# Regional Report of The State of The Marine Environment 2000

ROPME/GC-10/001/1

# Regional Report Of
# The State Of The Marine Environment

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بسم الله الرحمن الرحيم

*In the name of God,*
*the Compassionate, the Merciful*

# FOREWORD

The State of the Marine Environment Report-SOMER is prepared in compliance with the provisions of ARTICLE XVII (d-ii) of the Convention. The ARTICLE stipulates that the Council is to "review and evaluate the state of marine pollution and its effects on the Sea Area on the basis of reports provided by the Contracting States and the competent international and regional organisations". To this effect, the first Regional Report on the State of the Marine Environment was prepared based on the information provided by Member States and the data and information available at the ROPME Secretariat and was published in March 1999. SOMER 1999 was then distributed to National Focal Points (NFPs), academic and scientific institutions in Member States, as well as to regional and international environmental personalities and organisations.

ROPME Secretariat continued its efforts to acquire new data and information on the characteristics and dynamics of the marine ecosystem and the impacts of anthropogenic activities on the marine environment with a view to update the text of SOMER 1999. National data and information on the state of marine environment were received from NFPs Bahrain, Kuwait, Oman and Qatar.

The first draft of SOMER 2000 was prepared and presented for review to a meeting of contact persons convened at ROPME Secretariat in February 2000. The text of SOMER 2000 was then prepared on the bases of new data and information from Member States, particularly those on land-based and sea-based sources of pollution, fish landing and fish mortality. The results of the Contaminant Screening Project carried out in co-operation with IAEA-Monaco have also been reflected in the text.

This process is to gain momentum and ROPME is to build on the experience and produce new editions of the SOMER on a regular basis. Such continuity for the revision and preparation of SOMER is necessary for better understanding of our marine environment, which is considered as one of the most fragile and endangered marine ecosystems in the world. We need new data from national marine monitoring and research programmes, as well as comprehensive National Reports on the State of the Marine Environment to achieve the objective.

It is hoped that SOMER 2000 will reach a large audience from all walks of life. This is of particular interest since the protection and enhancement of the environment is not only the obligation of Member States but is also the duty of every individual. We all need to join hands to protect the integrity and diversity of our marine environment and to ensure that any use of marine resources is equitable and ecologically sustainable.

We shall be grateful for any comments, amendments, and proposals for the improvement of the SOMER, especially those based on the experience in their practical application.

ROPME has received the support of Member States and the co-operation of many regional experts in preparing SOMER 2000. We are grateful to all the contributors and look forward to closer collaboration for better results.

The efforts of Dr. Nahida Al-Majed, Environmental Specialist in ROPME for incorporating the updated information into the Report is greatly appreciated. She also arranged the data and the final design of the Report. The contribution of Dr. Abdulnabi Al-Ghadban, Scientific Researcher in the Kuwait Institute of Scientific Research in the course of preparing the text of the Report is acknowledged.

The constructive contribution of Dr. Hassan Mohammadi, Acting Co-ordinator of ROPME is highly appreciated. He led the regional scientists in carrying out the surveys of land-based and sea-based sources of pollution and played the role of the main editor of SOMER 2000.

Captain Abdul Munem Al-Janahi, Director of MEMAC provided updated information, Dr. Peter Petrov, Remote Sensing Expert provided satellite images, and Mr. Ibrahim Hadi, Finance and Administrative Officer provided all necessary facilities for the production of the Report. Typing and reproduction were carried out by Ms. Lucy Pereira, Mr. Francis Picardo and Mr. Basheer Ahmed. To all of them I extend my gratitude.

Finally, I would like to express my sincere thanks and appreciation to all those who provided new data and information and sent their comments and suggestions. SOMER will remain a dynamic process. Each issue will be the result of interaction among all those concerned. It shall be an open book that reflects the State of the Marine Environment with a transparency that exposes all dimensions that concerns every person interested in this very vital aspect of our lives. Let us all co-operate to make SOMER a truthful reflection of our marine environment. I hope that the Report is useful and informative to the reader and would contribute towards a better understanding of our Marine Environment.

Dr. Abdul Rahman Al-Awadi
Executive Secretary of ROPME

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# INTRODUCTION

The present Report is the updated version of the first comprehensive State of the Marine Environment Report – SOMER of ROPME Sea Area (RSA) that was produced in 1999. Since then more data and information on the state of the marine environment in the RSA have become available with special reference to land-based activities. Scientific literature on the region has considerably increased and analytical techniques have been improved. Satellite observations have come more into use for large scale studies, which have enabled ROPME to develop a better understanding of the marine environment including some of the recent changes in the physiogeography and coastal morphology of the region.

