ISSN 1110-0354
Bull. Nat. Inst. Of Oceanogr. & Fish., A.R.E., 2000. Vol. (26): 271 - 282

OIL POLLUTION IN GULF OF ADEN /ARABIAN SEA COASTS OF YEMEN

By

HASSAAN, M.A.H.*; MAHEUB, A.R.S. AND NABEEL, A. AL-SHIWAFI

**University of Sana'a – Faculty of Science. Depart. of Oceanogr. p.o. Box 11826. Sana 'a – Yemen*

Key words: Oil pollution, Gulf of Aden, Arbian Sea, Yemen.

ABSTRACT

The present investigation involves an assessment of the level of contaminants including: petroleum hydrocarbons in sediment and molluscs from the Gulf of Aden Arabian Sea aiming to establish their background concentrations.

The study revealed comparable level of petroleum hydrocarbons in this region to that reported for other parts of the world. the concentration of petroleum hydrocarbons in the mussels ranged from 8800 ng g at al-syquia to 22400 ng g (dry weight) at Ras Quases in April and from 13.000ng g at Aden to 43.000 ng g (dry weight) at Ras Quases in august. the concentration of petroleum hydrocarbons in beach element ranged from 120 ng g at sayhout to 840 ng/g (dry weight) bulk sediment at Aden in April and from 300 ng/g at Bulhaf to 2.100 ng/g dry weight bulk sediment at Al-Mukalla expressed as Marib light crude oil equivalents. The rather high concentrations observed in August samples in comparison to that in April was attributed to the changing in wind direction and thus deposit oily on the Yemeni beaches along the gulf of Aden Arabian Sea. It was suggested that both beach sediments and molluscs were subjected to the same point-source pollution of oil contamination which are: tankers discharging of oily ballast water: effluent from the petroleum refineries located on the coastal areas: and loading facilities and transportation activities.

INTRODUCTION

There are different types of impacts on the coastal and marine environment of Yemen. These impacts are mainly caused by human and developmental activities, which introduce pollutants to the marine environment and cause the detraction of some special habitats. The most widely recognized issue is that of oil-related pollution, where considerable attention has been focused. However, other areas of concern include the impact of growing industrial and domestic effluents, unplanned coastal development as well as various miscellaneous anthropogeic activities such as fishing, Hunting and tourism.

The Gulf of Aden and the Arabian Sea are among the busiest tanker routs. Most of the oil produced in the region is exported via sea and pipelines, while local refineries and consumption are located in coastal area. The widespread of oil pollution in the Arabian Sea and Gulf of Aden are not surprising (DouAbul & Heba, 1995; DouAbul & Al-Shiwafi, 1996). Although enough data are not available for the Gulf of Aden, probably the pattern may be similar to that of the Arabian Gulf, which shows that the impacts are mainly from tanker and ship traffic. (Linden ***et al.***, 1990). The preliminary survey along the Red Sea coast of Yemen showed that oil-related pollutants occurred in region, especially around some industrial areas, while beach tar is also widespread along the coast of Yemen (Rushdi ***et al***, 1991). The growing importance of Yemen as an oil producing nation, and its close proximity to one of the world's busiest shipping lanes means a high risk of oil pollution in various forms. Chronic and incidental oil pollution takes place in the following forms:

Shipping discharges in the Gulf of Aden of dirty ballast/tank washing overboard at sea.; Shore facilities in Aden port; Aden refinery effluent; oil spill which occurred in the region and offshore hydrocarbon exploration.

In the present study molluscs and sediments were sampled from twelve locations along the beach of the Gulf of Aden/Arabian Sea and analyzed for their content of petroleum hydrocarbons in an attempt to establish the background concentration of these pollutants.

MATERIAL AND METHODS

Samples of beach sediments and mollusc ***Tivela ponderosa*** were collected from 12 stations along the Gulf of Aden/Arabian Sea in two occasions. The first occasion was during 3-20 April 1996 while the second was during 10-25 August 1996 in order to give more accurate results of the type and level of studied pollutants and to take into account the variation in regards to monsoon and other variation e.g. water temperature, wind driven waves, tidal currents, suspended particulate matters and others. The sites were physically located using a Global Positioning Satellite (GPS) receiver (Table 1 and Fig. 1). The sediment samples were drained-off water, placed in screw capped glass jars and stored frozen in the Department of Oceanography till time of analysis. Representative slips of each of the sediment was collected in a plastic bags for grain size analysis.

Just before analysis, sediment samples were thawed, dried in an oven at 40°C over night, ground by an agate mortar. Because of the nonhomogeneous nature of these sediments, they were sieved through a 63 mμ sieve (silt and clay fraction).

