TECHNICAL REPORT

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Project Title: The use of FBC wastes in the reclamation of coal slurry solids

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ABSTRACT

Fluidized bed combustion (FBC) is a relatively new technology that is used commercially for the combustion of coal. In Illinois, this technology is valuable because it allows the combustion of Illinois high sulfur coal without pollution of the atmosphere with vast quantities of sulfur oxides. In FBC, coal is mixed with limestone or dolomite either before injection into the combustion chamber or in the combustion chamber. As the coal burns, sulfur in the coal is oxidized to SO_2 and this is trapped by reaction with the limestone or dolomite to form gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$). Solid by-products from FBC are generally a mixture of calcium oxide, gypsum, coal ash, and unburned coal. The present research project is designed to provide initial data on one possible use of FBC waste. FBC wastes from five different locations in Illinois are mixed with coal slurry solids (CSS) from two different coal preparation plants at Illinois coal mines. In mixtures of FBC waste and coal slurry solids, the alkaline components of the FBC waste are expected to react with acid produced by the oxidation of pyrite in the coal slurry solid. An objective of this research is to determine the chemical composition of aqueous leachates from mixtures of FBC wastes, generated under various operating conditions, and the coal slurry solids. These data will be used in future research into the ability of such mixtures to support seed germination and plant growth. The ultimate of this and future research is to determine whether mixed FBC waste and coal slurry solids can be slurry pond reclamation.

The calcium carbonate equivalent of each FBC waste was determined, and the pyrite content, exchangeable acidity, and calcium carbonate content of two CSS samples were determined. These values are needed in order to calculate the amounts of FBC waste needed to neutralize the acidity produced if all the pyrite in the CSS samples is oxidized. In addition, we determined the particle size distributions of the solid samples, including an agricultural limestone sample, used in some experiments as a control material. The cation exchange capacity of the CSS samples, and the paste pH, and bulk and particle densities were determined for all the FBC wastes and CSS samples. The FBC and CSS samples were sent to a third-party laboratory for testing of leachate for eight metals according to the U.S. EPA toxicity characteristic leaching procedure (TCLP).

Mixtures of FBC wastes or agricultural limestone and CSS samples were prepared for both laboratory leaching experiments and outdoor weathering experiments. Both sets of experiments have begun. Leachates are being collected from the laboratory experiments, but no leachate has yet been collected from the outdoor weathering experiments.

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EXECUTIVE SUMMARY

A major task for this quarter was to determine the amount of each of the five fluidized bed combustion (FBC) wastes to mix with each of two coal slurry solids (CSS) so that the alkalinity of the FBC waste would neutralize the acid produced upon oxidation of all the pyrite in the CSS. To do this required that we know the calcium carbonate equivalent, a measure of the alkalinity, of each FBC waste, the total acid producing potential (calculated from pyrite content and exchangeable acidity) of the CSS samples, and the calcium carbonate content of the CSS samples. The properties were determined, then we calculated the required proportions of FBC:CSS. We wanted to confirm the calculated proportions before setting up experiments, but this effort was becoming a research project in its own right, so this line was terminated. Mixtures of FBC wastes and CSS samples were prepared for both laboratory leaching experiments and outdoor weathering experiments, based on the calculated proportions.

In addition to FBC waste, parallel mixtures were prepared for the laboratory leaching experiments using sized agricultural limestone. The agricultural limestone was sieved into the same particle size ranges as used in determining the particle size distributions of the FBC samples. Portions of agricultural limestone of each size range were weighed out in order to prepare a particle size distribution of agricultural limestone approximating that found for each FBC waste. The mixtures containing agricultural limestone are used as controls to which the behavior of the mixtures containing FBC waste will be compared. Similar mixtures were not prepared for the outdoor weathering experiments, however a mixture of each CSS sample with "as received" agricultural limestone was prepared.