More data were available as NFPs Bahrain, Kuwait, Oman and Qatar submitted national data and information on the state of the marine environment to ROPME Secretariat. The results of the Contaminant Screening Project (ROPME-IAEA) are also illustrated in this repeat.

The main objectives of this Report, which is prepared pursuant to the Decision of the ROPME Council, are therefore:

- To document and assess the current state of the marine environment of RSA, given due attention to recent changes in the environmental conditions and the impacts of human activities on the marine environment and coastal areas;
- To identify the current regional concerns and emerging issues which present major challenges; and
- To suggest regional strategies and priority actions that commensurate with these concerns and issues to enable the governments and decision-makers to meet these challenges at the national level, as well as in regional and global contexts.

The Report is structured in seven Chapters. Chapter 1 gives a brief background about the Regional Organisation for the Protection of the Marine Environment (ROPME), the Sea Area addressed this Report, and some socio-economic considerations for the ROPME Region. Chapter 2 described the general climatic and meteorological conditions prevailing in the region, as well as the physical, geological, chemical and biological characteristics of the ROPME Sea Area (RSA). The scientific information used in this review includes data obtained from ROPME's Marine Pollution Monitoring and Research Programme as well as the latest published articles in the scientific journals. Chapter 3 described the major habitats prevailing in the RSA in the first part of the Chapter. However, in the second part, a brief account is given of the living and non-living resources of the RSA, which have been or are being exploited in the region, with a view to establishing the possible impact of development activities on the marine environment. Chapter 4 discusses the main socio-economic activities and structures in the RSA. More information are illustrated from the national reports on land-based activities as submitted by NFPs Bahrain, I.R. Iran, Oman, Qatar, Saudi Arabia and UAE. Meanwhile for the sea-based activities the overall picture is still not clear due to the limitation of information, in which data from only two Member States of I.R. Iran and Qatar are available. Chapter 5 focuses on specific groups of contaminants whose observed levels and distribution in the water column, sediments and biota are being used as indicators of the health of the marine environment. The Chapter also has the focus on the results of the ROPME–IAEA Contaminant Screening Project. The third survey took place in Kuwait and Saudi Arabia in October 1998 and the fourth survey in Qatar and UAE in March 2000. Chapter 6 presents the major maritime accidents and natural episodic events that have been recorded and observed in the recent past in the RSA. Chapter 7 is mainly a combination of the previous three Chapters (7, 8 and 9) as presented in SOMER 1999. The Chapter has the focus on some measures for the prevention and control of marine pollution and environmental degradation, including policies, legislation and institutional arrangements. A summary of the current and emerging issues that represent major challenges to be addressed at regional level and their implication at the national level is also presented. The Chapter recommends relevant strategies for environmental protection and sustainable development of RSA and an "Agenda for Action" that numerates priorities to be set in order to address the most pressing issues and problems described earlier.

This Report is published by ROPME after being reviewed by the Member States, with the hope that it will provide the environment protection authorities, decision-makers and the scientific community in the region with a balanced assessment of the current state of the RSA. It is also hoped that this Report succeeds in giving a futuristic vision on how to protect and sustain the marine ecosystems as a vital source of life for the present and future generations, taking into consideration that the economies of the region are almost entirely based on a single non–renewable commodity, which may be threatened by technological breakthrough any time in the future.

SOMER is intended to be periodically reviewed and updated. In the meantime, its conclusions and recommendations for action need to be considered by all those concerned in the respective Member States of the region when formulating national/regional programmes and activities in accordance with the provisions of the Kuwait Regional Convention and its Protocols.

# CHAPTER 1

## BACKGROUND


The Regional Conference of Plenipotentiaries on the Protection and Development of the Marine Environment and the Coastal Areas of Bahrain, I.R. Iran, Iraq, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates was convened in Kuwait from 15-23 April 1978. The Conference adopted on 23 April 1978 the Action Plan for the Protection and Development of the Marine Environment and the Coastal Areas, the Kuwait Regional Convention for Co-operation on the Protection of the Marine Environment from Pollution, and the Protocol concerning Regional Co-operation in Combating Pollution by Oil and other Harmful Substances in Cases of Emergency.

On I July 1979, the Kuwait Convention entered into force after the deposit of five instruments of ratification, in accordance with paragraph (a) of Article XXVIII of the Convention. Accordingly, the Regional Organisation for the Protection of the Marine Environment (ROPME) was established in 1979 consisting of three organs, i.e. the Council, the Secretariat and the Judicial Commission. ROPME Secretariat was established in Kuwait in January 1982, after a transitional period during which ROPME programmes were carried out by an Interim Secretariat under the supervision of the United Nations Environment Programme (UNEP), through its Regional Seas Programme.


