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DOE/PC/91283-78

Liquid Chromatographic Analysis of Coal Surface Properties

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**Quarterly Progress Report
For the Period April - June 1993**

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US/DOE Patent Clearance is not required
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**Prepared for the United States
Department of Energy under
the Contract No. DE-FG22-91PC91283**

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I. ABSTRACT

Experiments on equilibrium adsorption loadings of various probe compounds on 60 - 200 mesh Illinois #6 coal (PSOC-1539), Adaville #1 coal (PSOC-1544), Wyodak coal (FSOC-1545) and Pittsburgh #8 coal (PSOC-1549) were performed during the April - June period. The probe compounds include 2-methyl-1-pentanol (2M1P), 1-heptanol, benzene and toluene.

Equilibrium adsorption loadings of toluene are higher than those of benzene on the four chosen coals. Equilibrium adsorption loadings of aromatic compounds such as toluene and benzene on the four chosen coals obey the Langmuir isotherm model for single-layer adsorption up to 100 ppm in concentrations of probe compounds.

Equilibrium adsorption loadings of higher aliphatic alcohols such as 2M1P and 1-heptanol on the four chosen coals do not follow both the Langmuir isotherm model and the Freundlich empirical adsorption model.

Flotation of the coals, equilibrated with aqueous solutions of 2M1P and 1-heptanol, increase linearly with equilibrium adsorption loadings of these probe compounds on the coals. Equilibrium adsorption loadings of 1-heptanol on Illinois #6 coal increase with decreased adsorption temperatures.

II. INTRODUCTION

The main objectives of this research project are to refine further the inverse liquid chromatography technique for the study of surface properties of raw coals, treated coals and coal minerals in water, to evaluate relatively surface properties of raw coals, treated coals and coal minerals by inverse liquid chromatography, and to investigate mechanisms on equilibrium adsorption loadings of probe compounds on various coals.

Coals such as Pittsburgh #8 coal, Illinois #6 coal, Adaville #1 coal and Smith-Roland Wyodak coal are chosen as representatives of high-rank bituminous coal, high volatile bituminous coals and subbituminous coal, respectively.

Aliphatic alcohols such as 2-methyl-1-pentanol and 1-heptanol are utilized as probe compounds to investigate floatability of the coals, equilibrated with their aqueous solutions at room temperature. Aromatic compounds such as benzene and toluene are used in studying mechanisms on their adsorption on the coals.

III. PROJECT STATUS

1. Experiments

Experiments on equilibrium adsorption loadings of aromatic compounds such as benzene and toluene on Illinois #6 coal, Adaville #1 coal, Smith-Roland Wyodak coal and Pittsburgh #8 coal were performed in aqueous solutions at room temperature to identify the role of methyl group of toluene in the adsorption process.

Experiments on equilibrium adsorption loadings of aliphatic alcohols such as 2-methyl-1-pentanol and 1-heptanol on Illinois #6 coal, Adaville #1 coal, Smith-Roland Wyodak coal and Pittsburgh #8 coal were performed in aqueous solutions at room temperature to relate adsorption loadings of these compounds to flotation percentages of these coals equilibrated with their aqueous solutions at room temperature.

The coals were pulverized and sieved to obtain 60-200 mesh coal particles. Sieved 60-200 mesh coal particles were washed with distilled water (DW) to remove water-soluble organic compounds from the surfaces of the coal particles. Coal particles were submerged under water overnight, and then filtered next day to remove organic-dissolved water from surfaces of coal particles. These washing processes continued for several weeks. Washed coal particles were dried at 110°C for 4 hours.

Dry coal particles of 0.75 g were introduced into an empty column. The coal particles packed in the column were washed with DW for 10 hours to eliminate any water-soluble contaminants introduced in the coal-packed column during the process of packing dry coal particles into the column.

Experiments on flotation of the coals were carried on with 500-cc batch-type micro flotation apparatus at room temperature. Nitrogen gas was introduced at the bottom of the flotation apparatus.

Mr. Ricardo Rigby, a senior chemical engineering student, worked as an undergraduate research assistant for this project

during the April - June period.

