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State of the marine environment in the ROPME Sea Area

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PREFACE

The better understanding of the changing problems facing the marine environment is a continuing goal of UNEP's Oceans programme, as it provides the necessary scientific background for formulating UNEP's policy towards the protection of the oceans.

The main sources of factual information used in the assessment of the state of the marine environment aredata published in open scientific literature, data available in various reports published as "grey literature" and data generated through numerous research and monitoring programmes sponsored by UNEP and other organizations.

Several procedures are used to evaluate critically the large amount of available data and to prepare consolidated site-specific or contaminant-specific reviews.

GESAMP, the IMO/FAO/Unesco/WMO/WHO/IAEA/UN/UNEP Joint Group of Experts on Scientific Aspects of Marine Pollution, is charged by its sponsoring bodies with preparation of global reviews. Reviews dealing with several contaminants have been already published by GESAMP and others are being prepared for publication. The first global review on the state of the marine environment was also published by GESAMP in 1982, and the second global review was published in 1990[1/].

In parallel with the preparation of global assessments, the preparation of a series of regional assessments, following the general format of the second global review of GESAMP, was initiated by UNEP in 1986, with the co-operation of the Food and Agriculture Organization of the United Nations (FAO) and the Intergovernmental Oceanographic Commission (IOC). Fifteen task teams of scientists were set up, involving primarily experts from the relevant regions, to prepare the regional reports under the joint overall co-ordination of UNEP, FAO and IOC, and with the collaboration of a number of other organizations.

The present document is the product of the Task Team for the sea area covered by the Regional Organization for the Protection of the Marine Environment (ROPME) and thus known as "ROPME Sea Area". The final text of the report was prepared by Olof Lindén, as Rapporteur of the Task Team in collaboration with Mahmoud Y. Abdulraheem, Makram A. Gerges, I. Alam, Manaf Behbehani, Mohamed A. Borhan and Layth F. Al-Kassab, whose contributions are gratefully acknowledged.

1/ Publications of GESAMP are available from the organizations sponsoring GESAMP.

TABLE OF CONTENTS

1. INTRODUCTION

1.1 Aims of the report

The ROPME Sea Area is relatively small with a total area of about 240,000 square km. It is characterized by shallow waters of high temperature with little fresh water inflow and liberal evaporation resulting in highly saline conditions in some parts of the Sea Area. It is also regarded as having one of the most fragile and endangered ecosystems with a variety of critical habitats. Although the environmental information and the database available to date do not allow a thorough investigation of the state of the marine environment in the region, this report attempts to summarize the information so far available about the state of the marine environment in the Sea Area and to highlight the major problems which arise, whether they be pollution oriented or simply lack of data or an appreciation of the causes of problems and how they can be solved most efficiently and in a cost effective manner.

1.2 Geographical coverage

The area covered in the present report includes the coastal and marine waters of the eight countries forming the Regional Organization for the Protection of the Marine Environment (ROPME). The countries are: Bahrain, Iran, Iraq, Kuwait, Oman, Qatar, Saudi Arabia and United Arab Emirates (U.A.E.).

The ROPME Sea Area is defined as extending between the following latitudes and longitudes respectively: 16° 39'N, 53° 3'30"E; 16° 00'N, 53° 25'E; 17° 00'N, 56° 30'E; 20° 30'N, 60° 00'E; 25° 04'N, 61° 25'E (See Fig..1).

1.3 Preparation of the report

This report was prepared by a Task Team consisting of the following members: Mahmoud Y. Abdulraheem, Kuwait, I. Alam, Saudi Arabia, Manaf Behbehani, Kuwait, Mohamed A. Borhan, Oman, Layth F. Al-Kassab, Iraq, Makram A. Gerges, UNEP and Olof Lindén, rapporteur.

2. CHARACTERISTICS OF THE REGION

The inner part of the ROPME Sea Area (west of the Strait of Hormuz) (Fig. 1) is an extremely shallow sea and the entire area is situated on the continental shelf. The average depth here is only some 35 metres and the deepest parts, along the Iranian coast, are 90 to 100 metres.

The volume of the sea area west of the Straits of Hormuz is estimated at some 7,800 km^3. This area is characterized by a circulation pattern where water of normal oceanic salinity enters the area through the Strait of Hormuz at the surface, and a compensating outflowing current of high salinity water along the bottom. The river input, mainly through the Shatt al-Arab, is estimated at 37 km^3/year. About 3,100 km^3 of water is transported out of the Sea Area through the Strait of Hormuz. The lost water is replaced by an inflow from the Gulf of Oman estimated at 3,355 km^3. Using the data available, the water balance for the area was recently reviewed (Table 1, ROPME 1988).

The temperatures of the surface water normally range from 15 to 35°C although occasionally temperatures lower than 15°C may be recorded in coastal waters of the northern parts of the area. There is normally little stratification of the water as the entire water column is mixed due to strong winds. However, in the summer months a temperature stratification may develop in the central parts, the deep water being about 10°C cooler than the surface water.

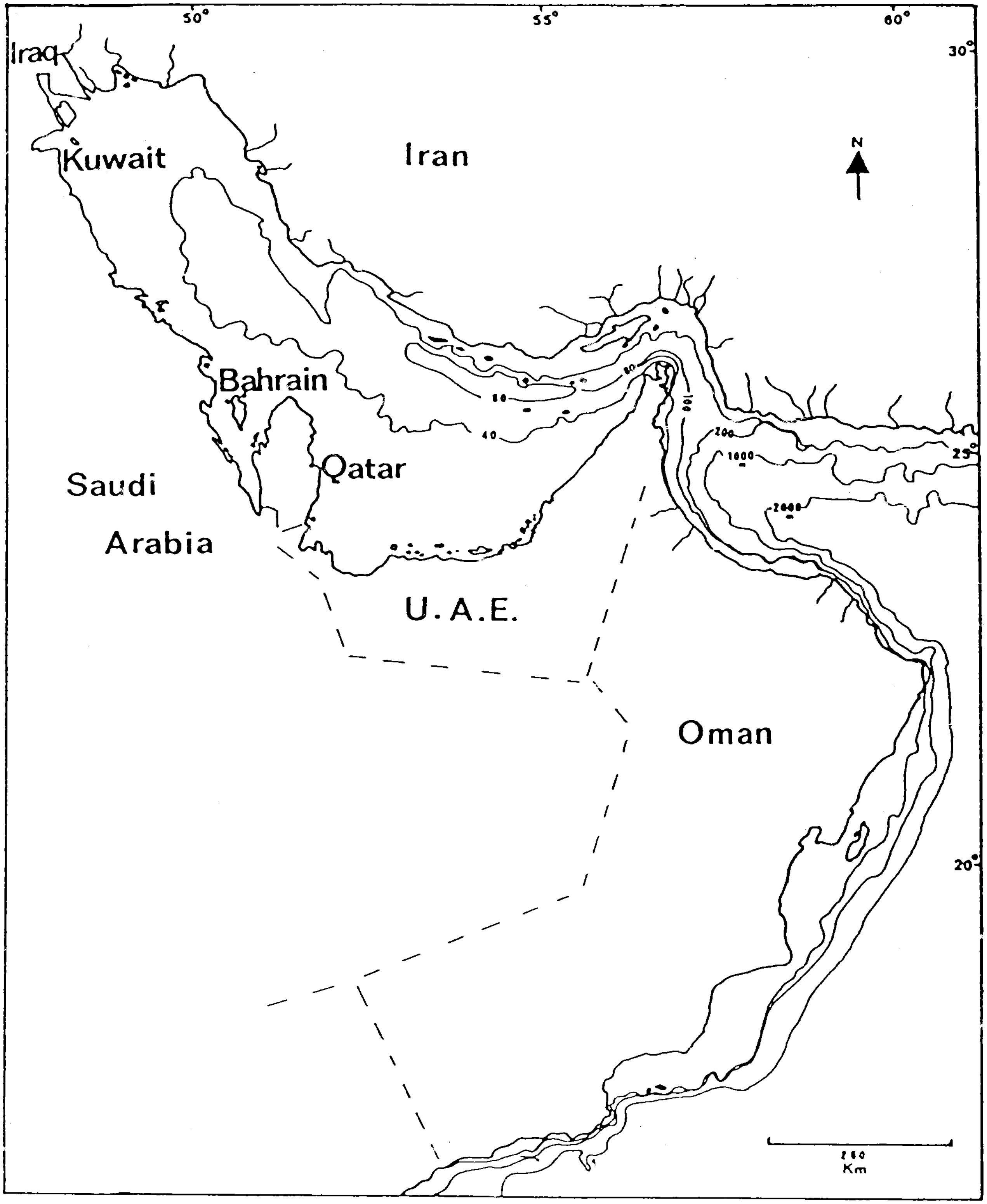

Figure 1. The ROPME Sea Area

Table 1. Water balance for the ROPME Sea Area (ROPME, 1988)

Basin	Evaporation 1/ Precipitation 2/ Runoff 3/ Total loss	-350 km^3 yr^{-1} 24 km^3 yr^{-1} 5 km^3 yr^{-1} -321 km^3 yr^{-1}
Strait of Hormuz	Inflow 4/ Outflow 4/ Total gain	2696 km^3 yr^{-1} 2375 km^3 yr^{-1} 321km^3 yr^{-1}
	Volume of basin 8400 km^3 Surface of basin 240000 km^2 Mean depth 35 m Residence time 3,5 yr	

1/ A volume of 0,4 g cm^{-2} day^{-1} (equivalent to 1460 mm yr^{-1}) average of those given by Privett (1959) has been used (compare with 100 mm yr^{-1} for the Mediterranean Sea).

2/ A precipitation of 100 mm yr^{-1} has been used.

3/ Average value given by Hartmann *et al.* (1971).

4/ Computed from the water and salt balances, taking a salinity of 37 for the surface inflow and of 42 for the bottom outflow.

There is a well-defined seasonal pattern of the sea surface temperature. It shows a temperature increase from north to south in December, then the difference is reduced in March and they both become almost equivalent temperatures in May and a reverse trend is observed in August (Fig. 2). Temperature in the north-western part of the area, however, shows a much wider range with a maximum of 32°C in August and a minimum of about 15°C in February.

The overall pattern of surface salinity shows a gradual decrease from the inner part of the Sea Area towards the Gulf of Oman and the Arabian Sea (Fig. 3, Wooster *et al.*, 1967). Salinities exceeding 40 are reported in the north-west part of the area (Kuwait). However, much higher salinities are observed in the shallow intertidal lagoons of U.A.E. Coast and the inner Gulf of Salwah. Here salinities of 70 or above are frequently found.

The tides are basically semi-diurnal, but the heights reached by the two tides of each day often differ considerably. The tidal range is least in the centre of the area, being about 1 to 2 metres in Bahrain. In the north, at the Shatt al-Arab, tides are normally about 2.5 metres, and in the south (in the Gulf of Oman), the range is about 2 metres. In Dubai and Lengeh (Iran) ranges of 3 to 4 metres are observed.

The general circulation pattern of the water in the area is counter-clockwise. Hence there is a water movement northwards along the Iranian coast and a corresponding one southwards along the southern coast (Fig. 4). Experiments carried out from May 1983 to March 1984 with satellite tracked radio buoys (MEPA, 1984) show consistent surface drifts towards the south-east all along the tracks that covered the central inner area, with speeds ranging between 0.2 to 0.7 knots (Fig. 5).

The large input of sediments in the north-western part of the Sea Area have created highly productive tidal flats, especially in Iraq, Iran and Kuwait. In the sub-tidal zone seagrass beds cover large areas of shallow bottom.

This is one of the most extensive biotopes in terms of area as well as one of the most important in terms of its contribution to the ecology of the Sea Area. Coral reefs occur scattered throughout the area, although the low temperatures in winter fall well outside the optimum range for coral reef development. Overall some 50% of the bottom sediments in the area west of the Strait of Hormuz is mud, 40% sand. Rock-coral and gravel account for the rest.