In the laboratory leaching experiments, one pore volume of water is added weekly to each mixture. Leachate is collected at the bottom of each solids container. The leachate is reserved for chemical analyses.

In the outdoor weathering experiments, mixtures of the FBC wastes and the CSS solids were prepared as for the laboratory leaching experiments, but in larger quantities. The containers of solids mixtures were placed outdoors in cabinets with open tops so that the mixtures are exposed to sunlight and precipitation. Leachate-collection bottles are placed in a protected compartment below the sample containers. The mixtures were placed outdoors on January 31, 1992. To date, the mixtures have been exposed to approximately 1.3 inches of precipitation, but no leachate has been collected.

In addition to the above mentioned determinations, the samples have been analyzed by x-ray fluorescence spectrometry for major and minor element composition, their particle size distributions were determined by dry sieving, the bulk and particle densities were determined, paste pH and cation exchange capacities were determined, the calcium speciations in the FBC samples were calculated, and the samples were sent to a third-party laboratory for testing according to the U.S. EPA toxicity characteristic leaching procedure (TCLP) for eight metals in aqueous leachates.

DISCLAIMER

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OBJECTIVES

The overall objective of this proposed research project is to develop an environmentally acceptable method for disposing of coal fluidized bed combustion (FBC) waste. The disposal method under study is to mix FBC waste with coal preparation plant slurry solids in order to prepare a medium suitable for growing plants after the closure of a slurry pond. The overall objective will not be met in one year of research. It will require a laboratory study to characterize the materials, then a greenhouse study conducted under the guidance of a soil ecologist, followed by an agronomic field study at a coal preparation plant.

The scope of the present project is to determine (1) the efficacy of FBC waste in buffering the acidity generated by the oxidation of pyritic coal slurry solids, and (2) the nature and chemical composition of effluent passing through mixtures of FBC waste and coal slurry solids. Another objective is to provide information on the potential leaching of groundwater contaminants, and on the chemical composition of the "soil" solution which, in turn, may determine the types of plants used for reclamation in future studies.

INTRODUCTION AND BACKGROUND

In the fluidized bed combustion of high-sulfur coal, powdered limestone is injected into the fluidized bed to serve as a trap for sulfur dioxide emitted from the coal as a result of combustion. When the sulfur dioxide reacts with the calcium carbonate of the limestone, it forms gypsum. Typically, the limestone is not completely converted to gypsum in the process, so much of the waste material may consist of calcium oxide. However, the waste will also contain mineral matter residue from the combusted coal, and possibly some uncombusted coal.

Presently, most of the fluidized bed combustion wastes from central Illinois are returned to the mine that supplied the coal, presumably for disposal in the backfill, in the case of a surface mine, or in abandoned rooms, in the case of an underground mine. This research project is a laboratory study of the suitability of the fluidized bed combustion waste as a neutralizing or buffering agent in the reclamation of coal slurry solids.

Coal slurry solids arise in the removal of pyrite and rock fragments in the process of cleaning the coal. Fine, pyritic, coaly particles and clay-rich particles are removed from the coal and are discharged in a water stream to a slurry pond. The water is drained from the slurry and it is

recycled. Eventually, the slurry pond reaches its solids-holding capacity and its use has to be discontinued. At this point, the mine operator must reclaim the remains of the pond in some manner.

A possible means of reclamation is to buffer the coal slurry solids with alkaline fluidized bed combustion wastes and grow plants on it to provide some stability against erosion. The major concerns in this application are the leachability of trace inorganic species from the waste into groundwater and the ability of the fluidized bed combustion waste to buffer the potential acidity produced by the oxidation of pyrite in the coal slurry solids. These aspects will be addressed by means of appropriate aqueous extractions of mixtures of five fluidized bed combustion wastes with two coal slurry solids.

EXPERIMENTAL PROCEDURES

One of the major tasks for this quarter was to determine the amount of a given fluidized bed combustion (FBC) waste to mix with a given quantity of coal slurry solid (CSS) to achieve neutralization of the acid that would be produced by the oxidation of all pyrite in the CSS.

