Appendix A

Neat Grout ANS 16.1 Individual Sample Data

Table A-1. U Grout Replicate A Neat Grout ANS 16.1 Data.

Time (d)	Sr (mg/L)	Al (mg/L)	Ca (mg/L)	Si (mg/L)	NO_3^- (mg/L)
0.083	0.100	0.334	18.971	0.800	0.180
0.292	0.055	0.320	10.865	0.749	0.235
1.000	0.105	0.602	13.455	1.824	0.255
2.000	0.109	0.589	21.745	2.354	0.310
3.000	0.082	0.472	17.634	2.126	0.265
4.000	0.083	0.484	16.978	2.144	0.280
5.000	0.055	0.394	13.629	2.054	0.230
19.000	0.167	1.853	23.673	11.719	2.090
47.000	0.082	1.558	9.313	13.261	1.590
90.000	0.073	1.331	6.659	15.115	1.110

			De (cm^2/s)		
Time (d)	Sr	Al	Ca	Si	NO_3^-
0.083	1.38E-10	8.97E-12	1.28E-09	2.74E-11	4.22E-10
0.292	5.48E-11	1.07E-11	5.50E-10	3.13E-11	9.32E-10
1.000	5.97E-11	1.13E-11	2.51E-10	5.57E-11	3.26E-10
2.000	7.87E-11	1.33E-11	8.06E-10	1.13E-10	5.95E-10
3.000	7.59E-11	1.46E-11	8.98E-10	1.57E-10	7.39E-10
4.000	1.09E-10	2.15E-11	1.18E-09	2.24E-10	1.16E-09
5.000	6.18E-11	1.84E-11	9.78E-10	2.67E-10	1.01E-09
19.000	7.05E-12	5.00E-12	3.64E-11	1.07E-10	1.04E-09
47.000	1.23E-12	2.58E-12	4.05E-12	9.90E-11	4.30E-10
90.000	8.78E-13	1.70E-12	1.89E-12	1.16E-10	1.89E-10

Time (d)	pH	Eh (mV)
0.083	10.8	368.2
0.292	11.0	183.6
1.000	10.6	176.5
2.000	10.8	217.9
3.000	10.3	213.9
4.000	9.9	227.3
5.000	10.8	187.5
19.000	11.0	128.1
47.000	11.1	380.1
90.000	11.1	389.0

Table A-2. U Grout Replicate B Neat Grout ANS 16.1 Data.

Time (d)	Sr (mg/L)	Al (mg/L)	Ca (mg/L)	Si (mg/L)	NO_3^- (mg/L)
0.083	0.046	0.238	6.622	0.048	0.180
0.292	0.055	0.324	9.998	0.704	0.270
1.000	0.118	0.612	14.661	1.924	0.255
2.000	0.118	0.589	25.172	2.461	0.290
3.000	0.091	0.492	19.872	2.179	0.240
4.000	0.082	0.456	17.230	2.133	0.280
5.000	0.056	0.401	15.345	2.161	0.230
19.000	0.155	1.859	21.558	11.016	1.890
47.000	0.082	1.549	9.683	13.534	1.500
90.000	0.073	1.376	11.107	16.710	1.110

			De (cm^2/s)		
Time (d)	Sr	Al	Ca	Si	NO_3^-
0.083	2.94E-11	4.58E-12	1.57E-10	9.89E-14	4.22E-10
0.292	5.48E-11	1.10E-11	4.67E-10	2.77E-11	1.23E-09
1.000	7.50E-11	1.17E-11	2.98E-10	6.18E-11	3.26E-10
2.000	9.24E-11	1.33E-11	1.08E-09	1.25E-10	5.22E-10
3.000	9.29E-11	1.58E-11	1.14E-09	1.64E-10	6.09E-10
4.000	1.07E-10	1.92E-11	1.21E-09	2.21E-10	1.16E-09
5.000	6.41E-11	1.90E-11	1.24E-09	2.93E-10	1.01E-09
19.000	6.09E-12	5.07E-12	3.02E-11	9.46E-11	8.41E-10
47.000	1.23E-12	2.54E-12	4.40E-12	1.03E-10	3.85E-10
90.000	8.78E-13	1.79E-12	5.21E-12	1.41E-10	1.89E-10

Time (d)	pH	Eh (mV)
0.083	11.1	355.0
0.292	10.9	181.0
1.000	10.8	178.0
2.000	10.9	216.0
3.000	10.3	203.0
4.000	10.8	212.0
5.000	10.8	193.0
19.000	11.2	134.0
47.000	11.1	366.0
90.000	11.1	391.0

Table A-3. U Grout Replicate C Neat Grout ANS 16.1 Data.

Time (d)	Sr (mg/L)	Al (mg/L)	Ca (mg/L)	Si (mg/L)	NO_3^- (mg/L)
0.083	0.036	0.236	7.334	0.129	0.170
0.292	0.055	0.329	11.274	0.746	0.225
1.000	0.100	0.621	13.808	1.869	0.250
2.000	1.092	0.593	25.606	2.556	0.290
3.000	0.082	0.484	19.060	2.132	0.260
4.000	0.046	0.423	5.390	2.031	0.270
5.000	0.065	0.391	13.301	2.123	0.235
19.000	0.155	1.867	25.424	11.452	2.090
47.000	0.091	1.557	14.040	15.135	1.490
90.000	0.082	1.378	10.326	15.808	1.010

			De (cm^2/s)		
Time (d)	Sr	Al	Ca	Si	NO_3^-
0.083	1.80E-11	4.48E-12	1.93E-10	7.12E-13	3.75E-10
0.292	5.48E-11	1.14E-11	5.91E-10	3.10E-11	8.59E-10
1.000	5.37E-11	1.20E-11	2.64E-10	5.77E-11	3.14E-10
2.000	7.87E-09	1.35E-11	1.12E-09	1.33E-10	5.22E-10
3.000	7.59E-11	1.53E-11	1.05E-09	1.57E-10	7.13E-10
4.000	3.36E-11	1.65E-11	1.18E-10	2.01E-10	1.08E-09
5.000	8.65E-11	1.81E-11	9.30E-10	2.84E-10	1.05E-09
19.000	6.09E-12	5.13E-12	4.20E-11	1.02E-10	1.04E-09
47.000	1.50E-12	2.58E-12	9.26E-12	1.29E-10	3.80E-10
90.000	1.11E-12	1.82E-12	4.49E-12	1.27E-10	1.58E-10

Time (d)	pH	Eh (mV)
0.083	10.8	365.0
0.292	10.9	172.0
1.000	10.8	175.0
2.000	10.8	209.0
3.000	10.4	202.0
4.000	10.5	237.0
5.000	10.6	203.0
19.000	11.0	130.0
47.000	11.2	375.0
90.000	11.1	388.0

Table A-4. T Grout Replicate A Neat Grout ANS 16.1 Data.

Time (d)	Sr (mg/L)	Al (mg/L)	Ca (mg/L)	Si (mg/L)	NO_3^- (mg/L)
0.083	0.073	0.028	14.097	0.625	0.019
0.292	0.086	0.051	15.697	0.489	0.019
1.000	0.182	0.174	36.784	1.421	0.028
2.000	0.187	0.220	47.850	1.782	0.038
3.000	0.147	0.186	40.863	1.722	0.038
4.000	0.100	0.184	16.329	1.676	0.029
5.000	0.118	0.209	30.554	1.925	0.019
19.000	0.975	0.611	208.154	3.825	1.010
47.000	0.564	0.639	95.820	4.554	1.010
90.000	0.664	0.757	82.308	4.463	0.820

			De (cm^2/s)		
Time (d)	Sr	Al	Ca	Si	NO_3^-
0.083	4.33E-11	4.22E-14	4.89E-11	5.04E-12	2.75E-12
0.292	7.82E-11	1.83E-13	7.93E-11	4.01E-12	3.58E-12
1.000	1.04E-10	6.29E-13	1.30E-10	1.01E-11	2.31E-12
2.000	1.35E-10	1.25E-12	2.69E-10	1.96E-11	5.22E-12
3.000	1.43E-10	1.52E-12	3.35E-10	3.10E-11	8.87E-12
4.000	9.26E-11	2.07E-12	7.51E-11	4.14E-11	7.28E-12
5.000	1.66E-10	3.44E-12	3.39E-10	7.02E-11	4.04E-12
19.000	1.40E-10	3.65E-13	1.94E-10	3.41E-12	1.40E-10
47.000	3.40E-11	2.89E-13	2.98E-11	3.52E-12	1.01E-10
90.000	4.23E-11	3.65E-13	1.98E-11	3.05E-12	6.03E-11

Time (d)	pH	Eh (mV)
0.083	11.0	329.0
0.292	11.0	146.0
1.000	11.0	121.0
2.000	10.9	154.0
3.000	10.3	158.0
4.000	10.8	166.0
5.000	11.1	131.0
19.000	11.1	66.0
47.000	11.0	367.0
90.000	11.4	346.0

Table A-5. T Grout Replicate B Neat Grout ANS 16.1 Data.

Time (d)	Sr (mg/L)	Al (mg/L)	Ca (mg/L)	Si (mg/L)	NO_3^- (mg/L)
0.083	0.073	0.027	15.806	0.733	0.019
0.292	0.073	0.050	5.825	0.470	0.029
1.000	0.191	0.169	38.283	1.211	0.028
2.000	0.191	0.210	49.536	1.503	0.018
3.000	0.146	0.191	37.910	1.548	0.038
4.000	0.082	0.174	10.897	1.539	0.029
5.000	0.127	0.182	30.473	1.656	0.039
19.000	0.866	0.593	160.838	3.359	0.910
47.000	0.592	0.629	95.092	3.999	1.010
90.000	0.592	0.793	52.029	4.718	0.820

			De (cm^2/s)		
Time (d)	Sr	Al	Ca	Si	NO_3^-
0.083	4.33E-11	3.91E-14	6.16E-11	6.92E-12	2.75E-12
0.292	5.64E-11	1.76E-13	1.09E-11	3.72E-12	8.31E-12
1.000	1.15E-10	5.97E-13	1.41E-10	7.35E-12	2.31E-12
2.000	1.42E-10	1.13E-12	2.89E-10	1.39E-11	1.17E-12
3.000	1.41E-10	1.59E-12	2.88E-10	2.51E-11	8.87E-12
4.000	6.24E-11	1.85E-12	3.35E-11	3.49E-11	7.28E-12
5.000	1.93E-10	2.63E-12	3.35E-10	5.20E-11	1.69E-11
19.000	1.11E-10	3.45E-13	1.16E-10	2.66E-12	1.14E-10
47.000	3.75E-11	2.80E-13	2.93E-11	2.70E-12	1.01E-10
90.000	3.37E-11	4.01E-13	7.94E-12	3.38E-12	6.03E-11

Time (d)	pH	Eh (mV)
0.083	11.0	324.0
0.292	10.5	141.0
1.000	11.0	124.0
2.000	11.1	165.0
3.000	10.6	150.0
4.000	9.6	190.0
5.000	11.1	193.0
19.000	11.1	83.0
47.000	11.1	379.0
90.000	11.4	373.0

Table A-6. T Grout Replicate C Neat Grout ANS 16.1 Data.

