

Supporting Information

An ionic liquid enhanced solvent extraction for oil recovery from oily sludge

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Table S1. Mass balance calculation of the F2, F3, and F4 fractions of TPH for orthogonal experiments of solvent extraction alone

Exp. No.		F2 _o (μg)	F2 _i (μg)	F2 _b (μg)	F3 _o (μg)	F3 _i (μg)	F3 _b (μg)	F4 _o (μg)	F4 _i (μg)	F4 _b (μg)	F2 _s /F2 _o	F3 _s /F3 _o	F4 _s /F4 _o	TPH _s /TPH _o
1	Rep1	105,869	97,816	4,657	148,833	120,486	16,551	39,267	26,898	11,192	0.97	0.92	0.97	0.94
	Rep2	106,609	93,683	5,066	149,873	113,599	18,709	39,542	26,118	12,025	0.93	0.88	0.96	0.91
	Rep3	106,102	95,226	3,621	149,160	115,632	18,784	39,354	24,042	11,095	0.93	0.90	0.89	0.91
2	Rep1	106,905	104,586	3,911	150,289	120,657	16,237	39,652	29,657	11,152	1.01	0.91	1.03	0.96
	Rep2	106,863	10,0243	3,399	150,230	114,618	17,441	39,636	29,439	10,760	0.97	0.88	1.01	0.93
	Rep3	106,102	100,362	1,985	149,160	120,210	17,865	39,354	29,627	9,550	0.96	0.93	1.00	0.95
3	Rep1	106,440	91,596	4,182	149,635	125,413	15,440	39,479	31,291	9,978	0.90	0.94	1.05	0.94
	Rep2	105,172	91,204	4,418	147,852	116,729	15,004	39,009	33,667	10,579	0.91	0.89	1.13	0.93
	Rep3	105,743	91,517	4,957	148,655	118,453	17,743	39,220	30,430	8,800	0.91	0.92	1.00	0.93
4	Rep1	105,700	101,445	902	148,595	129,972	7,357	39,205	36,083	4,241	0.97	0.92	1.03	0.95
	Rep2	105,996	99,683	745	149,011	120,081	10,748	39,314	33,437	8,908	0.95	0.88	1.08	0.93
	Rep3	107,138	106,462	1,641	150,616	124,304	14,271	39,738	33,333	6,588	1.01	0.92	1.00	0.96
5	Rep1	106,525	102,535	2,081	149,754	128,291	11,655	39,510	37,674	6,964	0.98	0.93	1.13	0.98
	Rep2	105,827	99,858	1,436	148,773	121,563	10,583	39,252	38,278	6,480	0.96	0.89	1.14	0.95
	Rep3	107,053	96,722	2,660	150,497	130,621	13,291	39,706	35,857	5,849	0.93	0.96	1.05	0.96
6	Rep1	106,673	81,048	3,396	149,962	124,989	13,008	39,565	40,064	5,496	0.79	0.92	1.15	0.90
	Rep2	106,948	96,484	3,197	150,349	123,480	11,663	39,667	36,636	6,740	0.93	0.90	1.09	0.94
	Rep3	105,256	102,705	2,078	147,971	126,867	14,095	39,040	34,328	6,127	1.00	0.95	1.04	0.98
7	Rep1	105,362	79,100	2,002	148,120	137,957	8,616	39,079	44,443	5,182	0.77	0.99	1.27	0.95
	Rep2	104,728	111,885	1,163	147,228	131,963	9,674	38,844	36,452	5,863	1.08	0.96	1.09	1.02
	Rep3	106,271	107,745	1,515	149,398	136,297	11,864	39,416	38,858	6,522	1.03	0.99	1.15	1.03
8	Rep1	104,051	83,927	1,435	146,277	125,923	11,001	38,593	39,451	5,564	0.82	0.94	1.17	0.93
	Rep2	106,102	107,317	2,889	149,160	127,029	12,996	39,354	37,254	6,215	1.04	0.94	1.10	1.00
	Rep3	106,123	99,805	1,825	149,190	132,324	9,029	39,361	37,371	5,345	0.96	0.95	1.09	0.97
9	Rep1	106,652	95,827	2,862	149,932	131,858	9,157	39,557	42,315	4,181	0.93	0.94	1.18	0.97
	Rep2	106,673	103,002	2,296	149,962	136,641	10,080	39,565	42,057	4,924	0.99	0.98	1.19	1.01
	Rep3	106,800	120,085	1,411	150,141	139,262	8,620	39,612	37,753	5,669	1.14	0.98	1.10	1.05
Average											0.95	0.93	1.08	0.96
F(2/3/4) _o : mass of F2/F3/F4 fractions of TPH in the original oily sludge sample;														
F(2/3/4) _i : mass of F2/F3/F4 fractions of TPH in the recovered oil;														
F(2/3/4) _b : mass of F2/F3/F4 fractions of TPH in the residual sand/clay;														
F(2/3/4) _s : sum of F(2/3/4) _i and F(2/3/4) _b ;														
TPH _s : sum of F2 _i , F2 _b , F3 _i , F3 _b , F4 _i , and F4 _b ;														
TPH _o : sum of F2 _o , F3 _o , and F4 _o .														