To achieve this objective it was necessary to determine:

- (1) the calcium carbonate equivalent of each FBC waste;
- (2) the pyrite content of each CSS;
- (3) the exchangeable acidity of each CSS; and
- (4) the calcium carbonate content of each CSS.

The calcium carbonate equivalent was determined according to ASTM Method C602, Section 14, Procedure for Blast Furnace Slag, Potentiometric Titration Method (ASTM, 1990). In this method, a known volume of dilute HCl is added to a weighed portion of the solid sample. The mixture is heated until the sample has dissolved and the solution has boiled for 5 minutes. The sample is cooled to room temperature, diluted with deionized water, then a small amount of hydrogen peroxide and an indicator are added. Excess HCl is back titrated with dilute NaOH solution while monitoring the pH of the solution potentiometrically, until the solution attains a pH of 4.8 and the pH remains constant for one minute. The weight percentage calcium carbonate equivalent of the solid is calculated based on the volume of HCl consumed in dissolving the sample.

The pyrite content of each of the two CSS samples was determined by oxidizing the pyrite with 30% hydrogen peroxide, then the sulfate and iron concentrations in solution are determined by ion chromatography and atomic absorption spectrometry, respectively.

Exchangeable acidity in the CSS samples was determined according to Method 9-4.2, Potassium Chloride Method (Page, 1982). In this method, exchangeable hydrogen and aluminum ions are displaced from the exchange complex by K^+ ions. The acidic solution is titrated with dilute NaOH solution to obtain total exchangeable H^+ and Al^{3+} . The exchangeable Al^{3+} is complexed with F^- , then excess NaOH is back titrated with dilute HCl solution.

The carbonate content of each CSS sample was determined by means of a Coulometrics carbon analyzer. Carbon dioxide is evolved from the sample by treatment with HCl solution. The evolved CO_2 is then titrated coulometrically. The concentration of CO_2 is then calculated to $CaCO_3$.

The particle size distribution of each of the five FBC wastes, two CSS samples, and one agricultural limestone sample was determined by dry sieving to segregate the particles into seven size ranges: >2000 , 1000-2000, 500-1000, 250-500, 125-250, 62-125, and $<62\mu m$. A portion of the agricultural limestone was divided into the seven particle size ranges for later use in matching the particle size distributions of the five FBC wastes.

The cation exchange capacity (CEC) of the two CSS samples was determined by exchange of potassium for other exchangeable ions. The amount of potassium remaining in solution after exchange was determined by atomic absorption spectrometry. The CEC in meq/100g was calculated from the amount of K^+ sorbed by the sample.

The concentrations of the major and minor elements comprising the FBC wastes, the CSS samples and the agricultural limestone fractions were determined by wavelength-dispersive x-ray fluorescence spectrometry.

Bulk and particle densities of the CSS samples were determined in order to calculate the amount of deionized water to be added each week to laboratory leaching experiments. The bulk density was determined by packing the solid into a tared 1-liter graduated cylinder followed by weighing the cylinder plus solid and measuring the volume occupied by the solid. The solid was packed by lightly tamping the cylinder on the laboratory bench top periodically during the filling operation. The particle density was determined by adding a known volume of water to the graduated cylinder. A known weight of solid was added to the water in the cylinder, then the volume of water was read again. The difference in volume was the volume occupied by the solid particles. In each case, density was calculated by dividing the weight of the solid by the volume it occupied.

Mixtures of FBC waste and CSS were prepared for both the outdoor weathering experiments and the laboratory leaching experiments.

Portions of each FBC waste and CSS sample were sent to Environmental Science and Engineering, Peoria, IL for testing in accordance with the U.S. EPA Toxicity Characteristic Leaching Procedure (TCLP). Determination of the eight metals, arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver in the test leachate was requested. No organic or pesticide determinations were requested.