Time (d)	Sr (mg/L)	Al (mg/L)	Ca (mg/L)	Si (mg/L)	NO_3- (mg/L)
0.083	0.073	0.023	15.676	0.760	0.019
0.292	0.105	0.059	23.057	0.474	0.009
1.000	0.182	0.164	34.892	1.160	0.028
2.000	0.191	0.201	48.875	1.393	0.028
3.000	0.164	0.219	37.748	1.548	0.038
4.000	0.137	0.200	32.921	1.474	0.029
5.000	0.109	0.183	28.913	1.565	0.028
19.000	0.556	0.582	92.503	3.068	1.010
47.000	0.601	0.630	96.322	3.726	1.110
90.000	0.601	0.730	76.777	4.263	1.020

			De (cm^2/s)		
Time (d)	Sr	Al	Ca	Si	NO_3-
0.083	4.330E-11	2.860E-14	6.060E-11	7.440E-12	2.750E-12
0.292	1.170E-10	2.450E-13	1.710E-10	3.770E-12	7.990E-13
1.000	1.040E-10	5.570E-13	1.170E-10	6.750E-12	2.310E-12
2.000	1.420E-10	1.040E-12	2.820E-10	1.200E-11	2.840E-12
3.000	1.770E-10	2.090E-12	2.840E-10	2.510E-11	8.870E-12
4.000	1.730E-10	2.450E-12	3.060E-10	3.200E-11	7.280E-12
5.000	1.420E-10	2.670E-12	3.020E-10	4.660E-11	8.750E-12
19.000	4.560E-11	3.310E-13	3.830E-11	2.210E-12	1.400E-10
47.000	3.850E-11	2.810E-13	3.010E-11	2.350E-12	1.230E-10
90.000	3.470E-11	3.400E-13	1.720E-11	2.770E-12	9.330E-11

Time (d)	pH	Eh (mV)
0.083	11.0	322.0
0.292	11.1	129.0
1.000	11.0	133.0
2.000	11.2	145.0
3.000	10.5	143.0
4.000	11.0	153.0
5.000	11.1	126.0
19.000	11.1	83.0
47.000	11.1	380.0
90.000	11.3	361.0

Table A-7. E Grout Replicate A Neat Grout ANS 16.1 Data.

Time (d)	Sr (mg/L)	Al (mg/L)	Ca (mg/L)	Si (mg/L)	NO_3^- (mg/L)
0.083	0.020	0.027	1.103	1.138	0.385
0.292	0.005	0.005	0.759	0.024	0.415
1.000	0.005	0.010	1.358	0.034	0.480
2.000	0.001	0.018	1.190	0.052	0.450
3.000	0.001	0.018	1.386	0.047	0.482
4.000	0.001	0.019	1.289	0.029	0.500
5.000	0.001	0.009	1.459	0.021	0.444
19.000	0.010	0.027	3.362	0.056	2.990
47.000	0.018	0.036	4.967	0.094	4.190
90.000	0.027	0.035	6.276	0.103	2.090

			De (cm^2/s)		
Time (d)	Sr	Al	Ca	Si	NO_3^-
0.083	4.90E-12	1.31E-13	2.82E-10	1.53E-11	1.69E-09
0.292	3.99E-13	5.88E-15	1.74E-10	8.87E-15	2.56E-09
1.000	1.19E-13	7.05E-15	1.65E-10	5.27E-15	1.02E-09
2.000	5.80E-15	2.79E-14	1.56E-10	1.52E-14	1.10E-09
3.000	9.85E-15	4.74E-14	3.60E-10	2.12E-14	2.15E-09
4.000	1.39E-14	7.46E-14	4.38E-10	1.13E-14	3.25E-09
5.000	1.79E-14	2.15E-14	7.21E-10	7.67E-15	3.30E-09
19.000	2.21E-14	2.39E-15	4.76E-11	6.74E-16	1.85E-09
47.000	5.21E-14	3.07E-15	7.50E-11	1.37E-15	2.63E-09
90.000	1.05E-13	2.62E-15	1.08E-10	1.48E-15	5.92E-10

Time (d)	pH	Eh (mV)
0.083	10.2	269.0
0.292	9.6	174.0
1.000	9.8	176.0
2.000	10.3	193.0
3.000	9.8	212.0
4.000	10.8	214.0
5.000	8.7	207.0
19.000	10.2	122.0
47.000	10.7	339.0
90.000	10.7	360.0

Table A-8. E Grout Replicate B Neat Grout ANS 16.1 Data.

Time (d)	Sr (mg/L)	Al (mg/L)	Ca (mg/L)	Si (mg/L)	NO_3^- (mg/L)
0.083	0.010	0.113	0.964	1.150	0.395
0.292	0.005	0.005	0.732	0.023	0.405
1.000	0.005	0.005	1.313	0.022	0.450
2.000	0.001	0.009	1.338	0.046	0.460
3.000	0.010	0.001	1.094	0.037	0.482
4.000	0.010	0.009	1.044	0.048	0.520
5.000	0.100	0.009	0.985	0.003	0.414
19.000	0.010	0.001	3.252	0.030	2.790
47.000	0.009	0.001	4.379	0.029	3.890
90.000	0.018	0.001	5.226	0.029	1.790

			De (cm^2/s)		
Time (d)	Sr	Al	Ca	Si	NO_3^-
0.083	1.21E-12	2.31E-12	2.15E-10	1.56E-11	1.78E-09
0.292	3.99E-13	5.88E-15	1.61E-10	8.15E-15	2.43E-09
1.000	1.19E-13	1.75E-15	1.55E-10	2.22E-15	8.95E-10
2.000	5.80E-15	6.98E-15	1.97E-10	1.20E-14	1.15E-09
3.000	9.85E-13	1.47E-16	2.26E-10	1.32E-14	2.15E-09
4.000	1.39E-12	1.67E-14	2.86E-10	3.10E-14	3.52E-09
5.000	1.79E-10	2.15E-14	3.30E-10	1.56E-16	2.87E-09
19.000	2.21E-14	3.30E-18	4.44E-11	1.93E-16	1.61E-09
47.000	1.30E-14	2.39E-18	5.84E-11	1.30E-16	2.27E-09
90.000	4.69E-14	2.15E-18	7.48E-11	1.17E-16	4.34E-10

Time (d)	pH	Eh (mV)
0.083	10.2	266.0
0.292	9.8	172.0
1.000	9.8	175.0
2.000	10.3	189.0
3.000	9.8	208.0
4.000	10.3	226.0
5.000	10.1	177.0
19.000	10.2	123.0
47.000	10.6	336.0
90.000	10.6	375.0

Table A-9. E Grout Replicate C Neat Grout ANS 16.1 Data.

Time (d)	Sr (mg/L)	Al (mg/L)	Ca (mg/L)	Si (mg/L)	NO_3^- (mg/L)
0.083	0.019	0.007	1.072	1.170	0.400
0.292	0.005	0.009	0.548	0.034	0.412
1.000	0.005	0.010	1.303	0.025	0.460
2.000	0.001	0.072	1.335	0.164	0.450
3.000	0.010	0.010	1.031	0.151	0.498
4.000	0.010	0.010	0.925	0.003	0.500
5.000	0.100	0.019	0.967	0.012	0.444
19.000	0.010	0.001	3.434	0.048	2.890
47.000	0.009	0.001	4.261	0.029	4.090
90.000	0.027	0.009	5.344	0.020	2.090

			De (cm^2/s)		
Time (d)	Sr	Al	Ca	Si	NO_3^-
0.083	4.39E-12	8.84E-15	2.64E-10	1.62E-11	1.82E-09
0.292	3.99E-13	1.90E-14	9.05E-11	1.77E-14	2.52E-09
1.000	1.19E-13	7.05E-15	1.52E-10	2.86E-15	9.35E-10
2.000	5.80E-15	4.47E-13	1.97E-10	1.52E-13	1.10E-09
3.000	9.85E-13	1.47E-14	2.01E-10	2.18E-13	2.29E-09
4.000	1.39E-12	2.07E-14	2.28E-10	1.21E-16	3.25E-09
5.000	1.79E-10	9.62E-14	3.21E-10	2.50E-15	3.30E-09
19.000	2.21E-14	3.30E-18	4.96E-11	4.94E-16	1.73E-09
47.000	1.30E-14	2.39E-18	5.53E-11	1.30E-16	2.51E-09
90.000	1.05E-13	1.73E-16	7.83E-11	5.59E-17	5.92E-10

Time (d)	pH	Eh (mV)
0.083	10.2	276.0
0.292	9.9	172.0
1.000	9.6	185.0
2.000	10.4	145.0
3.000	9.6	210.0
4.000	10.8	202.0
5.000	10.3	171.0
19.000	10.3	123.0
47.000	10.8	332.0
90.000	10.7	378.0

Table A-10. C75 Grout Replicate A Neat Grout ANS 16.1 Data.

Time (d)	Sr (mg/L)	Al (mg/L)	Ca (mg/L)	Si (mg/L)	NO_3^- (mg/L)
0.083	0.040	0.010	2.910	0.070	0.047
0.292	0.020	0.010	2.280	0.020	0.038
1.000	0.110	0.080	7.510	0.450	0.038
2.000	0.110	0.100	11.050	0.600	0.029
3.000	0.120	0.130	12.190	0.820	0.048
4.000	0.100	0.140	12.480	0.850	0.038
5.000	0.130	0.190	14.050	1.320	0.047
19.000	0.910	0.950	68.500	8.300	0.820
47.000	0.640	0.730	43.640	10.020	1.010
90.000	0.500	0.600	30.000	6.020	0.590

			De (cm^2/s)		
Time (d)	Sr	Al	Ca	Si	NO_3^-
0.083	2.53E-11	1.17E-14	5.59E-12	4.21E-13	3.26E-11
0.292	8.24E-12	1.52E-14	4.46E-12	4.46E-14	2.77E-11
1.000	7.39E-11	2.89E-13	1.45E-11	6.75E-12	8.25E-12
2.000	9.10E-11	5.58E-13	3.87E-11	1.48E-11	5.92E-12
3.000	1.85E-10	1.59E-12	7.98E-11	4.69E-11	2.76E-11
4.000	1.82E-10	2.60E-12	1.18E-10	7.10E-11	2.43E-11
5.000	3.94E-10	6.21E-12	1.93E-10	2.19E-10	4.80E-11
19.000	2.38E-10	1.91E-12	5.65E-11	1.08E-10	1.80E-10
47.000	8.51E-11	8.17E-13	1.66E-11	1.14E-10	1.99E-10
90.000	1.02E-10	1.08E-12	1.54E-11	8.07E-11	1.33E-10

Time (d)	pH	Eh (mV)
0.083	10.7	310.0
0.292	11.0	235.0
1.000	10.9	185.0
2.000	11.6	213.0
3.000	11.1	190.0
4.000	11.0	199.0
5.000	10.9	203.0
19.000	10.6	210.0
47.000	10.8	292.0
90.000	10.9	301.0

Table A-11. C75 Grout Replicate B Neat Grout ANS 16.1 Data.

Time (d)	Sr (mg/L)	Al (mg/L)	Ca (mg/L)	Si (mg/L)	NO_3^- (mg/L)
0.083	0.040	0.020	4.200	0.100	0.037
0.292	0.020	0.040	1.490	0.020	0.047
1.000	0.110	0.090	10.270	0.550	0.038
2.000	0.110	0.110	11.470	0.660	0.028
3.000	0.100	0.130	11.960	0.720	0.028
4.000	0.130	0.190	15.290	1.160	0.037
5.000	0.140	0.220	15.200	1.400	0.047
19.000	0.980	0.920	70.350	8.200	0.920
47.000	0.620	0.810	42.630	9.670	1.110
90.000	0.450	0.580	31.120	6.360	0.820

			De (cm^2/s)		
Time (d)	Sr	Al	Ca	Si	NO_3^-
0.083	2.53E-11	4.67E-14	1.17E-11	8.60E-13	2.02E-11
0.292	8.24E-12	2.43E-13	1.90E-12	4.46E-14	4.25E-11
1.000	7.39E-11	3.66E-13	2.71E-11	1.01E-11	8.25E-12
2.000	9.10E-11	6.74E-13	4.17E-11	1.79E-11	5.53E-12
3.000	1.29E-10	1.59E-12	7.69E-11	3.62E-11	9.39E-12
4.000	3.06E-10	4.82E-12	1.76E-10	1.33E-10	2.30E-11
5.000	4.58E-10	8.30E-12	2.27E-10	2.46E-10	4.80E-11
19.000	2.75E-10	1.79E-12	5.96E-11	1.05E-10	2.25E-10
47.000	8.00E-11	1.00E-12	1.58E-11	1.06E-10	2.39E-10
90.000	8.29E-11	1.01E-12	1.66E-11	9.00E-11	2.57E-10

Time (d)	pH	Eh (mV)
0.083	10.7	311.0
0.292	10.7	237.0
1.000	11.2	172.0
2.000	10.5	198.0
3.000	10.9	192.0
4.000	10.4	195.0
5.000	10.8	206.0
19.000	11.2	198.0
47.000	10.9	284.0
90.000	10.9	312.0

Table A-12. C75 Grout Replicate C Neat Grout ANS 16.1 Data.