Since its establishment, ROPME has provided technical co-ordination to the Kuwait Action Plan and assisted its eight Member States in the implementation of the Convention and its Protocols, as well as a number of projects, covering environmental assessment and environmental management, including public awareness and training.

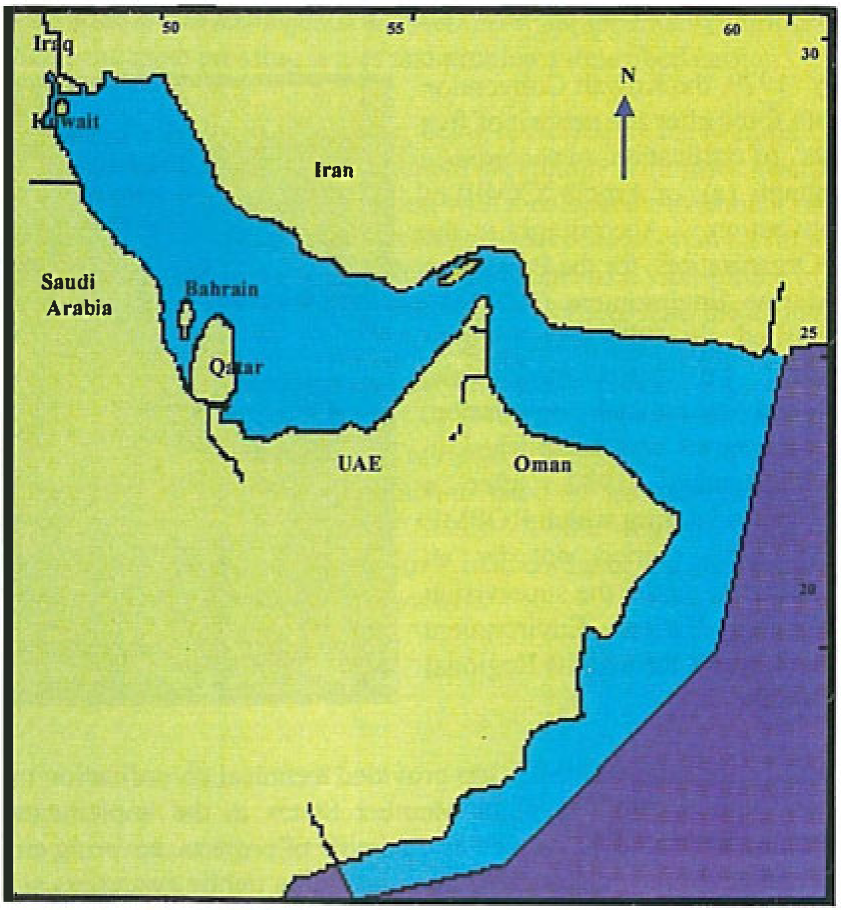
## 1.1 The ROPME Sea Area

### 1.1.1 Definition

The ROPME Sea Area (sometime in the past referred to as the Kuwait Action Plan Region) is the sea area surrounded by the eight Member States of ROPME: Bahrain, I.R. Iran, Iraq, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates. The term "ROPME Sea Area" was coined by Plenipotentiaries of the Member States to achieve unanimity in denoting the area covered by the Kuwait Regional Convention of 1978. It in fact reflects the goodwill of the Member States to co-operate in protecting their common marine environment in spite of the existing geopolitical boundaries.

According to Article II of the Kuwait Regional Convention, the ROPME Sea Area (RSA) is defined as extending between the following geographic 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 Figure (1.1).

**Figure (1.1): ROPME Sea Area.**



### 1.1.2. Historical perspective

The oldest records of human maritime activity is most likely to be found in the RSA, in the form of trade between Delmon (Bahrain), Oman and India (Price, 1982). For centuries the secrets of riding the monsoons was kept in the hearts of the sailors controlling the trade between the Region, India and Eastern Africa. It was not until the first century BC that the Greeks discovered the monsoons and challenged the Region's sailors. However, by the third century AD and as the Roman Empire declined, the fleets of the Sassanids became the main contenders for marine supremacy in the Region.

The dawning of Islam in AD 610 has radically changed the narrow localised outlook of the people of the Region into an amalgam of cultures, especially those of the Arabian Peninsula, Mesopotamia, Persia, the Phoenicians and the Egyptians, to become known as the Moslem Empire. As if these people were awaiting the opportunity, they rapidly spread their new faith from Spain to India, interacting further with the Greek, Chinese and Indian cultures. The shipping and sea trade industries prospered during the Islamic Empire as trade between Moslem ports grew as well as with other countries. The security provided by the power of the new empire and the new developments in sailing technology especially the introduction of the lateen sails, the use of the magnetic compass, invention of the sextant and development of more accurate maps enabled the Moslem sailors to expand trade to China and enjoy supremacy of the seas.