2. Experimental Results

Experimental data on equilibrium adsorption loadings of benzene, toluene, 2-methyl-1-pentanol and 1-heptanol on the 60 -200 mesh coals were shown in Tables 1 and 2.

Experimental data on flotation of the coals, equilibrated with aqueous solutions of 2M1P and 1-heptanol, are shown in Tables 3 and 4.

Equilibrium adsorption loadings of benzene are lower than those of toluene on the four chosen coals. Equilibrium adsorption loadings of both benzene and toluene on Adaville #1 coal and Wyodak coal are higher than those on Illinois #6 coal and Pittsburgh #8 coal. Equilibrium adsorption loadings of aromatic compounds such as toluene and benzene on the four chosen coals obey the Langmuir isotherm model for single-layer adsorption up to 100 ppm in concentrations of probe compounds. (see Figures 1 and 2).

Equilibrium adsorption loadings of both 2M1P and 1-heptanol on Adaville #1 coal are highest, whereas equilibrium adsorption loadings of both 2M1P and 1-heptanol on Pittsburgh #8 coal are lowest among those on the four chosen coals (see Figures 3 and 6).

Flotation of Pittsburgh #8 coal with aqueous solutions of both 2M1P and 1-heptanol is highest among the coals, and Flotation of Wyodak coal is lowest among the coals (see Figures 4 and 7).

Flotation of the coals, equilibrated with aqueous solutions of both 2M1P and 1-heptanol, is plotted against equilibrium adsorption loadings of both 2M1P and 1-heptanol on the coals (see Figures 5 and 8). Flotation of coal increase with increased adsorption loadings of both 2M1P and 1-heptanol on the coals.

Adsorption loadings of 1-heptanol on Illinois #6 coal appear to increase with decreased adsorption temperatures (see Figure 9).

IV. FUTURE EXPERIMENTAL PLANS

Experiments on equilibrium adsorption loadings of probe compounds on treated coals will be conducted to investigate change in surface properties of these treated coals in comparison with those of raw coals. Flotation experiments of these coals will be conducted to find relationships between flotation data and adsorption data of probe compounds.

V. PUBLICATIONS/PRESENTATIONS

"Investigation of Surface Properties of Coal with Probe Compounds in Aqueous Solution", was accepted for presentation at the Eighth Symposium on Separation Science and Technology for Energy Applications", Getlinburg, Tennessee, October 24 - 28, 1993.

"Adsorption of Various Probe Compounds on Coal in Aqueous Solutions", was accepted for presentation at the 1993 AIChE Annual Meeting, St. Louis, Missouri, November 7 - 12, 1993.

Table 1. Equilibrium adsorption loadings of benzene and toluene on various 60-200 mesh coals, and their equilibrium concentrations in aqueous solutions at room temperature (23 - 27°C).