Time (d)	Sr (mg/L)	Al (mg/L)	Ca (mg/L)	Si (mg/L)	NO_3^- (mg/L)
0.083	0.070	0.020	6.330	0.150	0.047
0.292	0.030	0.010	3.440	0.050	0.038
1.000	0.090	0.050	7.770	0.320	0.047
2.000	0.140	0.130	13.460	0.830	0.028
3.000	0.170	0.200	17.930	1.270	0.028
4.000	0.130	0.170	15.890	1.080	0.038
5.000	0.110	0.140	12.630	1.020	0.047
19.000	0.950	0.940	66.750	7.880	0.820
47.000	0.630	0.760	44.110	9.740	1.010
90.000	0.470	0.550	29.160	6.130	0.910

			De (cm^2/s)		
Time (d)	Sr	Al	Ca	Si	NO_3^-
0.083	7.75E-11	4.67E-14	2.66E-11	1.93E-12	3.26E-11
0.292	1.86E-11	1.52E-14	1.02E-11	2.81E-13	2.77E-11
1.000	4.99E-11	1.13E-13	1.55E-11	3.41E-12	1.27E-11
2.000	1.49E-10	9.38E-13	5.69E-11	2.83E-11	5.53E-12
3.000	3.71E-10	3.79E-12	1.72E-10	1.12E-10	9.39E-12
4.000	3.06E-10	3.87E-12	1.91E-10	1.15E-10	2.43E-11
5.000	2.80E-10	3.35E-12	1.55E-10	1.32E-10	4.80E-11
19.000	5.19E-10	3.72E-12	1.07E-10	1.93E-10	3.59E-10
47.000	8.26E-11	8.85E-13	1.70E-11	1.07E-10	1.99E-10
90.000	9.06E-11	9.13E-13	1.46E-11	8.39E-11	3.14E-10

Time (d)	pH	Eh (mV)
0.083	10.5	313.0
0.292	10.9	229.0
1.000	10.8	180.0
2.000	10.3	200.0
3.000	10.9	186.0
4.000	10.7	189.0
5.000	11.0	214.0
19.000	10.6	223.0
47.000	10.6	262.0
90.000	10.8	296.0

Table A-13. S Grout Replicate A Neat Grout ANS 16.1 Data.

Time (d)	Sr (mg/L)	Al (mg/L)	Ca (mg/L)	Si (mg/L)	NO_3^- (mg/L)
0.083	0.010	0.040	0.060	0.910	0.038
0.292	0.160	0.120	2.720	0.220	0.028
1.000	0.170	0.340	10.260	1.090	0.038
2.000	0.110	0.200	6.910	0.720	0.028
3.000	0.160	0.540	12.400	1.980	0.019
4.000	0.100	0.380	10.390	1.630	0.028
5.000	0.090	0.290	8.470	1.450	0.010
19.000	0.680	1.510	46.430	7.630	0.820
47.000	0.340	1.140	13.110	7.480	1.400
90.000	0.170	0.590	7.500	4.400	0.720

			De (cm^2/s)		
Time (d)	Sr	Al	Ca	Si	NO_3^-
0.083	1.14E-12	2.40E-14	6.66E-15	1.21E-10	1.56E-11
0.292	3.87E-10	2.81E-13	1.79E-11	9.32E-12	1.10E-11
1.000	1.30E-10	6.72E-13	7.50E-11	6.83E-11	6.04E-12
2.000	6.62E-11	2.86E-13	4.21E-11	3.65E-11	4.04E-12
3.000	2.41E-10	3.53E-12	2.32E-10	4.70E-10	3.14E-12
4.000	1.31E-10	2.45E-12	2.28E-10	4.47E-10	9.67E-12
5.000	1.38E-10	1.86E-12	1.96E-10	4.53E-10	1.58E-12
19.000	9.71E-11	6.21E-13	7.25E-11	1.56E-10	1.32E-10
47.000	1.75E-11	2.55E-13	4.20E-12	1.08E-10	2.78E-10
90.000	8.66E-12	1.34E-13	2.69E-12	7.38E-11	1.44E-10

Time (d)	pH	Eh (mV)
0.083	10.4	300.0
0.292	10.6	222.0
1.000	10.1	202.0
2.000	10.3	203.0
3.000	11.0	200.0
4.000	9.8	205.0
5.000	10.5	212.0
19.000	10.8	226.0
47.000	10.5	205.0
90.000	10.9	224.0

Table A-14. S Grout Replicate B Neat Grout ANS 16.1 Data.

Time (d)	Sr (mg/L)	Al (mg/L)	Ca (mg/L)	Si (mg/L)	NO_3^- (mg/L)
0.083	0.060	0.030	2.850	0.120	0.038
0.292	0.020	0.020	1.290	0.030	0.028
1.000	0.110	0.011	6.100	1.090	0.037
2.000	0.130	0.140	8.250	0.640	0.028
3.000	0.200	0.440	14.550	1.930	0.019
4.000	0.120	0.250	10.470	1.160	0.028
5.000	0.090	0.200	7.450	1.030	0.010
19.000	0.690	1.150	41.390	7.740	1.020
47.000	0.340	1.230	12.100	6.960	1.590
90.000	0.180	0.570	7.600	4.500	0.820

			De (cm^2/s)		
Time (d)	Sr	Al	Ca	Si	NO_3^-
0.083	4.16E-11	1.33E-14	1.50E-11	2.12E-12	1.56E-11
0.292	6.03E-12	7.80E-15	4.01E-12	1.72E-13	1.10E-11
1.000	5.37E-11	7.00E-16	2.67E-11	6.83E-11	5.72E-12
2.000	9.38E-11	1.40E-13	6.03E-11	2.88E-11	4.04E-12
3.000	3.75E-10	2.35E-12	3.18E-10	4.45E-10	3.14E-12
4.000	1.91E-10	1.07E-12	2.31E-10	2.28E-10	9.67E-12
5.000	1.38E-10	8.80E-13	1.51E-10	2.30E-10	1.58E-12
19.000	1.00E-10	3.60E-13	5.76E-11	1.60E-10	2.04E-10
47.000	1.75E-11	2.97E-13	3.57E-12	9.37E-11	3.57E-10
90.000	9.71E-12	1.26E-13	2.77E-12	7.71E-11	1.87E-10

Time (d)	pH	Eh (mV)
0.083	10.2	301.0
0.292	11.0	205.0
1.000	10.0	228.0
2.000	10.1	198.0
3.000	10.5	210.0
4.000	10.0	201.0
5.000	10.7	199.0
19.000	10.9	203.0
47.000	10.6	223.0
90.000	10.8	232.0

Table A-15. S Grout Replicate C Neat Grout ANS 16.1 Data.

Time (d)	Sr (mg/L)	Al (mg/L)	Ca (mg/L)	Si (mg/L)	NO_3^- (mg/L)
0.083	0.080	0.060	3.360	0.190	0.037
0.292	0.060	0.010	1.660	0.040	0.028
1.000	0.140	0.340	7.510	0.460	0.038
2.000	0.250	0.440	15.740	1.830	0.028
3.000	0.130	0.220	9.710	1.020	0.019
4.000	0.150	0.380	12.580	1.790	0.028
5.000	0.130	0.340	10.460	1.640	0.019
19.000	0.680	1.440	46.140	7.580	1.020
47.000	0.330	1.240	11.960	7.070	1.500
90.000	0.160	0.560	7.400	4.600	0.820

			De (cm^2/s)		
Time (d)	Sr	Al	Ca	Si	NO_3^-
0.083	7.38E-11	5.39E-14	2.09E-11	5.34E-12	1.47E-11
0.292	5.42E-11	1.94E-15	6.64E-12	3.07E-13	1.10E-11
1.000	8.83E-11	6.72E-13	4.05E-11	1.21E-11	6.04E-12
2.000	3.44E-10	1.38E-12	2.19E-10	2.37E-10	4.04E-12
3.000	1.59E-10	5.87E-13	1.41E-10	1.25E-10	3.14E-12
4.000	2.98E-10	2.45E-12	3.34E-10	5.38E-10	9.67E-12
5.000	2.89E-10	2.55E-12	2.98E-10	5.82E-10	5.70E-12
19.000	9.71E-11	5.63E-13	7.17E-11	1.54E-10	2.04E-10
47.000	1.65E-11	3.02E-13	3.48E-12	9.68E-11	3.16E-10
90.000	7.68E-12	1.21E-13	2.62E-12	8.07E-11	1.87E-10

Time (d)	pH	Eh (mV)
0.083	10.6	297.0
0.292	10.1	216.0
1.000	9.8	232.0
2.000	10.2	192.0
3.000	10.9	206.0
4.000	9.5	195.0
5.000	10.2	211.0
19.000	11.0	207.0
47.000	10.6	197.0
90.000	10.9	211.0

Appendix B

Grout with Interferences ANS 16.1 Individual Sample Data

Table B-1. U Grout with 9% Organic Sludge - Strontium ANS 16.1 Data.

		Sr (mg/l)				
Time (d)	Sample 1	Sample 2	Sample 3			
0.083	0.010	0.010	0.010			
0.292	0.010	0.010	0.020			
1.000	0.080	0.080	0.110			
2.000	0.110	0.090	0.120			
3.000	0.110	0.130	0.120			
4.000	0.060	0.050	0.060			
5.000	0.050	0.040	0.040			
19.000	0.230	0.270	0.260			
47.000	0.150	0.160	0.140			
90.000	0.190	0.150	0.130			
		De (cm^2/s)			Leach Index (LI)	
Time (d)	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
0.083	1.46E-12	1.46E-12	1.46E-12	11.8	11.8	11.8
0.292	1.90E-12	1.90E-12	7.62E-12	11.7	11.7	11.1
1.000	3.61E-11	3.61E-11	6.83E-11	10.4	10.4	10.2
2.000	8.41E-11	5.58E-11	9.96E-11	10.1	10.3	10.0
3.000	1.43E-10	2.01E-10	1.69E-10	9.8	9.7	9.8
4.000	5.99E-11	4.16E-11	5.99E-11	10.2	10.4	10.2
5.000	5.35E-11	3.42E-11	3.42E-11	10.3	10.5	10.5
19.000	1.40E-11	1.92E-11	1.79E-11	10.9	10.7	10.7
47.000	4.30E-12	4.88E-12	3.76E-12	11.4	11.3	11.4
90.000	6.21E-12	3.87E-12	2.93E-12	11.2	11.4	11.5
		pH			Eh (mV)	
Time (d)	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
0.083	10.3	10.2	10.3	323.0	322.1	398.0
0.292	10.6	10.5	10.6	382.1	375.5	384.2
1.000	11.4	11.2	11.2	402.4	395.0	388.5
2.000	11.2	11.0	11.8	403.0	421.0	401.2
3.000	11.0	11.1	11.0	412.3	422.0	412.0
4.000	11.1	11.1	11.1	416.8	404.1	420.1
5.000	11.0	11.0	10.9	411.0	398.0	412.0
19.000	11.6	11.6	11.3	412.0	403.0	421.0
47.000	11.3	10.2	10.9	412.0	423.0	432.0
90.000	11.7	11.8	11.7	414.8	412.6	421.5

Table B-2. U Grout with 12% Nitrate Salt - Strontium ANS 16.1 Data.

