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Long-term effect of massive crude oil spill during the Gulf War on intertidal invertabrates

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Abstract : A massive oil spilled during the Gulf War of 1991 covered ashore from the southern area of Kuwait to the west side of the Abu Ali Island in the western Arabian Gulf, and a large amount of oil is still left along the intertidal level of these beaches. Surveys were carried out at three times during the period from February 1992 to November 1994, and collected oiled sediment samples on the Gulf coast. This paper reports on the information as the follows; 1) oil contents of sediment samples in intertidal zone, 2) changes of chemical composition in n-alkanes and identification of polycyclic aromatic hydrocarbon in sediment samples at Munifah Beach 3) influence of oil spilled on intertidal invertabrates, on the bassis of biological data obtained at each sites in western Arabian Gulf coast. The contamination by polycyclic aromatic hydrocarbon in an inner layer of sand still persisted and so the infauna at habitat of a deeper layer in sandy beach, such as *Umbonium vestiarium* and *Dosinia* sp., was not yet found in Manifah Beach, which was the most oil-polluted site on early November 1994.

Key words : *Crude oil spill, Gulf War, Infauna, n-alkane, PAH (Polycyclic aromatic hydrocarbon)*

1. Introduction

From late January and early April in 1991, crude oil more than 160 million gallons was spilt into the seawater of Arabian Gulf (IOC, 1991). The oil slicks moved toward the southeast, staying ashore under the influence of northerneast winds. As a result, the spilt oil was trapped by Abu Ali Island near Al-Jubail. Most of the Saudi Arabia shoreline from Kuwait to Abu Ali Island ranging over more than 500 km, were covered heavily by oil (Fig.1). According to Saudi Arabian Officials, the amount of the light fraction in the spilt oil lost by evaporation have been estimated as high as 50 percent, and approximately 38 million gallons were stranded along the Saudi shoreline (IOC, 1991). The remained oil penetrated into and persisted in the sediments throughout the intertidal zone (HAYES *et al.*, 1993). The purpose of the present studies is to clearfy the duration of the persistent contamination of oil and its long-term effects on invertabrates in intertidal the zone sediments.

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2. Materials and methods

The survey sites was selected on basis of IOC report (1991). According to this report, the spilt oil covered most of shore from Abu Ail Island to southern area in Kuwait City. On the first survey, sampling was carried out at eight sites on mid-February 1992, which were Al Khobar Beach near Dhahran and eastern side of Abu Ali Island as non-polluted area, and the western side of Abu Ali Island, Munifah, Safaniya, Grummah Island and other points as polluted area. Second survey was conducted on late August 1993 at six sites, which were along Manifah Beach, the western and eastern sides of Abu Ali Island as polluted sites, and

