of compacted fly ash has been shown to range from very low (10^{-7}cm/sec.) to low (10^{-4}cm/sec.) (G.A.I. Consultants, 1986). Fly ash is very easy to compact when the moisture content is maintained within 3-4% of the optimum (typically 17-20%). To minimize dusting during hauling and placement, the ash is typically conditioned at the plant with the addition of water. Simple testing will allow the optimum moisture content range to be achieved in the ash conditioning process. At the mine site the ash is required to be placed in lifts of 2 ft maximum and compacted with a vibratory or rubber-tired roller. Haulage equipment can often be utilized to obtain the desired compaction.

The ash solids analysis, leachate analysis, background water quality information, and operational plan are reviewed before a final decision is made on an application. On approvable sites the mining permit is revised to include fly ash disposal.

BENEFICIAL USE OF FLY ASH

The physical and chemical properties of coal ashes are dependent on the coal's geological origin, combustion conditions, efficiency of particulate removal, and degree of weathering before disposal or usage. Coal residues, applied on cropland, are not practical sources of essential plant nutrients: nitrogen, phosphorus, and potassium; however they can effectively serve as a supplementary supply for plant nutrients such as calcium, sulfur, boron, and molybdenum. Fly ash can also be an effective amendment in neutralizing soil acidity (Adriano, et al. 1980). The alkalinity of a fly ash is related to the sulfur content of the raw coal. The pH of coal ashes has been shown to range from a low of 4.5 to as high as 12.0 (Plank and Marsten, 1974).

Alkaline fly ashes have high calcium carbonate equivalency. This alkalinity and small particle size make these ashes attractive for use as a liming substitute or for improving the physical properties of soil at sites with acidic coarse textured soil. Other potential benefits of utilizing fly ash in reclamation include - providing fines for seedbed improvement and to increase plant available moisture retention, improving the soil bulk density, and providing plant micronutrients. These uses are appropriate on coal refuse reprocessing or remining sites, where sufficient topsoil material is not available.

The accumulation of boron, molybdenum, selenium and soluble salts in fly ash amended soils appear to be the most serious constraints associated with land application of fly ash to soil. Boron, Mo, and Se from the fly ash are readily accumulated in the plant tissue in significant quantities. High boron and soluble salts concentrations in the soil can be toxic to growing plants, whereas high Mo and Se uptake by plants are potentially hazardous to foraging animals.

Total boron concentrations in fly ash range from 48-618 ppm (Baker and Chesnin, 1975). Soils normally contain 4 to 88 ppm total boron (Capp, 1978). The saturation extract procedure (Bingham, 1982) has been found to be the best indicator for potential boron toxicity (Keren and Bingham, 1985). Saturation extract concentrations of boron in solution above 1 ppm are toxic to sensitive species. Boron as measured by the hot water soluble test is considered toxic above 20 ppm.

High fly ash applications to soils can increase molybdenum levels in forage crops to levels potentially toxic to animals feeding on the forage. Higher soil pH can increase the availability of soil molybdenum (Doran and Martens, 1972). Molybdenum concentrations ranging from 5 to 20 ppm are potentially hazardous (Alloway, 1968). The oxalic acid extractable test procedure is used to determine molybdenum

soil concentrations (Reisnauer, 1965). Plant uptake analysis testing of Mo, Cu, and other potentially toxic metals should be undertaken before allowing extensive grazing.

Total selenium concentrations in the soil mixture ranging over 4 ppm are potentially hazardous, particularly to close grazing animals (Alloway, 1968). However because plants can accumulate toxic levels at soil levels below 4 ppm, it is advisable to test crops before feeding to livestock.

