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Biochemical Removal of HAP Precursors from Coal
De-AC22-95PC95155

Little Bear Laboratories, Inc.
Red Lodge, Montana

Executive Summary

Shake flask tests were completed of microbial pyrite and HAP precursor removal from Rosebud subbituminous coal. Significant amounts of Ni, F, Mn, Cd, Co and Be were removed from this coal. Analyses in connection with leach column tests of Pittsburgh coal were completed and confirmed significant removal of Ni, F, Mn, Cd, Co and As from this coal. Although Hg was not removed from Pittsburgh coal by microbial attack, there was a correlation between HCl leaching of Hg from this coal and the extent of depyritization. Since HgS is soluble in HCl, the results suggest HgS is exposed by chemical and microbial dissolution of coal pyrite. Column tests with cleaned Indiana No. 5 coal are in progress and show significant early dissolution of Ni, Mn, Cd, Co and As. A final shake flask test with Kentucky No. 9 coal was begun. Pittsburgh coal with a low content of fines was shipped to the Idaho National Engineering Laboratory (INEL) in preparation for slurry column tests of HAP precursor removal. Project results were presented at the PETC contractor's conference held in Pittsburgh. A project progress review meeting was also held with the PETC technical project monitor.

Concise Summary of Work Performed

A shake flask test with Rosebud coal was conducted and analyses of leach solutions and coal residues for HAP precursors was completed. Analyses of final leach solutions and residues from the Pittsburgh coal column test were completed. A test of mercury leaching from Pittsburgh coal by HCl was conducted. Column tests with Indiana No. 5 coal and shake flask tests with Kentucky No. 9 coal were set up and begun. Pittsburgh coal for slurry column HAP removal tests was shipped to INEL. Sieve analyses and settling tests with this coal indicated it would be suitable for the testing. Project progress was presented and reviewed at the PETC contractor's conference in Pittsburgh and in meetings with the PETC technical project monitor.

Variances

There were no major variances to the work plan. Following discussions at the contractor's conference and with the technical project monitor, testing of HCl leaching of mercury from samples of raw and treated Pittsburgh coal was conducted. These tests were done to gain insights into the occurrence of mercury in this coal, and to determine if mercury might be more amenable to chemical leaching following

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depyritization. In addition, Stockton coal was analyzed for its HAP precursor content in order to compare our analytical results with those obtained by PETC.

Open Items

There are currently no open items in the project.

Forecast for Upcoming Quarter

The column test with Indiana No. 5 coal and the the shake flask test with Kentucky No. 9 coal will be completed along with the analysis of final leach solutions and coal residues. Additional column tests with Indiana No. 5 and Pittsburgh coal will be conducted. These tests will use a higher starting concentration of ferric ions in an attempt to increase kinetics of pyrite oxidation and HAP precursor leaching. The INEL slurry column testing will begin.

Technical and Scientific Results

1. Shake Flask Tests--Results of Rosebud Coal (Task 2)

Rosebud subbituminous coal was obtained from the Penn State Coal Sample Bank (sample DECS-10). The material was sieved and the minus 100 mesh fraction used in the shake flask test. Flasks contained 20% solids in dilute mineral salts adjusted to pH 2. Two flasks were inoculated with pyrite oxidizing bacteria and two flasks served as controls and were amended with a biocidal thymol solution.

During active bioleaching, the rate of pyrite oxidation (Table 1) was calculated from the slope of the iron and sulfate dissolution curves shown in Figure 1.

Table 1. Rates of Pyrite Oxidation (% per day) in Rosebud Coal Shake Flask Test

	Based on solution Fe	Based on solution SO ₄
cells -1	2.3	2.5
cells -2	2.4	2.6
control -1	<0.1	<0.1
control -2	<0.1	<0.1

The rate of depyritization of Rosebud coal as estimated from solution measurements of iron and sulfate was considerably slower than in previous tests with Pittsburgh and Indiana coals. Furthermore, pyrite dissolution slowed markedly after about 2/3 had been removed from the coal. The estimated extent of pyrite dissolution based on solution iron was less than dissolution based on solution sulfate (Fig. 1). However, the analysis of the recovered coal residues (Table 2) indicated nearly complete biodepyritization. Thus, the solution sulfate concentrations provided a closer estimate

of the extent of pyrite biooxidation than did solution iron. Sulfate-sulfur concentrations in the recovered coal were higher than in the raw coal, suggesting some precipitation of sulfate had occurred. The low iron concentrations in solution suggest iron also precipitated during the test. Precipitation of sulfate and iron probably occurred also in the control flasks as the analysis of recovered coal indicated 30 to 41% pyrite removal (Table 2) whereas little or no dissolution of pyrite was indicated from concentrations of iron and sulfate in solution (Fig. 1). Consequently, the rates of pyrite removal calculated from solution iron and sulfate concentrations underestimated the true rates of depyritization.