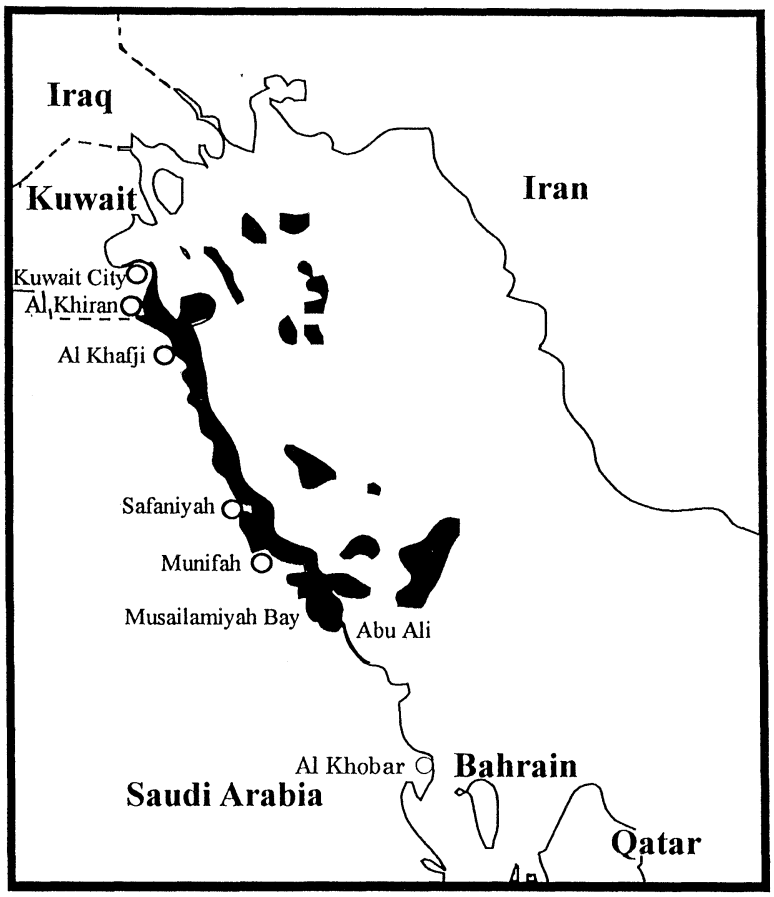

Fig. 1. Extent of the oil spill during the Gulf War and sampling sites for three time survey. A black part indicates the oil polluted area as monitored on March 6, 1991 (cited by GERGES, 1993)

along Al Khafji and Al Khiran where was located between Al Khafuji and Kuwait City. The third survey was carried out on early November 1994 at the same six sampling sites as ones conducted in the second survey and additional at Al Khober also.

Sediment samples were all collected at mid-tide levels of intertidal sandy beaches and salt marshes in each sites. The sediment-core samples for chemical analysis were collected manually with plastic tubes, which were 40 cm in length and 3 cm in diameter. The core sample were cut into several centimeter with a knife, and was analyzed for determination of oil content.

The analytical procedure of oil content in the core samples is shown in Fig. 2. The extracted fraction by n-hexane and by dichlorometane were analyzed according to American National Standard Test Method D-893 (1992). Each sample was prepared by the homogenizing the oil and/or sand mixture with a spatula in 50-ml vial. Sample of 10 gram was extracted by n-hexane of 10ml and made dry up after three time extractions (n-hexane-soluble fraction). The residue of sediment was extracted at three time by dichloromethane (dichlorometane-soluble fraction), and the fraction was mainly extracted for asphaltic components. Extraction efficiency was enhanced by using ultrasonic wave, and allowed to sit for one hour. After the extracted sample reached equilibrium, the vial was centrifuged at 3000 rpm for 10 minutes. An aliquot of the n-hexane-soluble fraction was

Fig. 2. Photograph of a core sediment sample collected at Munifah beach on early November 1994.

