Crude oil contamination of soil and groundwater in Kuwait

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Abstract

During the Gulf war seven hundreds of oil wells were destroyed by the retreating armies of Iraq. In particular, the Burgan oil field suffered heavy damage. Over 50millions of crude oil spilled out flooding the desert and as a result, extensive contamination of desert soils occurred. Field investigations indicated that crude oil penetrated the desert soils under the newly formed oil lakes to a depth of 150 cm for the 5 years following the Gulf war. The calculated penetration of this oil into the soil over the next 100years is determined to be approximately 10 meters. At the Burgan area groundwater was not contaminated because the upper aquifer was at a depth of more than 100 meters.

Key words:Kuwait, oil contamination, oil pollution, crude oil

1. Introduction

Kuwait is a small country located in the northern edge of the Arabian peninsula, bordered by the Arabian Gulf in the east. The total area of Kuwait is 18000km^2 and the rainfall is about 120 mm/yr mainly during winter. Drinking water is desalinated from sea water and brackish water. The Gulf war led to the contamination of air, water and soil in Kuwait. About 700 oil wells were set on fire. Oil well fires also damaged well heads and hence free flowing oil from these resulted in the formation of large oil lakes. Figure 1 shows the distributions of groundwater field and oil contaminated soil. The total amount of crude oil in these lakes was estimated to be about 50 million barrels (Al-Sulaimi 1993). The total area of oil lakes was 49 km^2 and the total amount of oil contaminated soil was 40 million m^3. Groundwater pollution may result from any of the following mechanisms : (1) direct penetration of oil from oil lakes ; and (2) penetrating rainwater can leach some of the products of combustion deposited at ground surface level.

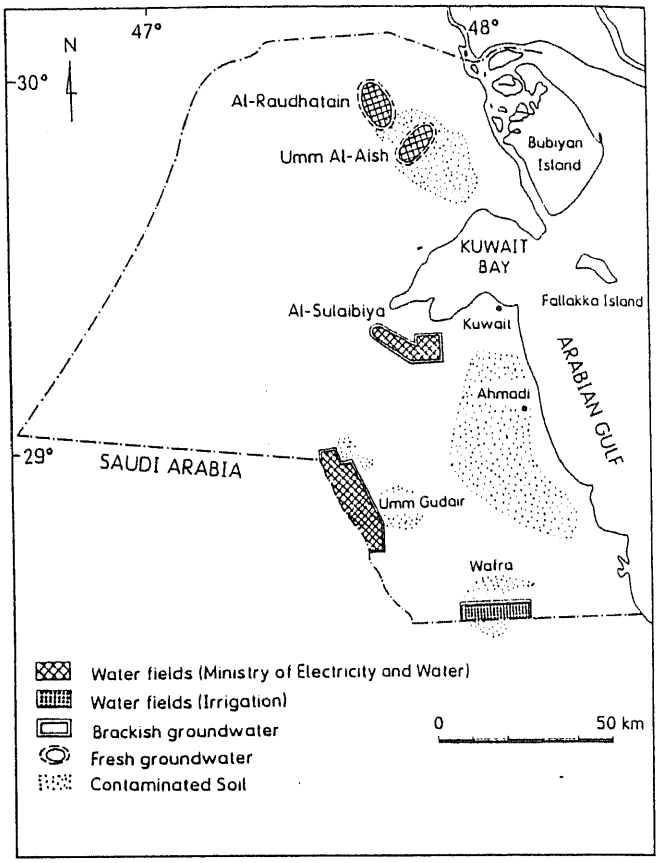

Figure 1 Distribution of groundwater field and oil contaminated soil (Al-Sulaimi et al., 1993)

2. Groundwater contamination in Kuwait

There are three aquifers in Kuwait. The first aquifer which is shallow and fresh is distributed only in northern Kuwait. At Al-Raudhatain and Umm Al-Aish, there are large drainage basins. Although average rainfall is only about 120 mm/yr, the geomorphology is conducive to the formation of large fresh-water lenses over brackish and saline groundwater (Sulaimi et al., 1993). However after oil the fires, these large catchment areas, covered with the products of combustion, contributed to the pollution of groundwater because runoff generated by rainfall dissolved some of the products of combustion. Figure 2 shows the first aquifer which was contaminated by rain water passing through oil contaminated soil. The

concentrations of vanadium and nickel in Kuwait crude oil were about 22.5 and 1.0 ppm, respectively. As a result, the concentration of vanadium, nickel, and total carbon in the groundwater reached 400, 100, and 200 ppb.