As Moslem Empire broke into smaller kingdoms divided by territorial disputes, the domain of the Moslem fleet shrank with time but remained strong in the Region until the arrival of European naval forces in the fourteenth century coming with bigger, metal-based ships and with maritime and sailing knowledge acquired, but further refined, from Moslem sailors. By 1515 the Portuguese colonisers began their campaign to control the area. They were soon followed by the Spanish, Dutch, French and the British. After stiff resistance by the Quwasims, with their fleet of about 700 ships and over 18000 men, that lasted until the second half of the 18th century, the British occupied Ras Al-Khaimah and marked an end to the supremacy of the "DHOWS" (Price, 1986). Maritime activity in RSA then became restricted to trade with India and Eastern Africa, pearl diving, fishing and inter-regional trade until the time of oil discovery and exploitation in the twentieth century.

### 1.1.3 Physical-geographical features of the RSA

The RSA comprises three geographically distinct parts that also exhibit distinct physical and biological characteristics and different meteorological conditions, as follows:

1.1.3.1 *The inner RSA*

This is the marine area west of 56°E longitude, extending along NW/SE axis from Strait of Hormuz to the northern coast of Iran. High mountains surround it on the Iranian side and low-land on the Arabian side. The coastline extends over a length of about 1000 km. with a water surface area of 239,000 $km^2$. The inner RSA is in effect a shallow embayment having a mean depth of about 35m with maximum depths between 90 and 100 m at its north-eastern side near the coast of Iran, and about 100 m near its narrow entrance at the Strait of Hormuz which connects it to the Gulf of Oman and the Arabian Sea (Emery, 1956; Kasslar, 1973). The Strait of Hormuz is only 56 km wide at its narrowest point and has no sill; the trough simply deepens to more than 100 m through the Strait and drops quickly to more than 2000 m within 200 km outside the Strait. The maximum width of this inner part of RSA is 338 km and its volume of water is estimated at about 7,800 $km^3$ by Linden *et al.* (1990) and at about 8,630 $km^3$ by Reynolds (1993).

The shallowness of this area makes its response to meteorological variables quick and dramatic. Being surrounded by a desert landmass on the one side and mountains on the other, enhances the water evaporation and makes the water exchange through the Strait of Hormuz quite active (Hunter, 1985). When considered closely, it is seen that the area is a mosaic of smaller areas particularly on the western side where one could distinguish an estuarine area in the extreme north near the mouth of Shatt Al-Arab, an extremely shallow area between Saudi Arabia, Bahrain and Qatar (Salwa Bay) and a broad shelf area between Qatar, the United Arab Emirates and Oman (Hassan and El-Samra, 1985). Figure (1.2) illustrates the bathymetry of the inner RSA.