Unweathered fly ash can contain appreciable soluble salts that can be phytotoxic. Soluble salts levels are measured by electrical conductivity, however there are different ways of preparing the soil prior to the test. One method, which is utilized by Pennsylvania State University, performs the test on a 2:1, water:soil, extract. Ash/soil mixtures measuring more than 1.5 mmho/cm, with this test procedure, are not considered suitable for the establishment of most species adapted to soils of Pennsylvania. The electrical conductivity of fly ashes, measured with the water:soil extract procedure, ranged from 1.5 to 2.3 mmho/cm. Coal mine refuse generally ranges from about 0.5 to > 3.0 mmho/cm, while surface mine spoils range from 0.2 to about 2.0 mmho/cm (Capp, 1978). The result of mixing soil and fly ashes with differing soluble salts levels is generally positive, although it can not be predicted from the individual components. Recent literature (Rhodes, 1982) indicates that the saturation extract procedure, where water is added to form a paste, is a better indicator for soil/fly ash mixtures containing gypsum. Soluble salts, as measured by electrical conductivity of a saturation extract of the soil, should be maintained at a level below 4 mmho/cm, unless documentation is provided that species are tolerant at higher levels.

A proposal for beneficial use is submitted to the Bureau's District Mining Office for approval. It must include a justification for use; a description and location of the proposed activity; application rates; consent from property owners; a complete chemical and leachate analysis of the ash (tables 1 and 2); information on the existing soil or on site material; a description of the method of mixing, blending, and incorporating of the fly ash; and an analysis for pH and fertilizer requirements of the soil/fly ash mixture.

This information is needed to assess the potential environmental consequences of the surface application of the fly ash. Potential problems that must be given adequate consideration include pollution of surface or ground water, and toxicity to plants and grazing animals.

Soil tests of the existing soil are necessary to determine plant nutrient levels. This test is part of the normal mining application procedure and will help document the justification for fly ash utilization. As part of this test, the calcium carbonate equivalency of the ash should be determined. When a fly ash with low calcium carbonate equivalency is applied to acidic soils, the addition of agricultural limestone is necessary.

Various laboratory test procedures are undertaken to determine proper application and mixing rates. To insure an optimum plant growth environment and to reduce the potential for mobilization of heavy metals, the pH of the soil/fly ash mixture should be maintained between 6.5 and 7.0 (Baker and Amacher, 1981). As the ash will react chemically with the soil, the proper ratio of fly ash to soil is determined by mixing different amounts of the two constituents and measuring the resulting pH. To insure that chemical equilibrium of the two constituents has been reached, the sample is subjected to at least two wetting and drying cycles before the pH is determined (Buck and Houston, 1986). Other ash constituents such as metals can also cause problems. A Baker Soil Test for Mn, Fe, Cu, Zn, Na, Al, Pb, Ni, and Cd and a total sorbed metals test for Cu, Zn, Pb, Ni, Cd, and Cr should be performed on the fly ash/soil mixture (Baker and Amacher, 1981). The Baker Soil Test is a measure of metals and other constituents that are available to the plants. The sorbed test measures what is potentially soluble in the soil. The solids analysis required in Module 25 is a digestive procedure that measures the total amount contained in the ash.

Due to plant toxicity and food chain uptake concerns, the soil/fly ash mixture tested as described in the text shall fall within the following limits.

Boron	<	20 ppm
Molybdenum	<	5 ppm
Selenium	<	4 ppm

Safe levels of metals loading have been determined for land reclamation sites where sewage sludge is utilized (Baker, et al. 1984). These loading restrictions have been adapted for fly ash beneficial use sites. The following are Pennsylvania's standards for maximum lifetime heavy metals loading rates for nonagricultural land reclamation sites.

Cadmium	3	lb/acre
Copper	100	lb/acre
Chromium	100	lb/acre
Lead	100	lb/acre
Mercury	0.5	lb/acre
Nickel	20	lb/acre
Zinc	200	lb/acre

The metals loading rates for agricultural purposes are lower than those for land reclamation. The following are typical background soil constituent levels. Comparison of the composition of the ash with the composition of the soil to be amended is another useful check in determining proper mixing rates.

