GROUNDWATER TREATABILITY STUDY USING GRANULATED PEAT

By

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INTRODUCTION

Extensive research has focused on raw peat for removing contaminants such as dissolved metals and organics from wastewaters. Raw peat has significant cation exchange capacity due primarily to the carboxyl groups of its humic acid constituents. Efforts to capitalize on peats natural exchange capacity for industrial use has been hampered by the impermeability of peat to water flow, the tendency of organic matter to leach from peat, the instability of peat at pH values above 8, and its high dust content in dried form. Studies conducted by the Natural Resources Research Institute (NRRI) in conjunction with Peat Technologies Corporation (PTC) have focused on solving the impermeability, leaching, stability, and dust problems associated with using peat on an industrial scale. These efforts have identified a manufacturing process in which peat is converted into a highly porous, non leaching, stable granule for use in wastewater purification.

The focus of this program was to evaluate the treatability of a groundwater contaminated with relatively high levels of dissolved organics using granulated peat. The organic contaminants include methyl ethyl ketone (MEK), acetone, tetrahydrafuran (THF), vinyl chloride, toluene, and others.

METHODS - BATCH STUDY

The first phase of the treatability study was conducted in batch mode in which the sorption potential of three candidate peat types were evaluated. Weighed amounts of each candidate peat type were dried at 105°C, placed into 500 mls of representative contaminated groundwater, and gently shaken for one hour on a shaker table. The resulting effluent was then filtered and sent to the WMX Environmental Monitoring laboratory for analysis. The dosing of peat into each flask ranged from 4 grams to 32 grams of peat per 500 mls. Efficacy was judged by the amount of contaminant adsorbed by each peat type. A series of controls is also run in which only groundwater was shaken to help track volatile loss. The characteristics of the peats used in the study are listed in Table 1.

The amount of contaminant adsorbed onto each peat was calculated by the difference between the average control concentration and the resulting effluent concentration. The difference was then multiplied by the volume of solution used (500 mls) and divided by the mass of peat used in the particular test. The sorption capacity was reported for VOC, MEK, acetone, and THF as the mg of contaminant adsorbed per gram of peat. For purposes of simplicity, the VOC sorption capacity was reported as the summation of the MEK, acetone, and THF.

METHODS - FIXED BIOFILM STUDY

The candidate peat type identified as having the greatest sorption potential was selected for further study in Phase 2. The original study was proposed to evaluate a flow-through peat adsorption column using the best peat, based on the results from the batch study. However, because of the low adsorption capacities, Phase 2 evaluated a combination adsorption/biological column (or fixed film bioreactor). This portion of the study focused on the operation of a fixed film bioreactor containing granular peat where the removal potential could be enhanced by biological degradation. This mode of deployment was chosen because it could help promote biofilm development on the interstitial surfaces of the granular peat.

The dimensions of the bioreactor are shown in Figure 1. The reactor was constructed of clear cast acrylic tubing and had a diameter of 6 inches and was 28 inches in height. The corresponding reactor volume was 13 liters.

The reactor was challenged at an average flow rate 2.0 ml/minute with contaminated groundwater in upflow mode while simultaneously injecting air co-currently. The reactor loading averaged 433 mg COD per liter of reactor volume per day. The air flow rate was set at 1 scfh. Effluent and influent samples were taken periodically over a 52-day period and analyzed for VOC, COD, and TSS content. Nutrient and pH adjustment was managed periodically to foster microbial population with the addition of phosphoric and sodium hydroxide, respectively.

RESULTS - BATCH STUDY

The results from the batch portion of the study are shown in Table 2. The table shows the grams of peat and peat type used for each test, feedwater concentration, control concentration, effluent concentration, resulting effluent concentration, sorption capacity for VOC, MEK, acetone, and THF, and the corresponding removal percentages.

The results show that there was no significant correlation between either peat type and peat loading on the resulting effluent concentration. This was somewhat surprising because conventional wisdom would suggest a correlation between peat dose and resulting effluent concentration. In addition, hydrocarbon adsorption has been shown to vary markedly with peat type (Cohen, et al. 1991). However, because of the spread or variation in the data presented here, a definite relationship couldn't be identified. A definable relationship probably would have surfaced with the addition of more repetitions.

The VOC contaminant loadings observed throughout the batch phase tests for each of the peat types ranged from essentially zero to 11.83 mg per gram of peat. This is somewhat lower as that reported by Cohen, where prepared solutions of benzene, toluene, and xylene contaminant loadings of 2.92 mg to 36.2 mg per gram of organic carbon are reported. These differences are probably a function of the particular feedwaters used. When using prepared feedwaters, difficulties are often encountered in obtaining a purely dissolved solution. Any existence of free organic (undissolved) would favor the adsorption onto peat. This study used an actual contaminated water with dissolved organic, whereas Cohens' study used laboratory prepared feedwaters which most likely would have free phase organic present.