The whole samples of mollusc were used after removing the shells, and the tissues were washed with distilled water to remove any traces of sand. The composite sample was dried in an oven at 40°C over night, ground by an agate mortar.

The extraction method was based upon that of Wade et al, (1988). A total of 5g dried tissues or 10g dried sediment was Soxhlet-extracted with methylene chloride and concentrated on a water bath at 40°C . The extracts were then fractionated by a column chromatography containing alumina: silica gel (80-100 mesh). The extracts were sequentially eluted from the column with 50ml of hexane (aliphatic fraction) and 200 ml of 1:1 (v/v) n-hexane-dichoromethane (aromatic fraction) and concentrated for instrumental analysis. The determination of petroleum residues was carried out following the Infra-red spectrophotmetric method that approved by Standard Methods committee (Levy, 1979). For the present work a Pye Unicam SP 3-3000 Infra-Red Spectrometer was used. Blank determinations were carried out by repeating the procedure with a preextracted samples. Using a calibration with Marib light

Table (1): Sampling Locations

Station Number	Nearest City
GA-I	Al-Syguia
GA-II	Um-Omaira
GA-III	Aden
GA-IV	Shugra
GA-V	Ahour
GA-VI	Bulhaf
GA-VII	Al-Mukalla
GA-VIII	Ras Quases
GA-IX	Sayhout
GA-X	**Hasueen**
GA-XI	Al Muhafef
GA-XII	Hoof

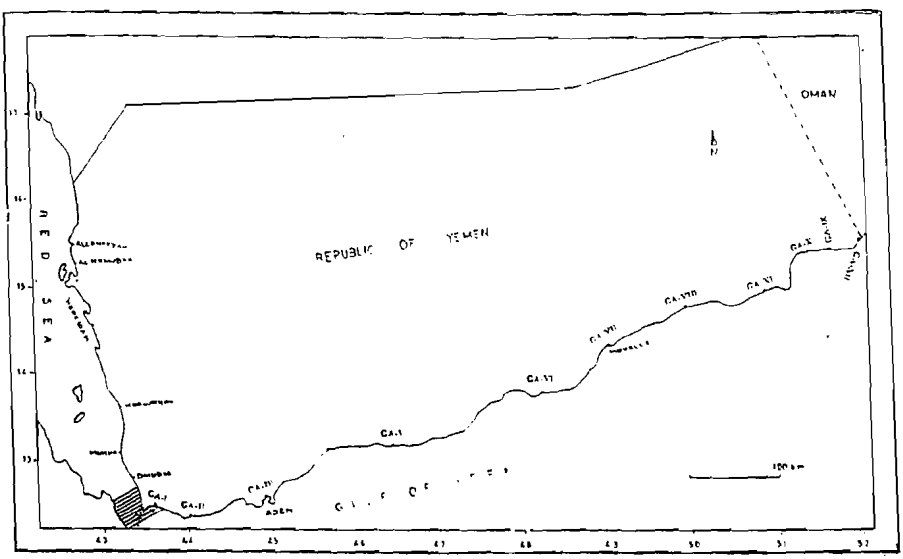

Fig. (1): Location Map.

crude and reference oil prepared as a mixture by volume of 37.5% iso-octane, 37.5% hexadecane, and 25% benzene at 2930^{-1} absorbance .

Total organic carbon (TOC) and grain size analysis were performed on representative slips of the bulk sediment samples in order to give a better appraisal of petroleum hydrocarbons in the sediments. Percentage organic carbon (% TOC) was carried out according to the procedure of El-Wakeel & Riley (1957). Granulometery were conducted by the combined dry sieve and pipette method Folk (1974).

RESULTS & DISCUSSION

The results of the analyses (Table 2) represent average concentrations from at least six determinations. The concentration of petroleum hydrocarbons in the muscles ranged from 8800 ng/g at Al-Syquia to 22400 ng/g dry weight at Ras Quases in April and from 13,000 ng/g at Aden to 43,000 ng/g dry weight at Ras Quases in August. The concentration of petroleum hydrocarbons in beach sediment ranged from 120 ng/g at Sayhout to 840 ng/g dry weight bulk sediment at Aden in April and from 300 ng/g at Balhaf to 2,100 ng/g dry weight bulk sediment at Al-Mukalla expressed as Marib light crude oil equivalents. The rather high concentrations observed in August samples in comparison to that of April may be due to changing in wind direction and oil drifted on the surface that washed ashore on the Yemeni beaches along the Gulf of Aden/ Arabian Sea. (Canadian Occidental Company, 1993).