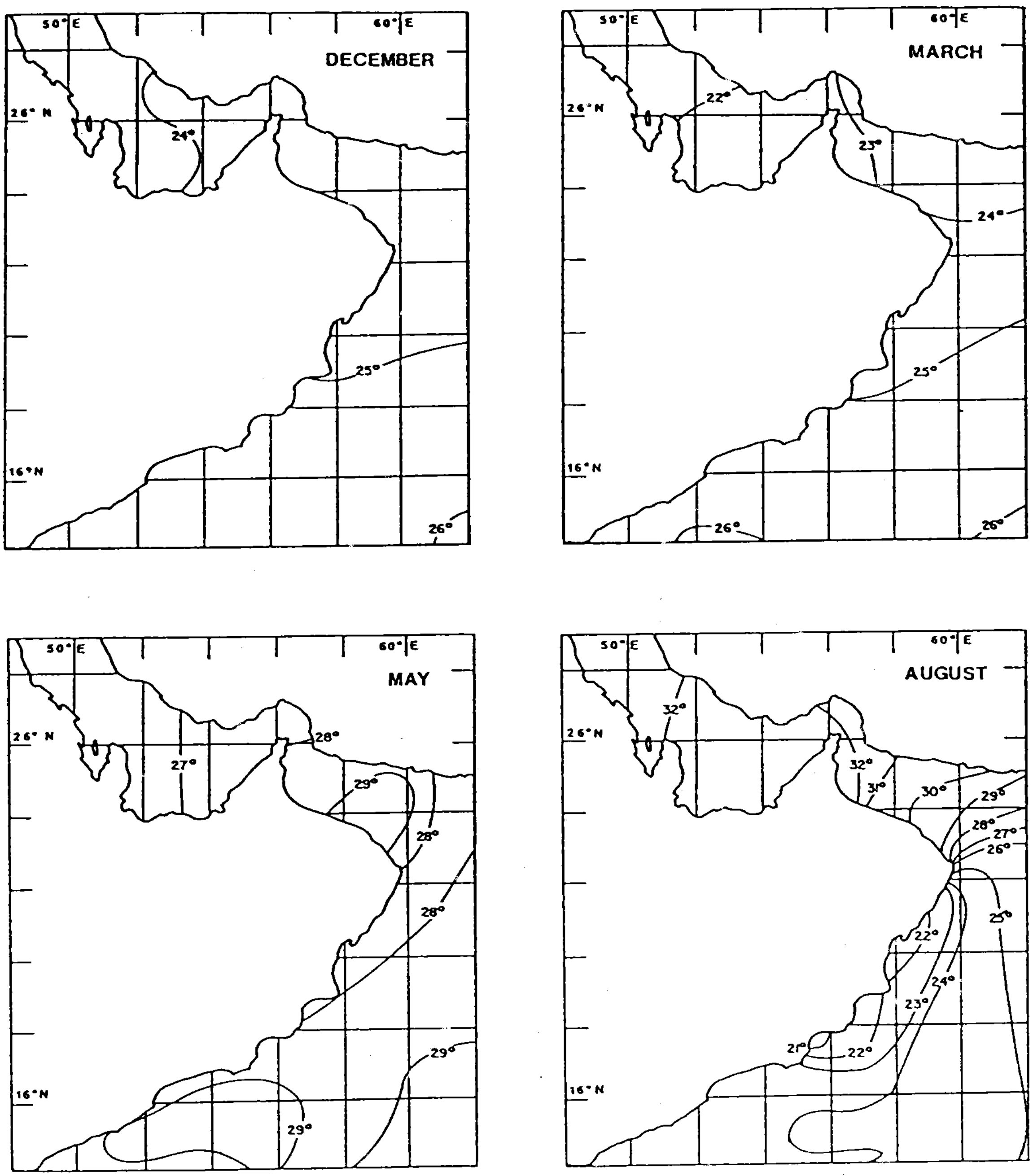

Figure 2. Sea surface temperature (°C) during December, March, May and August (KNMI, 1952)

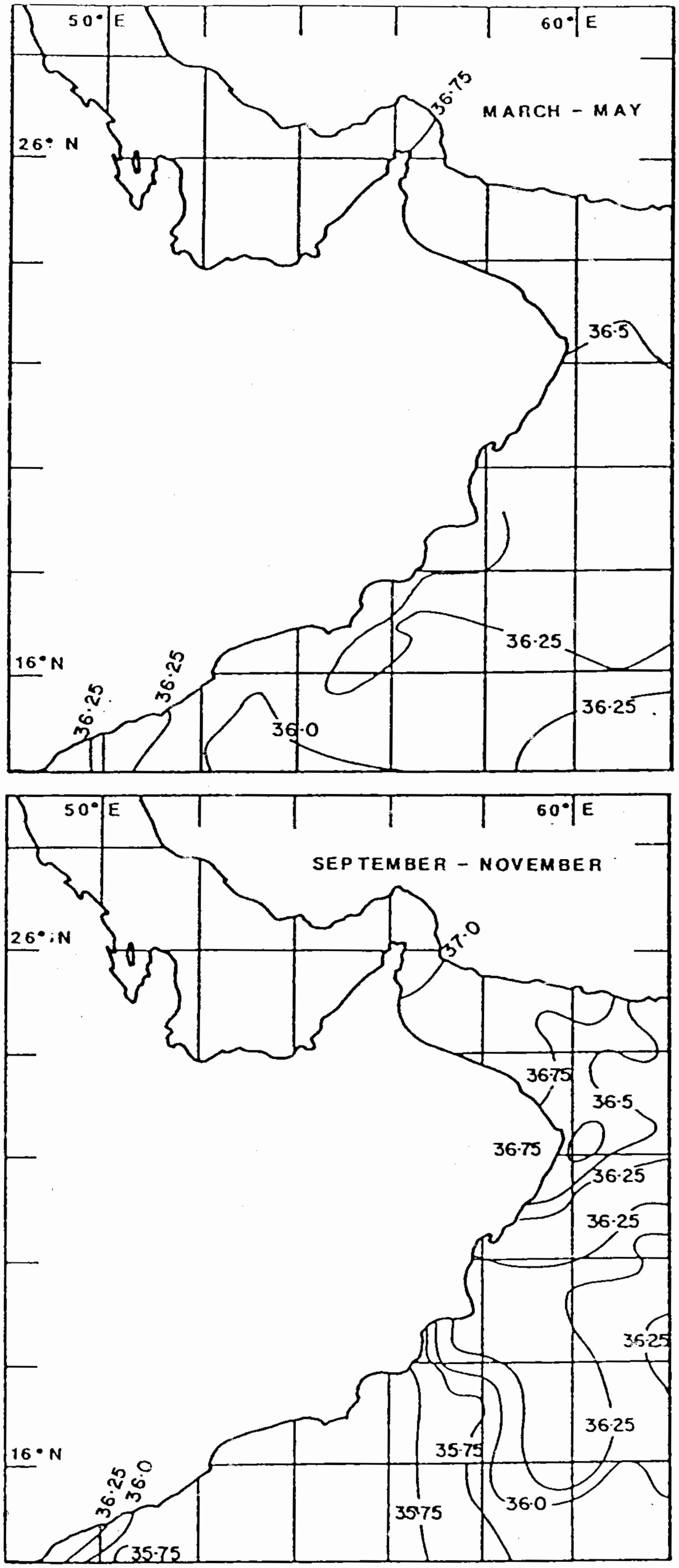

Figure 3. Surface salinities (%) during March-May and September-November (Wooster et al., 1967)

3. MARINE CONTAMINANTS

3.1 Concentrations (levels and distribution) in water, sediment and biota

Heavy metals

Some data on the levels of heavy metals in fish and bivalves from the area are shown in Table 2. Comparison of levels in bivalves taken from different areas may be difficult since sometimes different species were sampled. In addition, information on sex, stage of development etc are often lacking. In general, increased levels of lead, mercury and copper have been found in areas influenced by port activities and heavy industrialization. In rock and pearl oysters in Bahrain increased concentrations of lead were noted in an area influenced by effluents from a refinery (Lindén, 1982). In samples of rock oyster from Oman, Fowler (1985) reported a more or less consistent decrease in the copper concentrations in stations from north to south along the coast. This was probably related to higher anthropogenic input in the more industrialized north. The levels of cadmiun in pearl oysters from Um Al Quwan, U.A.E. (11-34 µ/g) and in mussels from Raysut Head, Oman (16-26 µ/g) reported by Fowle, (1985), also appear sto be slightly elevated. Increased concentrations of vanadium was found in bivalves from north-east Bahrain and from Jebel Ali, U.A.E. and Kuwait Bay (Lindén, 1982; Fowler, 1985; EPD, 1986). High levels of vanadium may be related to oil contamination in the area.

Table 2. Trace elements with ranges in biota from the ROPME Sea Area (Concentrations in µg/g dry weight except for Hg, which is reported in wet weight)

Area	Sample type	Hg	Cd	Cu	Pb	V	Remarks
Bahrain	Bivalves	0,1-0,18	3,3-4,2	3,9-16,4	1,0-4,5	1,7-6,6	1),3),4)
Bahrain	Bivalves	0,009-0,1	1,5-5,0	3,0-37,5	1,0-30,0	0,6-95,0	2),3),4),5),6)
Bahrain	Fish	0,135-0,397					1)
Bahrain	Fish	0,004-1,07	0,0003-0,071	0,1-0,47	0,1-0,03	0,1-0,7	8)
Kuwait	Clams	0,023-0,2	0,2-0,5	4,9-11,4	0,7-3,4	0,2-3,4	9)
UA.E.	Bivalves	0,015-0,041	2,6-34,2	3,0-9,7	0,39-0,9	1,6-25,0	1),4)
UA.E.	Fish	0,055-0,332					1)
Oman	Bivalves	0,023-0,226	6,2-25,5	7,0-265	0,3-3,5	1,1-4,7	1),5)
Oman	Fish	0,06-0,213					1)
Kuwait	Clams	0,02-0,20	0,1-0,9	11,8-18,0	2,2-3,6	1,2-3,5	10)
Iraq	Clams	0,3-1,0	0-0,6				11)

1) Fowler (1985)
2) Lindén (1982)
3) Rock Scallops
4) Pearl Oyster
5) Rock Oyster
6) Mussel
7) Hg-values in wet weight
8) Lindén, unpublished
9) EPD (1986)
10) Literathy *et al.* (1986)
11) MSC (1986)