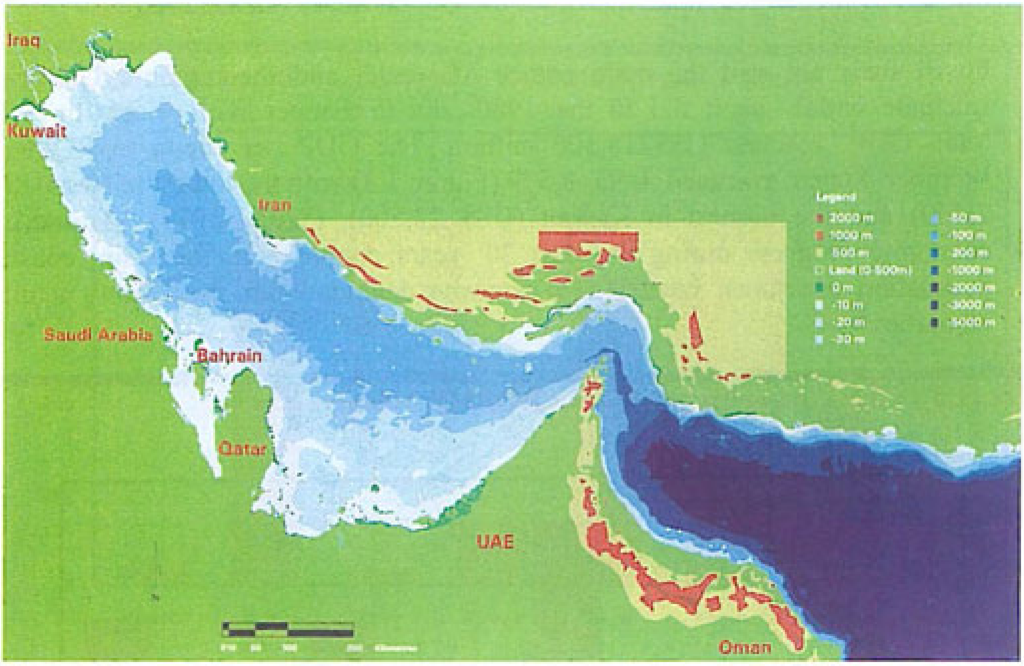
1.1.3.2 *The middle RSA*

This part comprises the Gulf of Oman, which is a deep basin with depths exceeding 2,500 meters along its central channel and 100 meters at the Strait of Hormuz. It has free access to the Arabian Sea and the Indian Ocean. It is, however, not in the monsoon belt. The middle RSA is an important link introducing the ambient oceanic waters to the inner part of RSA and allowing its warm saline water to form a bottom layer exiting via the Gulf of Oman. On the Iranian side, it extends from the Strait of Hormuz to Chah Bahar at the Pakistani border. The bathymetry of this part is shown in Figure (1.2).

1.1.3.3 *The outer RSA*

This part extends from Ras Al-Hadd to the southern border of Oman and exhibits a wide range of physico-geographic features ranging from the well developed sandy shores with a large continental shelf to rocky highlands with a narrow continental shelf. It is an integral part of the Indian Ocean, and lies around the low twenties of the northern latitudes, in the monsoon ring, bounded to the north by the relatively mountainous landmasses of Oman and Iran, and deepening rapidly to the south with no barriers separating it from the Arabian Sea and the rest of the Indian Ocean.

**Figure (1.2): Bathymetry of the RSA.**




(ROPME/UNEP, 2000)

## 1.2 Socio-Economic Considerations

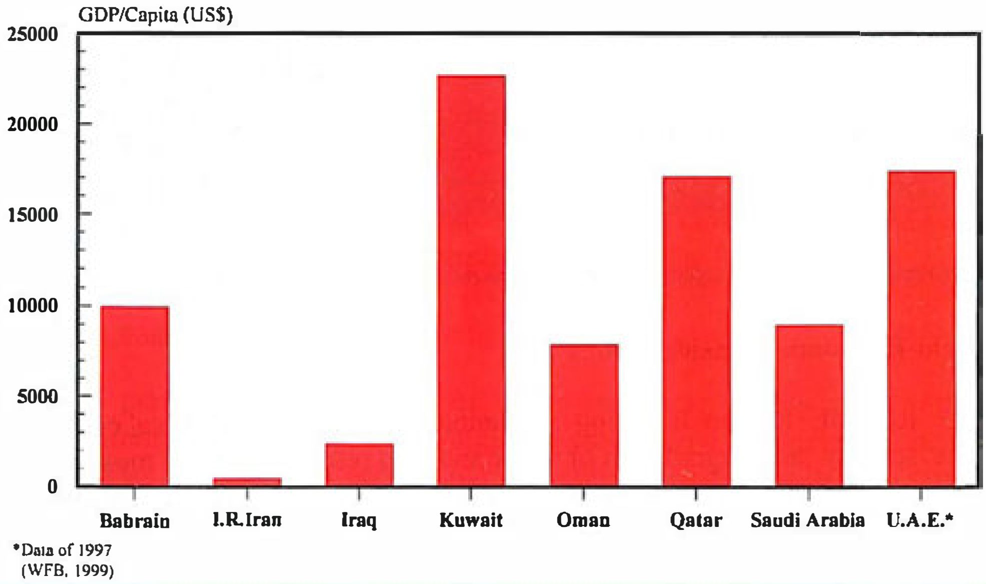
The ROPME Region is facing a number of major environmental challenges. The scarcity and degradation of water and land resources are the most pressing ones. Degradation of the marine and coastal environment, loss of biodiversity, industrial pollution and hazardous wastes are also major threats to the socio-economic development in the region.

The discovery of oil in the early 1930s heralded a new economic and environmental chapter in the region's history. The eastern areas of the Arabian Peninsula and northern Iraq emerged as the main sources of fossil fuel (oil and gas) in the world. With this came a period of rapid socio-economic transformation with unprecedented rates of urbanisation, hastily planned industrialisation, mass immigration towards the oil-rich states from other parts of the region, as well as an influx of expatriates from outside the region. The combined effects of these influences together with rapidly transformed life styles and consumption patterns have been overwhelming (GEO, 2000).

About 1.2 million barrels of oil are spilled into the RSA annually (ROPME/IMO 1996). The level of petroleum hydrocarbons in the area exceeds that in the North Sea by almost three times and is twice that of the Caribbean Sea (GEO, 2000). ROPME Member States generate from 2-8 times more hazardous wastes per capita than does the United States (GEO, 2000).