Table 5.--Typical levels of the constituents of background soil (ppm)*.

	usual range	typical
Aluminum	5,000-32,000	-
Arsenic	1-50	5
Barium	100-3,000	500
Boron	2-100	10
Cadmiun	0.01-0.7	0.5
Chromium	5-1,000	200
Iron	14,000-40,000	-
Lead	2-2,000	10
Manganese	200-3,000	850
Mercury	0.03-0.3	0.03
Nickel	5-500	40
Selenium	0.01-2.0	0.01
Copper	2-100	20
Molybdenum	0.2-5	2
Zinc	110-300	50
Sulfur	100-1500	850
Calcium	0.7-50	-

*adapted from Baker and Chesnin, 1975.

The Bureau of Waste Management has formulated an Interim Policy for Beneficial Use of Residual Waste. The following is an excerpt of the sections that apply to the use of coal ash as a soil substitute or soil additive.

INTERIM POLICY FOR THE BENEFICIAL USE OF RESIDUAL WASTE

PURPOSE

This policy was developed to address requests for exemptions from the residual waste permit requirements through a beneficial use determination by the Bureau of Waste Management. This policy also implements Act 168 of 1986, relating to the beneficial use of coal ash.

This policy will remain in effect until the Bureau promulgates its new residual waste regulations, scheduled for mid-1988.

SCOPE

(a) This policy sets forth beneficial uses of residual waste, including coal ash, and describes all notice requirements, design and operating standards, and siting criteria that are applicable to such beneficial uses.

(b) This policy applies only to those constituents of residual waste that are used or proposed to be used for a particular beneficial purpose in lieu of a marketable product, including a raw material or a finished product. This policy does not apply to residual waste landfills, residual waste disposal impoundments, the land application of residual waste, or any process that requires a residual waste processing permit under the Solid Waste Management Act.

(c) No beneficial use of residual waste shall be required to obtain a permit from the Department under the Solid Waste Management Act if such use complies with the provisions of this policy. However, any beneficial use of coal ash at a solid waste management facility for the disposal of solid waste, including coal ash, shall be subject to the requirements of the Solid Waste Management Act and regulations (e.g., coal ash as a cover supplement at a municipal waste landfill).

(d) All beneficial uses of residual waste described in this policy shall be subject to any applicable provisions of the environmental protection acts.

DEFINITIONS

The following words and phrases when used in this policy shall have the following meanings unless the context clearly indicates otherwise:

Beneficial use - Use, reuse, or reclamation of a material for commercial, industrial, or governmental purposes.

Coal ash - Fly ash, bottom ash, or boiler slag resulting from the combustion of coal.

Soil additive or soil substitute - The land application of coal ash, at specified loading or application rates, to replace soil that was previously available at the site or to enhance soil properties. The term does not include structural fills, valley fills, the use of coal ash to fill open pits from coal or noncoal mining, or the disposal of coal ash.

Structural fill - The engineered use of coal ash as a base or foundation for a construction activity that is completed promptly after the placement of the coal ash. The term does not include valley fills, the use of coal ash to fill open pits from coal or noncoal mining, or the disposal of coal ash.

Water source - The site or location of a well, spring, or water supply stream intake that is used for human consumption.

Wetland - Those areas which are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a

prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include, but are not limited to: swamps, marshes, bogs and similar areas. The term includes but is not limited to wetland areas listed in the State Water Plan, the United States Forest Service Wetlands Inventory of Pennsylvania, the Pennsylvania Coastal Zone Management Plan, and any wetland area designated by a river basin commission.

POLICY AND PROCEDURE

Section. Use of coal ash as a soil substitute or soil additive.

(a) Coal ash may be beneficially used as a soil substitute or soil additive without a permit from the Department under the Solid Waste Management Act if the person or municipality proposing such use complies with the provisions of this section.

(b) This section applies to any person or municipality that uses or proposes to use coal ash as a soil substitute or soil additive, whether or not such use of coal ash is part of an operation that requires a permit from the Department under the Surface Mining Conservation and Reclamation Act, 52 P.S. Sections 1396.1-.31, the Coal Refuse Disposal Control Act, 52 P.S. Sections 30.51-.66, or the Noncoal Surface Mining Conservation and Reclamation Act, 52 P.S. Sections 3301-3326.