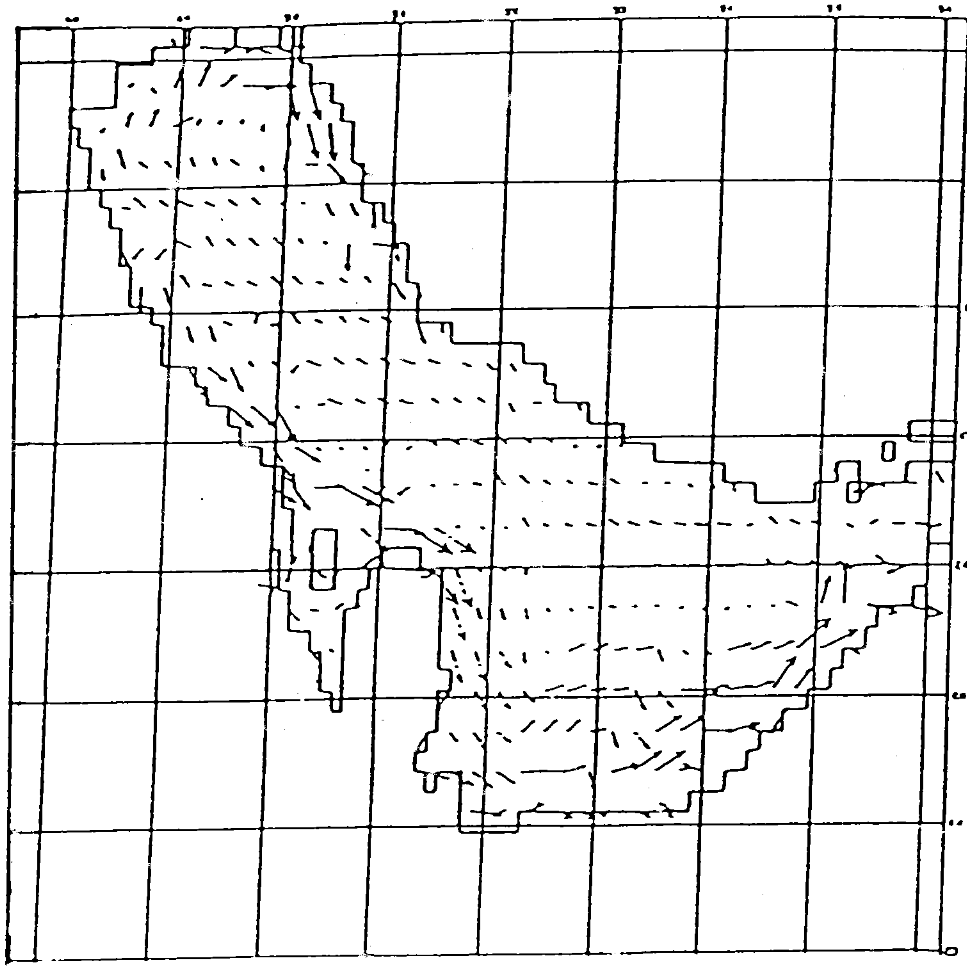

Figure 4. Surface current component due to wind stress using a 5 m/s wind from northwest (Galt et al., 1984)

The available data on mercury concentration in fish from the region are comparable to other regional seas. Thus preliminary data of mercury concentrations in groupers from the region show concentrations up to 0.75 ppm (Fig. 6), although the correlation between mercury concentration and size of fish (weight) was not very clear (ROPME/IAEA, 1988). These results were obtained as part of a regional assessment of the distribution of mercury in sediments and biota.

Several states in the region monitor levels of heavy metals in the marine environment as a part of their national monitoring programmes. Through the ROPME co-ordinated 18-month Marine Monitoring Programme heavy metals (mercury, cadmium, lead, vanadium and copper) are determined in tissues of bivalves from sampling stations distributed on the coastal areas of the eight Member States of ROPME. The complete results of this project are not yet available.

A study of the concentrations of heavy metals in seawater in the north-western region (EPD, 1986) indicates that copper, lead, cadmiun, vanadium and mercury have mean concentrations (with ranges in brackets) of 3.1 (1.5-8), 2.2 (1-3.7), 0.2 (0.1-0.4), 2.7 (0.8-8.6) and 0.09 (0.1-0.28) µg/l respectively.

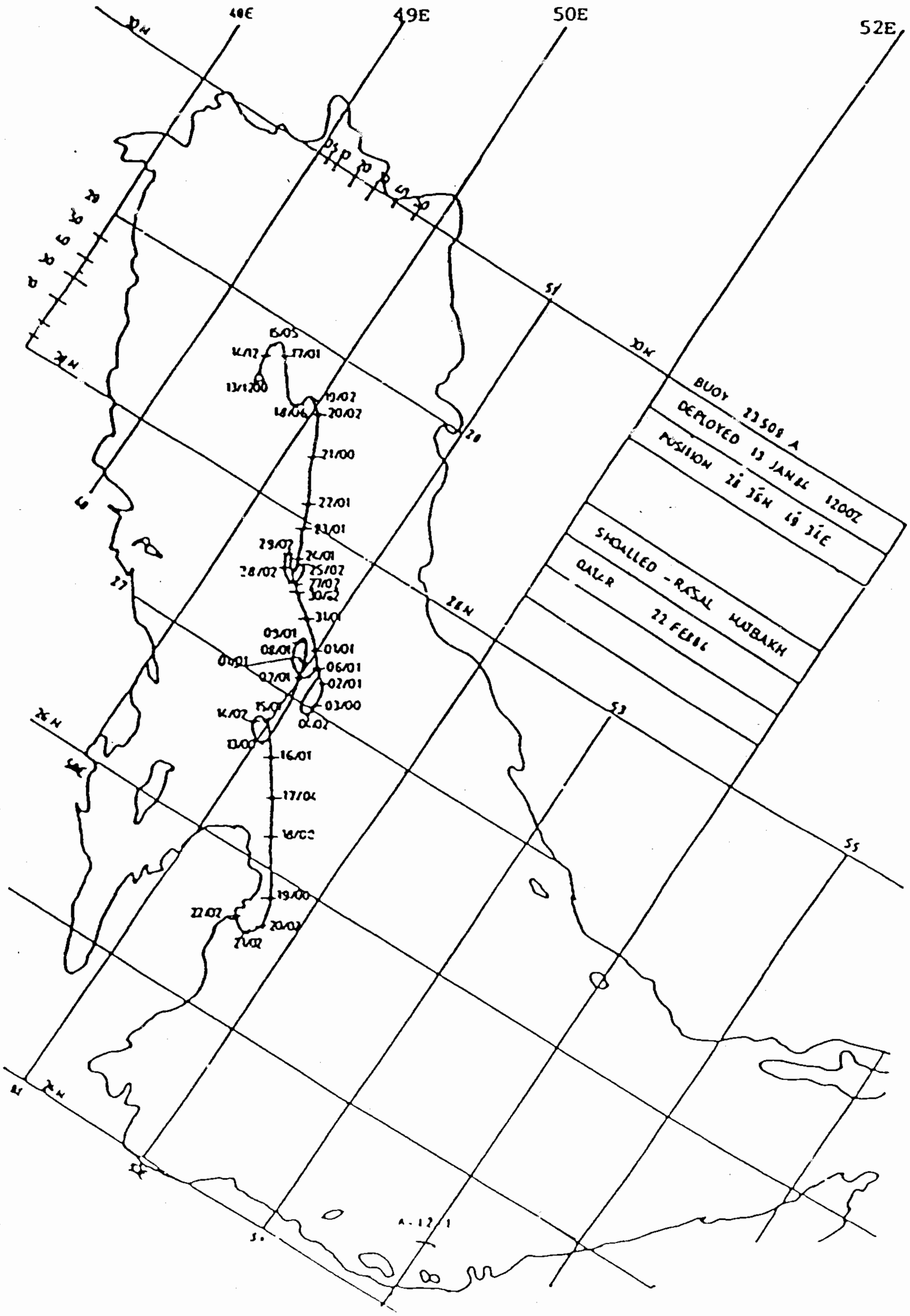

Figure 5. Surface drift as shown by satellite tracked radio buoys (MEPA, 1984)

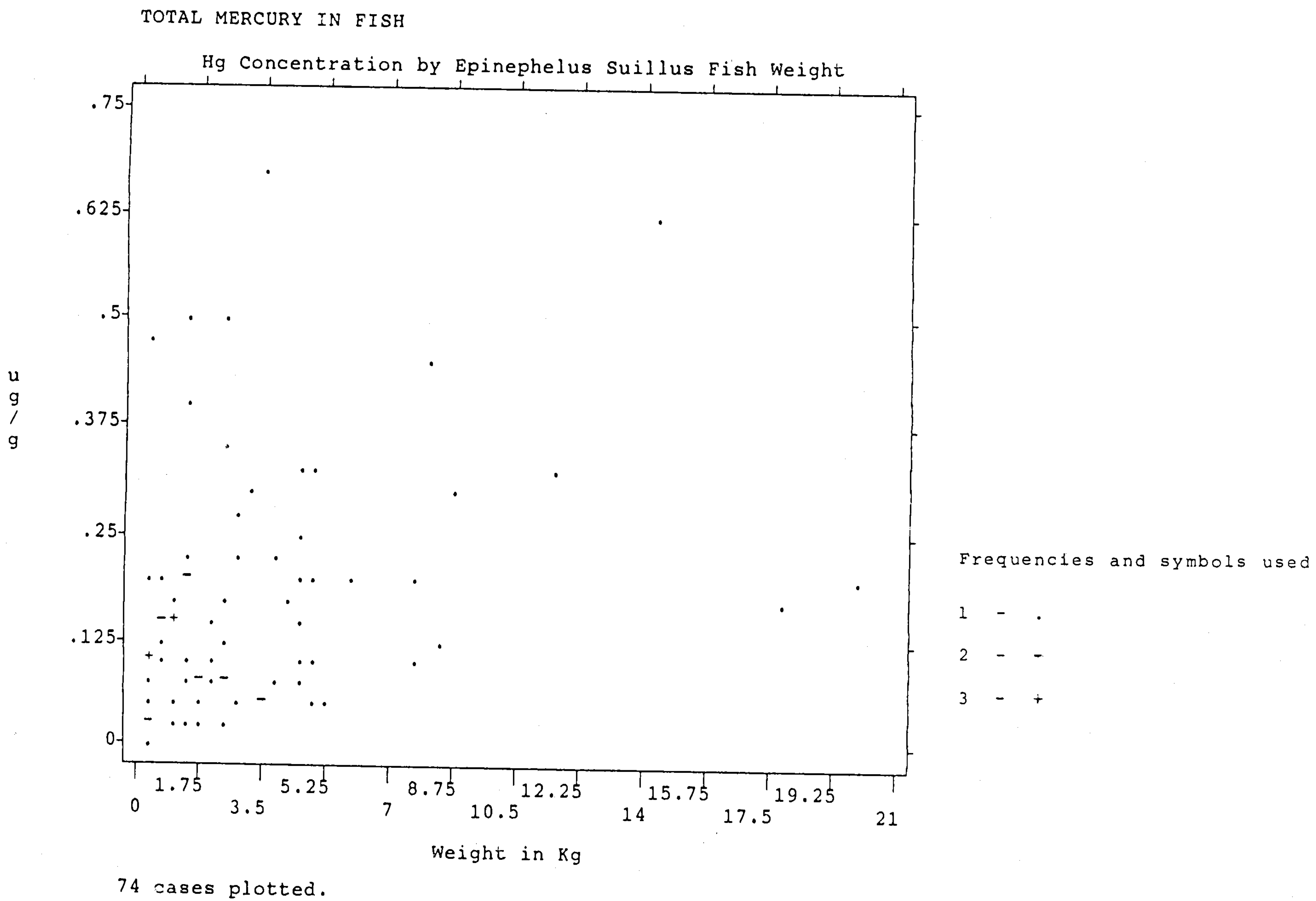

Figure 6. ***Total mercury in muscle of groupers according to weight (ROPME/IAEA, 1988)***

Table 3. Trace elements in sediments from the KAP region (Concentrations in ng/g dry weight except for Hg; µg/g d.w.)

Area	Cd	Cu	Hg	Ni	Pb	V	Zn	Remarks
Iraq	0.1-1.0	1.5-5.3		5-14	3-6	3-8	8-33	1)
Iraq	0.03,0.18	24.2,25	-		6.6	67.5,175	-	2) 8)
Bahrain	0.09-0.22	1.3-53	6-231	0.4-12	1-627	0.1-5.3	1-51	3)
Bahrain	0.02-0.05	5.6-10	13-106		1.7-15.1	4-27		4)
U.A.E.	0.02-0.06	2.4-9.2	55-89		0.6-3.7	5-56		4)
Kuwait	0.3	21.6	10-370		62	26.6	-	5)
Kuwait	0.09-0.23	20.1-29.9	50-170		3.3-6.8	38.2-44.6	-	6)
Saudi Arabia	2.5-5.0	5.4-16.6	3-37	21-65	0.6-4.2	0.6/29	4-23	7)

1) Al-Hashimi and Salman (1985)
2) MSC (1986)
3) Lindén (1982)
4) Fowler (1985)
5) EPD, 1986 (mean value except for Hg where the range is above)
6) Literathy *et. al.* (1986)
7) Sadiq and Zaidi (1985)
8) n = 2

The eastern central region study (Sadiq and Zaidi, 1985) indicated mean concentrations of cadmium, chromium, mercury, molyd-meon, nickel, lead and zinc to be 0.06, 2.32, 0.04, 11.01, 9.5, 9.1 and 10.9 µg/l respectively. Copper concentration from the south-western region were in the range of 3.8-17.8 µg/l (Hassan and El-Samra, 1985).