The second and third aquifer which are both deep and brackish to saline are distributed all over Kuwait. At the Burgan oil field area, a lot of oil escaped and four fifths of the total number of oil lakes (250) were found there. Therefore, groundwater pollution of the second and third aquifer had to be considered at the Burgan area.

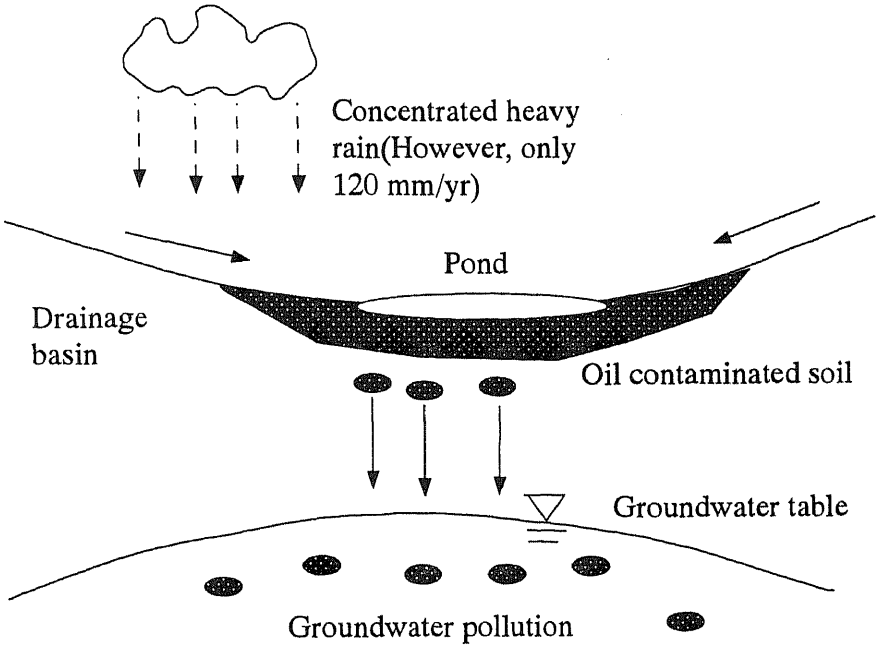

Figure 2 First aquifer which was contaminated by rain water passing through oil contaminated soil

We performed field investigation in September 1995 and oil penetration tests in sand columns in order to analyze oil penetration into the aquifer.

3. Study area and method

3.1 Sampling

Figure 1 shows the study area which is the Burgan oil field south of Kuwait city. The total amount of oil deposits in the Burgan oil field is the second largest oil field in the world. Surface sediments in the area are composed of fine gravel and coarse sand cemented by gypsum.

Around the No.105 oil lake, the oil penetration depth was measured at 150 cm on average by digging pits before our investigation. Three sampling points (AP-1, AP-2 and AP-3) were set around the No.105 oil lake after confirming the absence of mines and ammunitions. Uncontaminated soil was sampled from three pits in order to measure the physical properties of soil and to perform oil penetration tests in a laboratory. Undisturbed soil samples were used for measuring dry density. Disturbed soil sample was used for measuring water content, hydraulic conductivity

and oil penetration tests.

3.2 Physical properties

Water content was measured instantly on the spot. Table 1 shows water contents. Surface soil was very dry and water content increased with depth. Since water content 150 cm in depth was less than 8 %, oil was assumed to penetrate into dry soil. Dry density values were measured at 1.8g/cm^3 on an average from 9 undisturbed block samples.

Table 1 shows the hydraulic conductivity values. At the condition of 1.8g/cm^3 dry density measured for the undisturbed block samples, hydraulic conductivity values were 1×10^{-2} to 1×10^{-1} cm/sec.