Other portions of the seven solid samples were submitted to ISGS laboratories for determinations of trace element and mineralogical compositions.

RESULTS AND DISCUSSION

Calcium Carbonate Equivalent. The results of the CCE determinations, CaSO_4 (calculated from XRF results), and calcium carbonate (based on CO_2 determinations) are given in Table 1. Each result for CCE is the mean of three determinations.

The CCE indicates the acid-neutralizing ability of the material. In the case of the FBC samples, the expected acid-neutralizing constituents are CaO , Ca(OH)_2 , and MgO . Most, if not all, of the CaCO_3 , MgCO_3 , or $\text{CaMg(CO}_3)_2$ in the original limestone used in the fluidized bed should have been converted to CaO by loss of CO_2 at the combustion temperature of the process ($\geq 1500^\circ\text{F}$ [$\geq 815^\circ\text{C}$]). The CCE is measured on a weight basis and calculated to a stoichiometrically equivalent amount of CaCO_3 .

Pyrite Determination. The pyrite content in finely ground portions of each CSS sample was estimated by treating each sample with 30% H_2O_2 according to the method of Finkelman and Giffen (1986). The rate of change of pH was monitored during the reaction by means of a strip-chart recorder. The rate curves for samples were compared with rate curves prepared from the H_2O_2 -oxidation of known quantities of pyrite. The concentration of sulfate ion in each sample solution was also determined by ion chromatography.

The sulfate concentration was used to calculate the pyrite contents of the samples by assuming that all the sulfate in solution resulted from the oxidation of pyrite. We later learned from one of the ISGS organic geochemists that, in addition to oxidizing pyrite, H_2O_2 can also oxidize some

organic-sulfur species, which would contribute to the sulfate concentration in solution.

We then repeated the peroxide oxidation treatment of the two CSS samples and determined the iron concentration in solution, with the assumption that all iron in solution resulted from the oxidation of pyrite. The values derived from this procedure were used as our preferred pyrite contents in calculating the acid-generating potential of the CSS samples. The results of the three techniques are shown in Table 2.

The exchangeable acidity and exchangeable aluminum in the two CSS samples are listed in Table 3. The calcium carbonate content of each of the CSS samples is listed in Table 4.

The potential acidity due to oxidation of pyrite in the CSS samples was calculated based on the following overall chemical reaction:

in which 4 moles of acidity is produced for each mole of pyrite oxidized.

The total potential acidity of each of the two coal slurry solids was calculated on a gram-equivalent basis. Total potential acidity was calculated as the sum of the potential acidity due to pyrite oxidation plus the exchangeable acidity less the carbonate content.

The CCE value for each FBC waste sample and the agricultural limestone was converted to millequivalents CaCO_3/g solid. The results of these calculations are given in Table 5.

Finally, the amount of FBC waste or agricultural limestone required to neutralize the potential total acidity produced by each CSS sample was calculated. These results are shown in Table 6. Depending on the CSS sample, the relative amount of FBC required was between 1.4% and 10% of the CSS on a weight basis.

We attempted to confirm our calculations by combining each of the FBC wastes and the agricultural limestone, according to the ratios shown in Table 6, with CSS-2. Each of the six resulting mixtures was then treated with 30% H_2O_2 to accelerate the oxidation of the pyrite, followed by measurement of the solution pH. However, when this experiment was attempted, the final pH was either between 2 and 3 or between 10 and 11, as shown in Table 7. In this experiment, the FBC waste or agricultural limestone was

mixed with CSS-2 and the pyrite content used was that derived from sulfate ion (Table 2).