From the results presented here it is evident that all the site are contaminated to some extent with petroleum hydrocarbons. Samples collected from reference station "RF" contained negligible amounts (<0.12 μg/g). The rather high concentrations of petroleum residue encountered at station GA-VII (Al-mukalla) and station VIII (Ras Quases) are mainly due to the oil export activities from Masila Terminal. However, mean concentration of total alkanes and iso-perinods in intertidal zone sediments collected from Masila, Gulf of Aden in 1992 was 92 ng/g dry weight (Canadian Occidental Company, 1993). This indicates that our results are three orders of magnitude higher than that reported for Masila beach before oil export activities took place.

Table (2): Mean * Hydrocarbon concentrations in Environmental Samples from the Gulf of Aden/Arabian Sea as determined by Infra Red Spectrometry.

Station	**Petroleum hydrocarbon concentrations ng/g dry weight** (API Marib light crude oil equivalent)			
	April 1996		August 1996	
	Beach Sediment			
	<63 fraction	Bulk sediment	< 63u fraction	Bulk sediment
GA-I	5200	500	5200	520
GA-II	7200	720	6000	600
GA-III	8400	840	9000	900
GA-IV	4400	440	4000	400
GA-V	6000	600	5000	500
GA-VI	8000	80	3000	300
GA-VII	5600	560	21000	2100
GA-VIII	6400	640	5000	500
GA-IX	1200	120	16000	1600
GA-X	4000	400	15000	1500
GA-XI	6800	680	7000	700
GA-XII	4000	400	6000	600

Biological Materials (*Tivela ponderosa*)

Station	April 1996			August 1996		
	Fat content (%)	Dry weight	Wet weight	Fat Content (%)	Dry weight	Fat weight
GA-I	0.64	8800	1700	0.62	20000	5000
GA-II	0.75	17600	7300	0.73	26000	7100
GA-III	0.70	20800	4300	0.43	13000	4900
GA-VIII	0.45	22400	6200	0.47	43000	11000
GA-XII	0.55	19200	1100	0.80	22000	6200

* = Mean of at least three.

Petroleum hydrocarbon concentration found in muscles and sediments by other workers are compared to our data in Tables 4 & 5. Goldberg (1975) has reported that unpolluted open ocean sediments contain 1-4μg/g. dry weight hydrocarbons, less than 100 μg/g in coastal sediments and up to 12 000μg/g in highly polluted areas. However, It should be borne in mind that the efficiency of hydrocarbons adsorbance onto sediment particles are governed mainly by its grain size and total organic matter content. The sandy nature of the Gulf of Aden coasts of Yemen sediments coupled with its very low content of organic matter (<0.1% TOC) render its low capacity for hydrocarbons adsorption. (Table 6). Thus it may be suggested that although the extent of oil pollution in the region may be severe, however, it is not reflected accurately by its sub-tidal sediments.

Tar is the petroleum residues which deposited along coastal beaches and has been used as semi-quantitative measures of the extent of oil pollution in the marine environment.

During the survey we noted several features regarding tar load on the Yemen beaches in the Gulf of Aden /Arabian Sea. On any beaches most of the tar accumulated in bands along the high tide mark. On the same beaches large lumps were seen far above the high tide mark, these were probably deposited during storms or strong winds. In general, the nature of tar at all beaches was varying from fresh to very hard lumps. Since there is no baseline study for Yemen beaches along the Gulf of Aden/ Arabian Sea the results of the present survey suggest that the source of oil contamination in Yemeni waters are; the lack of enforcement of national and inter-national de-ballasting regulations which result in the tankers discharging the oily ballast water and the engine used oil in the sea area; effluent from the petroleum refineries located on the coastal areas; and loading facilities and transportation activities exacerbate the problem.

Both the Red Sea and the Gulf of Aden are designed special areas under the international MARPOL convention. This means operational discharges from shipping are restricted. Nevertheless evidence suggest that oil pollution from these source has a far greater effect on the marine environment than accidental spills. An example of a chronic oil pollution source on the Yemen Coast is the authorized discharge of ballast water effluent of the SAFER supertanker storage at Ras Isa. Similar problems occur in the Gulf of Aden with vessels deballasting

Table (3): Mean* Hydrocarbon Concentration in Environmental Samples from the Gulf of Aden/Arabian Sea as determined by Spectrofluorometry.