Fossil fuels are still the main source of wealth and the region's GDP can fluctuate widely as it did in the 1980s, due to changes in oil prices. In 1995 total GDP reached US$218,500 million. The GDP per capita in ROPME Member States averaged US$ 8,579 (Figure 1.3) with the lowest in Iraq (US$ 2,400) and the highest in Kuwait (US$ 22,700), (WFB, 1999). However, economic progress during the past 30 years, coupled with increasing coastal population pressures, have led to extensive degradation of the region's natural resources.

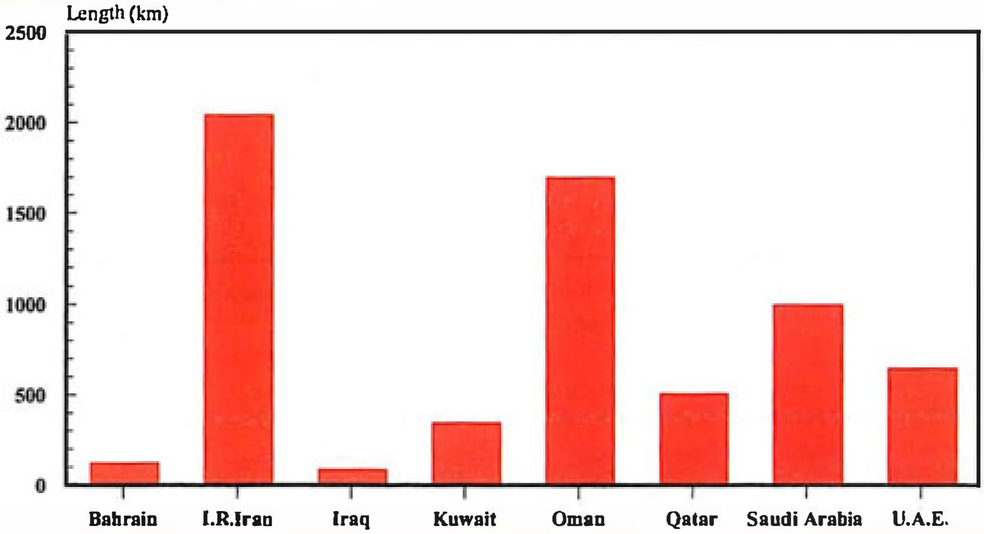
**Figure (1.3): Gross domestic product in ROPME Member States.**




During the past half century, population increased more than fivefold from just under 20 million in 1950 to 111.4 million in 1999 (WFB, 1999). The average population growth rate is ranging from 1.07% in I.R. Iran to 5.1 in U.A.E. Whereas it is 2.44, 3.19,3.88, 3.45, 3.62, 3.39% in Bahrain, Iraq, Kuwait, Oman, Qatar and Saudi Arabia, respectively. The average life expectancy rate is around 72 years ranging from 66.5 in Iraq to 77.2 in Kuwait. The females in this region are generally exceeding the males in terms of life expectancy rate (2-5). The harsh environmental condition may have accounted for this variation.

The coastlines of ROPME Member States is short in Iraq (90 km) but reach 2,043 km in I.R. Iran and 1,700 km in Oman (Figure 1.4). Marine resources have supported coastal populations for hundreds of years, and nourished the development of a maritime and trading culture linking Arabia and Africa with Europe and Asia.

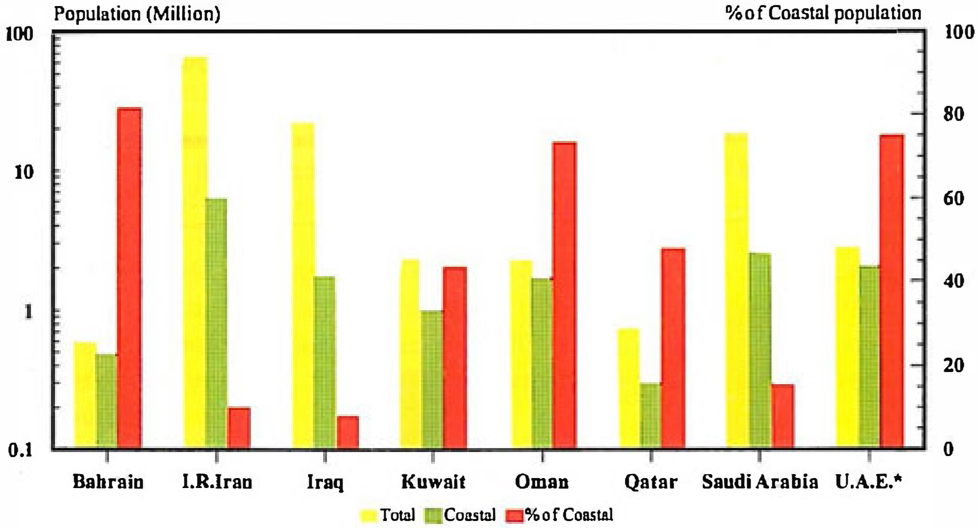
**Figure (1.4): The length of coastline in ROPME Member States.**




Until the turn of the century, the environmental impact of human development on coastal areas was limited to port areas. Fisheries were mainly artisanal, which left fish stocks nearly undisturbed. However, by the end of World War II the marine environment began to show symptoms of ecological imbalance caused by physical alteration of the coastline and coastal habitats by infilling and dredging, increased sewage output, the release of industrial effluents, dumping of oily wastes from tankers and oil-loading terminals, and dumping of litter from both land and sea-based sources.