From Table 7, the two samples for which the pH remained acidic after treatment with H_2O_2 were FBC-3 and the agricultural limestone, which, according to the data in Table 1, contained 39.8 and 93.1% $CaCO_3$, respectively. Schumb et al. (1955) indicated that the pH of a H_2O_2 solution, when saturated with CO_2 , is somewhat lower than when the solution is exposed to air. For example, a solution of 10% H_2O_2 has a pH of about 3.8 when saturated with CO_2 , but it is about 5.2 when the solution is exposed to air. The high concentrations of $CaCO_3$ in FBC-3 and the agricultural limestone are probably enough to saturate the solution with CO_2 upon reaction of the $CaCO_3$ with the acid produced by pyrite oxidation, thus keeping the solution acidic.

We thought that perhaps some side reactions between the H_2O_2 and the FBC wastes were occurring. Another set of experiments was conducted to confirm our calculations of the FBC:CSS ratios. In the second set of experiments, the pyrite concentration in CSS-2 was based on the total iron in solution (Table 2). The H_2O_2 was added to the CSS-2 samples containing no FBC waste and allowed to react, then the excess H_2O_2 was destroyed by boiling. After the solutions had cooled, the required amounts of the various FBC waste or agricultural limestone were added to individual CSS samples. The pH was measured after 16 hours. The results of these experiments are shown in Table 8. The resulting pH values were between 3 and 3.5. The experiments were repeated once more, with addition of approximately 63% more of each FBC waste. The final pH values of the solutions after 16 hours of reaction time were between 3.25 and 4.5.

The confirmation experiments were inconclusive. After several weeks' work of trying to confirm our calculated proportions of FBC wastes and CSS, we decided that we did not have time in the project to pursue that line further. We are using our calculated proportions (Table 7) of FBC waste and CSS.

Particle Size Distribution. The particle size distributions of the five FBC wastes and the agricultural limestone (all air dried) are shown in Figure 1(a). Wastes FBC-1, FBC-2, and FBC-5 are similar in their particle size distributions; 50% or more of the particles in these three wastes are smaller than $62\mu m$ (230 mesh). There is a nearly uniform particle size distribution in FBC-3, and in FBC-4, over half the particles are larger than $500\mu m$ (35 mesh). The particle size distribution of the agricultural limestone is similar

to that of FBC-4. The cumulative particle size distributions are shown in Figure 1(b).

The particle size distributions of the two CSS samples were also determined. The results are shown in Figures 2(a) and (b). The particle size distributions of these samples are opposite to each other. That is, most of the particles in CSS-1 are smaller than 250 μm (60 mesh), whereas in CSS-2, most of the particles are larger than 250 μm [fig. 2(b)].

The agricultural limestone was sieved into the same size ranges as were used for measuring the particle size distributions in the FBC wastes. Portions of each size fraction of the limestone were weighed and mixed in order to approximate the particle size distributions of the individual FBC wastes. These sized limestone samples are used as control samples for comparing the behavior of the mixtures of FBC wastes and the CSS samples in laboratory leaching experiments.

Laboratory Leaching Experiments. Mixtures of CSS-1 and CSS-2 with each of the FBC wastes and with sized agricultural limestone were prepared. In all, there are 20 of these mixtures. In addition, each of the CSS samples and the FBC wastes are being leached separately. The bulk and particle densities of the CSS samples (Table 9) were used to determine the porosity of each sample, also shown in Table 9. One pore volume of deionized water is added to the top of each mixture weekly. Leachates are collected below the sample containers. The leachates are composited biweekly, and aliquots will be analyzed by ion chromatography, graphite furnace atomic absorption spectrometry, and inductively coupled plasma emission spectrometry.

Outdoor Weathering Experiments. Mixtures of the FBC wastes or the "as received" agricultural limestone were prepared with each of the CSS samples in the same proportions as listed in Table 6. Mixtures of CSS and sized agricultural limestone were not prepared for the outdoor weathering experiments. The mixtures were placed in containers and cabinets constructed for this purpose. The containers were constructed from PVC pipe, 9 inches in inside diameter, cut into 13-inch lengths. A friction-fit pipe cap was placed over one end of each pipe length. Each pipe cap was drilled and tapped in the center of its flat side to accommodate a threaded $\frac{1}{2}$ " tube adapter so that a leachate drain tube could be attached. The cabinets are open at the top to allow exposure of the mixtures to sunlight and precipitation. Each container was covered with a single layer of fiberglass window screen mesh to keep debris out of the samples.