Table 1 Water content and hydraulic conductivity values at each depth

	Depth(cm)	Hydraulic conductivity (cm/sec)	Water content (%)
AP-1	10	0.015	0.43
		0.014	
	30	0.021	1.49
		0.024	
	60	0.029	3.04
		0.025	
	100	0.009	3.83
		0.009	
	110	0.016	
		0.004	
	130		4.49
	150	0.035	
		0.009	
	160		4.23

	Depth(cm)	Hydraulic conductivity (cm/sec)	Water content (%)
AP-3	10	0.098	0.23
	30	0.061	0.86
	40	0.033	1.66
	60	0.074	2.80
	100		2.73
	150		7.76
	180		8.26

	Depth(cm)	Hydraulic conductivity (cm/sec)	Water content (%)
AP-2	10	0.086	0.22
		0.070	
	30	0.073	0.61
		0.026	
	50	0.038	2.16
	70	0.041	2.34
	80	0.039	
	100	0.012	3.61
	130		3.41
	170		3.51

3.3Oil penetration test

Figure 3 shows the experimental apparatus for the oil penetration test. An oil head was fixed to be 5 or 10 cm. Dry soil was compacted till the dry density reached 1.8 g/cm^3 because at the oil penetrated depth, water content was very low. Figure 4 and 5 show examples of oil penetrated results at the condition of oil head 5 and 10 cm. For both conditions, oil penetrated depths were 15 to 20 cm for 10 days. According to Philip's moist equation, oil penetrated depth and elapsed time were shown as follows (Kayane、1980) :

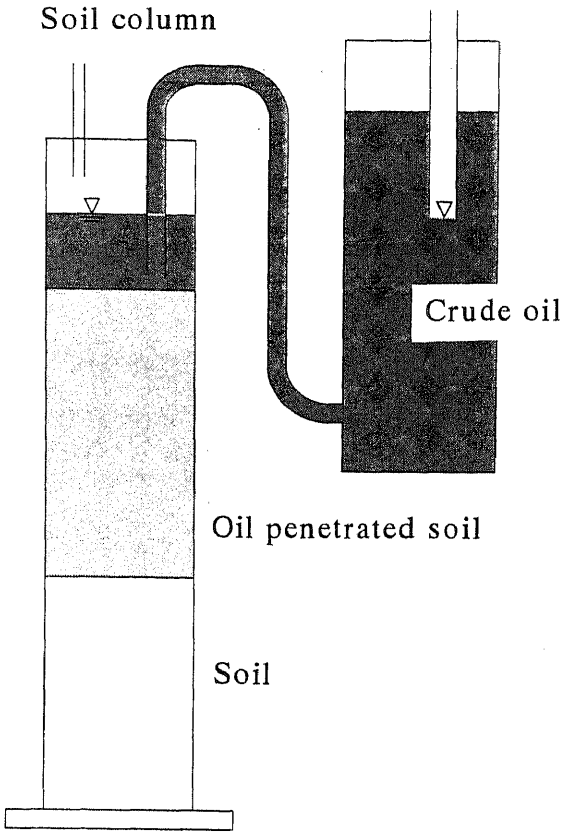

Figure 3 Experimental apparatus for the oil penetrating tests

$$I(T)=AT+BT^{0.5} \qquad (1)$$

Where I(T) is an oil penetrated depth;T is an elapsed time; A is a coefficient of oil conductivity; B is a coefficient of absorption.

Oil penetrated depth is not due to the oil head according to Philip's equation. Oil penetrated depths calculated from the experimental results were 200 to 1500cm for 5 years after the Gulf war ended. Oil penetrated depth within oil lakes was about 150 cm which was smaller than the minimum of calculated oil penetrated depth. Oil compositions of the oil penetrated soil was measured by gas chromatography before extracting oil from samples using diethyl ether as a a solvent. Figure 6 shows examples of oil compositions of each penetrated depth. The X axis shows an intensity measured by gas chromatography per soil weight. The Y axis shows carbon numbers. Surface sand contained more oil than the deeper sand. However, oil composition at each depth was the same. Oil composition did not change during oil penetrated into sand.