Significant amounts of HAP precursor elements Ni, F, Mn, Cd and Be were removed from Rosebud coal based on an analysis of raw coal compared recovered residues (Table 2). Se concentrations in recovered coal were also lower than in raw coal, although levels were near detection limits. More sensitive indicators of HAP precursor mobilization where coals contain low concentrations of HAP precursors are solution analyses (Table 3). Solution analyses are also more accurate than residue analyses (Table 2) for determination of % HAP precursor removal. Solution analyses confirmed the removal of Ni, F, Mn, Cd, and Be from the coal, and also indicated Co dissolution. Furthermore, solution analyses did not provide evidence of Se removal from Rosebud coal.

Intermediate solutions in the Rosebud Coal shake flask test (Table 3) indicated that Ni, Co, and Cd tended to increase in concentration with time as the extent of pyrite oxidation increased. In contrast, Mn, F, and Be increased relatively little after the initial analysis at day 27. Interestingly, As was not significantly leached from Rosebud coal. The other coal samples examined to date in shake flasks and leach columns showed significant microbial leaching of As associated with pyrite oxidation. Possibly As is associated more with the organic fraction in Rosebud coal.

There was little microbial enhancement of Ni, F, Mn, Cd and Be dissolution above control values, suggesting that the acidic conditions were the main factor in solubilization of these HAP precursors from Rosebud coal.

Mass balances for HAP precursors in Rosebud Coal were largely within a range of 80 to 120% (Table 4). Values outside this range were associated with elements present at near detection limits (Co, Se). However, Mn mass balances were low (77 to 79%). Redigestion and reanalysis of raw coal did not improve the Mn mass balance.

Figure 1. Kinetics of Depyritization in Rosebud Coal Shake Flask Test 3

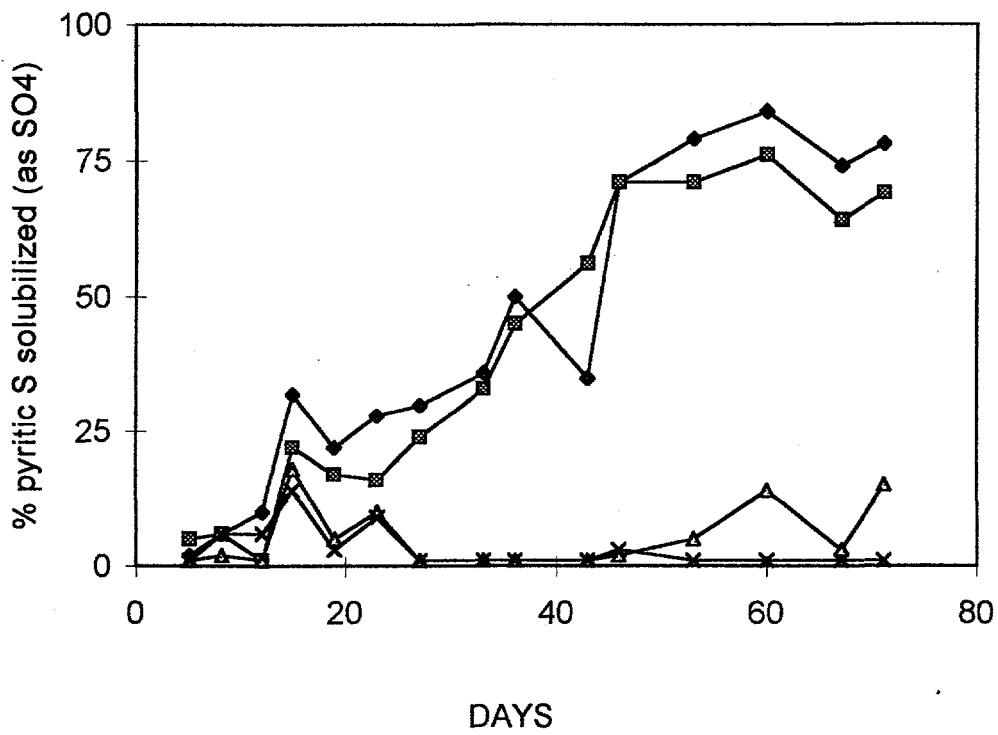
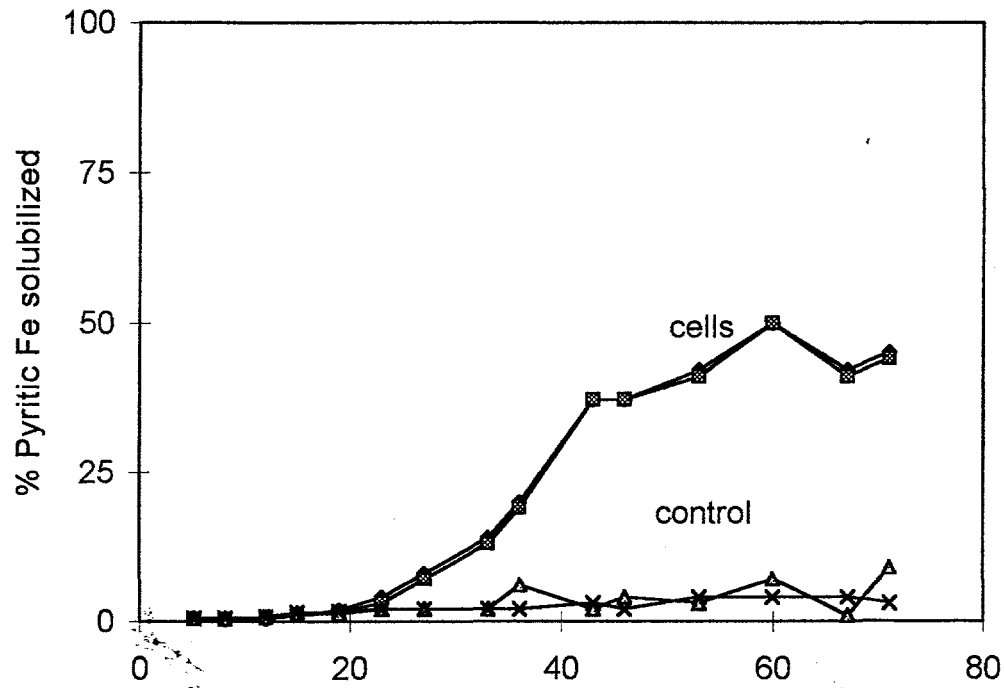