The reference by Cohen states that the best hydrocarbon absorbing peats tended to be low in fiber content, low in birefringent organics, and high in ash content. These characteristics were considered in the selection of which peat to use in the fixed biofilm portion of the study.

RESULTS - FIXED BIOFILM STUDY

For peat to be successfully deployed in fixed film mode with air injection, it must be able to withstand frictional breakdown, be resistant to plugging, and most important, not be prone to compaction over time. In addition, it should have a relatively high surface area (100 m^2/gm to 300 m^2/gm) for sorption and biological activity to occur. Peat 1 most closely matched to these desired characteristics. The presence of natural binders combined with humic constituents in Peat 1 contributes to its structural strength and organic binding capacity. In addition it has been shown in the past that it resists bed compaction significantly.

Peat 1 was granulated at Peat Technologies Corporation in Central Lakes, Minnesota. The size fraction utilized for the fixed film study was <4.75 mm to >0.60 mm (- 4 + 30 Mesh). This peat has been shown to offer good resistance to attrition and able to pass water at 18 gal/min/ft^2 at 1 foot of hydraulic head.

The treatment results for the fixed biofilm study are shown in Table 3 which lists the days over which the study occurred, the effluent concentration of each contaminant, the total average influent concentration, and the total average effluent concentration. The results are summarized in Table 4 which lists influent and effluent averages and percentage removed for each contaminant. The treatment results are presented graphically in trend charts in Figures 2-9.

Characteristically evident throughout each of the figures is a general trend toward decreasing effluent concentration through day 40, which would indicate a progression toward steady state conditions. Visual evidence of biological activity appeared with the formation milky residue at the beginning of day 26 with an increase in suspended solids noted at day 40. Thereafter, a trend toward contaminant breakthrough becomes evident. As shown in the Figures, contaminant breakthrough occurs between day 40 and day 43 and it doesn't seem to reestablish steady-state potential.

One plausible explanation may be that the sorption capacity of the reactor was approaching saturation causing an increased biological load. The microorganisms may not have been able to handle the increased biological load. A comparison of the sorption capacities for the batch phase of this study versus the fixed film portion of the study is shown at the bottom of Table 3 for Peat 1. The highest values obtained in the batch study for MEK, acetone, and THF were 3.75, 0.625 and 0.583 mg contaminant per gm of peat, respectively. It appears the THF sorption capacity of the reactor was exceeded and may have been limiting, thereby causing an increased biological load. Figure 2, depicting THF breakthrough at day 40, seems to support this explanation also.

It is possible the reactor may have responded to the increased biological load given more time. There seems to be a significant variation in the effluent concentration after day 40 which Figures 2-9 clearly shows. This variation makes it extremely difficult to tell whether the reactor was actually starting to respond biologically or progressively approaching breakthrough.

SCALE-UP APPROACH

There are two approaches (both based on the COD removal obtained in this treatability study) taken to scaling up the data. The COD removal factor is used to estimate the volume of peat required and estimate peat costs. The first approach is a high strength option while the second is a low strength groundwater option. The design parameters for the high strength and low strength options are shown in Table 5 and Table 6.

HIGH STRENGTH OPTION

For the high strength option a COD design factor of 331 mg COD removed per liter of reactor per day was used. This value comes from the average removal obtained throughout the 52-day operation of the bioreactor. This factor corresponds to a reactor volume of 290,805 ft^3 with granular peat costs totaling $5.8 million.

LOW STRENGTH OPTION

For the low strength option, the COD design factor of 331 mg COD removed per liter of reactor per day was also used. This factor corresponds to a reactor volume of 145,403 ft^3 with granular peat costs totaling $2.9 million.

RECOMMENDATIONS

The significant variation observed in both the influent and effluent concentrations throughout this study makes it extremely difficult to have any degree of confidence in the COD removal factors identified. The variation is most likely brought on by the relatively small scale nature of the experiments and the volatile nature of the contaminants. In addition, it is questionable that the biofilm reactor actually achieved steady-state conditions. The variation would probably disappear with an increase of a few orders of magnitude of scale. A field demonstration may provide a more definitive evaluation of this fixed biofilm technology.

For a field demonstration, the recommended approach would consist of a lateral flow trough containing a mixture of peat screenings and granular peat. Groundwater is deployed laterally through the trough with efficacy judged by the net contaminant degradation through time. This type of system is operating successfully for treating septic tank effluent from a major prison facility near Saginaw, Minnesota.

The scale-up from the laboratory to a field demonstration should be at least 3 orders of magnitude to get reliable scale-up factors. A trough area measuring 3-feet wide by 1-foot deep by 100-feet long should provide the necessary volume to process 60 gal/hr of the low strength feedwater. This kind of a demonstration would likely yield more consistent and less variable results than the laboratory-scale results presented previously.