		Sr (mg/l)	
Time (d)	Sample 1	Sample 2	Sample 3
0.083	0.010	0.010	0.010
0.292	0.010	0.010	0.010
1.000	0.020	0.020	0.020
2.000	0.040	0.020	0.030
3.000	0.050	0.020	0.040
4.000	0.020	0.010	0.020
5.000	0.030	0.010	0.010
19.000	0.130	0.120	0.130
47.000	0.080	0.060	0.070
90.000	0.060	0.140	0.130

		De (cm^2/s)			Leach Index (LI)	
Time (d)	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
0.083	1.36E-12	1.36E-12	1.36E-12	11.9	11.9	11.9
0.292	1.77E-12	1.77E-12	1.77E-12	11.8	11.8	11.8
1.000	5.27E-13	5.27E-13	5.27E-13	12.3	12.3	12.3
2.000	1.03E-11	2.60E-12	5.81E-12	11.0	11.6	11.2
3.000	2.75E-11	4.41E-12	1.76E-11	10.6	11.4	10.8
4.000	6.21E-12	1.55E-12	6.21E-12	11.2	11.8	11.2
5.000	1.79E-11	2.00E-12	2.00E-12	10.7	11.7	11.7
19.000	4.14E-12	3.57E-12	4.14E-12	11.4	11.4	11.4
47.000	1.14E-12	6.42E-13	8.74E-13	11.9	12.2	12.1
90.000	5.78E-13	3.13E-12	2.69E-12	12.2	11.5	11.6

		pH			Eh (mV)	
Time (d)	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
0.083	10.0	10.3	10.2	398.0	376.2	388.1
0.292	8.9	10.0	10.1	376.4	398.4	396.5
1.000	10.3	10.4	9.8	398.2	402.6	429.8
2.000	11.0	11.1	11.1	411.0	403.0	422.6
3.000	10.8	10.8	10.6	399.0	400.2	412.0
4.000	10.9	10.8	11.2	406.9	403.2	403.5
5.000	11.0	11.1	11.0	409.0	411.0	423.0
19.000	11.3	11.4	11.3	399.2	410.0	412.0
47.000	11.5	11.4	11.6	405.0	413.8	399.8
90.000	11.4	11.6	11.5	407.2	405.2	408.3

Table B-3. U Grout with 50% INEEL Soil - Strontium ANS 16.1 Data.

		Sr (mg/l)	
Time (d)	Sample 1	Sample 2	Sample 3
0.083	0.010	0.010	0.010
0.292	0.010	0.010	0.010
1.000	0.040	0.070	0.060
2.000	0.080	0.080	0.070
3.000	0.040	0.070	0.100
4.000	0.030	0.050	0.050
5.000	0.020	0.040	0.020
19.000	0.080	0.050	0.120
47.000	0.050	0.070	0.080
90.000	0.060	0.060	0.020

		De (cm^2/s)			Leach Index (LI)	
Time (d)	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
0.083	1.13E-12	1.13E-12	1.13E-12	11.9	11.9	11.9
0.292	1.48E-12	1.48E-12	1.48E-12	11.8	11.8	11.8
1.000	7.03E-12	2.16E-11	1.58E-11	11.2	10.7	10.8
2.000	3.47E-11	3.47E-11	2.66E-11	10.5	10.5	10.6
3.000	1.47E-11	4.51E-11	9.21E-11	10.8	10.3	10.0
4.000	1.17E-11	3.24E-11	3.24E-11	10.9	10.5	10.5
5.000	6.67E-12	2.67E-11	6.67E-12	11.2	10.6	11.2
19.000	1.32E-12	5.16E-13	2.95E-12	11.9	12.3	11.5
47.000	3.73E-13	7.31E-13	9.56E-13	12.4	12.1	12.0
90.000	4.83E-13	4.83E-13	5.37E-14	12.3	12.3	13.3

		pH			Eh (mV)	
Time (d)	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
0.083	10.5	10.2	10.1	388.5	389.2	366.1
0.292	10.3	10.2	10.2	376.0	402.1	398.5
1.000	11.0	11.2	11.2	412.0	413.0	411.5
2.000	11.1	11.2	11.2	400.0	412.0	405.3
3.000	10.2	10.1	9.8	398.2	411.0	416.0
4.000	11.0	11.0	11.0	399.5	399.5	423.1
5.000	11.3	11.4	11.3	402.6	407.8	407.4
19.000	11.3	11.4	11.5	399.0	413.0	412.0
47.000	11.7	11.5	11.6	423.0	413.0	401.6
90.000	11.6	11.5	11.8	412.0	412.8	415.9

Table B-4. T Grout with 9% Organic Sludge - Strontium ANS 16.1 Data.

		Sr (mg/l)	
Time (d)	Sample 1	Sample 2	Sample 3
0.083	0.040	0.040	0.030
0.292	0.010	0.020	0.010
1.000	0.080	0.170	0.060
2.000	0.080	0.140	0.090
3.000	0.100	0.100	0.080
4.000	0.060	0.140	0.070
5.000	0.060	0.110	0.040
19.000	0.690	0.750	0.730
47.000	0.710	0.680	0.770
90.000	1.350	1.450	1.390

		De (cm^2/s)			Leach Index (LI)	
Time (d)	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
0.083	1.37E-11	1.37E-11	7.67E-12	10.9	10.9	11.1
0.292	1.12E-12	4.46E-12	1.12E-12	12.0	11.4	12.0
1.000	2.13E-11	9.59E-11	1.20E-11	10.7	10.0	10.9
2.000	2.62E-11	8.00E-11	3.31E-11	10.6	10.1	10.5
3.000	6.95E-11	6.95E-11	4.45E-11	10.2	10.2	10.4
4.000	3.52E-11	1.91E-10	4.78E-11	10.5	9.7	10.3
5.000	4.53E-11	1.52E-10	2.02E-11	10.3	9.8	10.7
19.000	7.42E-11	8.74E-11	8.29E-11	10.1	10.1	10.1
47.000	5.67E-11	5.20E-11	6.68E-11	10.2	10.3	10.2
90.000	1.85E-10	2.12E-10	1.95E-10	9.7	9.7	9.7

		pH			Eh (mV)	
Time (d)	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
0.083	10.5	10.5	10.5	398.0	376.2	347.8
0.292	10.1	10.2	10.2	382.1	376.5	386.2
1.000	11.1	11.0	11.1	403.0	421.6	388.5
2.000	11.1	11.1	11.3	400.2	412.0	401.2
3.000	11.0	11.0	10.8	412.3	422.0	412.0
4.000	10.9	10.9	10.9	421.0	404.1	416.2
5.000	11.0	11.5	11.4	411.0	426.0	412.0
19.000	11.8	11.8	11.8	409.0	412.0	421.0
47.000	11.6	11.7	11.5	399.8	416.3	405.0
90.000	11.9	11.8	11.9	407.8	412.7	415.6

Table B-5. T Grout with 12% Nitrate Salt - Strontium ANS 16.1 Data.

		Sr (mg/l)	
Time (d)	Sample 1	Sample 2	Sample 3
0.083	0.020	0.020	0.010
0.292	0.010	0.020	0.020
1.000	0.050	0.040	0.110
2.000	0.070	0.080	0.160
3.000	0.100	0.100	0.100
4.000	0.050	0.070	0.120
5.000	0.080	0.040	0.110
19.000	0.880	0.210	1.180
47.000	0.600	0.900	0.800
90.000	0.330	0.340	0.710

		De (cm^2/s)			Leach Index (LI)	
Time (d)	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
0.083	3.42E-12	3.42E-12	8.56E-13	11.5	11.5	12.1
0.292	1.12E-12	4.46E-12	4.46E-12	12.0	11.4	11.4
1.000	8.28E-12	5.31E-12	4.01E-11	11.1	11.3	10.4
2.000	2.62E-11	8.00E-11	3.31E-11	10.6	10.1	10.5
3.000	6.95E-11	6.95E-11	6.95E-11	10.2	10.2	10.2
4.000	3.52E-11	1.91E-10	4.78E-11	10.5	9.7	10.3
5.000	8.06E-11	2.02E-11	1.52E-10	10.1	10.7	9.8
19.000	1.21E-10	6.90E-12	2.17E-10	9.9	11.2	9.7
47.000	4.05E-11	9.11E-11	7.21E-11	10.4	10.0	10.1
90.000	1.10E-11	1.17E-11	5.11E-11	11.0	10.9	10.3

		pH			Eh (mV)	
Time (d)	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
0.083	10.2	10.2	10.6	398.0	376.2	347.8
0.292	10.5	10.5	10.4	376.6	398.1	396.4
1.000	11.0	11.2	11.2	398.2	402.6	441.2
2.000	11.1	11.0	11.1	411.0	393.0	396.2
3.000	11.4	11.2	11.3	399.0	403.0	421.2
4.000	11.2	11.0	11.1	407.1	402.3	403.5
5.000	11.6	11.4	11.5	410.5	411.0	423.0
19.000	12.0	12.0	11.7	399.2	412.0	403.0
47.000	11.9	11.5	11.6	400.0	401.0	396.0
90.000	11.9	11.7	11.9	205.8	412.7	412.9

Table B-6. T Grout with 50% INEEL Soil - Strontium ANS 16.1 Data.

		Sr (mg/l)	
Time (d)	Sample 1	Sample 2	Sample 3
0.083	0.020	0.020	0.030
0.292	0.010	0.020	0.020
1.000	0.070	0.050	0.080
2.000	0.110	0.070	0.120
3.000	0.840	1.020	1.030
4.000	0.060	0.040	0.070
5.000	0.050	0.030	0.050
19.000	0.500	0.420	0.560
47.000	0.490	0.510	0.400
90.000	0.570	0.440	0.190

		De (cm^2/s)			Leach Index (LI)	
Time (d)	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
0.083	3.42E-12	3.42E-12	7.67E-12	11.5	11.5	11.1
0.292	1.12E-12	4.46E-12	4.46E-12	12.0	11.4	11.4
1.000	1.62E-11	8.28E-12	2.13E-11	10.8	11.1	10.7
2.000	2.00E-11	2.62E-11	1.04E-10	10.7	10.6	10.0
3.000	4.90E-09	7.22E-09	7.37E-09	8.3	8.1	8.1
4.000	2.44E-11	4.78E-11	1.41E-10	10.6	10.3	9.9
5.000	3.14E-11	1.13E-11	3.14E-11	10.5	10.9	10.5
19.000	3.88E-11	2.74E-11	4.88E-11	10.4	10.6	10.3
47.000	2.71E-11	2.93E-11	1.80E-11	10.6	10.5	10.7
90.000	3.29E-11	1.96E-11	3.64E-12	10.5	10.7	11.4

		pH			Eh (mV)	
Time (d)	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
0.083	10.2	10.2	10.1	366.5	381.2	376.5
0.292	10.2	10.5	10.4	376.0	402.2	398.5
1.000	11.1	11.1	11.0	401.6	423.0	412.6
2.000	11.4	11.4	11.4	399.8	403.6	402.0
3.000	11.0	11.0	11.0	398.2	411.0	416.0
4.000	10.8	11.0	10.9	400.0	399.5	423.1
5.000	11.0	11.3	11.4	402.6	402.8	407.8
19.000	11.9	11.8	11.6	415.6	411.2	411.0
47.000	11.6	11.8	11.5	415.6	423.5	412.8
90.000	11.8	11.5	11.7	421.5	413.7	412.0

Table B-7. E Grout with 9% Organic Sludge - Strontium ANS 16.1 Data.

		Sr (mg/l)				
Time (d)	Sample 1	Sample 2	Sample 3			
0.083	0.010	0.010	0.010			
0.292	0.010	0.010	0.010			
1.000	0.010	0.010	0.010			
2.000	0.010	0.010	0.010			
3.000	0.010	0.020	0.020			
4.000	0.010	0.020	0.030			
5.000	0.010	0.010	0.010			
19.000	0.010	0.010	0.010			
47.000	0.100	0.120	0.110			
90.000	0.030	0.020	0.020			
		De (cm^2/s)			Leach Index (LI)	
Time (d)	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
0.083	1.31E-12	1.31E-12	1.31E-12	11.9	11.9	11.9
0.292	1.71E-12	1.71E-12	1.71E-12	11.8	11.8	11.8
1.000	5.08E-13	5.08E-13	5.08E-13	12.3	12.3	12.3
2.000	6.26E-13	6.26E-13	6.26E-13	12.2	12.2	12.2
3.000	1.06E-12	4.29E-12	4.29E-12	12.0	11.4	11.4
4.000	1.50E-12	6.04E-12	1.35E-11	11.8	11.2	10.9
5.000	1.93E-12	1.93E-12	1.93E-12	11.7	11.7	11.7
19.000	2.38E-14	2.38E-14	2.38E-14	13.6	13.6	13.6
47.000	1.72E-12	2.50E-12	2.10E-12	11.8	11.6	11.7
90.000	1.40E-13	6.26E-14	6.26E-14	12.9	13.2	13.2
		pH			Eh (mV)	
Time (d)	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
0.083	7.9	8.8	8.8	325.6	333.8	356.4
0.292	8.5	7.8	7.7	366.5	378.6	398.6
1.000	9.5	8.4	9.8	398.0	376.2	388.1
2.000	9.9	9.9	9.7	376.4	398.4	396.5
3.000	10.5	10.5	10.4	398.2	402.6	441.2
4.000	10.2	10.3	10.4	411.0	403.0	421.6
5.000	10.0	10.1	10.1	399.2	409.0	412.0
19.000	9.7	10.5	10.0	397.0	399.8	416.3
47.000	10.1	10.3	10.2	407.1	402.3	403.5
90.000	10.2	10.7	10.5	406.4	412.6	417.8

Table B-8. E Grout with 12% Nitrate Salt - Strontium ANS 16.1 Data.

