CR 92.006

June 1992

NCEL

Contract Report

An Investigation Conducted by
G. B. Wickramanayake, M. F. Arthur,
A. J. Pollack, and S. Krishnan
BATTELLE
Columbus Division

REMOVAL OF AQUEOUS PHASE PETROLEUM PRODUCTS IN GROUNDWATER BY AERATION

Abstract This study evaluated the effectiveness of conventional air stripping for removal of jet fuels (JP-5 and AVGAS) from groundwater, using samples collected near the Patuxent River Naval Air Station fuel farm in MD. Using an air flow rate of 0.5 L/min, fuel contaminants (a mixture of JP-5 and AVGAS) were removed in excess of 97% within 30 minutes. At the same flow rate, 96% of a less volatile fuel contaminant (primarily JP-5) was removed in 30 minutes. These results indicate that even low volatility jet fuel can be removed from groundwater to low levels (<2 mg/L) by air stripping. Iron precipitation during aeration of groundwater could plug packed-bed air strippers unless pre-aeration and iron precipitate removal was implemented before packed-bed air stripping.

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		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2,000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Pub. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

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mm	millimeters	0.04	inches	in
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m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
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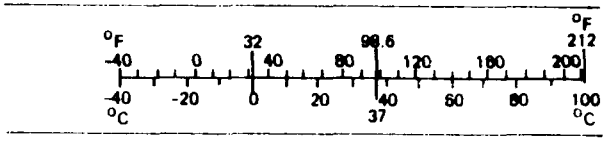
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-018

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	June 1992	Final; August 1988 - December 1988

4. TITLE AND SUBTITLE

REMOVAL OF AQUEOUS PHASE PETROLEUM PRODUCTS IN GROUNDWATER BY AERATION

5. FUNDING NUMBERS

PR - 71-033
C - DAAL03-86-D-0001
WU - DN668034

6. AUTHOR(S)

G. B. Wickramanayake, M. F. Arthur, A. J. Pollack, and S. Krishnan

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

BATTELLE
Columbus Division
505 King Avenue
Columbus, Ohio 43201-2693

8. PERFORMING ORGANIZATION REPORT NUMBER

CR 92-006

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

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Washington Navy Yard
Washington, DC 20374-2121

Naval Civil Engineering Laboratory
Code L71
Port Hueneme, CA 93043

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

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13. ABSTRACT *(Maximum 200 words)*

This study evaluated the effectiveness of conventional air stripping for removal of jet fuels (JP-5 and AVGAS) from groundwater, using samples collected near the Patuxent River Naval Air Station fuel farm in MD. Using an air flow rate of 0.5 L/min, fuel contaminants (a mixture of JP-5 and AVGAS) were removed in excess of 97% within 30 minutes. At the same flow rate, 96% of a less volatile fuel contaminant (primarily JP-5) was removed in 30 minutes. These results indicate that even low volatility jet fuel can be removed from groundwater to low levels (<2 mg/L) by air stripping. Iron precipitation during aeration of groundwater could plug packed-bed air strippers unless pre-aeration and iron precipitate removal was implemented before packed-bed air stripping.

14. SUBJECT TERMS

Air stripping, jet fuel, JP-5, groundwater, volatile organic compounds

15. NUMBER OF PAGES

10

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

INTRODUCTION

The objective of this study was to examine air stripping for the removal of hydrocarbons present in two groundwater samples suspected to be contaminated with jet fuels. The groundwater samples were collected at the Patuxent Naval Air Test Center fuel farm and sent to Battelle for the proposed study by the Naval Civil Engineering Laboratory, Port Hueneme, California.

MATERIALS AND METHODS

Two groundwater samples obtained from Wells No. 20 and 25 contained visible layers of fuel floating on the water surface. Water samples as well as the non-aqueous phase liquid (NAPL) floating on the top were analyzed by gas chromatographic methods as described below.