Table S2. Mass balance calculation of the F2, F3, and F4 fractions of TPH for orthogonal experiments of IL enhanced solvent extraction process

Exp. No.		F2 _o (μg)	F2 _t (μg)	F2 _i (μg)	F2 _b (μg)	F3 _o (μg)	F3 _t (μg)	F3 _i (μg)	F3 _b (μg)	F4 _o (μg)	F4 _t (μg)	F4 _i (μg)	F4 _b (μg)	F2 _s / F2 _o	F3 _s / F3 _o	F4 _s / F4 _o	TPH _s / TPH _o
1	Rep1	105,341	78,621	18,324	710	148,090	98,182	37,636	10,853	39,071	12,897	21,739	10,653	0.93	0.99	1.16	0.99
	Rep2	107,497	80,939	26,914	661	151,121	102,186	43,929	11,166	39,871	17,075	24,857	5,061	1.01	1.04	1.18	1.05
	Rep3	105,806	93,527	22,459	657	148,744	101,161	42,726	11,766	39,244	13,412	21,116	7,276	1.10	1.05	1.07	1.07
2	Rep1	105,320	77,363	17,634	737	148,060	105,123	34,762	9,659	39,063	16,113	20,704	9,674	0.91	1.01	1.19	1.00
	Rep2	104,791	66,603	13,988	978	147,317	105,949	43,430	10,420	38,867	21,248	22,882	4,540	0.78	1.08	1.25	1.00
	Rep3	106,482	96,918	15,843	679	149,695	111,224	35,393	11,908	39,495	17,858	18,664	7,028	1.07	1.06	1.10	1.07
3	Rep1	105,447	86,525	11,372	410	148,239	115,224	26,216	7,502	39,111	19,651	19,912	8,721	0.93	1.00	1.23	1.01
	Rep2	105,193	87,197	16,765	612	147,882	112,516	36,823	9,785	39,016	24,887	23,012	3,628	0.99	1.08	1.32	1.08
	Rep3	105,595	85,474	10,795	201	148,447	113,586	30,676	12,047	39,165	19,039	17,529	5,440	0.91	1.05	1.07	1.01
4	Rep1	107,582	91,128	13,250	635	151,240	110,960	39,374	9,193	39,902	17,112	25,876	6,635	0.98	1.05	1.24	1.05
	Rep2	105,806	92,027	11,853	238	148,744	106,100	42,328	9,279	39,244	22,173	22,419	4,082	0.98	1.06	1.24	1.06
	Rep3	104,960	82,947	6,520	208	147,555	105,687	41,431	12,473	38,930	16,766	21,448	5,801	0.85	1.08	1.13	1.01
5	Rep1	107,053	90,705	13,556	495	150,497	115,875	31,023	8,038	39,706	19,720	22,821	6,914	0.98	1.03	1.25	1.04
	Rep2	105,700	83,990	15,302	740	148,595	113,091	32,281	9,242	39,205	25,819	19,717	5,255	0.95	1.04	1.30	1.04
	Rep3	104,516	90,602	12,000	197	146,931	104,409	31,658	13,913	38,766	18,489	18,242	6,374	0.98	1.02	1.11	1.02
6	Rep1	107,095	90,032	8,147	812	150,557	113,313	31,430	11,220	39,722	22,355	21,923	8,293	0.92	1.04	1.32	1.03
	Rep2	107,201	76,835	17,204	188	150,705	100,882	38,155	8,816	39,761	23,782	24,441	5,293	0.88	0.98	1.35	0.99
	Rep3	104,580	76,035	10,706	526	147,020	105,760	25,943	17,432	38,789	20,305	15,751	5,816	0.83	1.01	1.08	0.96
7	Rep1	105,320	95,031	10,767	215	148,060	108,837	29,403	7,933	39,063	21,032	19,230	7,254	1.01	0.99	1.22	1.02
	Rep2	106,398	85,364	8,702	355	149,576	102,902	25,985	9,173	39,463	22,733	15,913	3,960	0.89	0.92	1.08	0.93
	Rep3	104,749	75,054	14,839	186	147,258	94,846	35,125	12,831	38,852	15,800	18,737	6,181	0.86	0.97	1.05	0.94
8	Rep1	106,377	105,510	3,605	399	149,546	122,904	21,351	7,173	39,456	24,786	17,544	7,222	1.03	1.01	1.26	1.05
	Rep2	106,398	87,722	6,239	317	149,576	118,831	22,586	4,369	39,463	29,347	13,775	5,416	0.89	0.97	1.23	0.98
	Rep3	106,863	88,730	10,127	787	150,230	104,311	29,355	14,738	39,636	19,059	16,018	7,709	0.93	0.99	1.08	0.98
9	Rep1	104,876	81,642	4,378	382	147,436	123,428	26,409	6,607	38,899	26,931	17,614	8,188	0.82	1.06	1.36	1.01
	Rep2	106,208	97,020	17,188	185	149,308	118,540	29,321	3,822	39,393	31,440	15,792	4,951	1.08	1.02	1.32	1.08
	Rep3	106,017	87,683	8,841	819	149,041	115,452	19,670	14,425	39,322	22,265	12,689	8,026	0.92	1.00	1.09	0.98
Average														0.94	1.02	1.20	1.03