From the late 1980s to the early 1990s, the region was affected by two Wars, which had devastating effects on the environment. Subsequent reconstruction resulted in substantial developments along the shores of the affected countries. The uncontrolled expansion of coastal cities in which much of the region's population lives during the 1990s put even more pressure on the marine and coastal environment. The population continues to encroach on coastal areas. In Bahrain, U.A.E. and Oman, for example, 81.7, 74.6 and 73.4% of the population occupy the coastal areas, which constitute only 37.3% of total area Figure (1.5). Such a dense population would pose more stress to the marine area.

**Figure (1.5): Total and coastal population in ROPME Member States.**




* Estimated Figure

Discharges into the sea come mainly from industries that are represented by petroleum processes and refining, petrochemicals, desalination, cement and construction materials, textiles, ship repairing and food processing. In the northern part, pollutants related sources are associated with sewage, organic pollutants such as pesticides, heavy metals and oil (WFB, 1999). Population growth and the concentration of population along the coasts do not match the pace of infrastructure development. Liquid wastes from coastal cities, villages and resort areas are often discharged directly or indirectly to the sea without treatment, causing eutrophication in coastal waters (GEO, 2000). Recreational sites along the coasts may contribute to the eutrophication problems along the north western part of the RSA.

In the Arabian Peninsula, land-based pollution from industry dominates and includes:

- Petroleum hydrocarbons from refineries, petrochemical industries, oil terminals, oil spills from ships and pipeline disposal at sea of oil-contaminated ballast water and dirty bilge, sludge and slop oil.

- Solid waste discharges include household refuse of 0.5-1.5 kg/person/day and food wastes of 1.4-2.4 kg/person/day (IMO 1995). However, this situation is being improved as a result of co-operation between ROPME, GCC and the European Union.

- About 20-30% of the sewage discharged into the sea is estimated to be untreated or only partially treated (ROPME 1996). This poses a potential threat of eutrophication in confined areas such as bays.

- Sand and dust depositions from the atmosphere as high as 29g/m$^2$/year have been reported (Gharib *et al.*, 1985).

- Levels of persistent organic pollutants (POPs) are still relatively low but screening of contaminants in marine sediments and biota have also revealed low levels of halogenated pesticides, PCBs and organic phosphorous compounds. (IAEA, 1999).

- Heavy metal concentrations are generally low but there are hot spots near the old outfalls of chemical plants where there are relatively high levels of mercury (Al-Majed, 2000). Copper and nickel levels are also relatively high near the outfalls of desalination and power plants (Saeed *et al.*, 1999).

- Discharges of concentrated and hot brines from desalination plants.

The region contains only about 8% of the world's mapped coral reefs (GEO, 2000) but almost two-thirds of those in the RSA are classified as at risk, mainly as a result of over-fishing and because more than 30% of the world's oil tankers move through this area every year (Downing and Roberts, 1993).

Fisheries are an important resource in the ROPME Member States. The fish harvest is decreasing because of coastal pollution, over-fishing, the use of destructive fishing techniques, and inadequate fisheries management (GEO, 2000).

The impact of the events of the past 30 years or so on the environment has been considerable. The most pressing environmental concerns are seawater quality, degradation of marine and coastal environments, and coastal reclamation. Other major environmental issues include deteriorating conditions in coastal settlements, the loss of biodiversity, industrial pollution, and inappropriate management of toxic chemicals and hazardous wastes. Power and desalination also accounts or results in an increase of temperature in the receiving basins. This will eventually add more stress to the ecosystem health in the region.