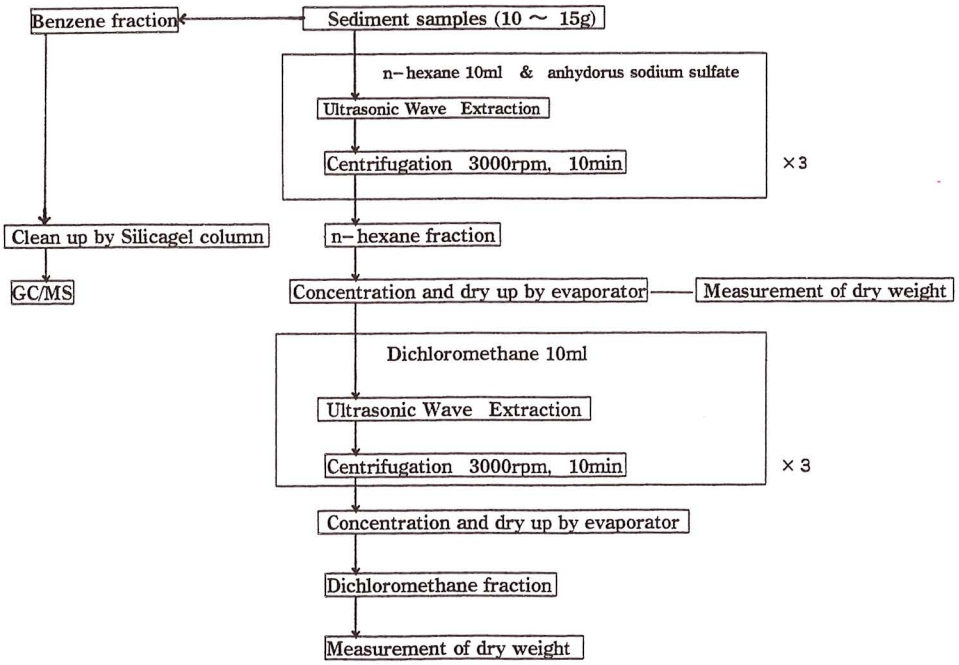

Fig. 3. Flow chart of analytical method of sediment samples collected at each sites. GC/MS operating parameters is following as TSUJIMOTO *et al.* (1998).

purified by silicate gel column, and then injected into a Gaschromatograph (Varian 3400)-Massspectrometer (Quadrupole 710, Finnigan MAT Inst. Co.). The component of n-alkane in the n-hexane-soluble fraction and of polycyclic aromatic hydrocarbons in benzene-soluble fraction were detected by single ion monitoring method of GC/MS (modified by FARRINGTON *et al*, 1982).