The heavy metal concentration in sediments from the area are summarized in Table 3. Background concentration from offshore areas far away from industrial regions are typical for offshore continental shelf areas of the world oceans. Relatively higher concentration of copper, cadmium, mercury, lead, zinc and vanadium have been reported from impacted areas such as close to harbours and industrial areas (Lindén, 1982; Fowler, 1985; Al-Hashimi and Salman, 1985; Sadiq and Zaidi, 1985; Literathy *et al.*, 1986; EPD, 1986).

Petroleum hydrocarbons

Petroleum hydrocarbon concentrations in sea water in the north-western region were reported to be in the range of 0.10-0,33 µg/l (EPD, 1986). Another study reported the concentration level at the surface, at ten meters depth, and at the bottom to be in the range of 0.7-4.6, 0.7-7.71, and 1.1-4.8 µg/l respectively (Literathy *et al.*, 1986). From the western-central region hydrocarbon concentrations in sea water were reported in the range of 0.12-1.4 µg/l (KFUPM/RI, 1987), while the corresponding figures from the south-western region were in the range of 0.48-16.8 µg/l (Fowler, 1985).

The concentrations of petroleum hydrocarbon in sediments starting at north-western region passing through the western-central region to south-western region were 0.3-310, 0.5-816, 0.1-119 µg/g dry weight respectively (Douabul, *et al.*, 1984; Zarba *et al.*, 1985; Literathy *et al.*, 1986; Fowler, 1985; Burns *et al.*, 1982; EPD, 1986)

(Table 4). The lower concentrations represent background levels while the upper range shows concentrations in areas under direct influence of petroleum input. Concentration levels of up to 3.950 µg/g dry weight have been reported from more industrialized parts of the west-central region (Lindén, 1982).

Different species of bivalves have been analyzed for petroleum hydrocarbons (Table 5). The concentrations found are sometimes rather high, although such organisms have usually been collected in areas close to industrial outlets or other point sources of petroleum hydrocarbons. However, direct comparison of the results from different locations are difficult, as different species have been collected and the analytical techniques may have varied considerably between different laboratories.

Table 4. Petroleum hydrocarbons in sediments from the ROPME Sea Area (concentrations µg/g dry weight)

Area	Concentration (ranges)	Technique	Reference
Iraq	0,4-44,0	Fluorescence	Douabul *et al.* (1984)
Iraq	3,3-9,3	Fluorescence	MSC (1986)
Kuwait	2-310	Fluorescence	Zarba *et al.* (1985)
Bahrain	6-3,950	GC	Lindén (1982)
Kuwait	13,7-375	Fluorescence	Literathy *et al.* (1986)
Kuwait	0,3-80	Fluorescence	EPD (1986)
Bahrain	0,5-8,6	Fluorescence	Fowler (1985)
U.A.E.	0,1-14,7	Fluorescence	Fowler (1985)
Oman	0,1-119	Fluorescence	Fowler (1985)
Oman	0,8-19	Fluorescence	Burns *et al.* (1982)

Chlorinated hydrocarbons

Assessment of chlorinated hydrocarbons in sediment and biota from the region has been reported by Lindén, (1982), Badawy *et al.*, (1985), Fowler, (1985), EPD, (1985) and Literathy *et al.* (1985). In general the data indicates relatively low levels of contamination by these compounds compared to other regional seas. Levels of aldrin, lindane, dieldrin and DDT in sediments from the north-western part of the region were all below 1 ng/g (Literathy *et al.*, 1986). The levels of PCB's in the north-western part of the region were generally below 5 ng/g (Literathy *et al.*, 1986). Levels comparable to these ranges have been reported for Bahrain, Qatar, U.A.E. and Oman (Fowler, 1985). The levels of DDT ranged from 1-11 ng/g in fish from the north-western part of the region. Endrin levels ranged from 1-7 µg/kg in most fish samples but reached 45 µg/kg in few cases (Douabul *et al.*, 1987). DDT levels in clams from Kuwait ranged from 8.8-88 µg/kg whereas dieldrin values ranged from 2.2-36 µg/kg and other compounds were below 1 µg/kg (Literathy *et al.*, 1986). Concentrations of DDT with metabolites in bivalves ranged from below the detection limit up to 30 µg/kg in oysters from Abu Dhabi (Fowler, 1985). Levels of aldrin, DDD, DDE, DDT, dieldrin. endrin and lindane were generally below 5 ng/g in the tissues of clams collected from the west-central coastline, except for a station near a landfill where relatively higher values were obtained (KFUPM/RI, 1987).

Other halogenated hydrocarbons that may be of interest include halogenated methanes, mainly bromoform which have been determined in the vicinity of power/desalination plants. Levels ranging from 10-90 µg/l were measured near the outfalls (Ali and Riley, 1986). Low concentrations could be traced over a much larger area.

Table 5. Petroleum hydrocarbons in bivalves from the ROPME Sea Area. (concentrations ug/g dry weight)

Area	Species	Concentration (range)	Technique	Reference
Bukha, Oman	Rock Oyster	40-558	GC, p-fraction	Badawy *et al.* (1985)
Al Qurum, Oman	Rock Oyster	6,5-85	GC, p-fraction	Badawy *et al.* (1985)
Masirah, Oman	Rock Oyster	5-354	GC, p-fraction	Badawy *et al.* (1985)
Al Zallaq, Bahrain	Pearl Oyster	13-19	Fluorescence p+a fraction	Fowler (1985)
Askar, Bahrain	Rock Scallop	41,8-84	Fluorescence p+a fraction	Fowler (1985)
3 areas in UAE	Pearl Oyster	7,2-29,7	Fluorescence p+a fraction	Fowler (1985)
6 areas in Bahrain	Pearl + Rock Oyster	28-220	GC p-fraction	Lindén (1982)
6 areas in Kuwait	Pearl Oyster	39-348	GC p-fraction	Anderlini *et al.* (1981)
12 stat. Saudi Ar.	Clam 1)	1-21	GC p-fraction	KFUPM/RI (1987)
Kuwait	Clam 2)	0-683,3	Fluorescence	Literathy *et al.* (1986)
Kuwait	Clam 2)	7,2-91	Fluorescence	EPD (1986)
Iraq	Bivalve 3)	7-35	Fluorescence	MSC (1986)

1) *Meritrix meritrix*
2) *Cercinata callipyga*
3) *Corbicula fluminea*

The presence of lower molecular weight organic compounds such as phtalates or similar compounds has recently been shown in sediments and oyster samples. A more detailed assessment of the potential for their accumulation and impact has been suggested (IAEA/ROPME, 1987).

Beach tar

High concentrations of beach tar are frequently observed on beaches throughout the region (see Table 6 and Fig. 7). Hence, concentrations approaching 1.0 kg/m of shoreline or above are common. Such figures are often about 100 times higher than the upper values reported from other regions of the world. Within the region particularly high concentrations have been found in Saudi Arabia and Oman.

3.2 Transport and fluxes across boundaries

The geography, meteorology and physical oceanography of the region affect the water movement pattern and hence the transport of pollutants, floating, suspended, or dissolved in sea water. Limited research has been conducted to study transport from sea water to air i.e. volatile organic compounds from oil spills that evaporate due to the relatively high temperature and winds in the region. However, some data are available on the transport of dust from air to the ground and sea in the north-western part of the region (Table 7). The average monthly, dust settling in various sites in Iraq and Kuwait is frequently in the range of 10 to100 g/m^2 although maximum levels in certain sites in Kuwait are over 600 g/m^{2}or a monthly maximum of some 600 tons per km^2(ROPME, 1987). Such figures are probably among the highest in the world.

3.3 Selected contaminants

Petroleum hydrocarbons

Petroleum hydrocarbons have been of prime interest in the monitoring activities in the region. However, as seen from the above reviewed data, the levels of petroleum hydrocarbons in the water column, sediments and biota are not as high as might be expected in view of the rate of input of petroleum hydrocarbons into the marine environment. Several environmental factors probably contribute to a rapid degradation of petroleum hydrocarbons in the region. Thus, the high temperatures in combination with intensive solar radiation and the high rate of mixing of the water column, all speed up the weathering and degradation processes. Large numbers of heterotrophic microorganisms adapted to the degradation of petroleum hydrocarbons have also been found in sea water samples from the region (Diab and Al-Ghonaime, 1985). However, the high concentration of tar on beaches of the region is a matter of concern. Many beaches are virtually unusable for any purpose, as they are more or less paved with tar.

Halogenated hydrocarbons

An area of particular concern relates to the use of chlorine as an antifouling agent in sea water used in various cooling water systems or the release of chlorinated sewage effluents. As a consequence halogenated compounds may be formed and this may require a more detailed examination.

Table 6. Average quantities of tar on beaches in the ROPME Sea Area. (The figures given as g tar per meter of shoreline)

Area	Concentration		Reference	Remarks
Bahrain				
Al Jazaira	601)	(14-140)	Fowler (1985)	1) mean of three sampling occasions
West Palm beach	4761)	(310-596)	Fowler (1985)	
Transmitter beach	6101)	(240-858)	Fowler (1985)	2) mean of 12 beach profiles
UAE				3) Standard deviation
Um al Quwain	761)	(45-128)	Fowler (1985)	
Jebel Ali	1001)	(28-233)	Fowler (1985)	4) mean of 19 beach profiles
Abu Dhabi	61)	(4-9)	Fowler (1985)	5) mean of 9 beach profiles
Oman				
17 different beaches	1141)	(1-906)	Fowler (1985)	6) mean of 18 beach profiles
11 different beaches	5-2,3258)		Burns *et al.* (1982)	7) Annual range, bimonthly sampling at 1of 4 stations studies
Kuwait				
Kuwait City	752)	(1223))	Oostdam (1984)	8) range
Fintas-Shuaiba	914)	(109,73))	Oostdam (1984)	
C. Kuwait coast	1965)	(94,73))	Oostdam (1984)	
S. Kuwait coast	2586)	(773))	Oostdam (1984)	
S. Kuwait coast	19-5497)		Literathy *et al.* (1986)	
Saudi Arabia	0-28,7508)		KFUPM/RI (1987)	