Table 2. Analysis of Rosebud Coal, Shake Flask Test (-100 mesh, dry basis)

	Raw coal	Biotreated	Control	%loss-microbial	% loss-control
% carbon	62.73	62.72 63.19	63.59 63.26		
% hydrogen	3.86	3.84 3.78	3.90 3.90		
% nitrogen	1.01	1.04 1.04	1.03 0.99		
% sulfur	1.74	1.25 1.26	1.94 2.19	28 28	0 0
% ash	19.57	13.54 13.37	13.95 14.95	31 32	29 24
% oxygen (difference)	11.09	17.61 17.36	15.59 14.71		
Btu/lb	10541	10352 10350	10606 10623		
% pyritic S	0.86	0.05 0.05	0.51 0.60	94 94	41 30
% sulfate S	0.32	0.80 0.77	0.79 0.88		
% organic S (difference)	0.56	0.40 0.44	0.64 0.71		
HAPs, ug/g coal					
mercury	0.06 0.08	0.07 0.07	0.07 0.07	0 0	0 0
arsenic	1.7	1.9 1.5	1.5 1.9	0 12	12 0
cadmium	0.1	<0.1 <0.1	<0.1 <0.1		
chromium	4.4	4.4 3.8	4.0 3.9	0 14	9 11
selenium	1.1	0.9 0.6	0.8 0.4	18 45	27 64
antimony	<1.0	<1.0 <1.0	<1.0 <1.0		
beryllium	0.15	<0.1 <0.1	<0.1 <0.1	>33 >33	>33 >33
cobalt	0.9	1.3 1.1	1.0 0.7	0 0	0 22
lead	10.8	9.7 13.0	10.7 9.2	10 0	1 15
manganese	133	7.1 5.5	7.5 10.4	95 96	94 92
nickel	2.1	1.5 1.2	1.0 1.5	29 43	52 29
chlorine (%)	<0.01	<0.01 <0.01	0.01 <0.01		
fluorine	44	39 32	28 30	11 27	36 32