The benthic organisms in mid-tidal sediment

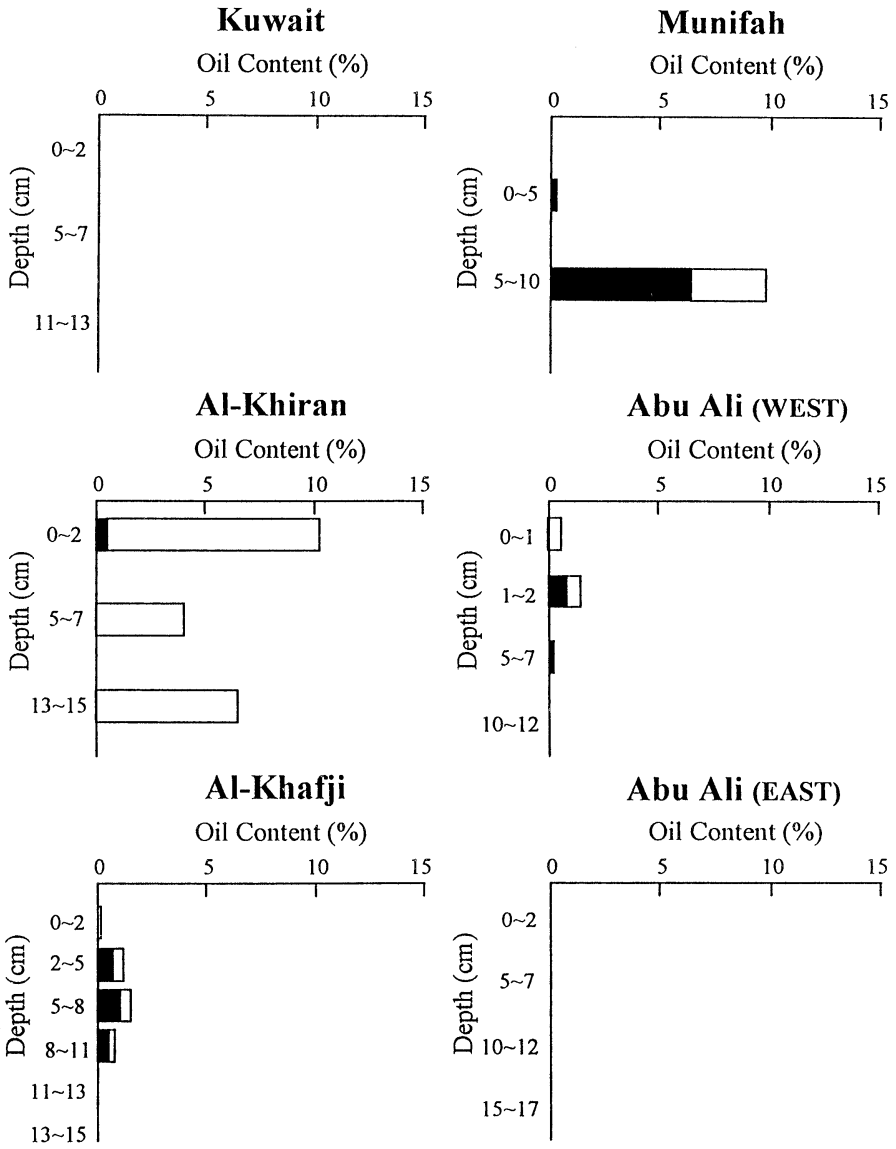

Fig. 4. Vertical distribution of oil content (%) in the sediment samples collected at each sites on late August 1993. Black and white bars indicate the n-hexane soluble fraction and the dichlorometane soluble fraction, respectively.

samples were collected in a quadrat of $10cm^2$ up to the depth of 10 cm and sieved with 2 mm mesh at each survey sites. Retained invertebrates were sorted their individual number live and dead animals.

3. Results and Discussion

In a core sample collected at Munifah Beach on November 1994, sedimented oil still found heavily remaining from surface to 10 cm depth layer (Fig. 3). As shown in Fig. 4, the analytical results of sediment samples collected on late August 1993 indicate that spilt oil at the southern area of Kuwait City and the eastern side of Abu Ail Island was not found clearly. That is, the polluted areas were restricted between Al Khiran coast and the west of Abu Ali Sand Bank, as almost same result by GERGES

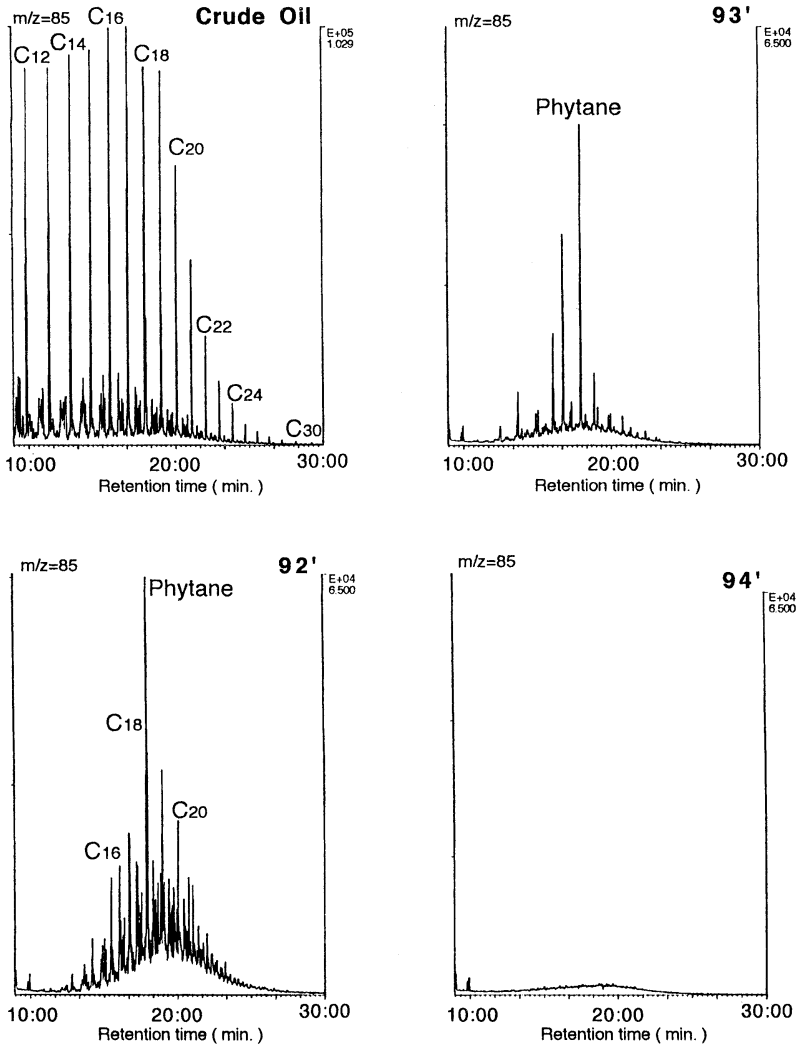

Fig. 5. Chromatograms of the n-hexane soluble fraction in sediment samples collected at Munifah beach. Numbers of peaks indicate chain length of n-alkanes.