Air Stripping Studies

The experimental set-up for air stripping of water samples is shown in Figure 1. Purified compressed air was used as the source of air for stripping. Approximately 200 mL of water was siphoned into a 250-mL gas washing bottle from the groundwater sample. The test sample did not contain any floating liquid. The water sample was aerated at an air flow of 0.5 Lpm at 10 psig. Aliquots of 2-mL were withdrawn from the reactor at different

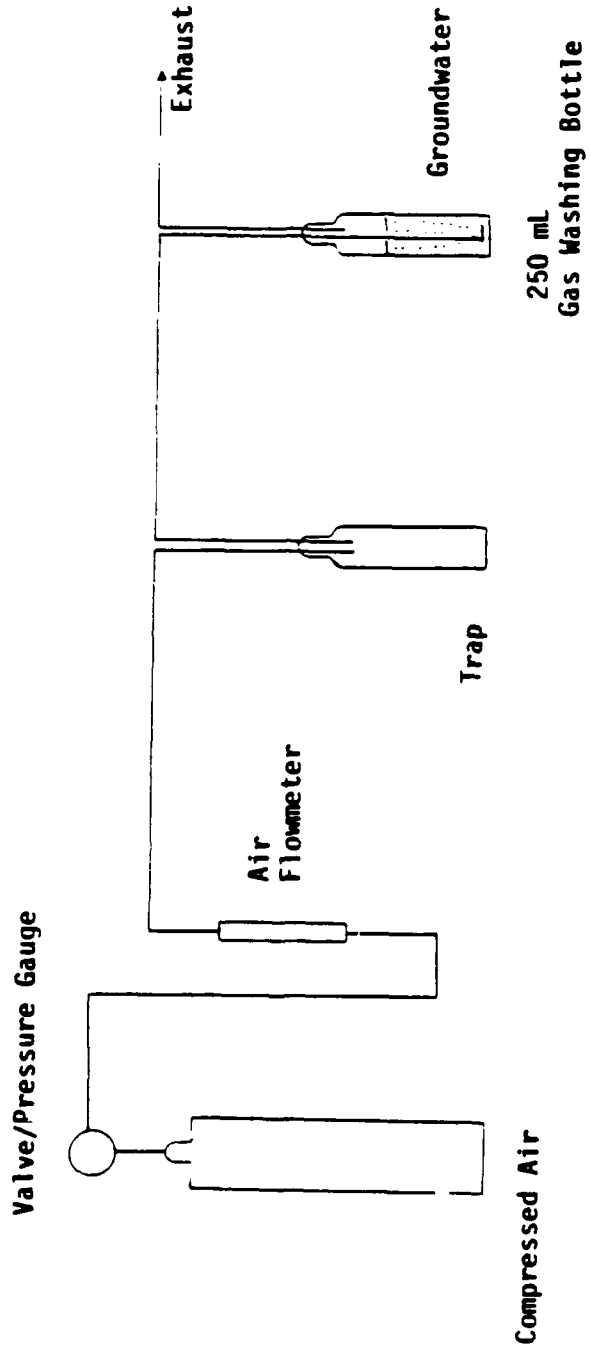

FIGURE 1. SCHEMATIC OF BATCH AERATION UNIT

time intervals and analyzed by gas chromatographic methods described below. Each aeration study was conducted for a period of 1 hr at room temperature.

Analytical Methodology

The qualitative/quantitative analysis of JP-5 in groundwater samples was accomplished using a gas chromatograph (G.C.). The G.C. system included a Varian Model 3700 gas chromatograph equipped with a flame ionization detector (FID) and a Varian Model 4270 integrator.

Organics present in the water samples were chromatographically resolved with the aid of a 6 ft. x 2 mm i.d. 3% OV101 packed column. Optimum analytical results were achieved using a G.C. oven temperature program that holds at an initial temperature of 40°C for 4 minutes then increases to 250°C at 10°/minute. The detector temperature was maintained at 300°C. A 25 ml/minute nitrogen flow was used for the carrier gas. Direct aqueous injections were made of the well water samples. Jet fuel standards were prepared in a methylene chloride matrix using the organics floating on the surface of the groundwater samples as the neat material. A sub-ppm detection limit of hydrocarbon in water was possible with the FID.