Run #	Probe Compounds	Equilibrium Concn., ppm Alcohols, ppm	Equilibrium Adsorption, 10 ⁺⁶ mg/g-coal	Coal	Temperature, °C
290	benzene	19.96	711.96	Adaville	27
283	benzene	40.03	1,538.98	Adaville	
385	benzene	80.03	2,885.48	Adaville	
275	benzene	160.09	3,861.48	Adaville	
381	Benzene	319.95	5,784.49	Adaville	
420	benzene	640.05	7,458.03	Adaville	
288	benzene	19.96	542.67	Wyodak	27
284	benzene	40.03	1,261.55	Wyodak	
281	benzene	80.04	2,598.43	Wyodak	
277	benzene	160.09	3,964.37	Wyodak	
393	benzene	320.24	4,763.42	Wyodak	
406	benzene	320.31	4,984.32	Wyodak	
421	benzene	640.05	7,695.48	Wyodak	
287	benzene	19.96	584.23	Illinois	27
286	benzene	40.03	822.66	Illinois	
279	benzene	80.04	1,711.05	Illinois	
278	benzene	160.09	1,855.79	Illinois	
384	benzene	319.95	3,511.38	Illinois	
379	benzene	640.05	3 992.86	Illinois	
289	benzene	19.96	101.35	Pittsburgh	27
285	benzene	40.03	149.82	Pittsburgh	
280	benzene	80.04	501.67	Pittsburgh	
276	benzene	160.09	728.02	Pittsburgh	
382	benzene	319.95	544.49	Pittsburgh	
378	benzene	640.05	2,256.83	Pittsburgh	
267	toluene	30.00	3,116.02	Adaville	27
264	toluene	39.99	1,193.14	Adaville	
260	toluene	60.01	6,638.17	Adaville	
255	toluene	100.00	7,248.89	Adaville	
386	toluene	319.98	10,306.10	Adaville	
268	toluene	30.00	3,347.04	Wyodak	27
263	toluene	39.99	3,263.99	Wyodak	
258	toluene	60.01	5,498.43	Wyodak	
257	toluene	100.00	7,211.34	Wyodak	
389	toluene	319.98	7,716.56	Wyodak	
270	toluene	20.02	1,032.72	Illinois	27
269	toluene	30.00	1,433.77	Illinois	
262	toluene	39.99	1,592.08	Illinois	
261	toluene	60.01	2,041.00	Illinois	
256	toluene	100.00	3,624.23	Illinois	
387	toluene	319.98	4,252.29	Illinois	
172	toluene	10.01	581.87	Illinois	23
168	toluene	19.97	1,033.00	Illinois	
166	toluene	29.94	2,105.77	Illinois	
165	toluene	39.99	3,257.76	Illinois	
272	toluene	20.02	225.22	Pittsburgh	27

Table 1 (Continued)

266	toluene	30.00	445.12	Pittsburgh
265	toluene	39.99	360.63	Pittsburgh
259	toluene	60.01	630.64	Pittsburgh
254	toluene	100.00	836.02	Pittsburgh
388	toluene	319.98	1,528.82	Pittsburgh

Table 2. Equilibrium adsorption loadings of 2-methyl-1-pentanol (2M1P) and 1-heptanol on various 60-200 mesh coals, and their equilibrium concentrations in aqueous solutions at room temperature (23 - 27°C).

Run #	Probe Compounds	Equilibrium Concn., ppm Alcohols, ppm	Equilibrium Adsorption, 10 ⁶ mg/g-coal	Coal	Temperature, °C
318	2M1P	10.00	60.71	Adaville	27
314	2M1P	20.01	153.84	Adaville	
312	2M1P	40.04	514.94	Adaville	
312	2M1P	80.04	1,033.33	Adaville	
303	2M1P	160.13	2,373.17	Adaville	
396	2M1P	320.33	3,239.56	Adaville	
365	2M1P	640.57	4,173.68	Adaville	27
319	2M1P	10.00	89.59	Wyodak	
313	2M1P	20.01	202.56	Wyodak	
310	2M1P	40.04	895.70	Wyodak	
305	2M1P	80.04	1,107.47	Wyodak	
304	2M1P	160.13	1,836.51	Wyodak	
401	2M1P	320.33	2,671.26	Wyodak	
364	2M1P	640.57	3,509.14	Wyodak	
317	2M1P	10.00	22.51	Illinois	27
316	2M1P	20.01	57.01	Illinois	
309	2M1P	40.04	314.07	Illinois	
308	2M1P	80.04	245.09	Illinois	
362	2M1P	159.91	303.75	Illinois	
405	2M1P	320.33	759.62	Illinois	
410	2M1P	640.50	1,192.82	Illinois	
320	2M1P	10.00	3.54	Pittsburgh	27
315	2M1P	20.00	12.54	Pittsburgh	
311	2M1P	40.04	107.97	Pittsburgh	
307	2M1P	80.04	131.04	Pittsburgh	
297	2M1P	320.13	162.40	Pittsburgh	
366	2M1P	640.57	247.54	Pittsburgh	
346	1-heptanol	10.01	234.34	Adaville	27
350	1-heptanol	10.01	176.56	Adaville	
341	1-heptanol	20.01	700.32	Adaville	
336	1-heptanol	40.01	1,011.11	Adaville	
416	1-heptanol	80.04	1,152.37	Adaville	
415	1-heptanol	160.03	2,724.67	Adaville	
414	1-heptanol	319.93	4,275.24	Adaville	
324	1-heptanol	320.09	5,366.73	Adaville	
367	1-heptanol	640.34	9,959.41	Adaville	
347	1-heptanol	10.01	673.54	Wyodak	27
351	1-heptanol	10.01	498.42	Wyodak	
340	1-heptanol	40.01	854.33	Wyodak	
373	1-heptanol	40.01	776.15	Wyodak	
372	1-heptanol	80.06	961.65	Wyodak	
412	1-heptanol	160.03	2,211.55	Wyodak	
413	1-heptanol	319.93	4,024.74	Wyodak	
368	1-heptanol	640.34	8,965.21	Wyodak	
411	1-heptanol	640.58	7,691.76	Wyodak	
348	1-heptanol	10.01	15.72	Illinois	27
352	1-heptanol	10.01	121.38	Illinois	
343	1-heptanol	20.01	163.51	Illinois	
424	1-heptanol	40.01	354.92	Illinois	
334	1-heptanol	80.01	336.53	Illinois	