This mode of deployment wouldn't require reactor tanks and hence may offer reduced costs. Instead, lateral troughs are excavated in situ and filled with the granular peat mixture. This method also has the potential not to require a forced air deployment system, because the in place bed porosity of the granular peat does not limit the diffusion of oxygen to the lower portions of the bed.

Table 1.--Characteristics of peats used in the treatability study.

Peat	Cation Exchange Capacity meq/100 g	Moisture Content (%)	Ash Content (%)	Mesh Size
1	175	5.5	21.4	Minus 40 Mesh
2	112	6.7	11.9	Minus 40 Mesh
3	90	68	36.6	Minus 40 Mesh

Table 2.--Batch treatment results.

Parameter	Grams of Peat/ 500 mL	VOC (ug/L)	MEK (ug/L)	Acetone (ug/L)	THF (ug/L)	Capacity VOC (mg/g)	Capacity MEK (mg/g)	Capacity Acetone (mg/g)	Capacity THF (mg/g)	Percent Removal VOC	Percent Removal MEK	Percent Removal Acetone	Percent Removal THF
Feedwater		347333	203333	49000	95000								
Control 1		334000	200000	44000	90000								
Control 2		337000	200000	45000	92000								
Control 3		339000	200000	46000	93000								
Avg. Control		336666	200000	45000	91666								
Peat 1	4	321000	190000	44000	87000	1.96	1.25	0.13	0.58	4.65	5.00	2.22	5.09
Peat 2	4	316000	190000	40000	86000	2.58	1.25	0.63	0.71	6.14	5.00	11.11	6.18
Peat 3	4	242000	130000	30000	82000	11.83	8.75	1.88	1.21	28.12	35.00	33.33	10.54
Peat 1	8	258000	140000	35000	83000	4.92	3.75	.063	0.54	23.37	30.00	22.22	9.45
Peat 2	8	251000	140000	31000	80000	5.35	3.75	0.88	0.73	25.45	30.00	31.11	12.73
Peat 3	8	257000	140000	34000	83000	4.98	3.75	0.69	0.54	23.66	30.00	24.44	9.45
Peat 1	16	241000	130000	31000	80000	2.99	2.19	0.44	0.36	28.42	35.00	31.11	12.73
Peat 2	16	339000	200000	47000	92000	-0.07	0.00	-0.06	-0.01	-0.69	0.00	-4.44	-0.36
Peat 3	16	342000	200000	48000	94000	-0.17	0.00	-0.09	-0.07	-1.58	0.00	-6.67	-2.55
Peat 1	32	324000	190000	45000	89000	0.20	0.16	0.00	0.04	3.76	5.00	0.00	2.91
Peat 2	32	253000	140000	32000	81000	1.31	0.94	0.20	0.17	24.85	30.00	28.89	11.64
Peat 3	32	237500	130000	29500	78000	1.55	1.09	0.24	0.21	29.46	35.00	34.44	14.91

Table 3.--Fixed Biofilm Results Using Granulated Peat. Average reactor loading was 433 mg COD/ l-reactor/day. All values in ppm except where noted.

Days	MEK	4-methyl 2-pentanone	Acetone	THF	Toluene	Vinyl Chloride	COD	TSS	pH
5	99	0.44	30	41	0.40	0.04	891	5	6
12	200	0.63	67	33	1.25	0.13	1100	21	5
18	140	0.29	54	24	0.59	0.06	562	27	5
26	7	0.11	26	18	0.14	0.01	378	27	6
26	11	0.12	29	19	0.14	0.01	378	25	6
31	9.7	0.11	27	18	0.14	0.01	390	22	6
36	0.03	0.02	0.11	6.4	0.03	0.00	169	3	6
40	0.06	0.03	0.03	11	0.06	0.01	136	6	6
43	84	0.38	44	31	0.33	0.03	359	48	6.5
45	1.1	0.99	10	21	0.10	0.01	261	81	6.8
45	100	0.37	55	27	0.50	0.05	505	23	7.0
52	0.18	0.07	3	26	0.13	0.01	393	38	7.1
Total Avg. Influent Conc.	110.87	0.66	28.4	55.37	1.42	0.06	1956.00	21.50	-
Total Avg. Effluent Conc., mg/g	54.34	0.30	28.76	22.95	0.32	0.03	460.17	27.17	-
Sorption Capacity Avg. mg/g	1.36	0.009	-0.009	0.778	0.26	0.0006	35.9	-	-
Batch highest values for Peat 1	3.75	-	0.625	0.583	-	-	-	-	-

Table 4.--Summary of Fixed Biofilm results.