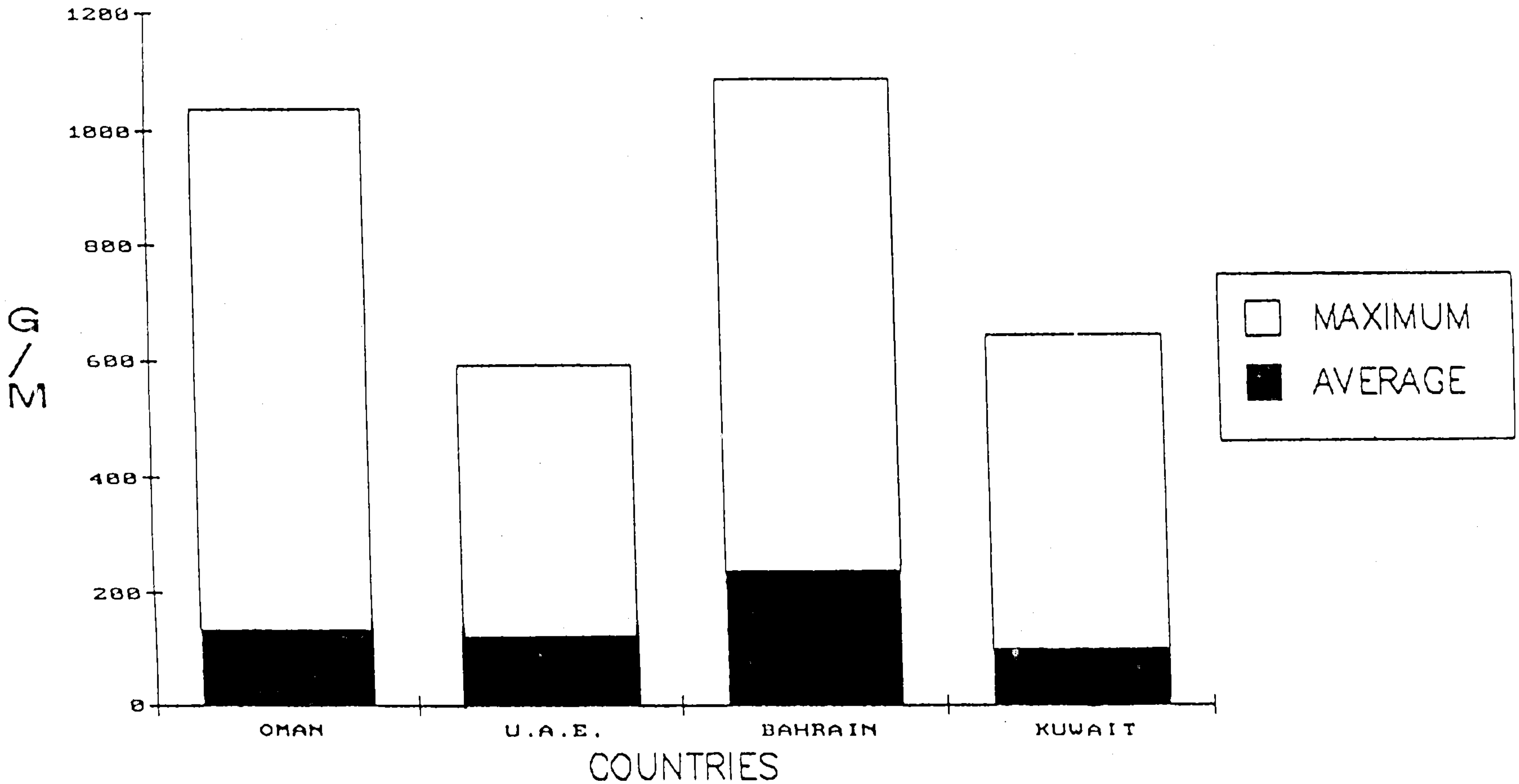

Figure 7. Monthlty dust fallout (g/m²) in the North Western part of the region (ROPME, 1987)

Table 7. Monthly dust fallout (g/m²) in the North Western part of the region (ROPME, 1987)

	1985			1986								
	Oct.	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**
IRAQ Range												
	-	2,7	5,4	5,2	5,4	7,9	7,0	4,4	15,0	15,9	4,4	2,6
	-	23,0	50,5	24,4	16,6	18,6	5,2	14,1	2,6	19,4	4,4	12,3
KUWAIT - Offshore (6 locations)												
Minimum	5,0	5,2	16,8	6,1	4,5	7,5	5,3	11,4	18,5	5,7	10,6	2,1
Maximum	73,5	36,8	57,3	24,3	30,2	34	20,4	82,3	161,4	100,5	26,9	23,5
Onshore (2 locations)												
Minimum	18,2	26,0	23,1	13,7	40,8	42,2	12,3	22,5	22,9	27,3	30,9	14,7
Maximum	41,5	33,7	57,5	23,0	61,7	51,2	24,0	35,6	605,8	104,1	94,4	35,9

Mercury

Although levels of mercury in sediments, bivalves and fish tissues from the region are not higher than the levels in other marginal seas, the relationships between the sources and the distribution in sediments and biota are not clearly understood. Sources other than chloralkali plants may be involved. The feeding habits and migration of fish stocks may also require a closer assessment in view of the inconsistency of data correlating weight to concentration (Figure 6).

Cadmium

The levels of cadmium in the marine environment of the region cannot be linked to a major source. Furthermore, data on sources of cadmium input are limited. There are indications that domestic sewage and wastes may be significant sources. When more complete data are available from the regional monitoring and land-based pollution assessment studies have been carried out in all states in the region a better understanding of the fate of cadmium will probably be achieved.

Vanadium and nickel

Vanadium and nickel levels tend to be elevated in areas subject to the release of crude petroleum. This may indicate that petroleum pollution is the common source. However, it should be mentioned that another major source of input of nickel into the marine environment is the corrosion of copper/nickel pipes and fittings used extensively in the desalination/power plants and cooling systems utilizing water.

3.4 Quality assurance, data validation and management

At the onset of the baseline studies which ROPME initiated in 1981-1982, there were at least four qualified laboratories in the area, to carry out the oceanography and oil and non-oil pollutant monitoring projects.

Since then, a number of actions have been carried out in order to improve the situation. Thus, much efforts have been spent on training of nationals, upgrading and unifying of equipment and methodologies of sampling and analysis, unifying data reporting and management formates and procedures etc. ROPME provided most of the participating laboratories with sampling and analytical equipment including spectrofluorometers, gas chromatographs and atomic absorption spectrophotometers. A manual on methods of sampling, sample preparation and analysis (MOOPAM = Manual on Oceanographic Observations and Pollutants Analyses Methods) and formats for data reporting were also compiled and distributed. Training workshops and on-the-job training courses were provided in sampling and analysis of trace contaminants both in and outside the Region.

Intercalibration exercises on pollutant measurements were also organized by ROPME in collaboration with the International Laboratory of Marine Radioactivity of IAEA. Seven laboratories participated in the analysis of trace metals in sediments and tissues The problems associated with clean-up and interference removal in sediment analysis received particular attention. Five laboratories participated in a petroleum hydrocarbon analysis exercise. Another batch of samples was distributed among regional laboratories with signs of a wide participation in the exercise. Furthermore, intercalibration in trace metal analysis using samples was conducted in Kuwait in November 1987. Intercalibration among national laboratories involved in the monitoring programme of individual States has also been carried out.

Efforts to improve data handling and management in the ROPME Region is also underway. These efforts include the use of computers in data compilation and analysis, and the establishment of a computerized regional database.

4. HUMAN ACTIVITIES AFFECTING THE SEA

4.1 Disposal of urban and industrial waste waters

The present population in the coastal areas of the region is about 5,825,000 distributed along a total length of coastline of 6166 kilometres. The majority (72%) of the population reside along the western and southern shores of the area. The highest concentration of population along the coast is in Iraq. The increase in the population of the coastal areas throughout the region is on average some 3% per year.

The total capacity of all existing sewage treatment facilities in the coastal region is currently sufficient to treat the domestic wastewater from a population of approximately 3,370,000, or equivalent to 58% of the population (ROPME, 1986). Proposals exist however, for various extensions to existing plants and also for the construction of a number of new plants. Completion of all known proposals, would result in a total treatment capacity in the coastal urban centres, sufficient to treat domestic wastewater from a population of approximately 7 million.

Treated sewage effluent is a valuable resource for irrigation in the arid coastal zones of the countries of the region. It has been estimated that the cost of producing treated sewage effluent is a quarter of the price of producing potable water from desalination (ROPME, 1986). As a consequence the amount of untreated domestic wastewater discharged to the sea is generally expected to decrease in the near future as increasing amounts are used for irrigation. The largest discharge of untreated sewage presently occurs from Bahrain, although all such discharges from this country are expected to cease by the year 2000, when all sewage will be treated before discharge into the sea.

No data are available on the quantities of untreated wastewater discharged form the Islamic Republic of Iran. Also, future plans for treatment of the wastewaters and reduction of discharges were not available at the time of this review. For Iraq, the recent completion of sewage treatment facilities at Basra are expected to significantly reduce present untreated wastewater discharges. The only country from which there are no discharges of treated or untreated wastewater is Qatar (Fig. 8, Taylor, 1986).

There is a considerable growth of the industrial sector throughout the coastal areas of the region. In general,

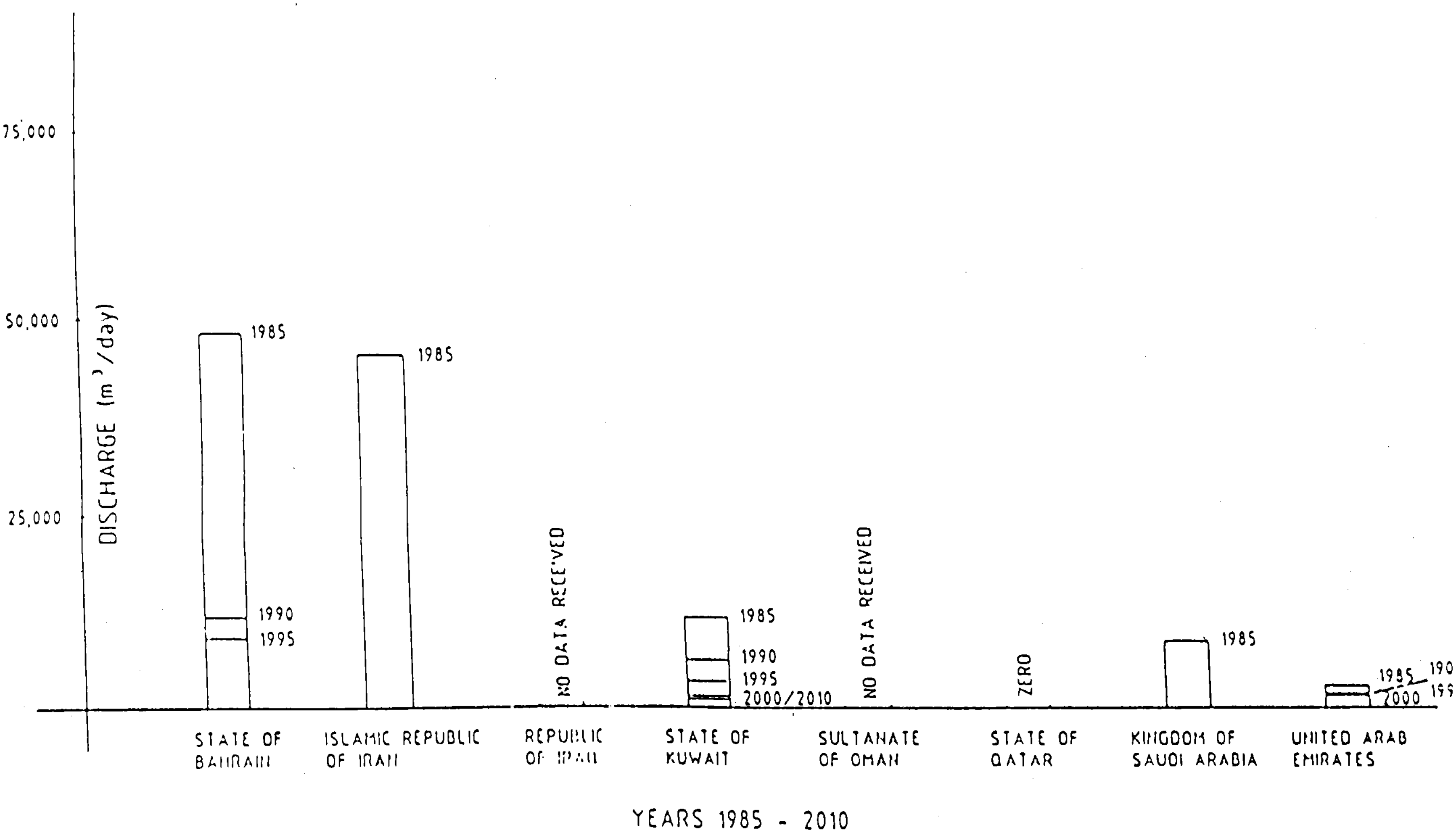

Figure 8. Discharge of untreated domestic waste water (Taylor, 1986)

heavy industries are located in industrial zones at some distance from the major population centres. Light industries on the other hand, are more common closer to the towns and cities.

The major industrial areas are the Jubail industrial centre in Saudi Arabia with very large petrochemical and other industries, and the new industrial areas of Jebel Ali in Dubai and Ruwais in Abu Dhabi. Significant industrial expansion is also noted in all other countries of the region.