Table 3. % of Coal HAP Presursors in Leach Solutions in Rosebud Shake Flasks

	Day 27	Day 36	Day 46	Final (day 71)
% pyrite biooxidation (based on solution SO ₄ concentration)	30 (cells)	50	71	78
	24 (cells)	45	71	69
	<1(control)	<1	2	15
	<1(control)	<1	2	<1
Arsenic	4	15	8	7
	4	15	8	7
	3	2	<1	<2
	3	2	<1	<2
Cadmium	32	62	75	50
	40	58	71	86
	20	31	31	36
	24	23	38	30
Chromium	7		9	14
	7		9	14
	5		6	10
	6		6	8
Selenium	<3	<3	<3	<3
	<3	<3	<3	<3
	<3	<3	<3	<3
	<3	<3	<3	<3
Beryllium	71	83	87	104
	71	86	89	102
	48	55	65	107
	45	51	59	88
Cobalt	19	25	28	32
	18	24	24	29
	12	15	15	19
	13	17	12	16
Lead	4	4	5	8
	6	3	6	5
	2	1	2	3
	2	<1	3	3
Manganese	68	67	64	72
	69	68	68	73
	58	61	59	72
	56	58	61	72
Nickel	20	23	8	27
	19	23	24	26
	15	16	17	24
	15	16	18	24
Fluorine	34		33	39
	35		32	39
	36		35	46
	37		34	43

Hg, Sb, and Cl were not solubilized and are not shown above

Table 4. Mass Balances for Rosebud Coal Shake Flask Test*

	starting coal mg	solution mg	final coal mg	% recovery	% loss (by solution)
Hg	cells cells control control	<0.0001	0.0023		<5
		<0.0001	0.0024		<5
		<0.0001	0.0024		<5
		<0.0001	0.0023		<5
arsenic	0.059	0.004	0.063	114	7
		0.004	0.050	91	7
		<0.001	0.051		<2
		<0.001	0.065		<2
cadmium	0.004	0.002	<0.004		50
		0.003	<0.004		75
		0.001	<0.004		25
		0.001	<0.004		25
chromium	0.154	0.022	0.149	110	14
		0.022	0.130	98	14
		0.015	0.138	99	10
		0.012	0.130	92	8
selenium	0.032	<0.001	0.019	63	<3
		<0.001	0.031	97	<3
		<0.001	0.028	88	<3
		<0.001	<0.017		<3
antimony	<0.018	<0.001	<0.017		
		<0.001	<0.017		
		<0.001	<0.017		
		<0.001	<0.017		
beryllium	0.005	0.006	<0.003		100
		0.005	<0.003		100
		0.006	<0.003		100
		0.004	<0.003		80
cobalt	0.031	0.010	0.043	171	32
		0.009	0.039	154	29
		0.006	0.033	126	19
		0.005	0.024	93	16
lead	0.378	0.030	0.325	87	8
		0.019	0.445	123	5
		0.010	0.371	101	3
		0.010	0.307	84	3
manganese	4.655	3.334	0.238	77	72
		3.382	0.188	77	73
		3.349	0.260	77	72
		3.343	0.347	79	72
nickel	0.074	0.020	0.050	95	27
		0.019	0.041	81	26
		0.018	0.035	72	24
		0.018	0.050	91	24
fluorine	1.54	0.60	1.30	123	39
		0.60	1.09	110	39
		0.64	0.97	105	46
		0.66	1.00	108	43

*Four values are shown for each HAP precursor. As shown for Hg above, the first two rows are for the two inoculated flasks, the last two rows are for control flasks. Chlorine was not detected in raw coal or in residues and is not shown. Mass balances were determined by adding the total mg in solution (mg/l x liters) to the mg recovered in coal residues (mg/kg x kg) divided by the mg in raw coal (mg/kg x kg).

2. Shake Flask Test--Kentucky No. 9 Coal (Task 2)

Toward the end of the quarter, the fourth and final shake flask test was begun with Kentucky No. 9 bituminous coal (Penn State Coal Bank Sample DECS-18). As with the previous shake flask tests, 20% solids were employed and duplicate inoculated and uninoculated flasks were employed.

The early kinetics of pyrite biooxidation in Kentucky coal were rapid as estimated from concentrations of Fe and sulfate in solution. Complete results of pyrite oxidation kinetics will appear in the next quarterly report, along with HAP precursor concentrations in the raw coal, treated coal and in leach solutions.

3. Column Test--Pittsburgh No. 8 Coal (Task 3)

The bulk of the work on this test was completed and reported in the previous (third quarter) report. However, analyses of the final leach solution and coal residues had not been completed. Table 5 shows the final analysis of coal residues and Table 6 the analysis of the final leach solution.

The extent of depyritization estimated from solution iron and sulfate measurements was somewhat underestimated when compared to the pyritic sulfur analysis of the recovered coal residue. Significant As, Cd, Co, Mn, and Ni was removed from the coal due to microbial activity. Somewhat lesser amounts of these elements were removed from coal in the control columns, with the exception of arsenic which was undetectable in control column leachate. Smaller amounts of F, Be, and Se were removed from the coal by microbial activity.