Parameter	Average Influent (mg/l)	Average Effluent (mg/l)	Percent Removed
COD	1956	460	76.5
2M2P	.66	0.29	55.2
MEK	110.8	54.3	51.0
Acetone	28.4	28.8	-1.27
THF	55.4	22.9	58.5
Toluene	1.42	0.31	77.6
Vinyl Chloride	0.05	0.03	42.9
TSS	21.5	27.2	-
pH	6.7	5.9	-

Table 5.--High Strength Option

Parameter	Influent	Effluent
Flow	200 GPM	200 GPM
Chemical Oxygen Demand	2500 ppm	<500 ppm
Methyl Ethyl Ketone	112 ppm	<10 ppb
Tetrahydrafuran	68 ppm	<10 ppb
Toluene	2.6 ppm	<10 ppb
Experimental COD Contaminant Loading	331 mg COD/liter/day	
Reactor Volume	290,805 ft3	
Truck Loads of Peat	80	
Cost of peat Screenings @ $14/yd^3$	$150,787 Thousand	
Cost of peat Granules @ $20/ft^3$	5.8 Million	

Table 6.--Low Strength Option

Parameter	Influent	Effluent
Flow	500 GPM	500 GPM
Chemical Oxygen Demand	500 ppm	<200 ppm
Methyl Ethyl Ketone	23 ppm	< 10 ppb
Tetrahydrafuran	23 ppm	< 10 ppb
Toluene	0.5 ppm	< 10 ppb
Experimental COD Contaminant Loading	331 mg COD/liter/day	
Reactor Volume	145,403 ft3	
Truck Loads of Peat	40	
Cost of peat screenings @ $14/yd^3$	$75,374 Thousand	
Cost of peat Granules @ $20/ft^3$	$2.9 Million	

Figure 1. CDCL Granulated Peat Column

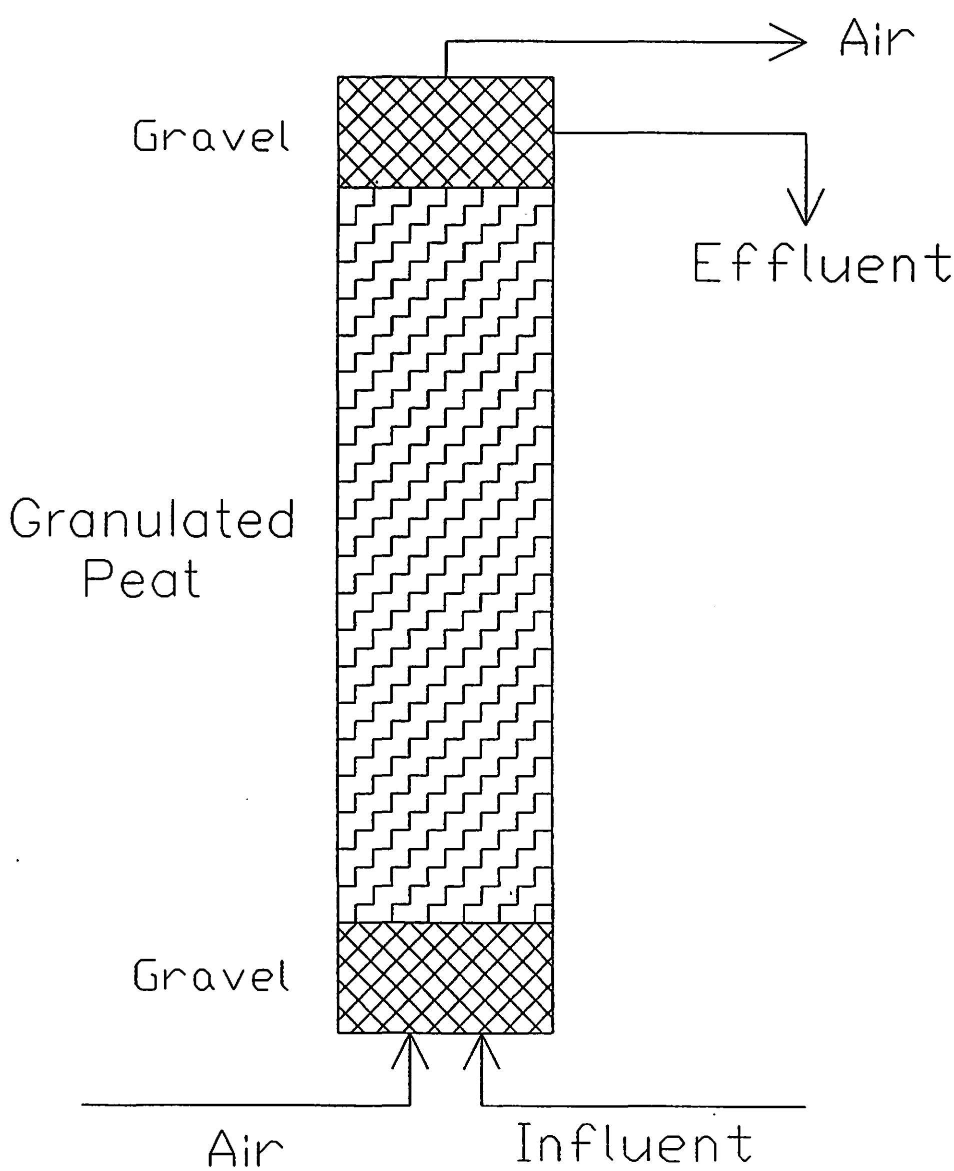


Figure 2.