The cabinets hold 7 containers each in linear fashion, on a shelf, and have protected space beneath the samples in which to place leachate collection bottles. Any leachate collected from the samples is analyzed as described for the laboratory leaching experiments. To date, no leachate has been collected, although about 1.25 inches of precipitation has fallen on the samples. Each cabinet has a plexiglass panel on the south-facing side so sun can shine on the samples. In the center position of each cabinet is placed a blank pipe so that the amount of precipitation falling on the samples can be collected and measured. The precipitation collected in the blank pipes is analyzed in the same manner as leachate.

Other Solids Analyses. Samples of the starting solids were analyzed by x-ray fluorescence spectrometry. The results of the analyses are given in Table 10.

A weighed portion of each air-dried FBC waste was treated with deionized water until the sample was saturated. Then the sample was oven-dried (with periodic mixing to prevent the sample from setting up), cooled, and weighed. The weight gain was taken as the amount of water consumed in the hydration of CaO to Ca(OH)_2 . One sample, FBC-3 lost weight upon oven drying, an indication that no CaO existed in the "as received" sample. This particular sample had been stored in an ash silo for several months before we received it. These data are shown in Table 11.

The calcium speciation in the FBC samples was calculated from data on the calcium carbonate equivalent (Table 1), the calcium carbonate content of each sample (Table 1), the moisture retained after treatment (Table 11), and the CaSO_4 content calculated from the SO_3 content (Table 10).

The difference between the CCE and the calcium carbonate content equals the calcium oxide plus calcium hydroxide content of the sample. The calcium oxide content is derived from the amount of water remaining in the sample after water treatment and oven drying. The difference between CCE less calcium carbonate content and calcium oxide is the amount of calcium hydroxide in the sample. The calcium speciations are shown in Table 12. Total calcium is equal to $\text{CaCO}_3 + \text{CaO} + \text{Ca(OH)}_2 + \text{CaSO}_4$.

The paste pH value for each FBC and CSS sample is shown in Table 13. The cation exchange capacities for the two CSS samples are also given in Table 13.

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Table 1. Calcium carbonate equivalents, CaSO_4 , and CaCO_3 contents of five FBC wastes and agricultural limestone sample (wt. %)

Sample	CCE (wt. %)	CaSO_4 (XRF) (wt. %)	CaCO_3 (wt. %)
FBC-1	65.1 $\pm$ 3.5	29.6	3.58
FBC-2	48.2 $\pm$ 3.6	28.4	4.00
FBC-3	77.8 $\pm$ 3.8	13.2	39.8
FBC-4	93.0 $\pm$ 3.4	27.7	9.75
FBC-5	50.2 $\pm$ 4.5	23.2	3.67
Agricultural limestone	94.8 $\pm$ 2.3	0.17	93.1

Table 2. Pyrite content of coal slurry solids by three methods of analysis (%)

Sample	pH rate of change	Sulfate in solution	Total iron in solution
CSS-1	3	2.55	3.64
CSS-2	13	16.1	12.4

Table 3. Exchangeable acidity, H^+ , and Al^{3+} in samples of coal slurry solids (meq/g)

Sample	Exchangeable Total acidity	Exchangeable H^+	Exchangeable Al^{3+}
CSS-1	0.016	0.016	0.0
CSS-2	0.023	0.023	0.0

Table 4. Calcium carbonate content in samples of coal slurry solids (wt. %)

Sample	CaCO ₃
CSS-1	4.8
CSS-2	15.9

Table 5. Total potential acidity of CSS samples and calcium carbonate equivalents of FBC wastes and agricultural limestone on gram-equivalent basis (meq/g)