Leach solution analyses showed As, Cd, Mn and Ni tended to increase over the course of the test along with depyritization. Co and F did not increase much beyond day 14-23 levels.

Mass balances for the Pittsburgh coal column test are shown in Table 7. One value for As, two for Se and one Mn value fell outside a 80 to 120% recovery range.

Table 5. Column Test Analysis of Pittsburgh No. 8 Coal (28 x 100 mesh, dry basis)

	Raw coal	Biotreated	Control	%loss-microbial	% loss-control
% carbon	65.09	66.26 67.66	65.12		
% hydrogen	4.55	4.37 4.47	4.37		
% nitrogen	1.34	1.29 1.32	1.27		
% sulfur	2.34	1.57 1.52	2.29	33 35	2
% ash	20.00	19.31 18.53	19.93	3 7	<1
% oxygen (difference)	6.68	7.20 6.50	7.02		
Btu/lb	11613	11858 12001	11701		
% pyritic sulfur	1.11	0.02 0.16	0.90	98 86	19
% sulfate S	0.12	0.23 0.15	0.09		
% organic S (difference)	1.11	1.32 1.21	1.30		
HAPs, ug/g coal					
mercury	0.11 0.11* 0.09*	0.10 0.10	0.08 0.09* 0.13*	0	0
arsenic	8.7 8.3	5.5 4.4	10.9	35 48	0
cadmium	0.3 0.3	<0.1 <0.1	<0.1	>67 >67	>67
chromium	26 29	27 26	29	2 6	0
selenium	1.8 1.7	1.2 1.2	1.5	31 31	14
antimony	<1.0 <1.0	<1.0 <1.0	<1.0		
beryllium	0.8 0.8 0.4* 0.8*	0.4 0.5 0.2* 0.5*	0.5 0.6*	43 29 71 29	29 14
cobalt	6.6 7.0 7.5* 6.9*	3.8 3.4	3.8	40 46	40

lead	16.7 17.6 22.0* 15.6*	14.0 16.0*	18.6	22 11	0
manganese ¹	49 (142)* 56* 49*	25 26.5 22* 17.5*	(110) 63*	51 48 57 66	0
nickel	16.0 16.5* 17.0* 16.6*	8.9 8.8 7.6* 7.9*	11.3 11.0*	46 47 54 52	32 33
chlorine (%)	0.07	0.06 0.07	0.07	14 0	0
fluorine	120	142 155	165	0 0	0

¹ Values in parentheses are not included in average. The results for two sets of duplicate biotreated columns and a single set of duplicate control columns are shown. Starred (*) values are duplicate analyses of the coal. Up to 4 analyses of the raw coal were conducted and averaged for purposes of calculating % extraction and mass balances.

Table 6. % of Coal HAP Precursors in Leach Solutions¹ in Pittsburgh No. 8 Columns

	Day 14	Day 23	Final (day 70)
% pyrite biooxidation (based on solution SO ₄ concentration)	17 (cells)	35	69
	14 (cells)	34	64
	3 (control)	6	14
Arsenic	11	28	45
	22	24	30
	<1	<1	<1
Cadmium	30	58	65
	30	58	63
	10	12	21
Selenium	4	7	6
	2	6	4
	<1	<1	<1
Beryllium	5	7	8
	5	8	7
	2	1	5
Cobalt	22	32	30
	23	33	26
	20	17	20
Manganese	11	17	47
	12	18	39
	10	11	26
Nickel	19	28	31
	28	52	44
	17	18	23
Fluorine	16	16	20
	16	16	20
	10	5	9

¹ Less than 1% of Sb, Hg, Cl, Cr, Pb was solubilized.