		Sr (mg/l)	
Time (d)	Sample 1	Sample 2	Sample 3
0.083	0.020	0.010	0.010
0.292	0.010	0.010	0.010
1.000	0.010	0.010	0.010
2.000	0.010	0.010	0.010
3.000	0.010	0.010	0.010
4.000	0.020	0.010	0.020
5.000	0.020	0.020	0.010
19.000	0.010	0.010	0.010
47.000	0.120	0.140	0.150
90.000	0.010	0.010	0.010

		De (cm^2/s)			Leach Index (LI)	
Time (d)	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
0.083	4.76E-12	1.19E-12	1.19E-12	11.3	11.9	11.9
0.292	1.55E-12	1.55E-12	1.55E-12	11.8	11.8	11.8
1.000	4.62E-13	4.62E-13	4.62E-13	12.3	12.3	12.3
2.000	5.69E-13	5.69E-13	5.69E-13	12.2	12.2	12.2
3.000	9.66E-13	9.66E-13	9.66E-13	12.0	12.0	12.0
4.000	1.36E-12	5.44E-12	1.22E-11	11.9	11.3	10.9
5.000	7.01E-12	7.01E-12	1.75E-12	11.2	11.2	11.8
19.000	2.17E-14	2.17E-14	2.17E-14	13.7	13.7	13.7
47.000	2.24E-12	3.08E-12	3.52E-12	11.6	11.5	11.5
90.000	1.41E-14	1.41E-14	1.41E-14	13.9	13.9	13.9

		pH			Eh (mV)	
Time (d)	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
0.083	7.6	7.6	8.0	382.1	376.5	386.2
0.292	8.7	8.5	8.0	393.0	396.2	388.5
1.000	8.9	7.7	9.2	403.0	421.2	401.2
2.000	9.2	9.1	9.6	412.3	422.0	412.0
3.000	9.6	10.0	10.0	402.4	402.7	414.0
4.000	10.1	10.2	10.4	412.0	403.0	421.0
5.000	10.6	10.6	10.3	401.0	396.0	405.0
19.000	11.0	11.0	11.1	421.0	404.1	416.2
47.000	10.8	10.6	10.9	411.0	426.0	412.0
90.000	10.6	10.8	10.7	411.6	412.3	411.9

Table B-9. E Grout with 50% INEEL Soil - Strontium ANS 16.1 Data.

		Sr (mg/l)	
Time (d)	Sample 1	Sample 2	Sample 3
0.083	0.010	0.010	0.010
0.292	0.010	0.010	0.010
1.000	0.010	0.010	0.010
2.000	0.010	0.010	0.010
3.000	0.010	0.010	0.010
4.000	0.020	0.020	0.010
5.000	0.010	0.010	0.010
19.000	0.010	0.010	0.010
47.000	0.010	0.010	0.010
90.000	0.010	0.010	0.010

		De (cm^2/s)			Leach Index (LI)	
Time (d)	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
0.083	9.72E-13	9.72E-13	9.72E-13	12.0	12.0	12.0
0.292	1.27E-12	1.27E-12	1.27E-12	11.9	11.9	11.9
1.000	3.77E-13	3.77E-13	3.77E-13	12.4	12.4	12.4
2.000	4.65E-13	4.65E-13	4.65E-13	12.3	12.3	12.3
3.000	7.90E-13	7.90E-13	7.90E-13	12.1	12.1	12.1
4.000	4.42E-12	4.42E-12	1.11E-12	11.4	11.4	12.0
5.000	1.43E-12	1.43E-12	1.43E-12	11.8	11.8	11.8
19.000	1.77E-14	1.77E-14	1.77E-14	13.8	13.8	13.8
47.000	1.28E-14	1.28E-14	1.28E-14	13.9	13.9	13.9
90.000	1.15E-14	1.15E-14	1.15E-14	13.9	13.9	13.9

		pH			Eh (mV)	
Time (d)	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
0.083	10.5	9.4	9.9	398.2	389.0	376.6
0.292	10.0	10.0	9.9	399.8	389.2	364.1
1.000	9.8	10.0	10.2	416.8	403.6	405.5
2.000	10.0	10.4	10.3	376.0	402.1	398.5
3.000	10.4	10.6	10.6	415.6	411.2	411.0
4.000	10.7	10.5	10.6	402.6	402.6	407.5
5.000	10.6	10.6	10.6	412.0	413.0	411.5
19.000	11.0	11.0	11.1	417.3	413.0	412.0
47.000	10.9	10.8	10.8	409.0	411.0	423.0
90.000	10.8	10.9	10.8	411.7	412.7	416.0

Table B-10. C75 Grout with 9% Organic Sludge - Strontium ANS 16.1 Data.

		Sr (mg/l)				
Time (d)	Sample 1	Sample 2	Sample 3			
0.083	0.020	0.030	0.010			
0.292	0.030	0.020	0.020			
1.000	0.080	0.050	0.090			
2.000	0.180	0.160	0.150			
3.000	0.100	0.120	0.170			
4.000	0.070	0.140	0.140			
5.000	0.070	0.050	0.060			
19.000	0.660	0.680	0.670			
47.000	0.310	0.320	0.330			
90.000	0.440	0.420	0.290			
		De (cm^2/s)			Leach Index (LI)	
Time (d)	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
0.083	6.64E-12	1.49E-11	1.65E-12	11.2	10.8	11.8
0.292	1.94E-11	8.66E-12	8.66E-12	10.7	11.1	11.1
1.000	4.12E-11	1.61E-11	5.18E-11	10.4	10.8	10.3
2.000	2.57E-10	2.04E-10	1.79E-10	9.6	9.7	9.7
3.000	1.34E-10	1.93E-10	3.90E-10	9.9	9.7	9.4
4.000	9.29E-11	3.73E-10	3.73E-10	10.0	9.4	9.4
5.000	1.20E-10	6.10E-11	8.78E-11	9.9	10.2	10.1
19.000	1.31E-10	1.40E-10	1.36E-10	9.9	9.9	9.9
47.000	2.09E-11	2.23E-11	2.37E-11	10.7	10.7	10.6
90.000	3.81E-11	3.47E-11	1.65E-11	10.4	10.5	10.8
		pH			Eh (mV)	
Time (d)	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
0.083	9.7	9.6	9.6	336.5	354.8	346.7
0.292	10.0	10.3	10.2	398.6	377.5	386.0
1.000	10.7	10.7	10.7	402.5	396.2	402.3
2.000	10.8	10.9	10.9	412.0	421.2	401.2
3.000	10.6	10.5	10.6	407.8	422.0	412.0
4.000	11.8	11.8	11.6	421.0	404.1	415.8
5.000	11.6	11.4	11.9	404.6	426.0	412.0
19.000	11.5	11.4	11.7	413.6	403.0	422.6
47.000	11.4	11.4	11.6	405.0	413.0	402.8
90.000	11.6	11.7	11.6	404.6	405.8	416.7

Table B-11. C75 Grout with 12% Nitrate Salt - Strontium ANS 16.1 Data.

		Sr (mg/l)	
Time (d)	Sample 1	Sample 2	Sample 3
0.083	0.010	0.010	0.010
0.292	0.020	0.020	0.010
1.000	0.040	0.040	0.040
2.000	0.050	0.060	0.060
3.000	0.027	0.030	0.040
4.000	0.040	0.020	0.030
5.000	0.030	0.030	0.040
19.000	0.080	0.290	0.290
47.000	0.160	0.180	0.200
90.000	0.320	0.280	0.280

		De (cm^2/s)			Leach Index (LI)	
Time (d)	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
0.083	1.54E-12	1.54E-12	1.54E-12	11.8	11.8	11.8
0.292	8.10E-12	8.10E-12	2.01E-12	11.1	11.1	11.7
1.000	9.60E-12	9.60E-12	9.60E-12	11.0	11.0	11.0
2.000	1.85E-11	2.66E-11	2.66E-11	10.7	10.6	10.6
3.000	9.16E-12	1.13E-11	2.01E-11	11.0	10.9	10.7
4.000	8.66E-11	3.47E-10	3.47E-10	10.1	9.5	9.5
5.000	2.05E-11	2.05E-11	3.64E-11	10.7	10.7	10.4
19.000	1.80E-12	2.36E-11	2.36E-11	11.7	10.6	10.6
47.000	5.21E-12	6.57E-12	8.17E-12	11.3	11.2	11.1
90.000	1.88E-11	1.44E-11	1.44E-11	10.7	10.8	10.8

		pH			Eh (mV)	
Time (d)	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
0.083	9.9	10.0	9.9	398.0	376.2	347.8
0.292	9.8	9.6	9.8	382.1	375.5	384.2
1.000	11.8	11.7	11.7	398.2	402.6	441.2
2.000	10.9	10.8	10.9	411.0	403.7	421.6
3.000	11.0	11.0	11.3	399.0	400.8	412.0
4.000	10.7	10.5	10.6	407.1	402.9	403.9
5.000	11.2	11.2	11.1	409.0	411.0	423.0
19.000	11.5	11.6	11.5	399.2	409.0	412.0
47.000	11.4	11.2	11.4	412.0	403.0	421.0
90.000	11.5	11.5	11.8	404.9	415.6	411.8

Table B-12. C75 Grout with 50% INEEL Soil - Strontium ANS 16.1 Data.

		Sr (mg/l)				
Time (d)	Sample 1	Sample 2	Sample 3			
0.083	0.020	0.020	0.030			
0.292	0.020	0.020	0.030			
1.000	0.110	0.110	0.080			
2.000	0.100	0.120	0.080			
3.000	0.100	0.100	0.140			
4.000	0.050	0.080	0.040			
5.000	0.040	0.060	0.050			
19.000	0.630	0.630	0.190			
47.000	0.430	0.320	0.300			
90.000	0.330	0.330	0.330			
		De (cm^2/s)			Leach Index (LI)	
Time (d)	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
0.083	5.00E-12	5.00E-12	1.12E-11	11.3	11.3	11.0
0.292	6.52E-12	6.52E-12	1.46E-11	11.2	11.2	10.8
1.000	5.87E-11	5.87E-11	3.09E-11	10.2	10.2	10.5
2.000	5.91E-11	8.54E-11	3.80E-11	10.2	10.1	10.4
3.000	1.00E-10	1.00E-10	1.98E-10	10.0	10.0	9.7
4.000	2.27E-11	5.71E-12	1.28E-11	10.6	11.2	10.9
5.000	2.93E-11	6.60E-11	4.57E-11	10.5	10.2	10.3
19.000	8.99E-11	8.99E-11	8.16E-12	10.0	10.0	11.1
47.000	3.02E-11	1.68E-11	1.47E-11	10.5	10.8	10.8
90.000	1.60E-11	1.60E-11	1.60E-11	10.8	10.8	10.8
		pH			Eh (mV)	
Time (d)	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
0.083	9.9	10.0	10.0	376.1	376.2	388.1
0.292	9.9	10.2	10.2	376.0	412.8	398.5
1.000	12.0	12.0	12.0	412.0	413.0	421.0
2.000	10.7	10.6	10.6	400.6	403.6	402.0
3.000	10.7	10.6	10.5	398.2	411.0	417.8
4.000	10.7	10.6	10.6	399.8	413.2	422.4
5.000	10.9	11.0	11.0	402.6	402.6	407.4
19.000	11.7	11.6	11.6	417.9	411.2	411.0
47.000	11.0	11.4	11.3	415.8	412.6	399.5
90.000	11.3	11.4	11.5	421.0	413.0	415.0

Table B-13. S Grout with 9% Organic Sludge - Strontium ANS 16.1 Data.