(c) At least 60 days before the proposed use of coal ash as a soil amendment, the person proposing such use shall submit a written notice to the Department. The notice shall contain at a minimum:

(1) A description of the nature, purpose, and location of the project, including a topographic map showing the project area, including any wells, springs, streams, and wetlands within 1/4 mile and any soils maps of the project area. The description shall include an explanation of how coal ash will be stored prior to use, how the soil will be prepared for the application of the coal ash, how coal ash will be spread and, how ash will be incorporated into the soil.

(2) The estimated beginning and ending dates for the project.

(3) An estimate of the volume of ash to be used for the project, and the proposed application rate.

(4) A chemical and leaching analysis for the ash to be used in the project. If the coal ash was generated at a facility for which the Department has previously approved a chemical and leaching analysis, the person may submit a copy of the analysis that was approved.

(5) A chemical analysis of the soil on which the ash is to be placed.

(6) An analysis showing how the application will be beneficial to the productivity or properties of the soil to which it is to be applied. The analysis shall be prepared and signed by an expert in soil science or agronomy.

(7) A signed statement by the owner of the land on which the coal ash is to be placed, acknowledging and consenting to the use of fly ash as a soil amendment.

(d) Coal ash used as a soil substitute or soil additive shall not be considered a beneficial use unless all of the following requirements are met:

(e) After receiving the information required by subsection (c), the Department may inform the person or municipality that provided the information whether the proposed usage is consistent with the requirements of this section.

(1) The person or municipality has provided to the Department the information required by subsection (c) at least 60 days before using coal ash as a soil substitute or soil additive.

(2) The pH of the coal ash and the pH of the soil shall each be in the range of 6.5 to 8.0 when mixed together in the manner required by the project, as shown by field and laboratory testing. Lime addition may be used to raise pH.

(3) No slope on which coal ash has been placed shall exceed 15%, except that the Department may allow slopes of up to 20% in writing.

(4) Surface runoff from the project area shall be controlled during the project. Collection of surface runoff shall be controlled in accordance with The Clean Streams Law and the regulations promulgated pursuant thereto.

(5) Surface water shall be diverted away from the disturbed area of the project.

(6) The person or municipality conducting the activity shall have a Department approved erosion and sedimentation control plan in accordance with Chapter 102 (relating to erosion and sedimentation control.

(7) Coal ash shall not be placed within 4 feet of the seasonal high water table.

(8) Coal ash shall not be placed within 8 feet of the permanent ground water table.

(9) Coal ash shall not be used so as to cause ground water pollution, contamination, or degradation.

(10) Coal ash shall be incorporated into the soil within 48 hours of application.

(11) Coal ash shall be applied at a rate per acre that will protect public health, public safety, and the environment.

(12) Coal ash shall not be applied to any soil currently being used for agriculture where the soil pH is less than 5.5.

(13) Coal ash shall not be applied if resultant chemicals or physical soil conditions would be detrimental or toxic to biota.

(f) Except as provided in subsection (g), coal ash may not be used as a soil substitute or soil additive:

(1) Within 100 feet of any intermittent or perennial stream.

(2) Within 300 feet of any ground water source.

(3) Within 500 feet upgradient of any surface drinking water source.

(4) Within 100 feet of any sinkhole or area draining into a sinkhole.

(5) Within 300 feet measured horizontally from any occupied dwelling, unless the current owner thereof has provided a written waiver consenting to such activities closer than 300 feet. The waiver shall be knowingly made and separate from a lease or deed unless the lease or deed contains an explicit waiver from the current owner.

(6) Within 300 feet of any important wetland, except as provided in 25 Pa. Code Section 105.7 (relating to important wetlands).

(g) If the applicant can affirmatively demonstrate to the Department that the coal ash does not contribute to environmental degradation comparative to the background soil, the Department may modify the isolation distances set forth in subsection (f).