RESULTS

A typical chromatogram of the NAPL obtained from Well No. 20 groundwater is shown in Figure 2. This neat injection of the material floating on the surface of the water sample displays a majority of the peaks and total area counts eluting within the first 3 minutes. This would tend to indicate qualitatively that the organics present at Well No. 20 are mainly lower molecular weight (light hydrocarbon) compounds that might be found in the gasoline fraction of jet fuels. Although this organic material is in contact with the well water, it does not presume that all species are actually present or present in similar relative proportion in the aqueous phase.

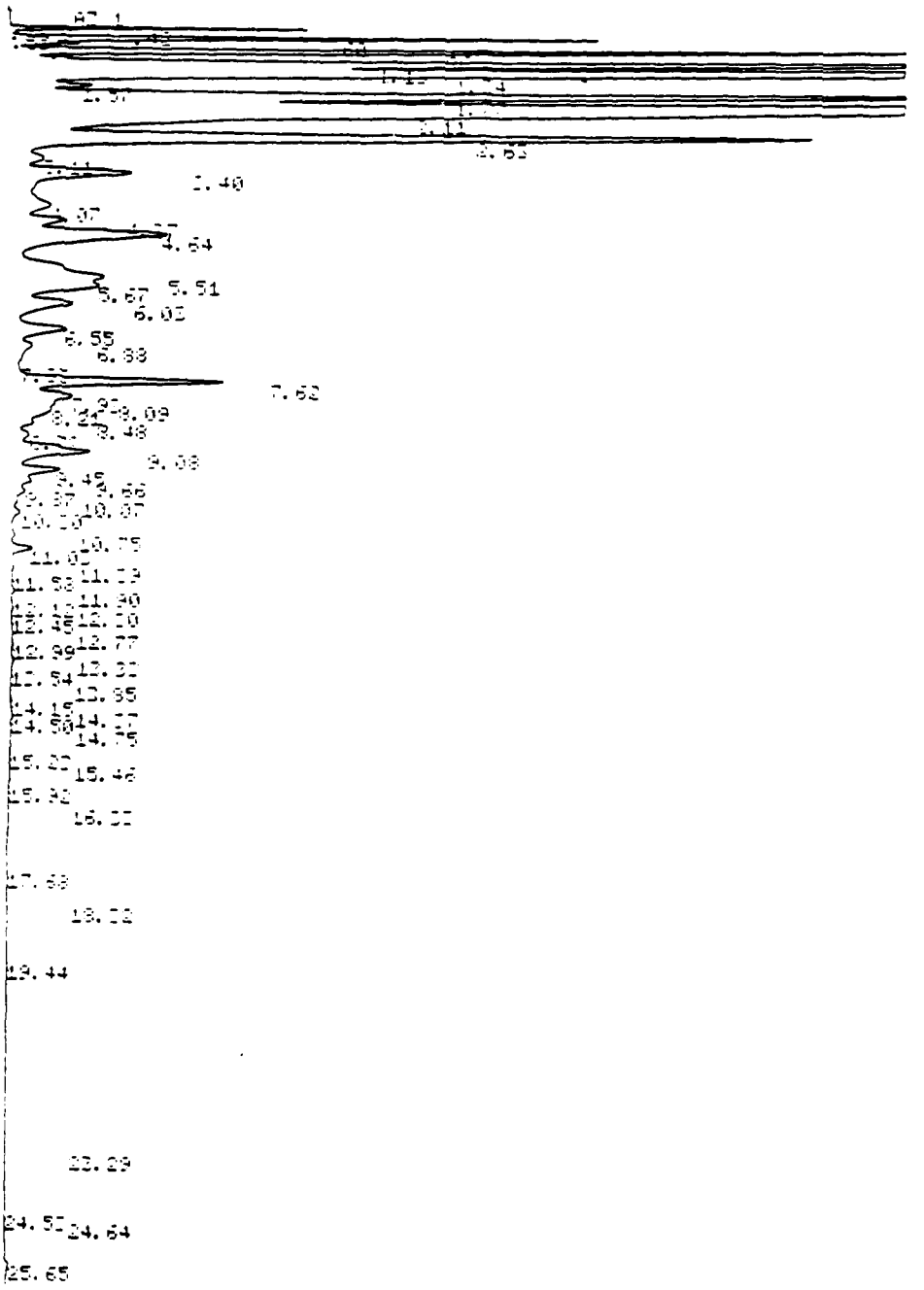

FIGURE 2. ORGANICS IN CONTACT WITH WATER AT WELL NO. 20.