Station	Ng/g dry weight Kuwait crude equivalents.	
	April 1996	August 1996
GA-I	2400	9200
GA-II	4300	9200
GA-III	1800	11900
GA-IV	3700	7400
GA-V	3000	7000
GA-VI	3800	8400
GA-VII	4300	12200
GA-VIII	3600	12100
GA-IX	3700	4300
GA-X	3500	4600
GA-XI	1600	1900
GA-XII	4600	7100

* = Mean of at least three determinations.

Table (4): Collected from Different Region of the World. Compiled from sources indicated in the footnote.

Area	Concentration (ng/g)	Source
Western Port Bay (Australia)	0.0-2300	Burns & Smith (1977)
Scottish Coast	19000-71000	Mackie et al. 1980
Northeast Gulf of Alaska	21000	Wise et al., (1981)
The Sound of Copenhagen	11000-47000	Jenesen (1981)
Antarctica	0.0-124000	Clark & Law 1981
Arabian Gulf	13100-34600	Al-Aaad & DouAbul,1987
Gulf of Aden/Arabian Sea	1700-11000	Present Study

Table (5): Comparison of hydrocarbon Content in Sediment Collected from Different Region of the World. Compiled from sources indicated in the footnote.

Area	Concentration (ng/g)	Source
Narragansett Bay (USA)	5000-120000	Farrington & Quinn (1973)
Eastern Passage, Nova Scotia (Canada)	5000-37000	Hargrave & Phillips (1975)
Soctian Shelf (Canada)	1000-94000	Keizer et al., (1978)
Ghafira Bay (Malta)	22000	Sammut & Nickless (1978)
St. Paul's Bay (Malta)	37800	Sammut & Nickles (1978)
Baffin Bay (Canada)	1250-33750	Levy (1979)
Falmouth Bay (UK)	48000	Law (1981)
Carmarthen Bay (UK)	34000	Law (1981)
Liverpool Bay (UK)	29000	Law (1981)
Coast of Oman	800-19000	Burns et al., (1982)
Arabian Gulf	400-44000	DouAbul et al., (1984)
Gulf of Aden/Arabian Sea	120-2100	Present Study

Table (6): Sedimentological Parameters

Station	% Total Organic Carbon (TOC)	Sediment type
GA-I	0.07	Coarse-Medium Sands
GA-II	0.07	Medium Sand
GA-III	0.09	Fine-Very Fine Sand
GA-IV	0.06	Very Fine Sand
GA-V	0.01	Fine Sand to Medium
GA-VI	0.05	Fine-Very Find Sand
GA-VII	0.02	Medium Sand
GA-VIII	0.10	Coarse Sand to very Coarse
GA-IX	0.07	Very Coarse-Coarse Sand
GA-X	0.06	Coarse Sand
GA-XI	0.05	Medium Sand
GA-XII	0.06	Medium Sand

at the Aden refinery. However, the problem of passing vessels deballasting in the Gulf of Aden or the Red Sea appears to be the greater cause of oil pollution in Yemen waters. Oil spilling are common and there is no organization to deal with spillage.

In the light of the above reasoning we may thus conclude that the impact of human activities on coastal environment is relatively low. However, tar balls were wide spread along the entire beach. Despite its high quantities at certain locations, tar pollution has no chemical effects upon marine organisms. Beach sediments were subjected to the same point-source pollution of oil contamination as the life sentinel muscles. This pollution is consequence of oil operations and heavy ship traffic.

It is also recommended that a continuos monitoring programme for the Gulf of Aden/ Arabian Sea beaches should be formulated and conducted to ensure that the concentrations of petroleum hydrocarbons are within the baseline levels established during the present survey.

REFERENCES

Al-Saad, H.T. & DouAbul. A. A-Z., 1987. Hydrocarbon concentration in the mussel, ***Corbicula fluminalis***, from the Shatt al-Arab River. Iraq. In: Fate and Fluxes of Petrolerum Hydrocarnons in the Arabian Gulf (Dou Abul, A.A.-Z & Baider H. Eds.). pp. 291-303.

Burns, K.A. & Smith. J.L., 1977. Distribution of petroleum hydrocarbons in westernport Bay (Australia): Results of chronic low level inputs. In: Fate and Effects of Petroleum Hydrocarbons in Marine Organisms and Ecosystems (Wolfe, D.A. Ed.) Pergamon Press, New York, pp. 442-453.

Burns, K.A.; Villenneuve, J.P.; Anderlini, V.C. & Fowler, S.W.; 1982. Survey of tar; hydrocarbons and metal pollution in the coastal waters of Oman. Mar. Pollut. Bull., 13, 240-247.

Canadian Occidental Petroleum Ltd, 1993. Vaol. 1: Environmental Impact Assessment, Environmental Studies Program, Masila Export Project, republic of Yemen, pp. 327.