Departmental approval for the beneficial use of fly ash on active mine sites is considered as a permit revision. As such the existing permit is amended to include ash utilization conditions.

CASE STUDIES

The two case studies which follow illustrate the successful use of fly ash as a soil amendment in revegetating active coal waste mining sites..

Harwood Coal Waste Site

The 10-acre Harwood Site, located near the city of Hazleton in northeastern Pennsylvania, was used as an anthracite refuse storage area for an abandoned coal-fired generating station owned by Pennsylvania Power and Light Company (P.P. & L.). The coal fines were removed by P.P. & L. in 1984. As required by Departmental regulations, P.P. & L. was responsible for reclamation of the site.

To determine the feasibility for beneficial use at this and other sites and to reduce reclamation costs, P.P. & L. decided to utilize fly ash from their Montour County bituminous fired generating station as a soil amendment. The remaining on-site waste material had a typical pH of 4.0, high coarse fragment content, and poor moisture retention. The ash from the Montour generating station had a pH of 6.0, excellent fine fragment content, and when combined with on site material would provide excellent moisture retention. The soluble salts level of the ash was very high in some samples (1.5-2.0 mmhos/cm. in a 2:1 water/soil extract), and boron, molybdenum and selenium levels were also very high (18.2, 35.4, and 6.4 ppm, respectively) (Buck, 1988).

Mixtures of fly ash and coal waste were made in the laboratory to determine the near equilibrium chemistry of the mixture. From these tests, an application rate of 230 tons/acre (17% moisture) was determined. The 230 tons/acre corresponds to a 2-inch thick applied depth of fly ash over the entire site. With this application rate and incorporation to a 10-inch plow depth, the soluble salts, molybdenum, selenium and boron concentrations were kept to within allowable Departmental standards.

Incorporation was achieved with a chisel plow during August 1984. Success of the vegetation has been excellent to date. Monitoring of the surface ground water at the site, which is being studied until June 1988, has not shown any negative affects of the ash usage. The pH of the surface water has increased from a pH of 3.4 before reclamation to nearly neutral values. Since metal solubility is reduced at neutral pH's, concentrations of aluminum, copper, iron, manganese, and zinc in the surface water runoff from the site have decreased significantly.

Brook Contracting Coal Waste Site

Another coal refuse reprocessing site where fly ash has been utilized in reclamation is the Brook Contracting site, located in the boroughs of Summit Hill and Lansford, Schuylkill County, Pennsylvania. The existing refuse material had a pH of 4.6. Laboratory tests determined that a 100 tons/acre application rate of P. P. & L. Montour Station fly ash, combined with an application of 2 tons/acre of agricultural limestone would yield a soil pH of 6.5. The ash and limestone was applied, incorporated, mulched, and seeded in April 1987. Revegetation success has been good. With the exception of manganese (6.15 mg/l), analysis of runoff samples has shown metal loadings to be below acceptable drinking water standards. The high manganese concentrations in the coal waste, not the fly ash application, was likely responsible for the elevated concentrations.

SUMMARY AND CONCLUSION

While the percentage of fly ash and bottom ash utilized for commercial or construction purposes has increased significantly, the amount that still must be disposed of is in the range of 6 million tons annually in Pennsylvania alone. The Pennsylvania Department of Environmental Resources has revised its coal activities permitting procedures to allow for a timely review of applications to dispose of fly ash on mine sites or utilize fly ash in reclamation activities. While not all mining sites or fly ashes are suitable for these activities, the new procedures are useful in identifying environmentally acceptable disposal sites and beneficial use sites.

LITERATURE CITED

Adriano, D., A. L. Page, A. A. Elseewi, A. C. Chung, and I. Straughun. 1980. Utilization and disposal of fly ash and other coal residues on terrestrial ecosystems: a review. Journal of Environmental Quality 9:333-344.

Alloway, W. H. 1968. Agronomic controls over the environmental cycling of trace elements. Adv. Agron. 20: 235-274.