Figure 2. (continued)

PEAK #	AREA%	RT	AREA BC
1	0.002	0.74	7647 BB
2	0.699	0.82	1208527 BB
3	0.019	0.87	31945 BB
4	2.49	0.9	4274582 BB
5	0.288	0.92	494303 BB
6	4.891	0.96	8396747 BB
7	3.15	1.17	13982762 BB
8	24.588	1.24	42213708 BB
9	0.221	1.57	382741 BB
10	9.06	1.77	15554982 BB
11	22.11	2.11	37949828 BB
12	8.971	2.62	15401148 BB
13	0.166	3.11	284715 BB
14	1.52	3.4	2610185 BB
15	0.49	4.07	840549 BB
16	0.481	4.37	825936 BB
17	2.552	4.64	4381103 BB
18	1.736	5.51	2066513 BB
19	1.16	5.87	1974474 BB
20	0.701	6.01	1204876 BB
21	0.663	6.66	1145976 BB
22	0.245	6.86	420446 BB
23	0.014	7.1	23872 BB
24	2.39	7.26	4102157 BB
25	0.947	7.36	1626097 BB
26	0.267	7.53	474556 BB
27	0.476	7.71	819211 BB
28	0.135	7.98	234394 BB
29	0.211	8.18	362351 BB
30	1.164	8.33	2000736 BB
31	0.25	8.46	444477 BB
32	0.213	8.66	374026 BB
33	0.151	8.87	262614 BB
34	0.051	10.37	87736 BB
35	0.098	10.7	168714 BB
36	0.039	10.75	67538 BB
37	0.22	11.03	378231 BB
38	0.05	11.29	85246 BB
39	0.012	11.56	20796 BB
40	0.031	11.9	52710 BB
41	0.017	12.12	29049 BB
42	0.008	12.3	13790 BB
43	0.004	12.45	6741 BB
44	0.019	12.77	32117 BB
45	0.046	12.94	79662 BB
46	0.021	13.11	37167 BB
47	0.017	13.54	29773 BB
48	0.012	13.86	21486 BB
49	0.03	14.15	52005 BB
50	0.028	14.27	48774 BB
51	0.017	14.5	29831 BB
52	0.045	14.75	77354 BB
53	0.013	15.22	21293 BB
54	0.029	15.46	50031 BB
55	0.007	15.92	12752 BB
56	0.	16.12	741 BB
57	0.002	17.65	4490 BB
58	0.002	18.72	4040 BB
59	0.	19.44	609 BB
60	0.001	22.19	367 BB
61	0.001	24.62	1795 BB
62	0.	24.84	611 BB
63	0.054	25.25	104884 BB
TOTAL	100.		171680954

Eight of the samples that were collected during the 60 minute air stripping process were analyzed by G.C. and the concentration of organics was calculated based upon the area counts of similar peaks in a jet fuel standard. The results of that analysis for Well No. 20 are presented in Table 1.

Except for sample No. 8, which may have been contaminated, there is apparent reduction of organics over time using air stripping on this water sample.

The analysis of the air-stripped water samples from Well No. 25 was performed in the same manner as previously described. Figure 3 shows a chromatogram for NAPL floating on the surface of the groundwater sample from Well No. 25. This sample shows that NAPL consists of low concentrations of light hydrocarbons and higher levels of the heavy hydrocarbon fractions.

The GC analysis of samples that were collected from Well No. 25 water during the air stripping process is presented in Table 2. A reduction in organic concentration over time is observed when the water sample is air stripped. The problem of apparent sample contamination was again evident with sample No. 10.