Sample	Total potential acidity	Calcium carbonate equivalent
CSS-1	0.27	--
CSS-2	0.99	--
FBC-1	--	13.0
FBC-2	--	9.63
FBC-3	--	15.5
FBC-4	--	18.6
FBC-5	--	10.0
Agricultural limestone	--	18.9

Table 6. Amount of each FBC waste or agricultural limestone required to neutralize the total potential acidity from one gram of coal slurry solid (g/g)

FBC waste or agricultural limestone	CSS-1	CSS-2
FBC-1	0.021	0.076
FBC-2	0.028	0.10
FBC-3	0.017	0.064
FBC-4	0.014	0.053
FBC-5	0.027	0.099
agricultural limestone	0.014	0.052

Table 7. Initial and final pH values after treatment of mixtures of CSS-2 and FBC wastes or agricultural limestone with 30% H_2O_2 . (FBC-2 was not included. The pyrite content of CSS-2 was based on the solution sulfate concentrations.)

Sample	Initial pH	Final pH
FBC-1	12.0	10.1
FBC-3	12.0	2.77
FBC-4	11.6	10.7
FBC-5	12.2	10.8
Agricultural limestone	7.81	2.92

Table 8. Initial and final pH values after treatment of CSS-2 with 30% H_2O_2 and boiling, and final pH values 16 hours after addition of FBC waste to neutralize acid produced

Sample	Initial pH	Final pH
FBC-1	1.88	3.28
FBC-2	1.88	3.26
FBC-3	1.87	3.12
FBC-4	1.90	sample spilled
FBC-5	1.90	3.08
Agricultural limestone	1.88	3.47

Table 9. Bulk and particle densities (g/cm^3) and porosity of coal slurry solids

Property	CSS-1	CSS-2
Bulk density	0.84	1.51
Particle density	1.35	2.46
Porosity	0.38	0.39

Table 10. Composition of solid samples by x-ray fluorescence analysis (wt. %)

Component	FBC-1	FBC-2	FBC-3	FBC-4	FBC-5	Ag LS†	CSS-1	CSS-2
SiO ₂	18.01	20.67	8.54	6.75	17.87	7.00	19.69	29.91
Al ₂ O ₃	5.80	5.90	1.99	1.84	4.56	1.34	5.80	7.59
Fe ₂ O ₃	5.39	10.95	3.18	2.87	5.41	0.62	3.02	19.73
CaO	45.17	34.99	47.22	61.91	29.85	45.68	3.17	9.53
MgO	1.05	0.83	0.62	1.00	0.83	4.20	0.40	0.80
K ₂ O	0.80	0.55	0.24	0.16	0.60	0.53	0.90	1.37
Na ₂ O	0.34	0.44	0.18	0.14	0.35	0.10	0.35	0.47
TiO ₂	0.29	0.28	0.09	0.08	0.24	0.08	0.29	0.34
P ₂ O ₅	0.17	0.10	0.06	0.06	0.13	0.03	0.14	0.45
MnO	0.09	0.06	0.02	0.11	0.07	0.04	0.03	0.10
SrO	0.07	0.02	0.03	0.04	0.05	0.02	0.01	0.01
BaO	0.03	0.01	0.03	<0.01	0.03	<0.01	0.02	0.04
SO ₃	17.40	16.72	7.78	16.31	13.67	0.10	--	--
LOI*	5.10	8.45	30.06	8.50	26.18	40.51	36.62	75.60
Total	99.71	99.97	100.04	99.77	99.84	100.25	--	--

*LOI = loss on ignition at 1000°C.