Table 2 (Continued)

419	1-heptanol	80.05	447.58	Illinois	
418	1-heptanol	160.05	1,035.62	Illinois	
419	1-heptanol	320.27	1,417.73	Illinois	
366	1-heptanol	640.34	2,565.26	Illinois	
177	1-heptanol	5.01	249.29	Illinois	23
176	1-heptanol	10.02	291.69	Illinois	
175	1-heptanol	20.05	699.00	Illinois	
174	1-heptanol	30.08	1,131.88	Illinois	
185	1-heptanol	40.06	1,190.54	Illinois	
196	1-heptanol	80.10	1,850.10	Illinois	
197	1-heptanol	160.39	2,629.67	Illinois	
198	1-heptanol	320.20	3,658.61	Illinois	
331	1-heptanol	160.08	301.65	Pittsburgh	27
369	1-heptanol	640.34	1,647.35	Pittsburgh	

Table 3. Flotation of various 60-200 mesh coals, equilibrated with aqueous solutions of 2-methyl-1-pentanol (2M1P) at room temperature (23 - 27°C).

Probe Compounds	Equilibrium Concen., ppm	Flotation, weight %	Coal
2M1P	0	18.65	Pittsburgh
2M1P	5	37.16	Pittsburgh
2M1P	5	38.28	Pittsburgh
2M1P	10	34.19	Pittsburgh
2M1P	10	39.45	Pittsburgh
2M1P	20	37.64	Pittsburgh
2M1P	20	26.26	Pittsburgh
2M1P	40	48.67	Pittsburgh
2M1P	60	52.31	Pittsburgh
2M1P	80	51.57	Pittsburgh
2M1P	120	57.88	Pittsburgh
2M1P	120	66.86	Pittsburgh
2M1P	120	56.86	Pittsburgh
2M1P	160	74.30	Pittsburgh
2M1P	160	71.31	Pittsburgh
2M1P	320	75.47	Pittsburgh
2M1P	0	1.01	Adaville
2M1P	0	1.34	Adaville
2M1P	5	2.36	Adaville
2M1P	5	3.80	Adaville
2M1P	10	2.60	Adaville
2M1P	20	4.50	Adaville
2M1P	20	3.43	Adaville
2M1P	40	11.76	Adaville
2M1P	60	15.03	Adaville
2M1P	80	20.69	Adaville
2M1P	120	23.46	Adaville
2M1P	160	34.83	Adaville
2M1P	320	31.88	Adaville
2M1P	0	1.11	Illinois
2M1P	5	1.59	Illinois
2M1P	10	1.90	Illinois
2M1P	20	4.50	Illinois
2M1P	20	2.29	Illinois
2M1P	40	10.41	Illinois
2M1P	60	10.65	Illinois
2M1P	80	9.15	Illinois
2M1P	120	15.99	Illinois
2M1P	160	14.02	Illinois
2M1P	320	11.53	Illinois
2M1P	320	11.42	Illinois
2M1P	0	0.59	Wyodak