DISCUSSION

The results indicate that given the air flow rate utilized most of the hydrocarbons present in aqueous phase can be removed by aeration. When the air flow rate was 0.5 Lpm, the removal of aqueous phase liquid organics from Well No. 20 groundwater exceeded 97 percent within the first 30 min. Similarly, the removal of aqueous phase liquid from Well No. 25 amounted to 96 percent for the same test conditions.

Data presented in the present study indicates that the groundwater examined is typical of fuel contaminated water and clean-up by air stripping following NAPL removal is feasible.

The design configuration of any aeration system must be based upon treatment objectives and other water quality considerations. For example, if low level treatment is required, packed column aeration may be necessary. However, packed column aerators are subject to iron fouling, which could be problematic when treating reduced groundwater.

TABLE 1. CONCENTRATION OF REPRESENTATIVE ORGANICS IN AIR-STRIPPED GROUNDWATER FROM WELL NO. 20

Sample No.	Duration of Air Stripping (min)	Concentration of Organics (ppm)
1	0.25	6.28
3	1.0	3.54
6	3.0	2.36
8	5.0	5.35
10	10.0	2.05
12	20.0	1.39
13	30.0	0.13
15	60.0	0.02

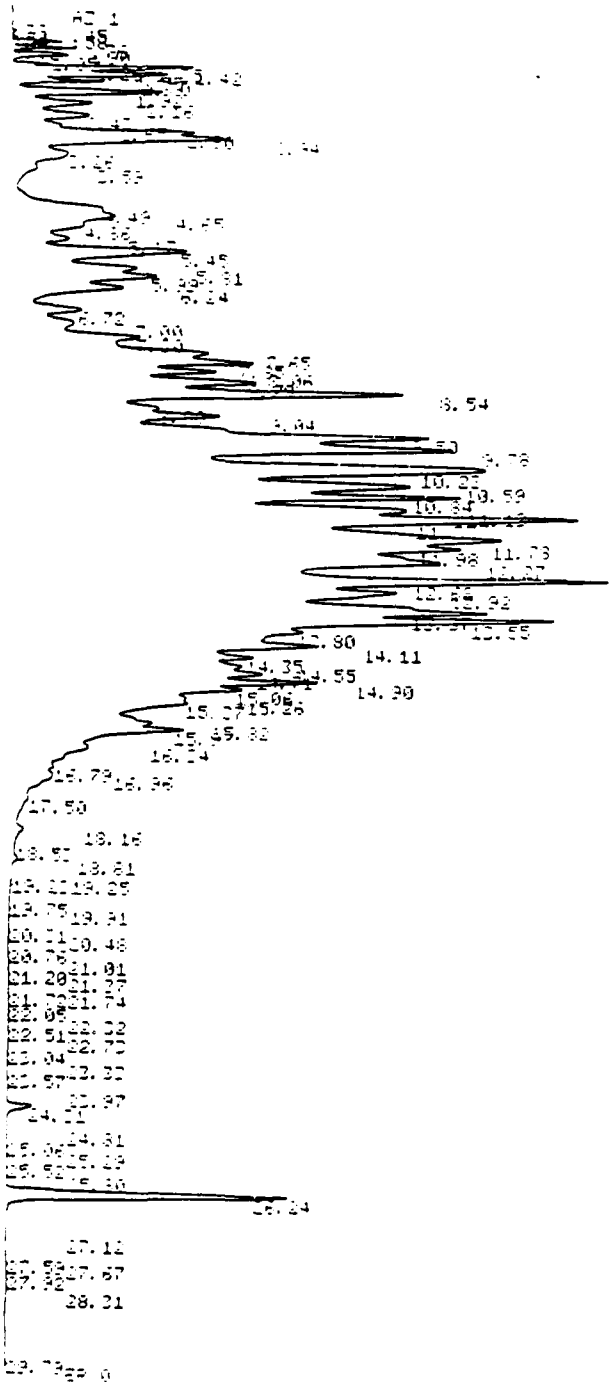

FIGURE 3. ORGANICS IN CONTACT WITH WATER AT WELL NO. 25.