Rapid inventories of liquid and air pollution sources in each country have shown that a relatively small variety of industries are responsible for the bulk of the liquid and air emission problems (ROPME, 1984). Table 8 summarizes the industrial discharges into the sea of the region separately for heavy and light industries and car service stations. From the results, it would appear that discharges from heavy industry are predominant as far as suspended solids and oil loads are concerned, while light industry dominates the BOD discharges. It should be noted, however, that most suspended solids originating from heavy industry come from uncontrolled

Table 8. Effluent discharges from heavy and light industries into the sea (ROPME, 1984)

		Heavy industries	Light industries	Car Service Stations	Total
WY*	103 m3/yr	203,863	5,691		209,554
	%	97,7	2,7		
BOD	tn/yr	3,751	11,863		15,614
	%	24	76		
SS	tn/yr	546,562	3,935		550,497
	%	99.3	0.7		
Oil	tn/yr	19,659	1,180	40,079	60,918
	%	32.3	1.9	65.8	
N	tn/yr	20,836	106		20,942
	%	99.4	0.6		
S	tn/yr	222	13		235
	%	94.5	5.5		
Phenols	tn/yr	164			164
	%	100			
Hg	tn/yr	24.14			24.15
	%	100			
Cr	tn/yr	7			7
	%	100			
Cu	tn/yr	107	3.5		110.5
	%	100			
F	tn/yr	3,575			3,575
	%	100			

* Excluding major cooling water effluents.

discharges from one single phosphoric acid fertilizer plant. The remaining suspended solids are released in similar quantities from light industries and heavy industries. Hence, light industries are probably more important pollution contributors than the heavy industries. A summary of the calculated total discharges of sewage and industrial effluents into the sea is given in Table 9.

A draft protocol dealing with the control of land-based sources of pollution is expected to become adopted by the countries of the region in the near future. The basic principles of the Montreal Guidelines (UNEP, 1985) were taken into account when this protocol was formulated.

An in-depth study on the control of land-based sources of pollution in the region is presently being carried out. The basic objective of the study is to develop within the next three years an effective and realistic strategy for abatement of pollution from land-based sources in the region and to promote the implementation of the related control measures. Local staff will also be trained during this period so that inspection of industries, enforcement of control measures and monitoring of effluents can be carried out successfully.

4.2 Development of coastal areas

During the last 50 years a number of development projects involving extensive dredging or land reclamation operations have been carried out in the coastal zone of the ROPME Sea Area. Countries particularly affected by this are Kuwait, Saudi Arabia, Bahrain and the United Arab Emirates (U.A.E.). The development of the coastal zone of Kuwait may serve as an example. The seafront of Kuwait City has been extended in several phases during the last decades, and the entire coastline between Kuwait Bay and the border to Saudi Arabia has in fact been subjected to various coastal development projects. Present plans involve development of an area in the north, for the construction of an extensive power/desalination plant at Sabnya on the northern mouth of Kuwait Bay.

Another example is the development around the coast of Bahrain. Here between 10 and 15 km^2 of shallow coastal water has been reclaimed during the last decades. In addition, during the same period an area of 15 to 20 km^2 has been dredged. The habitat of these areas probably to a very considerable extent consisted of sea grass beds, mangroves and coral reefs. After being filled, these areas have been used for industrial purposes, as residential areas, or for various infrastructures (e.g. the Bahrain-Saudi causeway). Present plans for new reclamation projects in Bahrain involve the filling of an area of almost 200 km^2, presently mainly consisting of coral reefs, primarily for the establishment of residential areas. Throughout the region the loss of marine habitats due to such infilling or dredging operations appears to be one of the most serious marine environmental problems. Such operations are affecting the most productive and biologically most diverse parts of the marine ecosystem; the shallow coastal tidal flats, the coral reefs and the seagrass beds.

4.3 Manipulation of hydrological cycles

Hydrological cycles are affected by various human activities, e.g. through the building of dams, causeways and the use of ground water for irrigation. Dam constructions reduce the input of sediments and nutrients which contribute to the productivity of the tidal flats and shallow areas. Several dams have been constructed on the major tributaries of Shatt al-Arab. On the Tigris and Euphrates about 5 major dams in Turkey, Syria and Iraq are controlling the river flow. On the third main tributary of Shatt al-Arab, the Karoon in Iran, there are two major dams. In addition there are plans for construction of more dams in several of the countries in the future.

Other human activities which influence the hydrological cycles in the region are the construction of causeways and bridges. The main example of this type of activity is the construction of the King Fahd causeway connecting the western shores of Bahrain with the eastern coast of Saudi Arabia. The 25 km long causeway bridge is situated in shallow water and is considered to be the longest in the world. It is comprised of five bridges and seven solid embankments. During the construction nearly 60,000,000 m^3 of mud and sand were dredged. It is feared that the changes in the hydrological cycles caused by the causeway will result in increased erosion and siltation and increase the salinity of the Salwah Bay.

Table 9. Known pollution loads discharged to the Sea Area from countries of the region (Bahrain, Kuwait, Saudi Arabia and U.A.E.) in tonnes/year (ROPME, 1986).

	Load currently discharged from member state				
Pollutant	**Bahrain**	**Kuwait**	**Saudi Arabia**	**U.A.E.**	**Total**
BOD (5)	2,647	2,342.8	2,191	469.8	7,650.6
SS 3,097	1,735.3	2,580	606.6	8,018.9	
Sulphide	-	87.4	-	28.2	115.6
Ammoniacal nitrogen	461	935.3	-	251.4	1,647.7
Nitrite nitrogen	-	25	-	19.8	44.8
Nitrate nitrogen	-	1,284.5	365.3	154.8	1,804.6
Calcium	-		-	1,013.2	1,013.2
Magnesium	-	-	-	1,391.4	1,391.4
Sodium	-	-	-	6,131.9	6,131.9
Potassium	-	-	-	617.4	617
Chloride	12,902	8,935.2	43,768	20,337.78	5,942.9
Sulphate	6,144	9,195.8	-	4,552.21	9,892.0
Alkalinity	-	9,121.3	-	4,785.61	3,906.9
Phosphate	768	968	512.7	308.22	5,569.0
Mercury	-	Free	-	-	-
Boron -	12.6	-	-	12.6	
Cadmium	-	2.4	-	263.7	266.1
Zinc -	0.4	-	0.75	1.2	
Copper	-	0.3	-	1.72	2.0
Nickel -	0.7	-	1.3	2.0	
Anionic detergents	-	-	-	2.0	2.0
Residual chlorine	-	10.4	-	50.5	60.9
C.O.D.	4,712.6	-	-		4,712.6

\- Data not provided

Note: No wastewater currently discharged from Qatar. Details of wastewater discharges to the sea from the Islamic Republic of Iraq and the Republic of Iran are not available and there are insignificant discharges by the Sultanate of Oman.

In Bahrain, over-exploitation of the underground water has caused the seepage of sea water to the aquifers, increasing the salt content of the ground water. This results in a number of negative effects, such as destruction of agricultural lands, increasing corrosion problems in pipes etc.

4.4 Other land use practices

Garbage and untreated sludge from septic tanks are frequently dumped in landfills throughout the region. Occasionally, during rain, parts of the dumped material may be carried to the coastal zone. Also, as a result of increasing agricultural activities, fertilizers and pesticides may end up in the marine environment, causing negative effects.

4.5 Disposal of contaminated sediments, mine tailings and industrial wastes

Offshore oil production activities in the region contribute significantly to the pollution of the marine environment. Hence drilling, well testing, maintenance, production and flaring all result in some impact on the environment.

Blow-outs are considered to be a normal part of the drilling operations. However, most of the spills are of low quantity and are seldom reported. However, major well blow-outs are a significant hazard during offshore drilling.

As a regular practice during maintenance of a production unit, oil is permitted to flow from the well. Usually the oil is connected up to a flare and burned off, but the burning may be incomplete so that crude oil is spilt into the sea.

Drilling muds, production and process waters are other sources of pollution resulting from offshore oil and gas production. These wastes contain dissolved and emulsified hydrocarbons as well as inorganic compounds.

Oily sludges are by quantity the most important type of solid wastes problems in the area (Table 10). In Bahrain, Qatar, Saudi Arabia and the U.A.E. these sludges are disposed on the ground, often in locations close to the sea. In Kuwait and Oman, they are burned, while about 10% of the sludges generated in the U.A.E. are directly discharged into the sea.

Table 10: Calculated industrial solid wastes and sludges generated in the Region (ROPME, 1986)

	Oily sludges ton/year	Oily sludges disposal	Toxic refinery sludges ton/year	Toxic refinery sludges disposal	Other major wastes	
KUWAIT	149,000	Open pit burning	210	Ground	Muds with Hg Muds with toxics Toxic solutions Organic waste	Chlor./Alkali) (Lead recovery) (Electroplating) (Slaughterhouse)
BAHRAIN	18,500	Ground	146	Ground		
QATAR	33,600	Ground	6.5	Ground	Organic waste	(Slaughterhouse)
OMAN	20,900	Open pit burning			Organic waste	(Slaughterhouse)
SAUDI ARABIA	624,000	Ground	238	Ground	Muds with Hg Organic waste	(Chlor./Alkali) (Slaughterhouse)
U.A.E.	127,900	Ground 90% Sea 10%	8	Ground	Organic waste	(Slaughterhouse)
IRAN	Data not available		Data not available		Muds with Hg	(Chlor./Alkali)
IRAQ	Data not available		Data not available		Data not available	

Either of these disposal methods are unsafe. Ground disposal may result in sea and underground water contamination. Open pit burning generates air pollution. The direct discharge into the sea may create a number of negative effects on marine life. Alternative ways of disposal of oily sludges are therefore considered. In general it appears that the problems with the solid wastes and sludges are becoming more acute and that there is an urgent need for adequate ways of disposal.

Solid wastes made up of building and road construction material are used as land-fill in coastal areas of many countries in the region. These materials include concrete, steel and asphalt. The most significant hazard, aside form destroying the coastal habitat, comes from the oil and tar content of the material. During summer time, the tar frequently melts due to the high temperature and this may damage the littoral communities. Also, due to the natural erosion processes due to tidal action and waves, this material will be washed into the lower inter tidal zone.

4.6 Disposal of solid matter

The results of inventories of the domestic solid waste generation in the region, shows that the annual *per capita* production is high. For certain countries (Kuwait and Oman) figures are almost double the quantities generated in developed countries (ROPME/84/118).

Open pit burning is practised extensively in some countries of the region. However, due to the air pollution, this method tends to be abandoned. Ground disposal is in most cases performed unsatisfactorily, but indications are that the situation will improve. Composting is receiving increasing attention in a number of countries since it yields a compost material of suitable quality for the sandy soils of the area. In a number of countries plans exist for increasing portions of the solid wastes to be composted. This is expected to follow the trend of increasing re-use of treated effluents for irrigation purposes.

Littering of the shoreline is a very obvious sign of environmental deterioration in many parts of the region. Particularly near more densely populated areas this has rendered many beaches impossible to utilize for recreation. The litter has probably in most cases been left there by visitors. However, also in very remote areas far from built-up places, like in the Hawar Islands in the south of the Gulf of Salwah, the beaches are severely contaminated by litter. In such cases, most of the litter has been transported by the sea to the beaches.

4.7 Marine transport of oil and other hazardous substances

Over 30% of the world's marine transport of oil cross the water of the region. Some 25 major oil terminals are located in the area and there are between 20,000 and 35,000 individual tanker sightings at the Strait of Hormuz every year. The region is likely to be the marine area that receives the largest quantities of oil pollution in the world. In 1979 Golob and Brus (1984) estimated that a total of about 144,000 metric tons of oil polluted the region. The same authors estimated that during the 10 years from 1979 to 1989, about 150,000 metric tons of oil will pollute the region each year. According to these estimates, oil pollution in the Sea Area represented 3.1% of the total oil pollution in the world, thereby contributing 47 times the average estimated amount for a marine environment of a similar surface area.