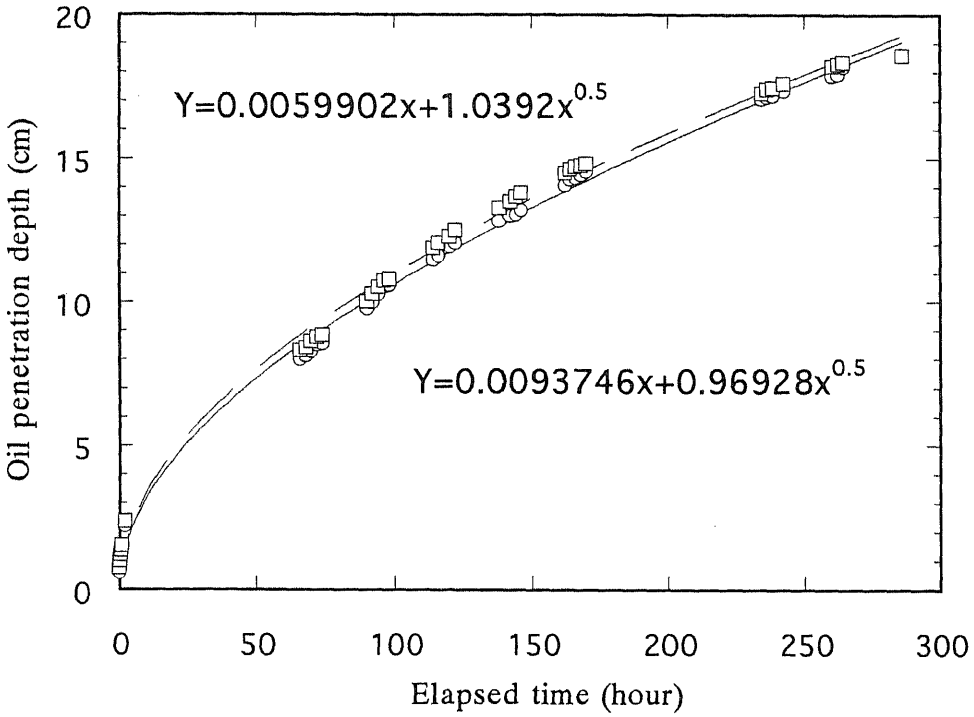

Figure 4 Oil penetration results at the condition of oil head 5 cm (Soil sample derived from the AP-1 pit 60 cm in depth)

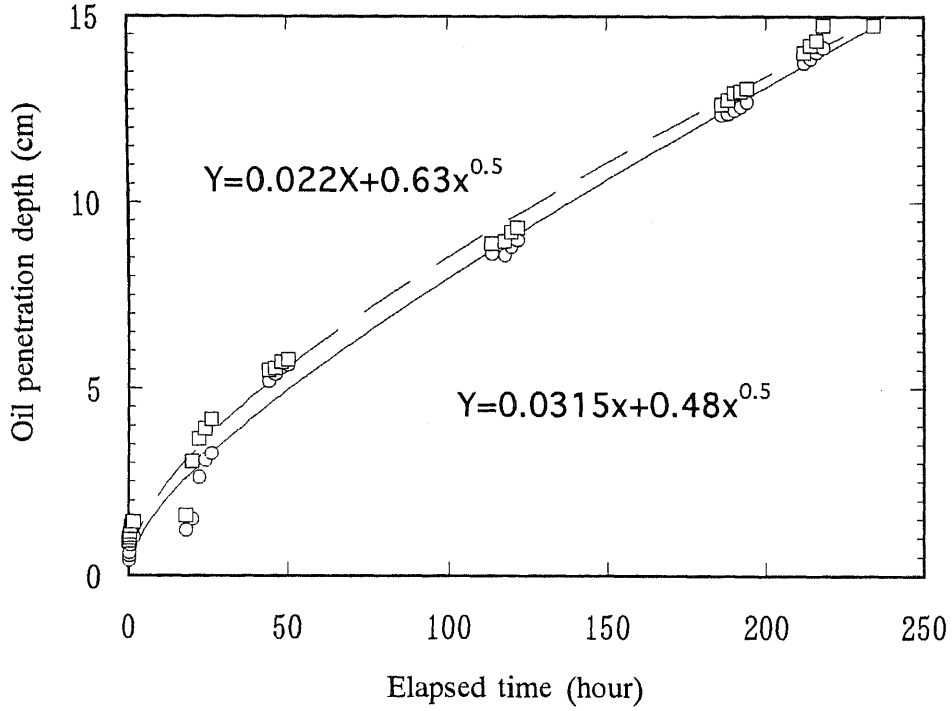

Figure 5 Oil penetration results at the condition of oil head 10 cm (Soil sample derived from the AP-1 pit 10 cm in depth)