Table 7. Mass Balances for Pittsburgh Coal Column Test*

	starting coal mg	solution mg	final coal mg	% recovery	% loss (by solution)
Hg cells cells control	0.0200	<0.0003	0.0196	98	<2
		<0.0003	0.0197	99	<2
		<0.0003	0.0198	99	<2
arsenic	1.820	0.821	1.078	104	45
		0.538	0.865	77	30
		<0.005	2.162	119	<1
cadmium	0.060	0.039	<0.040		65
		0.038	<0.040		63
		0.013	<0.040		21
chromium	5.400	0.075	5.369	101	1
		0.065	5.114	96	1
		0.011	5.832	108	<1
selenium	0.330	0.021	0.231	76	6
		0.014	0.236	76	4
		0.003	0.292	89	1
antimony	<0.100	0.004	<0.100		
		<0.004	<0.100		
		<0.004	<0.100		
beryllium	0.120	0.010	0.098	90	8
		0.008	0.098	89	7
		0.006	0.111	98	5
cobalt	1.260	0.382	0.745	89	30
		0.333	0.669	80	26
		0.249	0.754	80	20
lead	3.400	0.049	3.899	116	1
		0.040	3.501	104	1
		0.017	3.769	111	1
manganese	10.48	4.96	4.90	94	47
		4.06	4.43	85	39
		2.76	12.50	146	26
nickel	3.200	0.988	1.724	85	31
		1.420	1.554	93	44
		0.745	2.182	91	23
chlorine	140	<8.8	140	100	<6
		<8.8	120	86	<6
		<8.8	140	100	<6
fluorine	24.0	4.8	27.8	136	20
		4.7	30.5	147	20
		2.1	32.7	145	9

*Three values are shown for each HAP precursor. As shown for Hg above, the first two rows in each box are for the two inoculated columns, the last row is for the control columns

Tests of mercury extraction from the coal residues from the Pittsburgh coal column tests were conducted. Our research work to date has shown no evidence for microbial mobilization of mercury from coal in either the shake flask or column tests. Discussions at the PETC Contractor's Conference led us to test whether microbial oxidation of pyrite in coal might make mercury more available for leaching. If mercury occurs largely as an inorganic sulfide (HgS) associated with pyrite, it is unlikely that microbial activity or ferric ions will oxidize the sulfide and release mercuric ions. However, microbial oxidation of pyrite might expose the HgS to attack by other reagents. For example, HgS is soluble in HCl. Consequently, raw Pittsburgh coal and Pittsburgh coal from inoculated and control leach columns was subjected to HCl leaching. Ten g of coal was shaken with 20 ml of 6N HCl for 1 hour. The coal was filtered, rinsed with water, and the leach solution was analyzed for mercury. Our previous analysis indicated this coal contained 0.10 ug of mercury/g coal. Thus, the leach solution would contain 1.0 ug of Hg if all was extracted. Table 8 shows a correlation between the extent of coal depyritization and the leaching of Hg by HCl. Dilute HCl did not extract Hg. The results indicate that Hg is made more available for extraction with increasing depyritization. However, a reagent other than strong HCl would be required for application to coal-cleaning.

Table 8. Extraction of Hg from Pittsburgh Coal by HCl

% depyritized	Strength of HCl	% Hg extracted*
0 (raw coal)	6N	34
19 (control)	6N	49
92 (inoculated)	6N	69
	6N (dup extrn)	69
92 (inoculated)	1N**	3

* Ten g of raw coal contained 1.0 ug Hg (Table 5).

** extraction time 2 hours

4. Column Tests--Indiana No. 5 Coal (Task 3)

Indiana coal (28 x 100 mesh) was leached in a column-rotating biological contactor (RBC) apparatus as was done with Pittsburgh coal reported previously. Two sets of duplicate columns each containing 100 g coal were leached with 400 ml of solution. The leach solution for each set of columns was collected in a common reservoir. Microbial iron oxidation in the reservoir was encouraged by the RBC. The Indiana No. 5 coal (Illinois Basin Coal Sample Program #110) was a coarser fraction of that tested earlier in shake flask tests. The coal was originally cleaned in a washing plant by jigging. Consequently, microbial HAP precursor and pyrite removal with this coal represents cleaning beyond that achieved by conventional coal preparation.

The kinetics of depyritization of Indiana coal are shown in Figure 2. The rate of microbial depyritization of this coal was about 1% per day which was similar to that obtained in previous column tests with Pittsburgh coal (Table 9). The starting coal analysis is shown in Table 10. Analysis of biotreated and control residues was not completed by the end of the fourth quarter. Nonetheless, analysis of intermediate leach solutions indicated that significant amounts of As, Cd, Co, Ni and Mn were solubilized by microbial activity and in controls (Table 11).

Table 9. Daily Rates of Pyrite Biooxidation (%) in Leach Columns¹

column pair	Solution Fe Rate		Solution SO ₄ Rate	
	Pittsburgh Day 8-38	Indiana Day 5-34	Pittsburgh Day 14-38	Indiana Day 5-34
1	1.2	1.2	1.3	1.2
2	1.2	1.2	1.3	1.2
control	<0.1	0.3	0.2	0.4