		Sr (mg/l)				
Time (d)	Sample 1	Sample 2	Sample 3			
0.083	0.040	0.060	0.020			
0.292	0.050	0.050	0.070			
1.000	0.130	0.130	0.080			
2.000	0.150	0.120	0.110			
3.000	0.120	0.110	0.100			
4.000	0.080	0.090	0.080			
5.000	0.070	0.050	0.060			
19.000	0.390	0.320	0.440			
47.000	0.250	0.220	0.260			
90.000	0.340	0.340	0.390			
		De (cm^2/s)			Leach Index (LI)	
Time (d)	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
0.083	1.96E-11	4.41E-11	4.90E-12	10.7	10.4	11.3
0.292	3.99E-11	3.99E-11	7.82E-11	10.4	10.4	10.1
1.000	7.97E-11	7.97E-11	3.04E-11	10.1	10.1	10.5
2.000	1.31E-10	8.41E-11	7.11E-11	9.9	10.1	10.1
3.000	1.43E-10	1.21E-10	9.85E-11	9.8	9.9	10.0
4.000	8.94E-11	1.13E-10	8.94E-11	10.0	9.9	10.0
5.000	8.82E-11	4.50E-11	6.49E-11	10.1	10.3	10.2
19.000	3.38E-11	2.28E-11	4.31E-11	10.5	10.6	10.4
47.000	1.01E-11	7.82E-12	1.09E-11	11.0	11.1	11.0
90.000	1.68E-11	1.68E-11	2.20E-11	10.8	10.8	10.7
		pH			Eh (mV)	
Time (d)	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
0.083	9.0	9.1	8.9	345.0	340.0	378.7
0.292	8.9	8.9	9.0	382.6	377.0	393.0
1.000	10.6	10.5	9.9	393.0	396.2	388.5
2.000	10.8	10.8	10.8	403.0	413.0	403.6
3.000	10.7	10.8	10.6	411.0	405.8	412.0
4.000	10.4	10.4	10.3	422.0	406.7	416.3
5.000	10.3	10.2	10.3	411.0	423.0	412.0
19.000	10.9	10.2	10.2	412.0	404.6	421.0
47.000	10.6	10.4	10.1	401.0	401.4	405.9
90.000	10.8	10.9	10.8	401.5	412.6	414.8

Table B-14. S Grout with 12% Nitrate Salt - Strontium ANS 16.1 Data.

		Sr (mg/l)				
Time (d)	Sample 1	Sample 2	Sample 3			
0.083	0.020	0.020	0.020			
0.292	0.070	0.040	0.060			
1.000	0.140	0.080	0.070			
2.000	0.190	0.110	0.120			
3.000	0.100	0.130	0.120			
4.000	0.100	0.100	0.090			
5.000	0.080	0.060	0.050			
19.000	0.500	0.440	0.210			
47.000	0.380	0.300	0.310			
90.000	0.420	0.450	0.500			
		De (cm^2/s)			Leach Index (LI)	
Time (d)	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
0.083	4.58E-12	4.58E-12	4.58E-12	11.3	11.3	11.3
0.292	7.29E-11	2.37E-11	5.35E-11	10.1	10.6	10.3
1.000	8.70E-11	2.83E-11	2.17E-11	10.1	10.5	10.7
2.000	1.23E-10	7.87E-11	6.62E-11	9.9	10.1	10.2
3.000	9.25E-11	1.57E-10	1.34E-10	10.0	9.8	9.9
4.000	1.30E-10	1.30E-10	1.05E-10	9.9	9.9	10.0
5.000	1.07E-10	6.04E-11	4.19E-11	10.0	10.2	10.4
19.000	5.18E-11	4.01E-11	9.18E-12	10.3	10.4	11.0
47.000	2.16E-11	1.35E-11	1.44E-11	10.7	10.9	10.8
90.000	2.38E-11	2.73E-11	3.37E-11	10.6	10.6	10.5
		pH			Eh (mV)	
Time (d)	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
0.083	9.6	9.7	9.6	402.0	370.6	399.0
0.292	10.0	10.0	9.8	378.5	399.7	396.8
1.000	10.5	10.5	10.6	400.2	404.9	433.2
2.000	10.5	10.5	10.2	411.5	402.5	421.6
3.000	10.6	10.7	10.7	399.0	400.2	412.0
4.000	10.8	10.8	10.7	407.1	416.4	403.5
5.000	10.5	10.5	10.5	409.8	411.0	402.3
19.000	11.4	11.6	11.5	402.6	409.9	412.0
47.000	10.6	10.7	10.5	412.6	419.7	422.0
90.000	10.9	10.9	10.9	403.2	405.1	412.4

Table B-15. S Grout with 50% INEEL Soil - Strontium ANS 16.1 Data.

		Sr (mg/l)	
Time (d)	Sample 1	Sample 2	Sample 3
0.083	0.050	0.050	0.070
0.292	0.030	0.020	0.020
1.000	0.070	0.060	0.080
2.000	0.070	0.060	0.070
3.000	0.100	0.110	0.120
4.000	0.100	0.100	0.100
5.000	0.080	0.070	0.070
19.000	0.480	0.460	0.490
47.000	0.260	0.280	0.280
90.000	0.180	0.410	0.360

		De (cm^2/s)			Leach Index (LI)	
Time (d)	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
0.083	2.45E-11	2.45E-11	4.82E-11	10.6	10.6	10.3
0.292	1.15E-11	5.11E-12	5.11E-12	10.9	11.3	11.3
1.000	1.87E-11	1.37E-11	2.44E-11	10.7	10.9	10.6
2.000	1.69E-10	5.69E-11	6.74E-11	9.8	10.2	10.2
3.000	7.98E-11	9.66E-11	1.14E-10	10.1	10.0	9.9
4.000	1.12E-10	1.12E-10	1.12E-10	10.0	10.0	10.0
5.000	9.24E-11	7.09E-11	7.09E-11	10.0	10.1	10.1
19.000	4.12E-11	3.78E-11	4.29E-11	10.4	10.4	10.4
47.000	8.74E-12	1.01E-11	1.01E-11	11.1	11.0	11.0
90.000	3.78E-12	1.96E-11	1.51E-11	11.4	10.7	10.8

		pH			Eh (mV)	
Time (d)	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
0.083	10.0	9.9	10.0	376.7	398.7	366.8
0.292	10.0	9.8	10.0	376.0	403.0	399.0
1.000	10.7	10.6	10.4	415.0	403.6	404.5
2.000	10.6	10.7	10.5	377.0	402.1	402.0
3.000	10.9	11.1	11.1	416.5	411.2	411.0
4.000	10.8	10.9	10.9	403.5	412.0	407.5
5.000	10.7	10.7	10.7	412.0	402.7	413.0
19.000	11.7	11.7	11.6	418.0	414.0	419.0
47.000	11.3	11.2	11.4	409.0	411.0	416.9
90.000	11.3	11.6	11.7	406.5	404.3	408.4

Appendix C

Powdered Activated Carbon (PAC) as a VOC Adsorbent

Powdered Activated Carbon as a VOC Adsorbent

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SCOPE AND REPORT OBJECTIVES

This report addresses the feasibility of using powdered activated carbon (PAC) as an additive to a barrier grout wall or as an additive in grout to reduce the migration of carbon tetrachloride (CT), perchloroethylene (PCE), trichloroethane (TCA), and trichloroethylene (TCE). The report addresses the following four topics:

- PAC potential to effectively remove CT, PCE, TCA, and TCE volatile organic contaminants (VOC) from the vapor phase,
- Postulated effect of PAC as a grout additive,
- Postulated grout PAC concentration needed to accomplish positive effects, and
- Anticipated long-term waste form stability.

PAC potential to effectively remove CT, PCE, TCA, and TCE contaminants from the vapor phase

The potential effectiveness for activated carbon to treat vapor contaminated with CT, PCE, TCA, and TCE is a complicated undertaking and requires (at a minimum) examination of:

- Each component vapor phase and water vapor concentration.
- The equilibrium adsorption relationship for each material in the vapor phase and activated carbon (called an adsorption isotherm).
- A multi-component model to accurately predict how the components interact and the expected sorption capacity of each compound at equilibrium.
- A dynamic model to relate mass transfer from the diffusing gas into the carbon, used to determine the time needed to remove the vapors and how much contact is needed with the activated carbon.

To assess PAC potential, the adsorptive capacity for the contaminant on activated carbon could be compared to components that are currently removed from the gas phase with carbon. Nyer *et al*. (1996) present carbon adsorption capacity information for five compounds that are effectively treated:

Table C-1: Adsorption Capacity
(pounds compound per 100 pounds activated carbon)

Compound	At 10 ppm_v	At 100 ppm_v
Benzene	13	19
Carbon Tetrachloride	20	33
Methylene Chloride	1.3	2.7
Toluene	21	27
Trichloroethylene	19	33

Benzene and toluene are components of petroleum products; they are commonly removed from the gas phase with activated carbon as a result of remediation efforts. This comparative information indicates that at a concentration of 10-ppm_v, CT and TCE adsorption is similar to toluene and considerably better than for benzene. At 100-ppm_v, CT and TCE adsorb better than both toluene and benzene. These data indicate that powdered activated carbon potential for removing CT and TCE is quite good.

Information is needed for PCE and TCA to compare with the other compounds. Isotherm data were not available for all the components on the same activated carbon, but information is available for TCE and PCE on BPL activated carbon (Crittenden, *et al.*, 1989). They demonstrate an isotherm of a single component that covers a wide range of equilibrium concentrations can used be used to define the activated carbon adsorption performance (toluene was used in their study). This isotherm can be used to predict the gas phase adsorption of TCE and PCE using the Dubinin-Radushkevich (D-R) equation [see Appendix for the equation and brief discussion]. Using the D-R equation, the TCE and PCE isotherms of Crittenden *et al* (1989), and the molecular weights, liquid densities, and vapor pressures of TCE, PCE, CT and TCA, the adsorption isotherms for CT and TCA were predicted (Figure C-1).