Percent VOC Removal for Peat 1
at Various Loadings

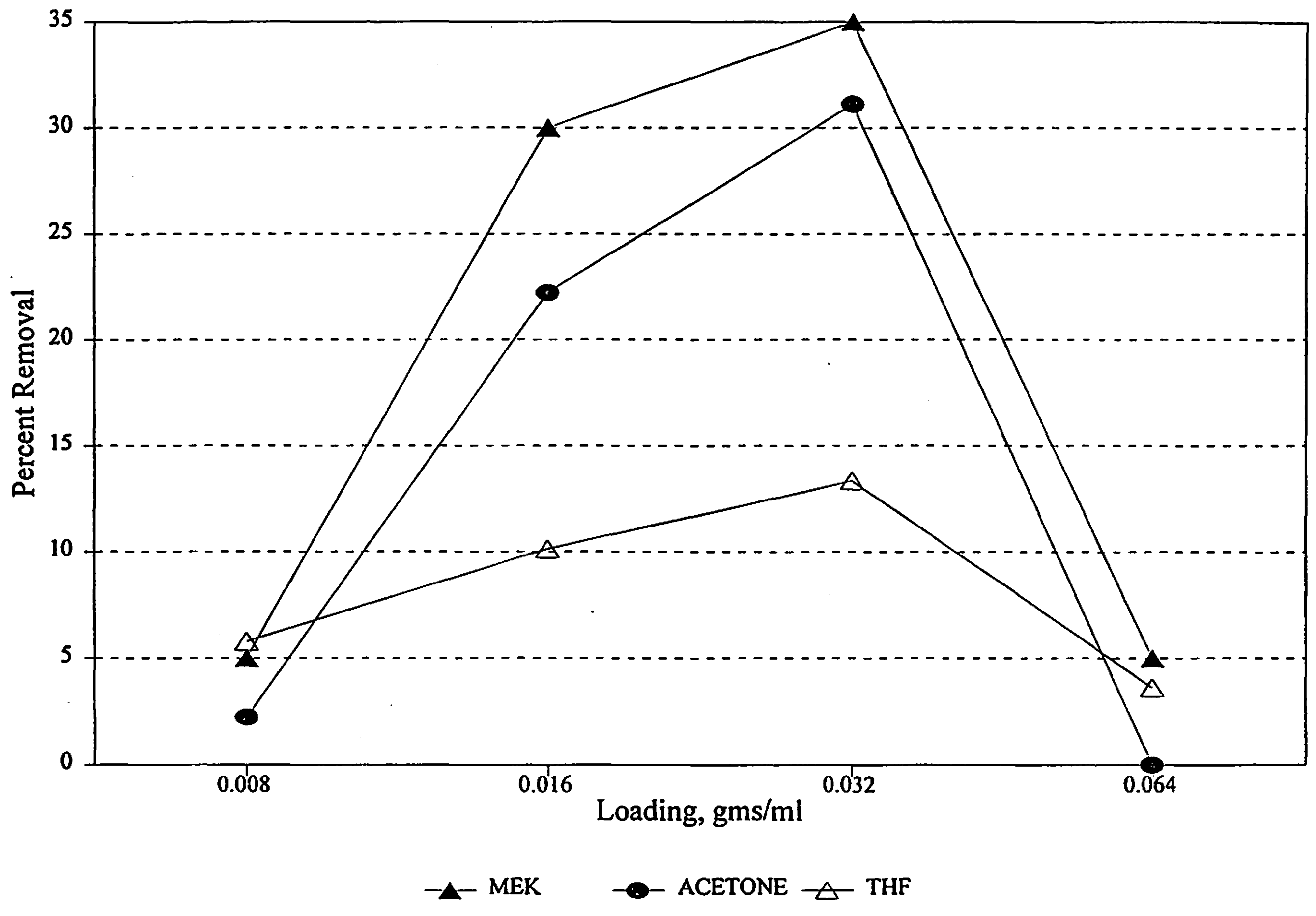


Figure 3.