Figure 3. (continued)

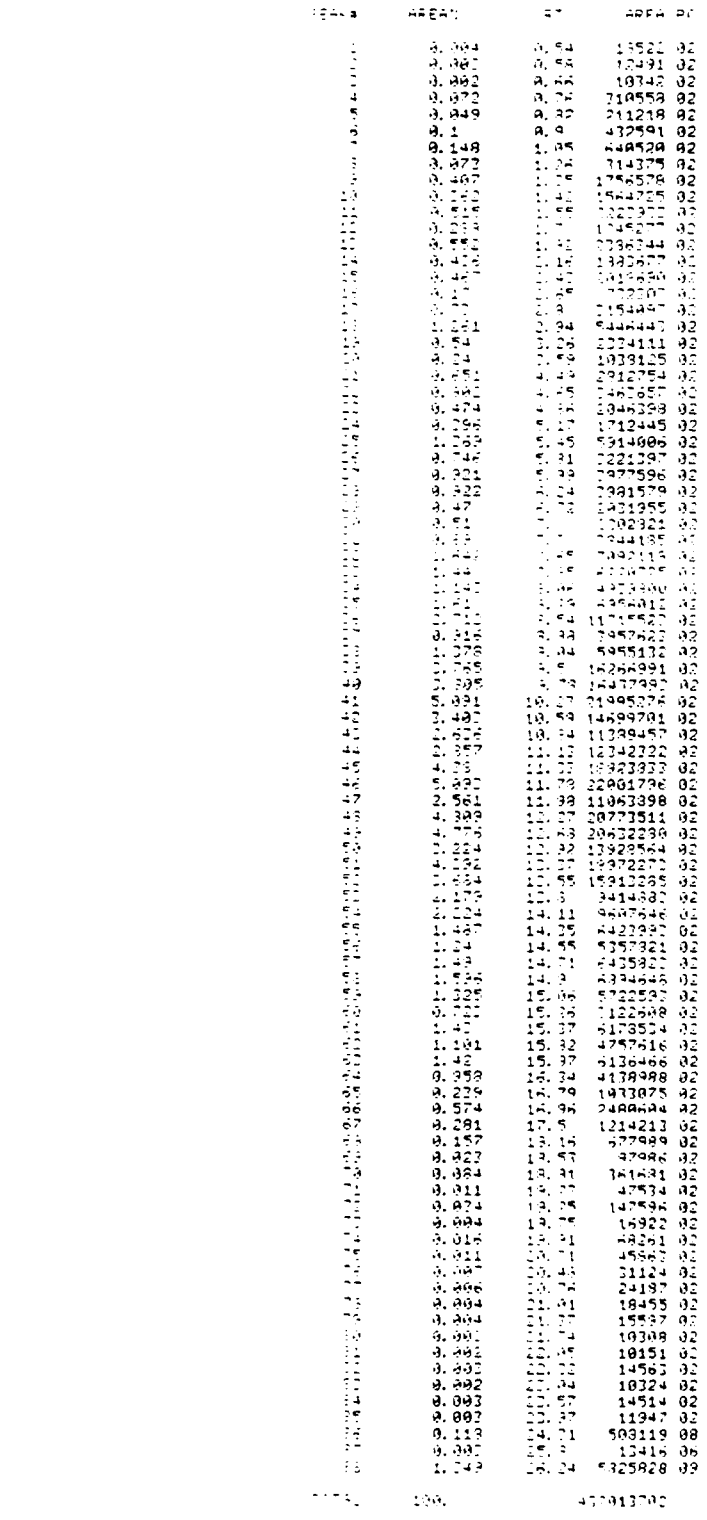

TABLE 2. CONCENTRATION OF REPRESENTATIVE ORGANICS IN AIR-STRIPPED GROUNDWATER FROM WELL NO. 25

Sample No.	Duration of Air Stripping (min)	Concentration of Organics (ppm)
1	0.25	63.33
3	1.0	16.30
6	3.0	6.75
10	10.0	39.26
11	14.0	3.65
12	20.0	2.80
13	30.0	2.45
15	60.0	1.64

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