The major cause of oil pollution in the region is the discharging of ballast water, dirty bilge, sludge and slop oil. In a recent study conducted by ROPME it is estimated that based on oil production and export figures for 1986 a minimum of approximately 2,900,000 tons of oily wastes comprised of 2,500,000 tons of ballast water and 400,000 of dirty bilge, sludge and slop oil will be dumped into the sea. Estimations for maximum quantities are for a total of 7,850,000 tonnes of oily discharges of which 7,100,000 tonnes will be ballast water and approximately 750,000 tons will be slop oil, oily bilge and oily sludge (ROPME, 1986).

There are no data for transportation of hazardous materials in the regional waters. However, most of these are probably chlorine and ammonia and petroleumproducts such as kerosine. With the increase in the number of refineries in the region the transport of refined materials will increase thus creating more hazardous conditions and greater potentials for marine pollution in case of spillage.

The largest sources of spilled oil in the area come from tanker transport accidents (57 %)(Golob and Brus, 1984). Fortunately for many years, the area has been saved from major accidents involving super tankers. In recent years, however, the military attacks on oil tankers has resulted in several spills. The quantities lost in such circumstances are not known. However, according to statistics compiled by MEMAC, 329 war related incidents have been reported between May 1981 and June 1987 (MEMAC, 1987). Of these, 13 incidents have beencon-firmed to have caused pollution and 17 incidents being classified as possible potential threats. In contrast, 82 general shipping incidents were recorded during the same period with pollution being confirmed in 11 incidents (for details see Table 11).

Table 11: Pollution alert reports from May 1981 to June 1987 (MEMAC, 1987)

War related incidents	
Pollution confirmed	13
Information N/A but possible potential threat	107
No pollution reported	126
Information N/A, not considered pollution potential	83
TOTAL INCIDENTS	329
General shipping incidents (from 1 January 1984)	
(a) Problems on board (fires, engine failure etc.)	28
(b) Groundings/touching submerged objects	20
(c) Collisions	6
(d) Sinking/Capsizing	13
(e) Illegal discharge	3
(f) Indicents due to heavy weather	6
(g) Miscellaneous: rupture of loading hose	6
Pollution confirmed	11
TOTAL INCIDENTS (a - g)	82
Miscellaneous Incidents (including oil slick sightings)	
Pollution confirmed	15
TOTAL INCIDENTS	20
TOTAL OF RECORDED (confirmed) POLLUTION INCIDENTS	**36**

A complete network of thousands of kilometres of pipelines are lying on the bottom of the sea in the region. These pipelines carry oil, gas and production water from the offshore oil wells to shore facilities and terminals. These pipelines and other offshore oil installations make navigation in the Sea Area difficult. Frequently the submerged pipelines are ruptured with resulting leakage of oil or oil products. However, few data are available to evaluate on the quantities of pollutants from such accidents as they are often not reported.

Recently the rupture of a pipeline near Mina Al-Ahmadi terminal in Kuwait caused the spillage of large quantities of oil. Some of this oil reached shorelines several kilometres south of the pipeline. Unofficial estimates put the level of spillage before the leak was stopped at between 15,000 and 20,000 barrels of crude oil. Several similar spills are known to have occurred in the last couple of years.

4.8 Exploitation of non-living marine resources

Oil and gas are produced from offshore deposits by almost all of the countries of the region. In addition, seawater is extracted for desalination and cooling.

There are approximately 34 offshore gas and oil fields in the region with additional fields waiting exploitation. In all there are over 800 producing offshore wells with the largest numbers being in Saudi Arabia, Iran and United Arab Emirates. As many as 50 wells can be drilled from a single platform. (Ryan and Brown, 1985)

The major hazard of drilling is well blow-out. Between 1980 and 1983 four major spills have been caused by well blow outs (see Table 12). The longest recorded blow out in the region is that of Nowruz which not only involved several platforms with multiple wells but also lasted for nearly eight months, spilling over half a million barrels of crude oil.

The utilization of seawater for the production of distilled water by desalination is a major industry in the area. The distilled water produced is blended with about 10% brackish water to produce potable water. The amount of water drawn into the plants is about 10 to 12 times the amount produced. The rest is used as cooling water. The effluents are normally 5°C higher than the ambient seawater temperature with an increase in salinity of about 3 per mille. The effluents also contain residual chlorine (mainly as brominated, iodated and chlorinated organics), corrosion products and polyphosphates. The effects of discharged water on the sea area as a whole is probably minor, but the long-term effects in local nearshore shallow areas may be considerable.

The utilization of brines produced by desalination plants to produce chlorine, caustic soda, sodium hydrochloride and sodium chloride by using the mercury cell technique hasresulted in the release of large quantities of mercury into the marine environment. However, most such plants have since then been replaced by new ones utilizing the membrane technique.

Other exploited non-living marine resources include gravel and sand. There are no statistics showing quantities of removed material or the impact on the ecosystem but since these materials are taken from coastal areas, damage is likely to result in areas directly and indirectly affected.

The countries of the region have adopted a protocol aiming at controlling the pollution resulting from exploration and exploitation of the continental shelf. Upon the ratification of this protocol it is expected that damage caused to the marine environment from exploitation of non-living resources will be reduced.

4.9 Exploitation of living marine resources

Although the region is quite rich in terms of commercial fin fish and shellfish species, the fisheries sector plays only a minor role in the national economics. In most countries the contribution of the fisheries sector to the gross domestic product is less than one percent. However, in Sultanate of Oman revenue from fish was 36.5% of the total oil export revenue for 1984 and is presently the most important export product after petroleum.

Table 12. Major oil spill incidents due to well blow-outs during 1980-1983 (1)

Date	Incident	Source and Location	Cause of Spill	Type of Oil	Volume of Spilled Oil (barrels)
August 1980	Bahrain	Source unknown, possible Juaymah Field, Saudi Arabia 26 57'N 50 50"E	Unknown	Heavy Crude	20,000*-40,000**
October 1980	Hasbah	Well No. 6, Hasbah Field Saudi Arabia	Blow-out due to drilling accident	Heavy Crude of 20 API	50,000
January 1983	Nowruz	Eight wells in Nowruz Oil Field, Iran 29 32'42"N 49 29'07"E	Blown-out wells Mostly due to military action	Heavy Crude of 20 API	500,000***
Unknown	Khafji	Well K-156i Khafji Oil Field, Saudi Arabia	Blow-out	Unknown	Unknown

(1) Till August 31,1983
* Bahrain Oil Company Estimate
** Estimated by Lehr and Belen (1983)
*** Estimated as of August 31, 1983

Of the eight countries in the region, only four have significant shrimp fisheries with approximately 180 trawlers in operation (Iran 80, Kuwait 70, Saudi Arabia 20, Bahrain 10).

Industrial exploitation of shrimp fisheries in the region dates to 1950's with artisanal vessels joining at a much later date. In 1967-68 there was a peak in landings (17,000 ton) but declined rapidly to around 10,000 ton by 1970-71. The present catch is about 9,000 ton. Important commercial species are *Penaeus semisulcatus* and *Metapenaeus affinis* in the northern areas and *Penaeus latisulcatus* in the southern areas.

In general, fisheries of the region seem to be suffering from over exploitation. This is particularly true in the case of the shrimp fisheries. Despite increasing effort, catches in Kuwait have remained fairly stable. Recruitment indices show, however, that the stocks have declined since 1965 in Kuwait. Catch rates in Saudi Arabia have declined in the last year or two in the industrial fisheries. Total landings in Iran have been declining from 1977 to 1984-85 and is presently less than 5,000 ton. In Bahrain there has been an increase in landing over last 4-5 years, as a result of increased efforts (171 ton in 1979-80, 778 ton in 1984-85, 1,000 ton in 1987).

The decline in the shrimp catches has been attributed to over-exploitation (Ellis, 1975, Morgan, 1985). However, environmental degradation, e.g. from land reclamation has also led to the elimination of nursery areas for shrimps. Furthermore, the reduced rate of outflow from Shatt al-Arab may have had quite significant negative effects on the reproduction. To these factors could be added the effects of bottom trawling and the destruction it causes to benthic communities. It should also be pointed out that the eight-year war in the region had contributed to decreased fishing efforts, particularly in the northern part of the region.

Several countries have taken remedial measures to protect the shrimp stocks. These include imposing of a closed season for shrimp fisheries and a decrease of the fishing efforts (no new licenses and a limit to the size of the fishing boats).

Based on the official fishery statistics, the total catch of fin fish in the region in 1986 was 230,000 tons. However, as the major part of the fishery is a small scale artisanal fishery, and as the infrastructure for collecting catch data is poor in many countries, the actual catch figure is likely to be higher. While the bulk of the shrimp fishery is carried out in the northern part of the region, the fin fish fishery is dominating in the Gulf of Oman.

Despite efforts to increase catches in the region the total production has not increased significantly in most of the region. As a consequence there is a net import of fish and fish products into the region. An exception is Oman, where total catch figures have increased considerably in the last decade and where export of fish is the second most important export product. Most of the fish catch in Oman comes, however, from the Arabian Sea.

Aside from over-exploitation due to inadequate fisheries management, degradation of the environment is probably a major cause of the decline in fish and shrimp catches. The environmental degradation itself can be attributed to several factors: (1) elimination of important nursery areas (especially for shrimp) by land reclamation and dredging in the coastal areas, (2) destruction of feeding and breeding habitats by bottom trawling and (3) increased marine pollution by discharge of liquid and solid wastes into the marine environment. In addition, selective fishing for some species of predator fish may have upset the balance between the different species.

5. BIOLOGICAL EFFECTS

5.1 Eutrophication

Little scientific data is available on the biological effects of the contamination by sewage, nutrients etc. in the Sea Area. However, signs of eutrophication close to urban or industrialized areas are common. For example, on the northern coast of Bahrain, particularly around Muharraq Island and in the Khawr al Qulayah, dense mats of filamentous green algae in the intertidal zone are obvious signs of organic pollution and increased levels of nutrients in the water. In Bahrain a number of industrial processes and other sources contribute to the problem: methanol/ammonia production, an oil refinery, slaughter-house and livestock industry, sewage treatment plants as well as release of untreated waste water etc. Similar pollution problems from sewage and agro-based industries cause increased growth of benthic algae in the north-west, off Shatt al-Arab, particularly in Kuwait Bay. Similar phenomena has been reported from the coasts of Dahran, Saudi Arabia; Abu Dhabi and Dubai, U.A.E.; and in the Muscat area of Oman.

In addition, intensive blooms of pelagic algae also in off-shore areas appear to become more frequent. This may be a sign of more large-scale eutrophication also in off-shore areas.

There are also reports on local "red tides" in Bahrain and Saudi Arabia. This may be taken as a sign of abnormal conditions in the pelagic zone, possibly related to eutrophication.

5.2 Long-term biological impact of contaminants

The marine environment of the region has in a relatively short period been subject to a number of environment degradation processes. These include the spilling of large quantities of oil and oily products from ships and industries, the discharge of untreated domestic and industrial waste, various impacts from coastal development projects, the over-exploitation of the fisheries resources etc. The little research that has been carried out concerning effects of the degradation on the marine environment in the region has been concerned with relatively short-term acute effects. Very few data on long-term biological effects of pollution and environmental degradation are available.

As mentioned above the spring and early winter blooms of pelagic algae cover vast areas of the marine waters of the area. It is not certain whether these blooms occur in natural cycles or due to the increase in levels of pollutants such as nutrients and organic matter. In other parts of the world oceans, similar blooms have increased in recent years both in frequency and intensity and this has been considered a sign of eutrophication.

No large scale appearance of red tide phenomenon has been reported. However, there is concern that such blooms may become common in the future as localized blooms off the Bahrain and Saudi coasts have become frequent in the last years.