Percent VOC Removal for Peat 2
at Various Loadings

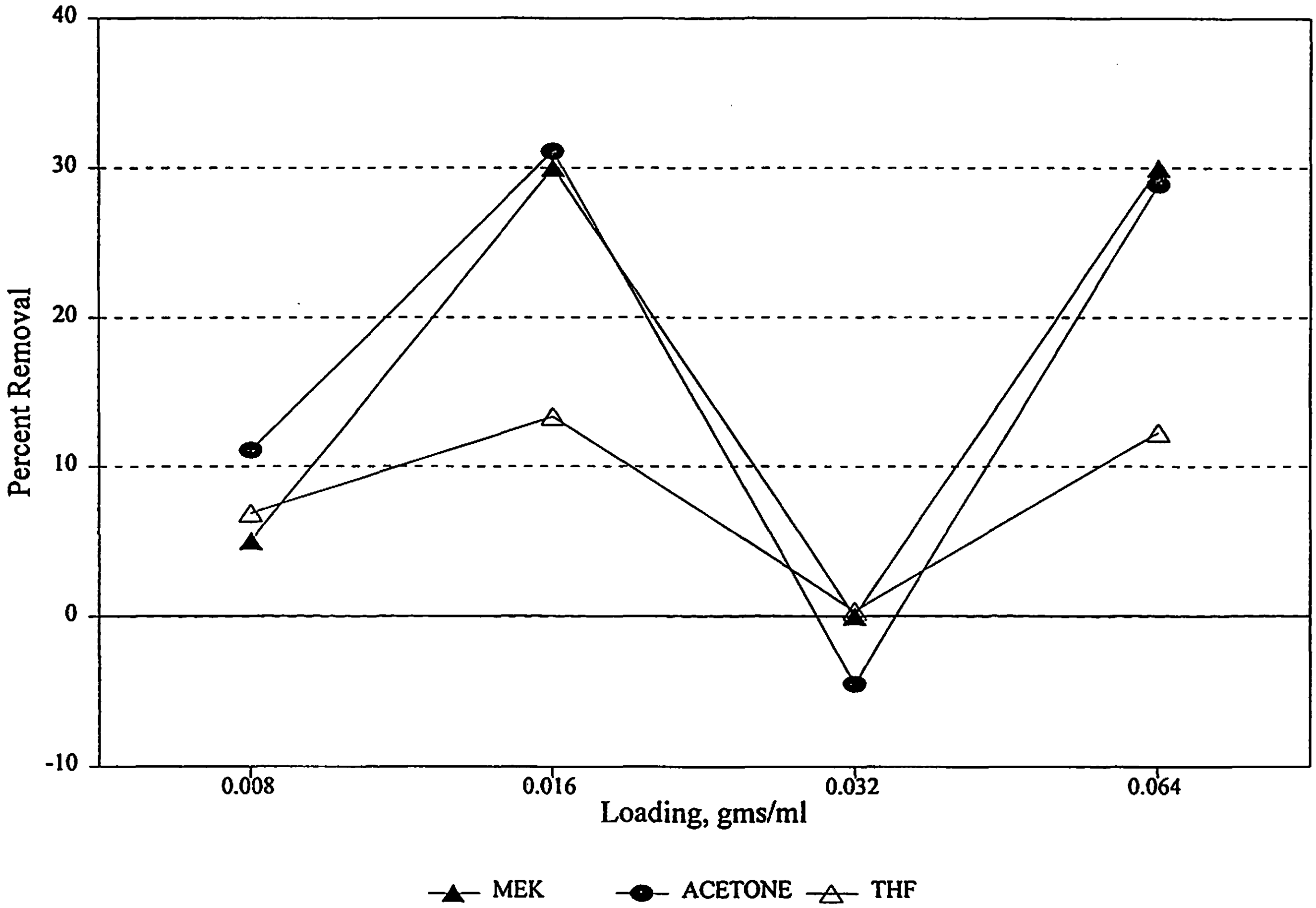
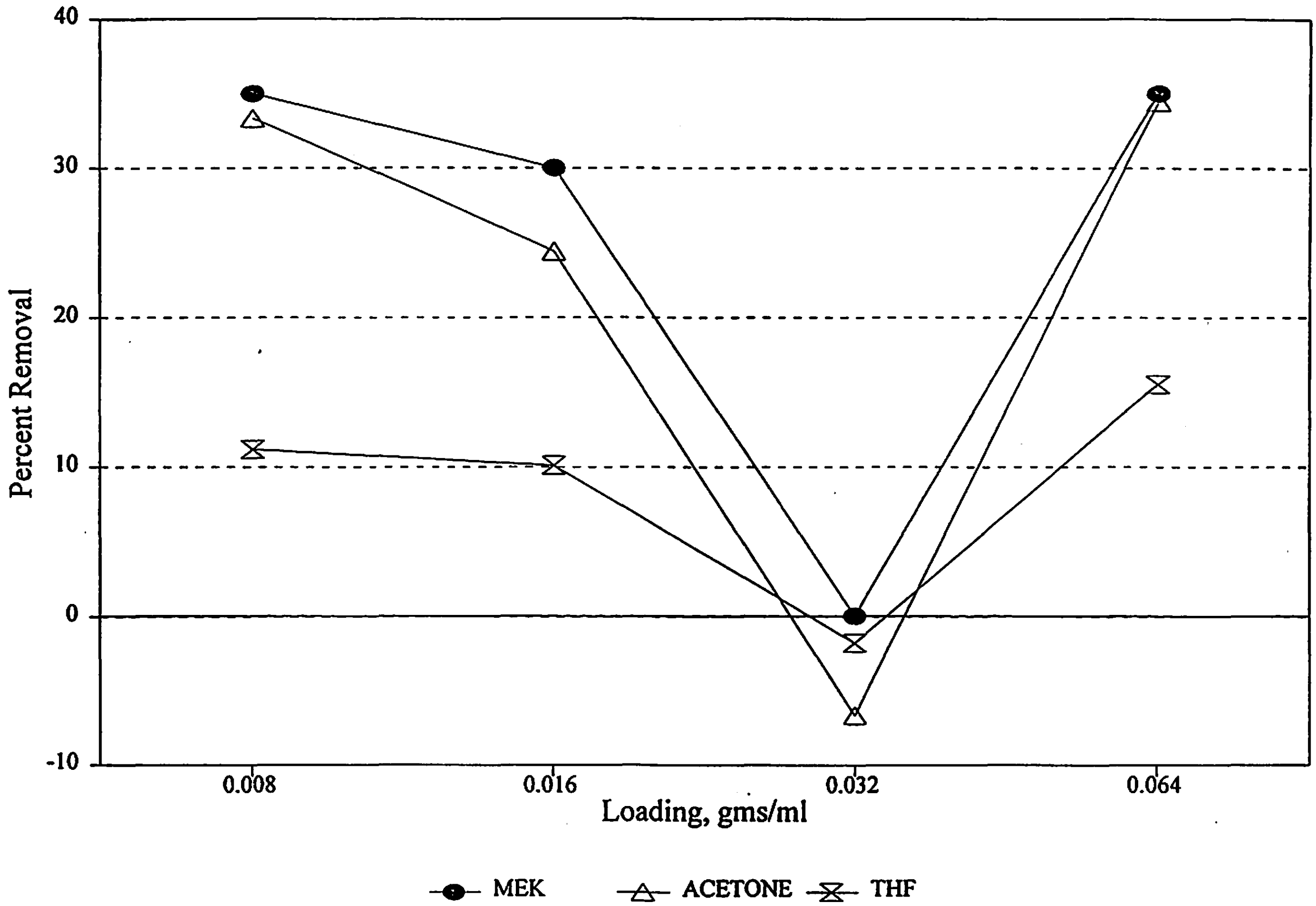