¹28 x 100 mesh coal; based on solution Fe or SO₄ concentrations

Figure 2. Kinetics of Depyritization of Indiana No. 5 Coal in Leach Column Tests

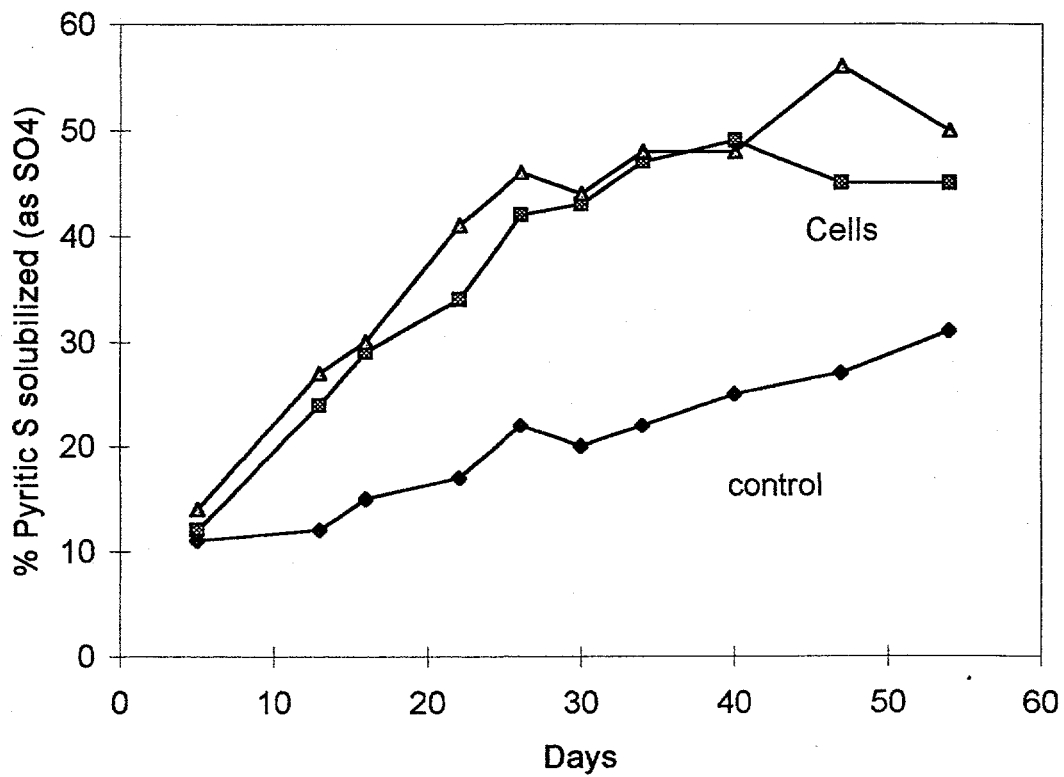
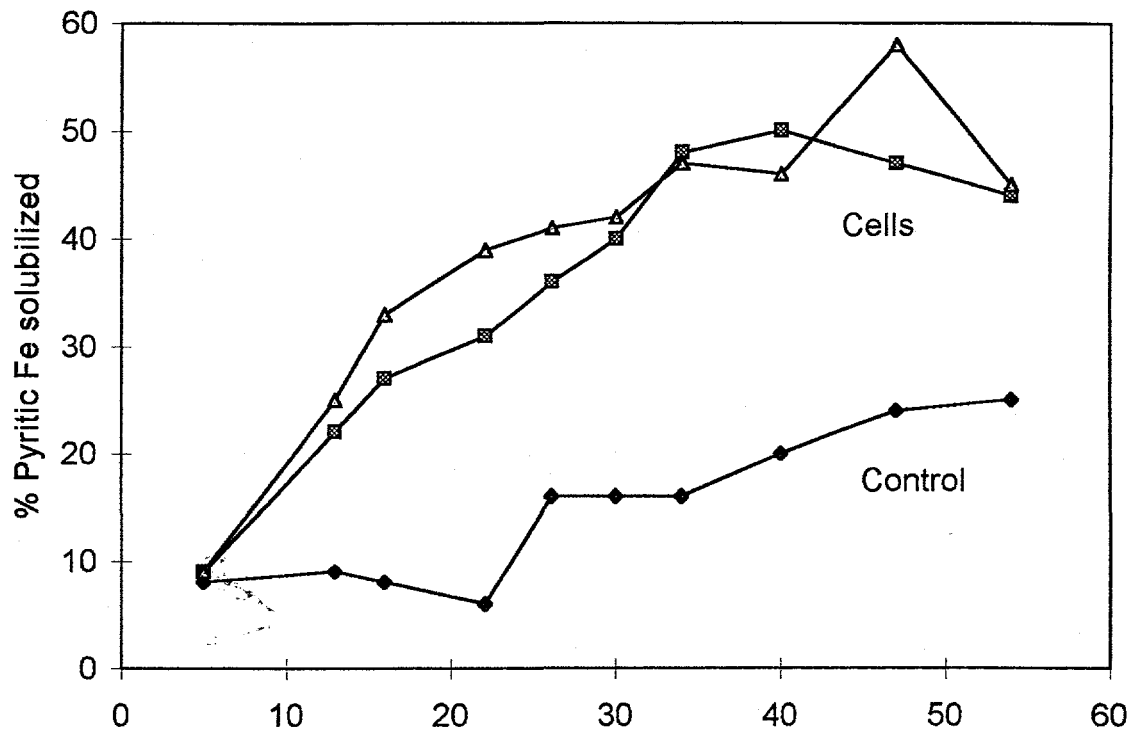