†Ag LS = agricultural limestone

Table 11. Initial moisture percent and weight gained as a percent of air-dried weight after water treatment of FBC wastes (wt. %)

Sample	Moisture	Weight gain
FBC-1	0.01	9.19
FBC-2	0.11	7.53
FBC-3	3.03	-3.25
FBC-4	0.00	14.65
FBC-5	0.05	7.30

Table 12. Speciation of calcium in FBC wastes (wt. %)

Sample	CCE	CaCO ₃	CaO	Ca(OH) ₂	CaSO ₄	Total Ca*
FBC-1	65.1	3.58	28.61	7.73	29.58	69.5
FBC-2	48.2	4.00	23.44	1.74	28.42	57.6
FBC-3	77.8	39.8	0.0	28.13	13.23	81.2
FBC-4	93.0	9.75	45.60	1.36	27.73	84.4
FBC-5	50.2	3.67	22.72	4.41	23.24	54.0

*Total Ca = CaCO₃ + CaO + Ca(OH)₂ + CaSO₄.

Table 13. Paste pH of FBC wastes and CSS samples and cation exchange capacity (meq K⁺/100 g) of CSS samples

Sample	Paste pH	CEC*
FBC-1	11.9	---
FBC-2	11.9	---
FBC-3	12.0	---
FBC-4	11.6	---
FBC-5	11.8	---
CSS-1	7.37	11.6
CSS-2	7.17	10.4

*Values for CEC are the means of two determinations.

Figure 1. Particle Size Distributions of Five FBC Wastes

Figure 2. Particle Size Distributions of Two CSS Samples

Cumulative CSS Sample Particle Size Distribution

PROJECT MANAGEMENT REPORT
December 1, 1991 through February 29, 1992

Project Title: The use of FBC wastes in the reclamation of
coal slurry solids

Principal Investigator: Gary B. Dreher, ISGS
Other Investigators: William R. Roy, ISGS
John D. Steele, ISGS
Project Monitor: Dan Banerjee, CRSC

COMMENTS

Milestones C, D, E, and F are underway.

This project is funded by the U. S. Department of Energy (METC) and by the Illinois Department of Energy and Natural Resources as part of their cost-shared program.

Projected and Estimated Actual Expenditures by Quarter

Quarter*	Types of Cost	Direct Labor	Materials and Supplies	Travel	Major Equipment	Other Direct Costs	Indirect Costs	Total
Sept. 1, 1991	Projected	791	1,700	400	425	6,435	975	10,726
to								
Nov. 30, 1991	Estimated Actual	283	1,139	260	405		209	2,296
Sept. 1, 1991	Projected	1,583	1,850	400	425	17,480	2,174	23,912
to								
Feb. 29, 1992	Estimated Actual	514	1,545	297	405	2,500	526	5,787
Sept. 1, 1991	Projected	2,374	2,000	400	425	22,363	2,756	30,318
to								
May 31, 1992	Estimated Actual							
Sept. 1, 1991	Projected	3,166	2,150	400	425	26,730	3,287	36,158
to								
Aug. 31, 1992	Estimated Actual							

* Cumulative by quarter

COSTS BY QUARTER - EXHIBIT C
THE USE OF FBC WASTES IN THE RECLAMATION
OF COAL SLURRY SOLIDS

Total CRSC Award \$ 55,693

SCHEDULE OF PROJECT MILESTONES

Begin September 1, 1991

Milestones:

- A. Write and submit QA plan (Task 1)
- B. Collect FBC waste, coal slurry solid, and limestone (Task 2)
- C. Characterize starting materials (Task 2)
- D. Prepare waste solid mixtures and conduct leaching experiments (Task 3)
- E. Analyze leachates, extracts, and solids from leaching experiments (Task 3)
- F. Prepare waste solid mixtures and conduct outdoor weathering experiments (Task 4)
- G. Analyze leachates and solids from outdoor weathering experiments (Task 4)
- H. Interpret data
- I. Technical reports prepared and submitted
- J. Project management reports prepared and submitted

Comments: Milestones C, D, and E slipped because of the unexpected need to obtain a second coal slurry solids sample. There is sufficient time in the schedule so that meeting the requirements of the research project will be met.

END

**DATE
FILMED**

9 / 3 / 92