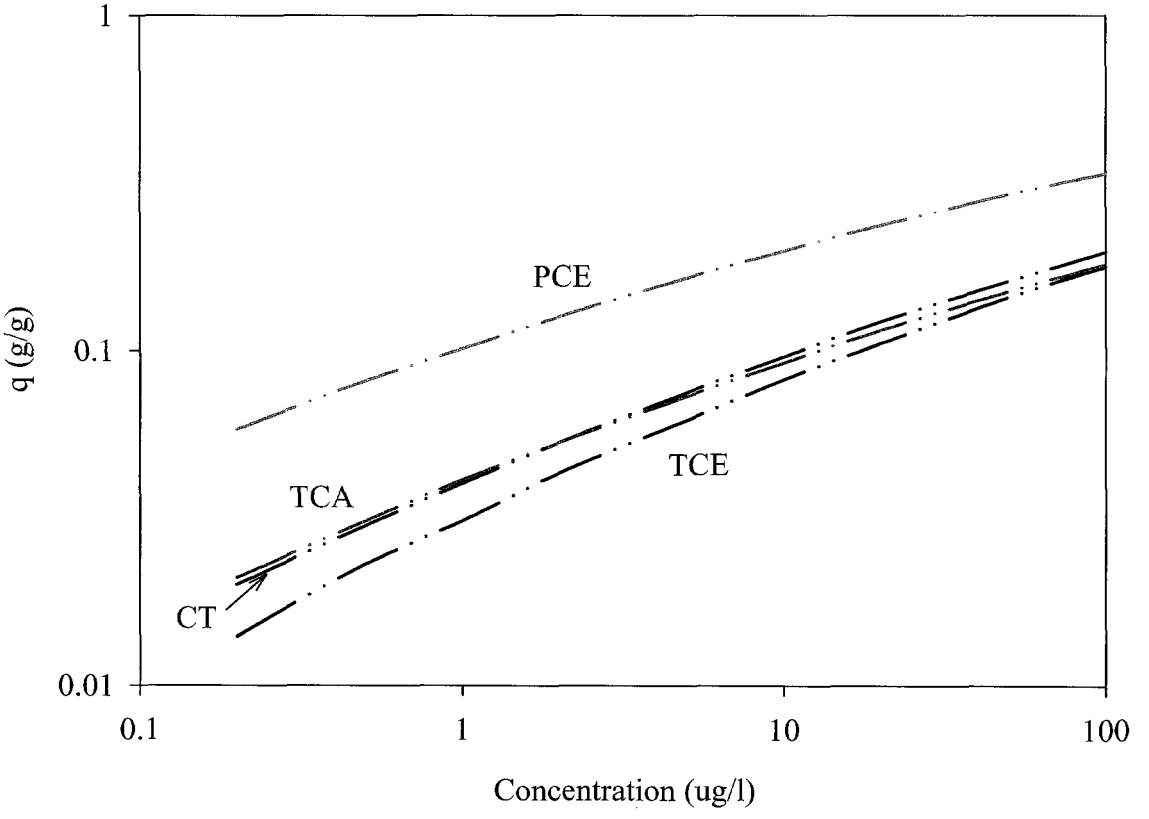

Figure C-1. Adsorption predictions for CT, PCE, TCE, and TCA

The experimental PCE and TCE isotherms indicate that PCE is considerably more adsorbable than TCE. Since TCE is effectively removed from the gas phase, PCE should have an even greater adsorption capacity on activated carbon. The projected isotherms for CT and TCA are nearly identical, with both projecting greater ability to sorb than TCE. From Table C-1, CT was projected to sorb slightly better than TCE at the lower concentration and about the same at the higher concentration -- the same trends can be observed with the projected isotherms. These data all indicate that activated carbon adsorption can effectively remove all four volatile organic contaminants from the vapor phase.

Multi-component adsorption equilibrium modeling and the dynamic mass transfer modeling required to evaluate CT, PCE, TCA, and TCE mixtures is beyond the scope of this project, largely because of the extensive computer programming and modeling requirements. Literature information can be used to assist in determining how multi-component equilibrium adsorption will be affected by additional components and with water vapor present. When both TCE and PCE are present (Crittenden, *et al.*, 1989), the presence of the other lowers the equilibrium loading of the other component on the adsorbent. The presence of TCE reduces the amount of PCE the carbon can adsorb and the PCE reduces the amount of TCE adsorbed. Since the PCE is the more strongly adsorbed component, the amount of TCE adsorbed would be more adversely affected by PCE than the PCE adsorption when the vapor phase concentrations are the same. Water vapor has the same negative effect on sorption as does a competing organic compound (Nyer *et al.* 1996 and Crittenden *et al.* 1989). When the gas phase concentration of the TCE in these studies was high (> 4000 ppm_v), the reduction in amount adsorbed was small; when the TCE concentration was small, an 85% reduction was observed.

Literature information provides insight into the dynamic sorption of multiple contaminants in an adsorption column treating air stripper off-gas (Mueller and DiToro, 1993). Considering the breakthrough curves of CT, PCE, TCA, and TCE, TCA exited the column slightly ahead of CT, which was immediately followed by TCE. PCE broke through the adsorber last. Using the isotherms above, the compound with the greatest amount adsorbed at a particular concentration (PCE) is expected to breakthrough last. TCE was expected to breakthrough the adsorber first. Mass transfer must also play an important role in the process. TCE diffusivity in the gas phase (8.3×10^{-2} cm^2/s) is greater than that for TCA and CT (both are 8.0×10^{-2} cm^2/s) and is likely to cause it to adsorb faster on the carbon. Since TCA and CT sorption is not substantially greater than that of TCE, that energy of sorption difference may not have been substantial enough to displace the TCE. An additional complicating factor is the difference in gas concentrations of the different species. Even though PCE diffusivity is smaller than the other components, its adsorption equilibrium capacity is considerably greater than the other components. This substantial difference in adsorption strength is the main reason its breakthrough is last.

Except for the last component in the gas stream to exit the adsorption column, PCE in this case, each component is displaced from the activated carbon. Immediately after component breakthrough, the effluent concentration continues its breakthrough and the effluent concentration is greater than the influent concentration. To prevent these higher concentrations in the effluent than in the influent, adsorber operation would have to be terminated prior to the weakest materials breaking through the adsorber. Dynamic modeling and the pilot study demonstrate that complete removal, within detection limits, is possible with TCA likely to breakthrough the column first. Estimates of the adsorption cycle run time are very important for the control of treated gas concentrations.

Postulated effect of PAC as a grout additive

The literature is sparse on the addition of materials to prevent the gas phase migration of organic compounds by sorption. The literature relates to contaminant sorption from the aqueous phase, or more accurately to the prevention of leaching from the solid into the aqueous phase. Organophillic clays and activated carbon have been tested. The activated carbon results are discussed to indicate its potential as an additive to the grout, keeping in mind that liquid phase application was tested and not the gas phase.

One study evaluated PAC for the adsorption of phenol, aniline and naphthalene (Hebatpuria, *et al.*; 1999a & b). In their research, sand was contaminated with phenol and allowed to age, and then PAC was added as a percentage of the sand weight, and the cement and water added to this mix. Leaching tests were performed on the solidified/stabilized soil using both the Toxicity Characteristic Leaching Procedure (TCLP) and the American Nuclear Society Test (ANS 16.1). PAC dramatically reduced the leaching of phenol and aniline (Hebatpuria, *et al.*; 1999b), indicating significant potential in reducing leached

contaminant concentrations to acceptable concentrations. The inability of PAC to reduce naphthalene leaching is a concern. It should be recognized that naphthalene did not leach significantly during the TCLP test (sample without PAC leached 1.3% of the naphthalene, whereas for phenol and aniline the values were 65% and 26% respectively); PAC didn't dramatically reduce the amount of leaching that occurred. A more detailed study of phenol adsorption determined that phenol sorption appeared irreversible (Hebatpuria, *et al.*; 1999a). Phenol desorption is a concern, since mixing cement with activated carbon increases the pH of the mix to above 12; phenol has a pK_a of 10, so at this pH the phenol becomes phenate anion which is substantially less adsorbable. Mixing the phenol contaminated sand, water, and cement simultaneously did not adversely affect adsorption, so the adsorption process is rapid and isn't adversely affected by the pH swing during the hydration of the cement. Changes in crystallization of the cement mixture was noted when PAC was present, probably from an accelerated hydration of the cement and less formation of $Ca(OH)_2$ gels.

PAC was added to sand and the mixture evaluated as a permeable-barrier media to remove benzene from groundwater (Rael, *et al.*, 1995). Several sorptive additives were evaluated, with PAC performing best and therefore studied more extensively. A column test with an empty-bed-contact-time (EBCT) of 350-minutes and 3% PAC removed 40-mg/L of benzene to less than its detection limit, with the PAC use rate slightly better than predicted in adsorption isotherm tests. This study does indicate that a classic breakthrough curve does develop and nearly theoretical carbon use is obtained with a fluid flowing through a permeable barrier. The adsorption of organics from the gas phase usually involves large activated carbon particles, several millimeters in diameter.

Adsorption is very rapid from the gas phase, where the diffusivities are much greater. Since PAC is considered for this application, it will result in even faster adsorption rates. PAC should provide easy processing in the grout nozzle. Most PAC is specified with 95% of the weight passing through a 325-mesh screen (openings are 37-microns), with a typical size smaller than 10-microns. This size is much smaller than the 2.4-mm opening in the grout nozzle and would not create a problem with plugging. One caution about the PAC and the process step: wet activated carbon is extremely corrosive. Therefore, the nozzle will have to be constructed of a material that is not easily corroded by PAC, such as stainless steel.

Postulated Grout PAC concentration needed to accomplish positive effects

The PAC concentration to be added will depend upon:

- VOC concentrations in the vapor phase,
- mass of waste material encapsulated by the grout,
- propensity of the VOC to sorb onto the PAC,
- rate at which the each VOC diffuses into the barrier,
- ability of each VOC to sorb onto grout, soil and other materials present in the waste cell,
- ability of other reactions to degrade and destroy each VOC,
- presence of water within the cell and its affect on vapor phase concentration and adsorption to PAC.

Other than the mass of the material trapped by the barrier grout wall and the ability of the VOC to sorb, the other factors require assumptions that could vary by at least an order-of-magnitude. In an effort to estimate the barrier ability to sorb VOC, the following assumptions were made:

1. VOC concentration in the vapor phase can be calculated:

- At equilibrium
- Without water present
- Using the fugacity approach (Mackay, 1979)

2. All VOC movement results from a concentration gradient from the vapor phase concentration calculated in the waste cell; these concentrations at the barrier wall are assumed to remain constant. [In other words, within the main cell, diffusion is not restricted and the vapor phase concentration will be immediately replaced as the VOC diffuses into the barrier wall and is sorbed in the PAC. Actually the contaminant concentration adjacent to the barrier would decrease; additional time would be required to replace the VOC, and therefore this estimate is conservative.]

3. The sorption mass transfer zone is 5-cm with the concentration decreasing from the main cell VOC concentration to zero using Fick's law of diffusion.

4. VOC diffusivity is substantially less than the gas phase diffusivity. TCE diffusivity in soil with a porosity of 0.29 was measured to be 2.5 × 10-4 cm2/s while the gas phase diffusivity is 8.3 × 10-2 cm2/s (Hutter et al., 1992). Other VOC diffusivity values will be adjusted proportionately to the TCE values.

5. The interior surface of the PAC is not blocked by the grout; i.e. all the adsorptive capacity of the PAC can be used.

6. Internal diffusion is much faster than the diffusion of VOC to the external PAC surface; therefore the PAC reaches equilibrium rapidly.

7. Maximum amount of PAC is 0.053-g/cm3 in the barrier wall; the value could be greater but this in line with the values used by Hebatpuria, et al. (1999 a, b).

8. VOC does not sorb on non-PAC materials; even though VOC is likely to sorb on the other materials, therefore this will overestimate the quantity of material going to the barrier wall.

9. No VOC destruction mechanisms are present.

10. Barrier thickness is 3-ft.

Fugacity calculations using assumption (1) resulted in the following equilibrium gas phase concentrations:

Table C-2. Gas phase VOC Concentrations.

Compound	Concentration g/L
CT	0.490
PCE	0.023
TCA	0.001
TCE	0.081

The projected vapor phase concentration of CT is greatest, followed by TCE; PCE is significant and TCA is small. The flux of each component into the barrier was determined based on Table C-2 and assumptions (2), (3), and (4). The total flux is estimated at 2.9×10^{-4} g/day/cm^2.

Multi-component modeling of the equilibrium situation is beyond the scope of this report and because the uncertainties are not likely to aid the estimates. TCE adsorbs the least of the compounds and CT was found to breakthrough a column treating air stripper off-gas before CT (Mueller and DiToro, 1993). The solid phase loading at these high influent concentrations is about 0.6-gVOC/gPAC based on the D-R equation used to generate Figure C-1 and assumptions (5) and (6). This high loading is near the maximum amount that can be sorbed on the PAC and therefore would depend upon the PAC.

Using this information and assumptions (7) through (10), the barrier would be expected to last 30-years before VOC started to breakthrough the barrier. This may not be satisfactory, but many assumptions could easily be varied by an order-of-magnitude.

- For instance, instead of using pure VOC in equilibrium with the gas phase to determine the concentrations in Table C-2, the gas phase concentrations would be reduced by a factor greater than 10 by including water. The reduced VOC transport rate would be countered with a reduced equilibrium concentration on the PAC resulting from lower VOC concentrations (about a 20% reduction in capacity) and water vapor competing for space. It is unlikely that these two considerations would reduce PAC capacity for the VOC by 90%; therefore the life expectancy of the PAC barrier would increase.

- The VOC diffusion rate within the barrier and within the main cell could be substantially smaller. This could result from a smaller solid phase porosity or VOC sorption on the solid matrix -- the overall effect would reduce the VOC transport to the PAC barrier.