Clark, A. & Law. R., 1981. Aliphatic and aromatic hydrocarbons in benthic invertebrates from two sites in Antarctica. *Mar. Pollut. Bull.*, 12, 10-40.

Dou Abul, A., A-Z. & Heba, H.M.A., 1995. Investigations following a fish kill in Bab el-Mandeb, Red Sea during November 1994. Report submitted to Environmental Protection Council (EPC) (Dutch Support Project to Technical Secretariat EPC. Yemen) 105 pp.

DouAbul, A.A-Z. & Al-Shiwafi, N.A., 1996. Petroleum hydrocarbons in the Red Sea coast of Yemen. Paper accepted in the International Conference on the Biology of Coastal Environment (ICBCE 97) Bahrain, 6-9 Appril 1996.

DouAbul. ,A-Z.; Al-Saad, H.T. & Darmoian, S. A.; 1984. Distribution of petroleum residues in surficial sediments from the Shatt al-Arab River and the NW region of the Arabian Gulf. Marne *Pollution Bulletin* 15, 198-200.

EL-Wakeed, S.K. and Riley, J.P., 1957. The determination of organic carbon in marine mud. J. Cons. Int. Explor Mer. 12:180-183.

Farrington, J.W. Quinn. J. G., 1973. Petroleum hydrocarbons in Narragansett Bay. I. Survey of hydrocarbons in sediments and **clams** ***(Mercenaria mercenaria)***. *Estuar. Coast. Mar. Sci.*, 1,7 1-79.

Folk, R.L., 1974. Petrology of sedi, entary Rocks. Hemphill pbublishing Co., Austin, Texas.

Goldberg, E.D., 1975. The Health of the Oceans. UNFSCO Press, Paris.

Hargrave, B.T. & Phillips, G.A., 1975. Estimate of oil in aquatic sediments by fluorescence spectroscopy. Environ. Pollut., 8, 193-199.

Jenesen, K., 1981. Level of hydrocarbon in museles Mytilus edulis and surface sediment from Danish Coastal area. Bull. Environ. Contam. Toxicol., 26, 202-206.

Keizer, P.D.; Dale, J. & Gordon, D. C. Jr.; 1978. Hydrocabons in surficial sediments from the scotian shelf. *Geochim Cosmochim. Acta*, 42, 165-172.

Law, R.J., 1981. Hydrocarbon concentrations in water and sediment from UK marine waters, determined by fluorescence spectroscopy. *Mar. Pollut . Bull.*, 12, 153-157.

Levy, E.M., 1979. Concentration of petroleum residues in the water and sediment of Baffin Bay eastern Canadian Arctic-1977. Bedford Institute of Oceanography Report Series, Bl-79-3.

Linden, O.; Abdulrahcem. M.; Gerges. M.A.; Alam, l.: Behbehani, M.; Borhan, M. A. & Al-Kassab, F.; 1990. Status of the marine environment in the ROPMEsea area. UNEP Regional Sea Reports and Studies, 112, Rev 1. 34p.

Mackie. P.R.; Hardy, R.; Whittle, K.J.; Bruce, C. & MeGill, A.S.; 1980. The tissue hydrocarbon burden in musscls from various sites around the Scottish Coast. In: ***Polynuclear Aromatic Hydrocarbons Chemistry*** and ***Biological Effects*** (Bjocesth, A. & Dennis. A. J., eds.) Batelle Press, Columbus, Ohio, pp. 379-397.

Rushdi, A.I.; Ba-Issa. A.A. and Ba-Bagi. A.; 1991. Preliminary investigations of oil pollution along the Red Sea Coast of Yemen. In: Proceeding of the Seminar on the Status of the Environment in the Republic of Yemen, Sana'a, Sanuary 1-5, 1991.

Sammut. M. & Nickless, G., 1978. Petroleum hydrocarbons in marine sediment and animals from the Island of Malta. Environ. Pollut. 11, 197-208.

Wade, T.L.; Atlas, E.L. Dropoks, J.M.; Kennicutt II M.C.; Fox, R.C.; Sericano. J.L.; Garcia-Ramero. B. & Defreitas, D.A., 1988. NOAA Gulf of Mexico Status and Trends Program: Trace organic contaminant distribution in sediments and oysters. Estuaries, 11, 171-179.

Wise, S.A.; Chester, S.N.; Guenther; FG.R.; Hertz, H.S.; Hilpert, L.P.; May, W.E. & Parris, R.M.; 1981. Interlaboratory comparison of determinations of trace level hydrocarbons in muscles. Anal. Chem., 52, 1828-1833.