F(2/3/4)_o: mass of F2/F3/F4 fractions of TPH in the original oily sludge sample;F(2/3/4)_t: mass of F2/F3/F4 fractions of TPH in the recovered oil from top oil layer;F(2/3/4)_i: mass of F2/F3/F4 fractions of TPH in the recovered oil from oil-IL interface;F(2/3/4)_b: mass of F2/F3/F4 fractions of TPH in the residual sand/clay;F(2/3/4)_s: sum of F(2/3/4)_t, F(2/3/4)_i, and F(2/3/4)_b;TPH_s: sum of F2_t, F2_i, F2_b, F3_t, F3_i, F3_b, F4_t, F4_i, and F4_b;TPH_o: sum of F2_o, F3_o, and F4_o.

Table S3. ANOVA for TPH, F2, F3, and F4 recovery in solvent extraction alone

Sources of variation	SS ^a	DF ^b	Mean square	F-value	Prob > F	Significance
<i>For TPH recovery</i>						
(A) So/SI ratio	494.59	2	247.30	30.21	<0.001	**
(B) Shaking speed	1.72	2	0.86	0.10	0.90	
(C) Extraction duration	70.03	2	35.01	4.28	0.03	*
Error	147.32	18	8.18			
Total	730.67	26				
<i>For F2 recovery</i>						
(A) So/SI ratio	100.54	2	50.27	0.88	0.43	
(B) Shaking speed	32.46	2	16.23	0.28	0.76	
(C) Extraction duration	258.73	2	129.37	2.26	0.13	
Error	1030.96	18	57.28			
Total	1784.37	26				
<i>For F3 recovery</i>						
(A) So/SI ratio	470.02	2	235.01	64.30	<0.001	**
(B) Shaking speed	11.20	2	5.60	1.53	0.24	
(C) Extraction duration	35.42	2	17.71	4.85	0.02	*
Error	65.79	18	3.66			
Total	632.08	26				
<i>For F4 recovery</i>						
(A) So/SI ratio	3415.07	2	1707.54	91.33	<0.001	**
(B) Shaking speed	276.35	2	138.17	7.39	0.0045	**
(C) Extraction duration	227.23	2	113.62	6.08	0.0096	**
Error	336.54	18	18.70			
Total	4522.00	26				

^a Sum of squares; ^b Degree of freedom; * Significant (P < 0.05); ** Highly significant (P < 0.01)

Table S4 ANOVA for TPH recovery in IL enhanced solvent extraction process.

Sources of variation	SS ^a	DF ^b	Mean square	F-value	Prob > F	Significance
<i>For TPH recovery</i>						
(A) So/SI ratio	1.79	2	0.89	0.05	0.95	
(B) IL/SI ratio	89.16	2	44.58	2.32	0.13	
(C) Shaking speed	28.00	2	14.00	0.73	0.50	
Error	345.68	18	19.20			
Total	554.09	26				
<i>Part1: TPH recovery in top oil layer</i>						
(A) So/SI ratio	139.83	2	69.92	4.01	0.036	*
(B) IL/SI ratio	125.79	2	62.90	3.61	0.048	*
(C) Shaking speed	135.12	2	67.56	3.87	0.040	*
Error	313.87	18	17.44			
Total	761.49	26				
<i>Part 2: TPH recovery in oil-IL interface</i>						
(A) So/SI ratio	111.44	2	55.72	7.99	0.0033	**
(B) IL/SI ratio	17.69	2	8.84	1.27	0.31	
(C) Shaking speed	284.74	2	142.37	20.42	<0.001	**
Error	125.48	18	6.97			
Total	575.12	26				

^a Sum of squares; ^b Degree of freedom; * Significant (P < 0.05); ** Highly significant (P < 0.01)