(1993). The surface of sediments at several sites on mid-February 1992 was still covered 220 cm thick with weathered oil which was already changed to asphalt. And, as this result is shown, oil content of the sand at the depth between 5 and 10 cm of Munifah Beach on late August 1993 was 98.3 g/kg at the maximum which was occupied by 67% of n-hexane-soluble fraction, and the rest was composed of dichlorometane-soluble fraction. The oil content of surface sand layer was less than that of layer ranging from 5 to 10 cm depth. The percentage of dichlorometane-soluble fraction at Al Khiran Beach was considerably high. It was assumed that the sedimental oil in the surface layer of these areas was weathered to the asphaltic component.

From the result of the crude oil by Single Ion Monitor of GC-MS of sediment samples from 1992 to 1994 at Munifah Beach (Fig. 5), showed that the sample mainly contains n-alkanes ranging from C_{12} to C_{24}. Phytane and UCM (unresolved complex mixture) in the sediment samples of 1992 were clearly detected, and phytane was dominat in the samples of 1993, but no peak of n-alkanes were detected in the

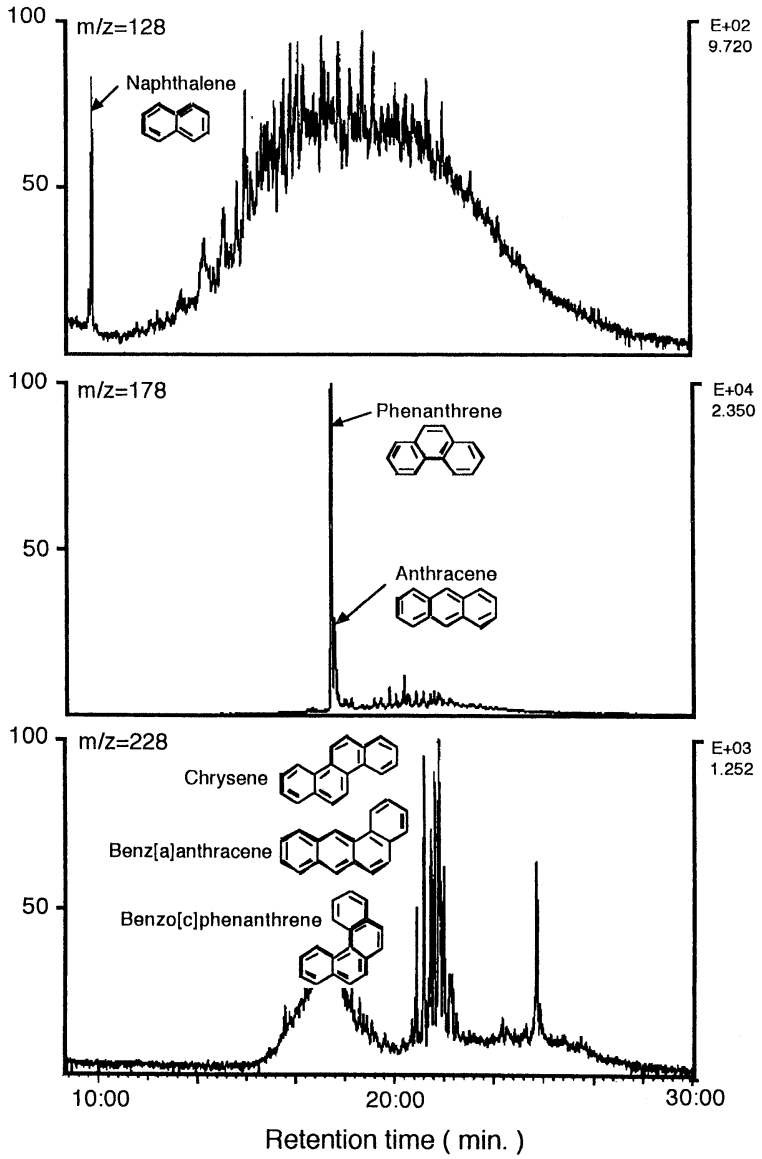

Fig. 6. Chromatograms of benzene soluble fraction in sediment samples collected at Munifah beach on early November 1994.