- If the waste monolith incorporates PAC in its mixture, in proportions similar to the 0.053g/cm^3, the PAC will be well saturated with VOC and will have a high gas phase equilibrium concentration. This gas phase concentration should still result in much smaller concentrations than projected in Table C-2. [The VOC would prefer to be associated with the activated carbon and therefore the gas phase concentration would be reduced (partition coefficient should be very large).] VOC release would be expected to be much slower, but VOC could be emitted immediately. As the gases transport through a PAC containing monolith that has already released its VOC, sorption/desorption would occur and the rate of movement (or the effective diffusivity) would be much lower than in the case evaluated. Fresh PAC in a barrier around the monolith, would provide the results projected; but the substantially reduced diffusivity would greatly increase the time before emissions would result.

Anticipated long term PAC stability IN GROUT

The PAC and sorbed VOC should be quite stable, with chemical degradation and/or biological activity having little effect on the PAC. Reactions could cause VOC degradation, but they would not be expected to occur either. VOC desorption could occur if a high concentration of a competing organic compound were exposed to the barrier or if the barrier temperature were increased substantially; again, this would not be expected.

The main concern would be the constant influx of VOC from the main cell. Once the PAC capacity is completely exhausted with the weakest adsorbing contaminant, TCE, the continuing inflow of the mixture of contaminants would permit PCE to displace TCE. High TCE concentrations could then diffuse from the barrier to the surrounding area, with all but the most strongly adsorbed material eventually being displaced from the adsorbent.

Summary and concluding thoughts

Addition of PAC to the exterior barrier confining the bulk of the waste could reduce the target VOC concentrations very low concentrations. Using several assumptions that would conservatively estimate the PAC effectiveness, it is estimated to be helpful for approximately 30-years. After that time, the weakest adsorbed VOC could be displaced by a more strongly adsorbed VOC and the displaced VOC would enter the vapor phase outside the cell. While the 30-year life may not appear good, there are several principal reasons to think this may be underestimated by a factor of 10 to 100:

- The equilibrium vapor phase concentrations are very high. Including water in the estimates would reduce these values by at least an order of magnitude. Sorption of the VOC to the solid matrix within the cell could also reduce these concentrations by an order of magnitude. Both these effects would drastically reduce the amount of VOC being transported to the barrier and the PAC. ***Vapor phase VOC concentrations need to be determined for the main cell design.***

- Effective diffusivities of the VOC in the main cell and within the barrier may greatly reduce the transport of VOC. The values used were deduced from gas phase values and correspond to transport in soils with 29% porosity. If the main cell and the barrier porosities are smaller and if the materials are retarded in their movement by constant sorption/desorption on the solid matrix, the amount of VOC transported to the barrier and the PAC would be substantially reduced. ***Effective VOC diffusivities need to be experimentally determined for the main cell and barrier wall materials.***

There is one main reason why the estimate could be optimistic:

- The matrix surrounding the PAC could block access to the activated carbon micropore surface area and prevent sorption from occurring. This would drastically reduce the sorptive capacity of the PAC and prevent VOC sorption. ***PAC needs to be imbedded into the barrier matrix and adsorption equilibrium studies determined.***

Appendix for PAC Report

Dubinin-Radushkevich (D-R) Equation:

$$q = \left[\frac{W_o \rho_1}{MW \cdot 10^{-6}}\right] \exp\left[\frac{-B}{\beta^2}\left(RT \ln \frac{P_s}{P}\right)^2\right]$$

Where:

q	=	the solid phase concentration of the VOC (μmol/g carbon);
W_o	=	the maximum adsorption space of the adsorbent (cm^3 /g);
B	=	the microporosity constant (mol^2/cal^2);
ρ_l	=	liquid density of the pure VOC (g/cm^3);
MW	=	the VOC's molecular weight;
β	=	the affinity coefficient of the VOC (dimensionless);
P_s	=	VOC's vapor pressure (mmHg);
P	=	partial pressure of VOC (mmHg);
R	=	gas law constant (1.986-cal/mol/°K); and
T	=	the temperature (°K).

This equation can be used to estimate an adsorption isotherm for a compound adsorbed onto an adsorbent from the gas phase. To use this equation, an adsorption isotherm has to be determined over a wide range of concentrations for a single chemical – referred to as the characteristic curve for that particular adsorbent. The characteristic curve and the reference compound molecular weight, liquid density, and vapor pressure are used to define the W_o and B. The β is an additional correction factor needed to predict another compound isotherm (for the reference compound β is 1). β depends on a compound molar volume, parachor, or polarizability relative to that of the reference compound; while all are claimed to work, different situations result in one working better for certain families of compounds. The D-R equation was used to predict the CT and TCA adsorption data, with both the TCE and PCE data used to generate the characteristic curve with molar volumes used to calculate the β.

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Appendix D

Interference Tolerance Testing Individual Test Results

Table D-1. Individual compressive strength test results in MPa for the interference tolerance testing of neat grout specimens and specimens containing the INEEL soil interference at various loadings.

			Grout Product				
			C75	E	S	T	U
Specimen	Interference Type	Interference Percentage	Modified Tank Closure	Enviro-Blend	Salt Stone	Tect HG	US Grout
Specimen A	None		51.72	1.01	11.16	42.97	16.24
Specimen B	None		61.43	1.10	11.07	43.97	18.22
Specimen C	None		44.85	0.98	4.78	43.77	18.95
Average	None		52.67	1.03	9.00	43.57	17.80
Std. Deviation	None		6.80	0.05	2.99	0.43	1.14
Specimen A	INEEL Soil	12	39.53	0.42	9.70	25.92	27.44
Specimen B	INEEL Soil	12	35.47	0.41	8.05	29.14	26.22
Specimen C	INEEL Soil	12	46.71	0.45	8.29	30.78	26.92
Average	INEEL Soil	12	40.57	0.43	8.68	28.61	26.86
Std. Deviation	INEEL Soil	12	4.65	0.02	0.73	2.02	0.50
Specimen A	INEEL Soil	25	40.51	0.17	6.34	24.14	20.65
Specimen B	INEEL Soil	25	40.37	0.16	6.43	25.94	21.78
Specimen C	INEEL Soil	25	44.22	0.20	6.05	25.50	21.64
Average	INEEL Soil	25	41.70	0.18	6.27	25.19	21.36
Std. Deviation	INEEL Soil	25	1.78	0.02	0.16	0.77	0.50
Specimen A	INEEL Soil	50	18.77	0.28	9.31	12.99	8.18
Specimen B	INEEL Soil	50	15.60	0.31	9.56	13.29	9.80
Specimen C	INEEL Soil	50	17.94	0.30	8.38	13.53	8.47
Average	INEEL Soil	50	17.44	0.30	9.08	13.27	8.82
Std. Deviation	INEEL Soil	50	1.34	0.01	0.51	0.22	0.71
Specimen A	INEEL Soil	75			2.78		5.22
Specimen B	INEEL Soil	75			2.63		5.76
Specimen C	INEEL Soil	75			2.92		5.67
Average	INEEL Soil	75			2.78		5.55
Std. Deviation	INEEL Soil	75			0.12		0.24

1 MPa = 145.04 pounds per square inch

Table D-2. Individual compressive strength test results in MPa for the interference tolerance testing of specimens containing the nitrate salt interference at various loadings.

			Grout Product				
			C75	E	S	T	U
Specimen	Interference Type	Interference Percentage	Modified Tank Closure	Enviro-Blend	Salt Stone	Tect HG	US Grout
Specimen A	Nitrate Salts	12	13.14	0.25	5.32	22.23	36.53
Specimen B	Nitrate Salts	12	20.04	0.30	4.24	22.44	31.83
Specimen C	Nitrate Salts	12	32.42	0.26	4.92		30.96
Average	Nitrate Salts	12	21.87	0.27	4.83	22.34	33.11
Std. Deviation	Nitrate Salts	12	7.98	0.02	0.45	0.11	2.45
Specimen A	Nitrate Salts	25	20.33	0.02	2.65	8.26	9.00
Specimen B	Nitrate Salts	25	15.84	0.03	2.92	8.16	9.79
Specimen C	Nitrate Salts	25	23.50	0.02	2.76	8.25	9.81
Average	Nitrate Salts	25	19.89	0.02	2.78	8.22	9.53
Std. Deviation	Nitrate Salts	25	3.14	0.00	0.11	0.04	0.38
Specimen A	Nitrate Salts	50	0.02		0.01		12.54
Specimen B	Nitrate Salts	50	0.02		0.01		12.17
Specimen C	Nitrate Salts	50	0.01		0.01		12.80
Average	Nitrate Salts	50	0.02		0.01		12.50
Std. Deviation	Nitrate Salts	50	0.00		0.00		0.26
Specimen A	Nitrate Salts	75	0.68	0.08	0.02		6.02
Specimen B	Nitrate Salts	75	0.70	0.08	0.02		5.97
Specimen C	Nitrate Salts	75	0.78	0.08	0.03		5.98
Average	Nitrate Salts	75	0.72	0.08	0.02		5.99
Std. Deviation	Nitrate Salts	75	0.04	0.00	0.00		0.02

1 MPa = 145.04 pounds per square inch

Table D-3. Individual compressive strength test results in MPa for the interference tolerance testing of specimens containing the organic sludge interference at various loadings.

			Grout Product				
			C75	E	S	T	U
Specimen	Interference Type	Interference Percentage	Modified Tank Closure	Enviro-Blend	Salt Stone	Tect HG	US Grout
Specimen A	Organic Sludge	3	51.43	0.88	9.56	29.16	22.08
Specimen B	Organic Sludge	3	44.51	0.95	8.53	29.41	21.26
Specimen C	Organic Sludge	3	56.06	0.92	8.29	30.27	24.42
Average	Organic Sludge	3	50.67	0.92	8.79	29.61	22.59
Std. Deviation	Organic Sludge	3	4.75	0.03	0.55	0.48	1.34
Specimen A	Organic Sludge	5	35.00	0.94	6.24	25.95	20.75
Specimen B	Organic Sludge	5	46.80	0.93	7.70	25.26	18.86
Specimen C	Organic Sludge	5	44.36	0.86	8.29	25.44	19.91
Average	Organic Sludge	5	42.05	0.91	7.41	25.55	19.84
Std. Deviation	Organic Sludge	5	5.09	0.04	0.86	0.29	0.77
Specimen A	Organic Sludge	7	44.56	0.68	7.65	19.34	17.24
Specimen B	Organic Sludge	7	40.66	0.74	4.78	19.49	18.93
Specimen C	Organic Sludge	7	43.34	0.70	7.95	19.50	18.51
Average	Organic Sludge	7	42.85	0.71	6.79	19.44	18.23
Std. Deviation	Organic Sludge	7	1.63	0.02	1.43	0.07	0.72
Specimen A	Organic Sludge	9	42.22	0.72	7.27	17.83	21.79
Specimen B	Organic Sludge	9	42.71	0.72	6.43	18.27	21.01
Specimen C	Organic Sludge	9	40.90	0.74	7.41		22.07
Average	Organic Sludge	9	41.94	0.73	7.04	18.05	21.62
Std. Deviation	Organic Sludge	9	0.76	0.01	0.43	0.22	0.45
Specimen A	Organic Sludge	12		0.72	6.58	16.20	
Specimen B	Organic Sludge	12		0.87	5.65	15.91	
Specimen C	Organic Sludge	12		0.81	6.87	16.43	
Average	Organic Sludge	12		0.80	6.37	16.18	
Std. Deviation	Organic Sludge	12		0.06	0.52	0.21	
Specimen A	Organic Sludge	25			4.24	1.41	
Specimen B	Organic Sludge	25			2.34		
Specimen C	Organic Sludge	25			3.90		
Average	Organic Sludge	25			3.49	1.41	
Std. Deviation	Organic Sludge	25			0.83		
Specimen A	Organic Sludge	50		0.37		0.04	
Specimen B	Organic Sludge	50		0.30		0.05	
Specimen C	Organic Sludge	50		0.40			
Average	Organic Sludge	50		0.36		0.05	
Std. Deviation	Organic Sludge	50		0.04		0.01	

1 MPa = 145.04 pounds per square inch