Outbursts of large numbers of jelly fish are observed in what appears to be increasing quantities each year. The "bloom" in 1987 was unusually strong with large quantities of jellyfish causing the clogging of the intakes of water desalination plants, refineries and other industrial plants using sea water for cooling. Fisheries were also affected by this bloom.

The long-term effects of oil pollution and heavy metals as well as the impact of the destruction of shallow habitats such as seagrass beds, coral reefs and tidal flats are of particular concern in the region. Research activities are presently directed at an increasing extent towards generating data on this subject.

5.3 Public health effects

The levels of both trace metals and persistent organics probably do not pose any immediate threat to human health. Fish caught from areas polluted with petroleum products have in some cases been reported to be tainted. The release of sewage, raw or partially treated, may represent a more immediate health threat to the public. There have been no detailed epidemiological surveys of the health risks to bathers. However, the public health authorities in several countries regularly conduct sea water analyses for total and faecal coliforms during bathing seasons.

The results of a two-year monitoring survey of total and faecal coliforms in 12 beaches of Kuwait has shown that 44-86 % of the samples collected showed high numbers of faecal coliforms. The highest monthly averages were found during the months of January - May whereas the lowest were in the hot months (June - September) which conceded to the bathing season (EPD, 1986). It should be noted that use of the coliforms as indicators of pollution by sewage in areas of high salinities have been questioned. Eutrococci and viruses have been suggested as alternatives but difficulties in culturing and identification may continue to limit their use for monitoring purposes.

The presence of mutagenic activities in extracts of organisms have been studied by Al Mossawi *et al.* (1982). With the employed technique the results showed no significant activity, suggesting low levels of carcinogenic pollutants.

The extensive utilization of sea water for desalination makes the region particularly sensitive to the contamination of sea water. The heavy use of chlorine, antiscale/antifoaming chemicals, antifouling paints, petroleum hydrocarbons and the release of organic matter - in the form of sewage deserves careful assessment as the changes of the seawater quality may affect the composition of the distillate produced by desalination.

5.4 Recovery and rehabilitation of damaged habitats

No more extensive attempts have been made to restore damaged habitats or to study the process of recovery of such habitats. However, an attempt was made to determine the rate of recovery of damaged coral reefs in Kuwait (Downing *et. al.* 1987). There has also been some experiments with the transplantation of mangroves in Bahrain, the U.A.E. and Kuwait.

5.5 Accidents and episodic events

Despite the large number of oil spills that have occurred in the Sea Area during the last decade, relatively few scientific reports on the effects of oil pollution on organisms or ecosystems are available. In a number of cases single observations of for example oiled birds have been reported, but no thorough long-term study of the biological effects of a single oil spill in the region is available.

In connection with the Ras Tanurah oil spill and the Hasbah 6 blow out in 1980, the oil caused drastic effects on the populations of seabirds along the coast of Saudi Arabia, Bahrain and Qatar. Mainly Socotra cormorants, but also herons and other wading birds were affected. Only in Bahrain it is estimated that at least several thousand birds were killed (Lindén, 1982). The oil from these two spills also affected other marine organisms. In the littoral zone of the coasts of Bahrain and Qatar, up to 100 % mortality occurred among littoral organism over extensive areas. Particularly beach living crustaceans (crabs, amphipods) were affected. The oil had been drifting for several days before it reached the littoral zone. Therefore most of the acute toxic compounds had been lost due to evaporation. Consequently, the mortality caused by the oil was mainly due to the physical effect of the oil rather than to chemical toxicity. The main physical effects were probably the clogging of mouth openings and breathing canals. The oil from the two spills in 1980 also caused damage to the populations of marine turtles and sea snakes. Also here the effects were caused by physical rather than chemical properties of the oil. Large numbers of oiled sea snakes were observed on the beaches of Bahrain in September - November 1980.

A few observations on various environmental effects were reported in connection with the oil spill from the damaged wells in the Nowruz Field, Iran, in 1984. Thus, oil contamination of beaches of Saudi Arabia, Bahrain and Qatar impacted the littoral fauna. Increased numbers of oiled birds presumably caused by the Nowruz oil, were also reported from several places along the southern coast of the Region. Also, about 50 dead dugongsand large numbers of sea snakes and turtles were sighted (Burchard, 1983). Whether these observations were directly related to the spill or not has been questioned, and according to our knowledge no final evaluation of the impact of the spill has been carried out. There have been speculations regarding deliberate dumping of toxic chemicals being responsible for the observed effects. Also, red tides, blooms of toxic dinoflagellates, may have caused the observed effects.

No reports of extensive fish kills have been reported in connection with oil spills in the region. Observations of occasional dead fishes are however frequent. In connection with the spill of 50,000 tons of crude oil in the Arabian Sea from the tanker Assimi in 1983, no indications of significant damage to the fish population were observed (Lindén, unpublished). Damage to fisheries are, however, a common problem. Particularly fish traps in the intertidal zone are easily damaged as the drifting oil clogs the nets and cause the traps to collapse.

5.6 Mortality of marine animals

During the period of late August through end of October 1986, sighting of dead dolphins and other marine animals on beaches of several countries of the region were reported. A total of 527 dead dolphins were reported from Qatar, Saudi Arabia, Bahrain and Iran (ROPME/WG.24/3, 1986). The majority of dead species were bottlenosed and humpback dolphins in addition to few common dolphins and finless porpoises. Furthermore, seven dugongs, one larger whale, fifty eight turtles and a large number of fish were also reported dead.

ROPME formulated an advisory committee of scientists that examined and reviewed reports and data on tissue analysis, plankton analysis for red tide species as well as meteorological and oceanographic data to determine possible causes of mortalities. However, no causal relationship could be established between the observed phenomena and human activities conducted in the region.

6. PREVENTION AND CONTROL STRATEGIES

Realising the need for collective action to control pollution and abate the degradation of the marine environment, the eight countries of the Region with UNEP playing a catalytic and co-ordinating role - agreed to establish the Regional Organization for the Protection of the Marine Environment (ROPME). The Kuwait Regional Convention and the Protocol on Combating Pollution by Oil, and Other Harmful Substances in Cases of Emergency that emerged, identified the basic elements of the strategy towards assessment of the marine environment, control and prevention of environmental pollution and development of legal and administrative instruments that allow for the rational exploitation and management of natural resources and other activities related to the marine environment.

One such instrument is the Protocol on Oil and Other Harmful Substances by which the Marine Emergency Mutual Aid Centre (MEMAC) was established. The Protocol has lead towards the enhancement of efforts to formulate national oil spill contingency plans and develop legislation towards prevention and control of oil spills in the ROPME Sea Area.

Two other protocols addressing Prevention and Control of Land-Based Sources of Pollution and Prevention of Pollution resulting from exploration and exploitation of the Continental Shelf, of which the latter was signed by the Parties to the Convention in March 1989, are expected to further reinforce the efforts towards Prevention and Control of marine pollution.

On the other hand, the development of regional strategy for coastal zone management is expected to enable the Member States to formulate regulations aiming at reducing pollution and ensuring development and management of natural resources on an ecologically sound basis.

At the National level, ROPME Member States, since signing the Kuwait Regional Convention, have endeavoured to develop the legislative, administrative and technical structure necessary to ensure the fulfilment of their obligations in accordance with the Convention.

It is apparent that all ROPME Member States have acquired the basic legal and administrative mechanisms enabling them to carry out environmental protection and management. However, some of the Member States are yet to designate a technical government body dedicated for carrying out the environmental monitoring and for inspection of industrial and commercial facilities to identify sources and levels of pollutants and ensure adherence to regulations, criteria or standards issued for the protection of the marine environment. It can also be observed that in spite of the importance attached to the problems of oil pollution by the ROPME Member States in their national environmental legislation, the administrative arrangements are not always developed to the expected level. The actual day-to-day activities of oil pollution surveillance, prevention and control and the contingency arrangements are often delegated to other government authorities or to committees in which the authority responsible for environment protection plays a co-ordinating role. In other Member States the role of the environment protection authorities are yet to be defined as National Oil Spill Contingency Plans are at an early stage of development.

7. TRENDS AND FORECASTS

Compared with most of the other regional seas, the ROPME Sea Area is relatively small and sparsely populated, with only around six million people living in the coastal areas. However, despite its low population, the region is probably more affected by human activities than most other regional seas.

Many of the pollution problems arise from the extraction and transport of petroleum. There are over 25,000 tanker sightings in the Strait of Hormuz each year, and over 800 oil producing wells are found on the seabed of the region. The oil is shipped from around 25 major oil terminals to the main consumer regions in the Far East and Europe. Considering the size of the region, the input of oil into the sea through spillage from these activities is probably the largest in the world. In recent years, military activities have further magnified the problem. As a consequence of repeated oil spills, most of the beaches in the region are heavily contaminated with tar: concentrations of one to 30 kilogrammes per metre of beach are common. However, the background levels of petroleum hydrocarbons in sediments and biota are not exceptionally high, probably due to rapid degradation and weathering.

In the more distant future, one might fear further deterioration of marine resources brought about by the very considerable land reclamation and dredging operations that are carried out in the region. Highly productive habitats such as seagrass beds, coral reefs and mangroves are being destroyed at a high rate in the region and much of the urban development in some countries is taking place on reclaimed land. The loss of renewable marine productivity through such human activities may be at least partly responsible for a drop in fishery production (mainly shrimp) in the region during the last decade. It is also clear that there has been considerable overfishing particularly for shrimp in many areas. Countries are taking remedial action to protect their stocks.

Signs of eutrophication are conspicuous in most coastal areas close to built-up areas. Blooms of pelagic plankton are therefore frequent and swarms of jelly-fish outbreaks have become common, though only in the last few years. Reports of red-tides seem to indicate that these are also more frequent than they used to be.

None of the countries in the region dump solid wastes from land into the sea. All solid wastes discharged into the sea originate from ships and offshore oil terminals. However, dumping of garbage and littering on beaches is a problem throughout the region, and even coasts remote from built-up areas are affected.

8. ECONOMICS

The economic costs for marine pollution can be divided into two types:

A. Direct costs which can be observed directly through market transactions including costs for cargo loss, clean-up, repair etc. Included here are also costs such as the loss of fish catch or loss of profit from tourism.

B. Non-market costs, which include loss of aesthetic values, recreation or other non-consumption use values, option values, bequest value etc.

From the ROPME Sea Area, scattered information is available on this subject. Thus, the direct clean-up costs following oil spills in the region have been reported in a few cases.

- The cost for the clean-up of the oil from the Hasbah 6 blow out was estimated at some 8.3 million US$ in Qatar only (Oudenhoven, 1983). This figure also includes the purchasing of equipment, some of which probably was not used during the spill.

- The direct clean-up cost for 5,000 barrels of oil spilt at Mina Abdula, Kuwait, in 1986 was approximately 600,000 US$ (EPD, Kuwait).

- It is estimated that the average cost of the clean-up of the oil spilt during about 50 minor incidents in 1985 and 1986 in Kuwait was some 2,000 US$ per spill (EPD, Kuwait).

- The total cost for response operations following 12 oil spills in the region during the period 1980 to 1983 have been estimated at some 53 million US$ (Ryan and Brown, 1985). The total quantity of lost oil during these incidents was about 500,000 tons, although the major portion came from one single incident: the Nowruz blow out.

- It has been estimated that the total capital investment represented by all the oil combating equipment stored in the region amounts to some 50 million US$ (Ryan and Brown, 1987).

Only one estimate of the direct economic loss to fisheries following oil spills in the region is available. This is an estimation of the costs for destroyed fishing gear in Bahrain following the Ras Tanurah oil spill in Saudi Arabia. the cost for fish traps that had to be renewed after the spill amounted to some 500,000 US$.

No attempt has been made to calculate either direct or non-market costs due to pollution other than oil, or to phenomena such as coastal reclamation etc. However, it has been put forward that the drastic reduction of the shrimp stocks in certain areas, e.g. the Bay of Kuwait is a result of coastal reclamation projects in combination with over-exploitation.

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