Baker, D. E., and M. C. Amacher. 1981. The Development and Interpretation of a Diagnostic Soil Testing Program. Bulleti No. 826. The Pennsylvania State University, Agricultural Experiment Station, University Park.

Baker, D. E., D. R. Bouldin, H. A. Elliott, J. R. Miller, et al. 1984. Criteria and Recommendations for Land Application of Sewage Sludge in the Northeast. Bulletin No. 851. The Pennsylvania State University, Agricultural Experiment Station, University Park.

Baker, D. E., and Leon Chesnin. 1975. Chemical monitoring of soils for environmental quality and animal and human health. In Advances in Agronomy, Vol. 27, Academic Press, N.Y.

Bingham, Frank T. 1982. Boron. In Methods of Soil Analysis, Part 2 - Chemical and Microbiological Properties, Second edition. Page (ed.), American Society of Agronomy, Madison, Wisconsin.

Buck, J. K., and R. J. Houston. 1988. Direct revegetation of anthracite refuse using coal fly ash as a major soil amendment. 1988 Mine Drainage and Surface Mine Reclamation Conference, U.S. Bureau of Mines.

Buck, J. K. 1987. Direct (soil-less) revegetation of anthracite waste using coal fly ash as a major soil amendment. Proceedings: Eight International Ash Utilization Symposium, Electric Power Research Institute.

Buck, J. K.,and R. J. Houston. 1986. Direct revegetation of four coal waste sites in Pennsylvania - four approaches. In Innovative Approaches to Mined Land Reclamation. Carlson and Swisher (Eds.), Southern Illinois University Press, Carbondale, Ill.

Capp, J. P. 1978. Power plant fly ash utilization for land reclamation in the eastern United States. In Reclamation of Drastically Disturbed Lands. Schaller and Sutton (eds.), American Society of Agronomy, Madison, Wisconsin.

Chapter 75. Solid Waste Management Rules and Regulations, Pennsylvania Code.

Davies, W. M., E. W. F. Gillham, and D. T. Simpson. 1971. An economic investigation into farming on land restored with pulverized fuel ash. J. Br. Grossl. Soc. 26: 225-30.

Doran, J. W., and D. C. Martens. 1972. Molybdenum availability as influenced by application of fly ash to soil. J. Environ. Qual. 1: 186-189.

G.A.I. Consultants. 1986. Fly Ash Design ual For Road and Site Applications. Electric Power Research Institute, Palo Alto, CA.

Keren, R. and F. T. Bingham. 1985. Boron in water, soils and plants. Advances in Soil Science 1:229-276.

Labuz, L. L., J. F. Villaume and J. W. Bell. 1986. Leachate composition at an experimental test cell of coal combustion fly ash. Proceedings: 1986 Materials Research Society Symposium.

Module 25 Fly Ash/Bottom Ash Disposal, addendum to surface mining permit application, Bureau of Mining and Reclamation, Pa. Dept. of Environmental Resources.

Plank, C. O. and D. C. Martens. 1974. Boron availability as influenced by application of fly ash to soil. Soil Sci. Soc. Am. Proc. 38: 974-977. http://dx.doi.org/10.2136/sssai1974.03615995003800060038x

Program Guidance Manual, fly ash/bottom ash disposal at active mine sites, Section II, Part 02, Subpart 06, Bureau of Mining and Reclamation, Pa. Dept. of Environmental Resources.

Reisnauer, H. M. 1965. Molybdenum. In Methods of Soil Analysis, Part 2 C. A. Black et al. (eds.) American Society of Agronomy, Madison, Wisconsin.

Rhodes, J. D. 1982. Soluble salts. In Methods of Soil Analysis, Part 2 - Chemical and Microbiological Properties, second Edition. American Society of Agronomy, Madison, Wisconsin.

Weeter, D. W., and M. P. Bahor. 1979. Technical Aspects of the Resourse Conversation and Recovery Act Upon Coal Combustion and Conversion Systems. Oak Ridge National Laboratory. ORNL/OEPA-10.