samples of 1994, which were fifteen months old after spilt out. This result suggests that the decomposition rate *in situ* was extremely lower than that in culture media (NELSON-SMITH, 1970), because the oil absorbed by sand invaded inner layer of the days go on, and then the decomposition of remaining oil is interrupted by newly covered sand which gave rise to anaerobic environment in an oily sand layer.

Figure 6 shows the mass-chromatogram of benzene-soluble fraction in sediment at Munifah Beach at the third survey of 1994. Polycyclic aromatic hydrocarbons, such as naphthalene, phenanthrene, anthracene and chrysence, still remained for long term after the Gulf War, as shown similarly to the result of the barge Florida spilt No. 2 fuel oil into Buzzzard Bay, Massachusetts on 29 September

Table 1. Species abundance and change of benthic organisms (>2mm) at the main sampling sites in the intertidal zone of southeastern coast of Arabian Gulf area

Locality	Al Khafji				Munifah			Abu Ali					Al Khobar	
	polluted		Non-polluted					polluted			Non-polluted			
year	93	94	93	94	92	93	94	92	93	94	93	94	92	94
ANNELLIDA														
Polychaeta														
unidentified spp.				++/		+/					+/	+/		
MOLLUSCA														
Gastropoda														+/
Umbonium vestiarum		/+		/+	/++		/+						/++	
Pseudomonilia gradata	/+	/+			/+	/+						/+		
Ocilinus kotschyi			++/+				/+							
Nodilittorina arabica		/+		+/			/+						+/	++/+
Cerithiopsidella cingulata		/+++	/+	+/++				++/++	/++	++/++	++/++	+/+		
Potamides conicus				/++	+/+++		+/++						++/+++	/+
Cerithium scabridium	/++	+/+	/+	/+										
Cerithium sp.	/+	/+		/+	/++	/+	/+		/+		/+	/+	++/++	+/
Clypeomorus b. persicus		/+		/+	/++		/+	/+	/+	+/+	/+	+/+	+/++	
Mitrella blanda	/+													
Atys cylindrica	/+													
Bivalvia*														
Brachydontes variabilis							/+						/+	
Modiolus sp.					/+			/+						/++
Pillucina fischeriana		+/+++												+/
Tellina arcinoensis					/+						/+		+/+	+/
Tellina (?*Arcopella*) sp.		/+		+/+										
Dosinia spp.	/+	/++	+/+	/+	+/++	/+	/+	/+	/++	/+	/++		+/++	+/+
Meretrix sp.														+/
ARTHROPODA														
Crustacea														
Balanus amphitrite											/+		+/+	

Abundance are shown in "plus" character as follows: +, <10 ind.; ++, <100 ind.; +++, <1,000> ind., arranged living/dead abundances.

*Abundance of dead bivalve shell was calculated as all valve number/2.

1969 reported by TEAL *et al.* (1992). The decomposition of these persistent components and their long-term effect to marine ecosystem should be pursued in the furture.

Taxobiogeological data collected at each sites for three time surveys are summerized in Table 1. Species names and abundance of invertebrates collected in each sample are listed up, and the fauna was mostly composed of molluscs, among which the dominant species were gastropods, *Cerithiopsidella cingulata* and *Cerithium scabridum*, and bivalves also. Total number of species at each site was less than fifteen at most. The diversity of biological communities in the intertidal zones of the Arabian Gulf was very low for three time surveys, even in non-oil-polluted sites. Seasonal changes of these communities in three seasons, that is, February, August and November were not clearly observed. This low diversity and narrow fluctuation throughout the year is due to the stressful environment, such as high salinity and high water temperature, as reported by KADO *et al.* (1992).