Figure 4.

Percent VOC Removal for Peat 3 at Various Loadings



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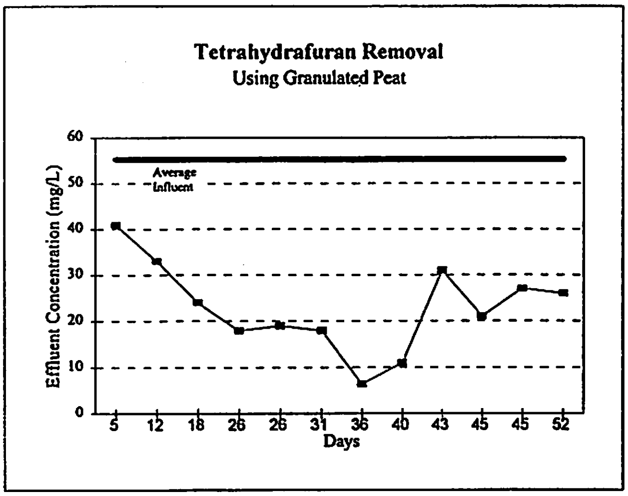

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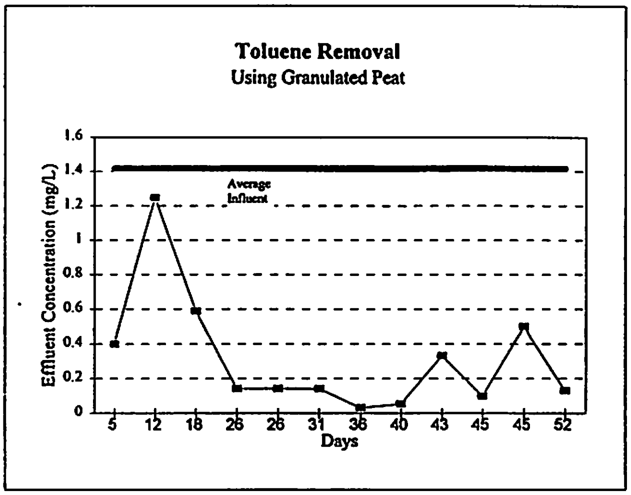