Table 3 (Continued)

2M1P	0	0.94	Wyodak
2M1P	5	2.08	Wyodak
2M1P	10	3.15	Wyodak
2M1P	10	3.18	Wyodak
2M1P	40	5.60	Wyodak
2M1P	60	5.74	Wyodak
2M1P	60	6.04	Wyodak
2M1P	80	5.69	Wyodak
2M1P	120	6.68	Wyodak
2M1P	160	9.13	Wyodak
2M1P	320	8.58	Wyodak

Table 4. Flotation of various 60-200 mesh coals, equilibrated with aqueous solutions of 1-heptanol at room temperature (23 - 27°C).

Probe Compounds	Equilibrium Concn., ppm	Flotation, weight %	Coal
1-heptanol	0	20.03	Pittsburgh
1-heptanol	5	25.85	Pittsburgh
1-heptanol	10	38.72	Pittsburgh
1-heptanol	20	49.31	Pittsburgh
1-heptanol	40	65.80	Pittsburgh
1-heptanol	60	80.03	Pittsburgh
1-heptanol	80	82.25	Pittsburgh
1-heptanol	120	83.08	Pittsburgh
1-heptanol	160	80.13	Pittsburgh
1-heptanol	320	74.97	Pittsburgh
1-heptanol	0	1.96	Adaville
1-heptanol	5	3.50	Adaville
1-heptanol	10	5.83	Adaville
1-heptanol	20	8.68	Adaville
1-heptanol	40	30.33	Adaville
1-heptanol	60	35.43	Adaville
1-heptanol	80	42.03	Adaville
1-heptanol	120	41.18	Adaville
1-heptanol	160	43.97	Adaville
1-heptanol	320	35.44	Adaville
1-heptanol	0	1.36	Illinois
1-heptanol	0	1.96	Illinois
1-heptanol	5	2.18	Illinois
1-heptanol	5	1.76	Illinois
1-heptanol	10	3.27	Illinois
1-heptanol	10	2.22	Illinois
1-heptanol	20	2.74	Illinois
1-heptanol	40	6.50	Illinois
1-heptanol	60	9.66	Illinois
1-heptanol	80	11.70	Illinois
1-heptanol	120	12.60	Illinois
1-heptanol	160	16.95	Illinois
1-heptanol	160	15.89	Illinois
1-heptanol	320	8.34	Illinois
1-heptanol	0	0.57	Wyodak
1-heptanol	0	1.36	Wyodak
1-heptanol	5	2.08	Wyodak
1-heptanol	5	1.05	Wyodak
1-heptanol	10	1.89	Wyodak
1-heptanol	10	1.77	Wyodak
1-heptanol	20	2.46	Wyodak

Table 4 (Continued)

1-heptanol	20	3.84	Wyodak
1-heptanol	40	3.28	Wyodak
1-heptanol	60	3.49	Wyodak
1-heptanol	80	6.89	Wyodak
1-heptanol	120	6.96	Wyodak
1-heptanol	160	4.42	Wyodak
1-heptanol	320	2.99	Wyodak

Figure 1. Equilibrium adsorption of benzene on 0.75-g 60-200 mesh coal in aqueous solutions at room temperature.

Figure 2. Equilibrium adsorption of toluene on 0.75-g 60-200 mesh coal in aqueous solutions at room temperature.

Figure 3. Adsorption of 2-methyl 1-pentanol (2M1P) on 0.75-g 60-200 mesh Coal at room temperature.

Figure 4. Flotation of various coals, equilibrated with 2-methyl-1-pentanol (2M1P) at room temperature.

Figure 5. Flotation vs Adsorption of 2-methyl-1-pentanol (2M1P) for various coals at room temperature.

Figure 6. Adsorption of 1-heptanol (1HPL) on various coals at room temperature.

Figure 7. Flotation Percentage of various coals against concentration of 1-heptanol (1HPL) at room temperature.

Figure 8. Flotation vs adsorption of 1-heptanol (1HPL) on various coal at room temperature.

Figure 9. Adsorption of 1-heptanol (1HPL) on Illinois #6 coal at room temperature.

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