Table 10. Analysis of Indiana No 5 Coal, Column Test (28 x 100 mesh, dry basis). Residue analyses are not yet available.

	Raw coal	Biotreated	Control	%loss-microbial	% loss-control
% carbon	72.92				
% hydrogen	5.03				
% nitrogen	1.54				
% sulfur	3.69				
% ash	9.44				
% oxygen (difference)	7.38				
Btu/lb	13180				
% pyritic S	1.92				
% sulfate S	0.07				
% organic S (difference)	1.70				
HAPs, ug/g coal					
mercury	not yet done				
arsenic	3.9 3.5				
cadmium	0.6 0.6				
chromium	11 11				
selenium	1.9 2.1				
antimony	<1 <1				
beryllium	1.3 1.3				
cobalt	4.1 4.4				
lead	7.5 7.3				
manganese	31 29				
nickel	15 15				
chlorine (%)	0.01				
fluorine					

Table 11. % of Coal HAP Precursors in Leach Solutions¹ in Indiana No. 5 Columns

	Day 16	Day 34	Final
% pyrite biooxidation (based on solution SO ₄ concentration)	29 (cells)	48	
	30 (cells)	47	
	15 (control)	22	
Arsenic	17	32	
	20	25	
	4	14	
Cadmium	50	66	
	43	49	
	17	28	
Selenium	5	9	
	6	7	
	1	3	
Beryllium	17	18	
	17	15	
	17	15	
Cobalt	41	40	
	41	32	
	37	35	
Lead	3	3	
	4	2	
	5	2	
Manganese	46	45	
	45	38	
	43	38	
Nickel	24	27	
	23	23	
	19	18	

¹ Less than 1% of Sb, Hg, Cl, Cr and F was solubilized.

5. Analysis of Stockton Coal for HAP Precursors

A PETC in house research project studied mass balances of HAP precursors associated with combustion of Stockton coal. In order to compare analytical results conducted by PETC with those at LBL, we analyzed the raw coal (ground to minus 60 mesh) for its content of HAP precursors. Results were not complete at the end of the quarter and will be presented in the next report.

6. INEL Slurry Column Test Work (Task 4)

The original Pittsburgh coal shipped to INEL contained too many fines for optimum slurry column testing. In cooperation with the Coal Preparation Division at PETC, an additional supply of Pittsburgh coal was located, prepared and shipped to INEL. Sieve analysis and settling tests on this coal at INEL indicated it had the desired properties and should perform well in slurry column tests. Organisms were cultured at INEL on this coal in preparation for slurry column tests.

7. Reporting Research Results (Task 5)

During the fourth quarter, results of work on this project were presented in a poster in early July at the PETC contractor's conference held in Pittsburgh. Discussions at the conference led to the Hg extraction experiments and the plan to analyze Stockton coal described above.

Meetings to review project progress were also held in Billings and Red Lodge with Dr. Mike Nowak, PETC's technical project monitor, and subcontractor Unifield Engineering. Discussions at this meeting indicated that improved kinetics of pyrite dissolution and HAPs removal from coal are desirable, and that additional column tests conducted with higher concentrations of ferric ions would be worthwhile.

Effects of Results on Future Work

The project results to date indicate the expected microbial pyrite dissolution and the leaching of several HAP precursors from coal. However, there is a need to explore ways of obtaining faster kinetics of pyrite dissolution and more complete HAP precursor leaching in simulated heap configurations (i.e., columns). Consequently, future leach column tests will be supplemented with added ferrous sulfate. Microbial activity will rapidly oxidize the ferrous iron to ferric, resulting in leach solutions with initial high ferric ions. More rapid pyrite oxidation and possibly more extensive dissolution of HAP precursors may occur under such conditions. Past test work relied on a slow build up of ferric ions from pyrite oxidation. In large scale processing, leach solutions with high ferric concentrations would be available.

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