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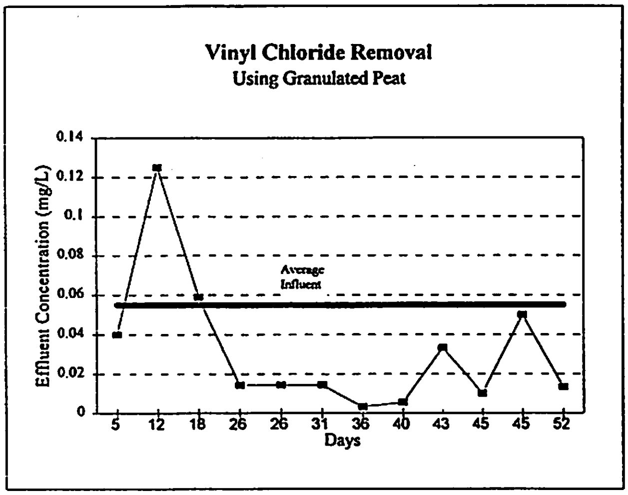

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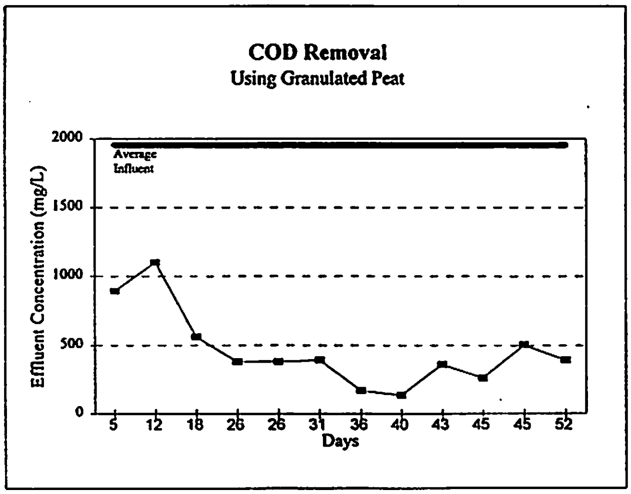

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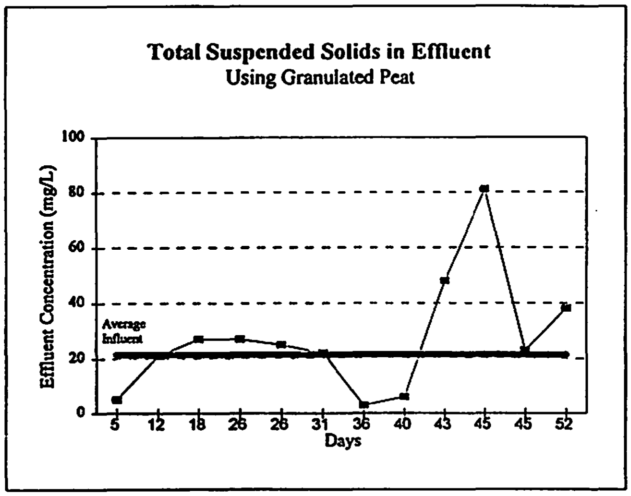

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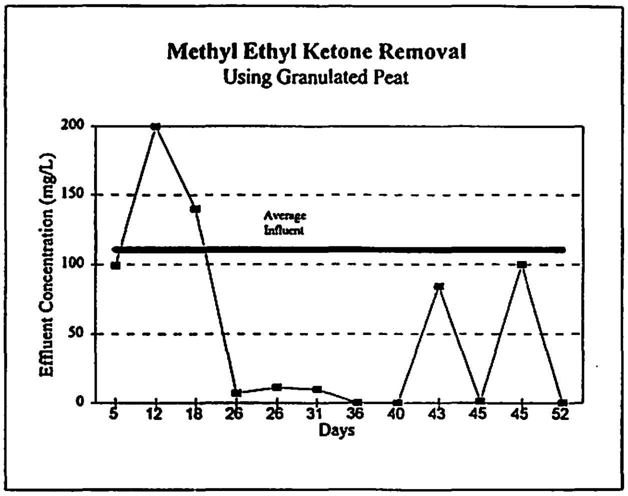

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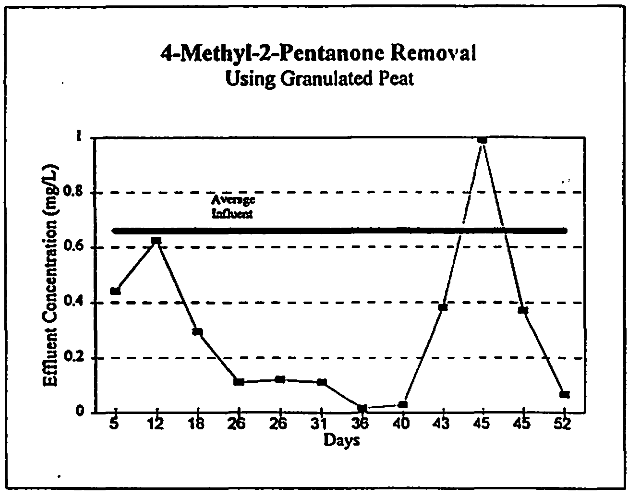

Figure 12.