4. Discussion and Conclusion

Oil penetration laboratory tests using Kuwait crude oil and the sampled soil were performed in Japan. As a result, penetrated depths were 15 to 20 cm for 10 days

and oil penetrated depths calculated from the experimental results were 200 to 1500 cm for 5 years after the Gulf war ended. Oil penetrated depth within oil lakes in the Burgan area was about 150 cm which was less than the calculated minimum values. The minimum values of calculated penetrated depths for 10 and 100 years were 3 and 10 m and the second aquifer at the Burgan area was 100 m in depth. The second aquifer was not thought to have not been contaminated directly by oil penetration because the calculated minimum depth was larger than the actual depth and the viscosity of oil became smaller with time by reason of volatilization.

In northern Kuwait, rain water penetrated through oil contaminated soil into the first aquifer and the first aquifer was thus contaminated by oil laden rain water. Therefore, in the Burgan area, the second and third aquifer had to be considered to have been contaminated by oil containing rain water which had penetrated through oil contaminated soil and oil lakes.

5. Reference

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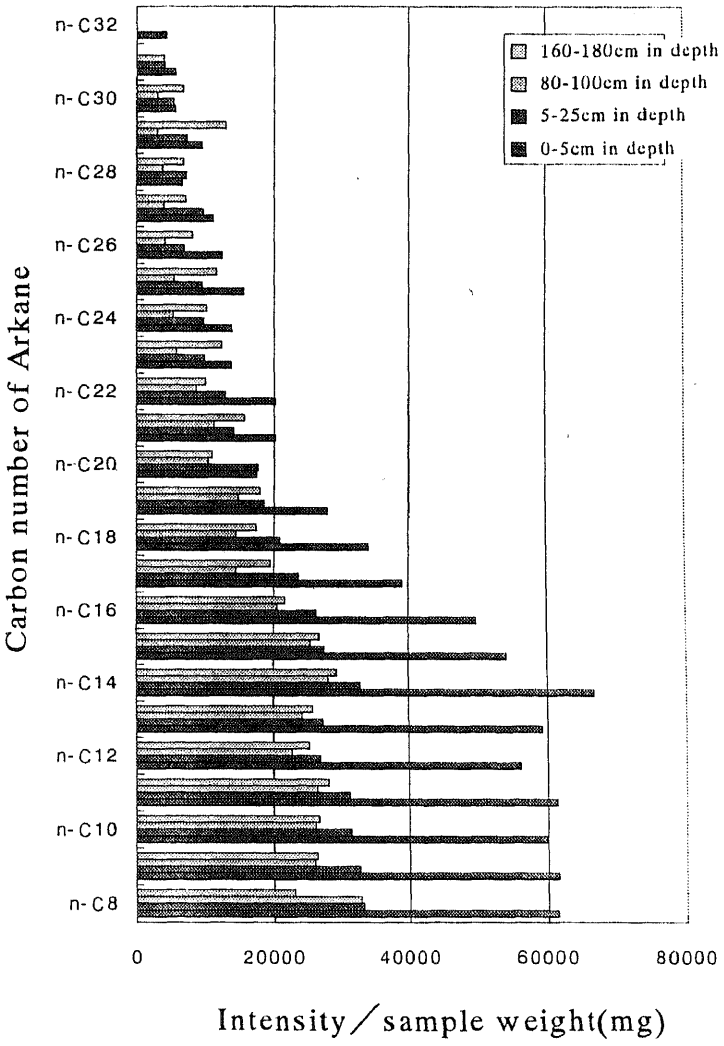

Figure 6 Oil compositions of penetrated soil at each depth
(Soil sample derived from the AP-1 pit 30 cm in depth)

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