Percentages of live and dead individuals of littoral animal at each sites is shown in Fig 7. At the heavily polluted sites of Munifah and Al Khafuji, living organisms were not found at all, while plently of living organisms were found at non-polluted site of Al Khobar Beach. In any case, percentages of live individuals were clearly low in the oil-polluted sites as compared with those of non-polluted sites. This fact appears to be a proof that oil-polluted areas in 1994 were still suffered from the adverse effects of the oil and was delayed recovery of marine

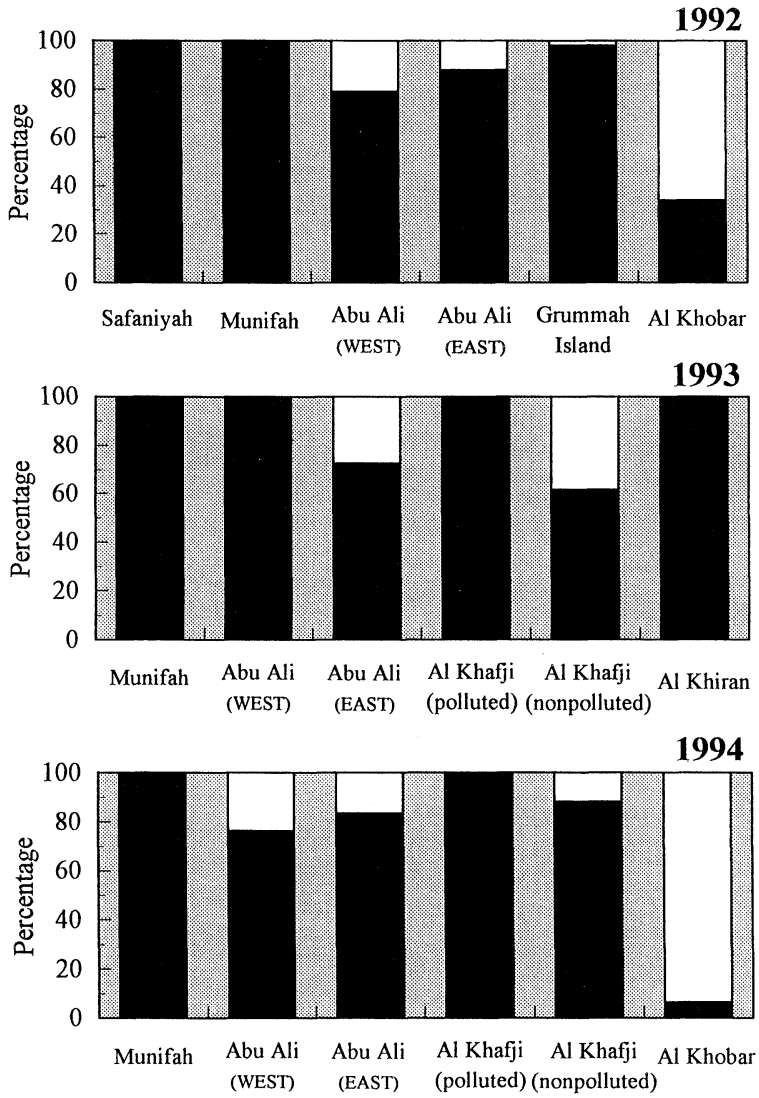

Fig. 7. Percentages of live and dead individuals at each site in mid-February 1992, late August 1993 and early November 1994. Black and white bars indicate dead and living organisms, respectively.

life. The infauna which organisms was living at habitat of a deeper layer in sandy beach, such as *Umbonium vestiarium* and *Dosinia* sp., were not yet found in Manifah Beach of the most oil-polluted site on early November 1994. It suggests that the remaining oil, both weathered and absorbed by sediments, is not only taking the favorite substrata away from inhabitants like sandhoppers and crabs, but also oxygen supply is reduced at to a deeper layer and consequently infaunal invertabrates are prevented from recovering. In addition, oozing oil may be discouraging invertebrate larvae from settling on sand.

The most polluted area at Munifah Beach is still contaminated by polycyclic aromatic hydrocarbons. The long-term monitoring on oil and organisms in oily beach urgently needed, and the favorable coastal environment should be recovered as soon as possible.

Acknowledgments

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