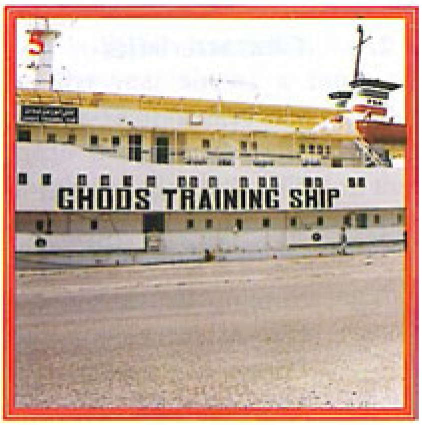
These rapid and profound changes have produced serious environmental management problems. State environmental authorities are generally young, and experts are needed not only to address current issues but also to study the depletion of natural resources and the pollution of the environment. Environmental issues are gradually coming to the forefront of national concerns. There are also encouraging sings of an emerging awareness among the public of the need to protect the environment. The past two decades have seen the emergence of environmental NGOs that are beginning to promote popular support for national efforts to protect the environment. The business community has also begun to take its environmental responsibilities more seriously (GEO, 2000).


War has caused extensive damage to the marine environment of the RSA. The Iran/Iraq War, which lasted eight years, targeted refineries, oil terminals, offshore oil fields and tankers; however, the 1991 War exceeded all other environmental disasters of the past four decades. About 6-8 million barrels of oil were released into the marine environment (PAAC, 1999). Fallout from burning oil products produced a sea surface microlayer that was toxic to plankton and the larval stages of marine organisms. The long-term impacts of these wars on fisheries and the marine environment in general have yet to be assessed. Several projects to assess the long-term impact of the 1991 environmental catastrophe on Kuwait's ecosystem including, terrestrial, marine and fishery are being carried out in Kuwait since 1991. Respiratory problem and other illnesses as related to the crises are also included in these studies. Ten projects covering the environment and health are all included in the agreement between the Public Authority for the Assessment of Claims (PAAC) and the Kuwait Institute for Scientific Research (KISR), (KISR/PAAC, 1998).

Over the next ten years, coastal areas will become more crowded and the pace of development, tourism and industrial expansion will increase the pressure on these areas. It is with this background in mind and based on the existing scientific data and information that the present State of the Marine Environment Report in being prepared.

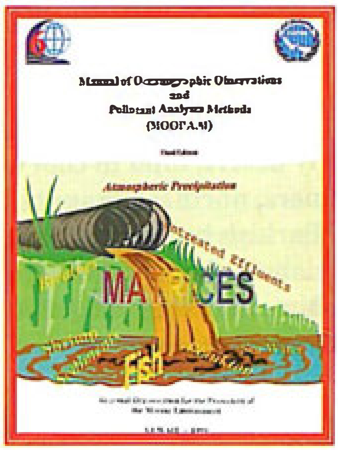
# CHAPTER 2

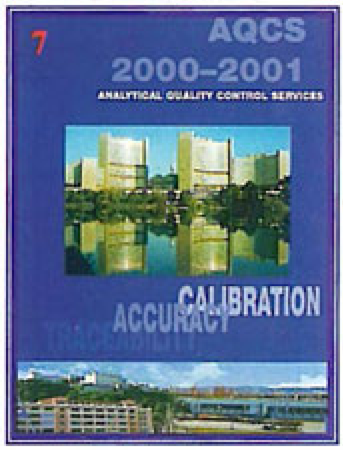
# ENVIRONMENTAL CHARACTERISTICS OF ROPME SEA AREA




The general climatic and meteorological conditions prevailing in the region, as well as the physical, geological, chemical and biological characteristics of the RSA are described below, so as to provide a reasonable review of the characteristics of the marine and coastal environment, based on the best available data and information.

The scientific information used in this review include data obtained from ROPME's Marine Pollution Monitoring and Research Programme, initiated under the Kuwait Action Plan (KAP) since the early years of its existence. ROPME's regional monitoring programme, originally known as the "18-Month Monitoring Programme", initially aimed at recording the oceanographic characteristics of the RSA as well as collecting baseline data on the levels of various oil and non-oil pollutants.




ROPME has developed its monitoring programme over the years to address coastal monitoring by Member States as well as to include data obtained from open sea cruises, remote sensing and through applying advanced techniques such as the Geographic Information System (GIS). Further, in all ROPME's monitoring activities, international standards and "Reference Methods" are routinely used in accordance with ROPME's Manual of Oceanographic Observations and Pollutant Analyses Methods (MOOPAM) and the application of quality assurance (QA) and quality control (QC) with mandatory intercalibration.

## 2.1 Characteristics

### 2.1.1 General climatic and meteorological conditions

The RSA is located in the North-Temperate tropical margin, a region that encompasses most of Earth's deserts. This region marks the boundary between tropical cellular circulation and the synoptic weather systems of mid-latitudes. Sinking dry air in these latitudes produces clear skies and arid conditions (Reynolds, 1993). Local climate is influenced strongly by the Taurus and Pontic Mountains of Turkey, the Caucuses Mountains of Iran, and the Hejaz Mountains of the Arabian Peninsula. Extra-tropical storms generally track from northwest to southeast along the axis of these mountain ranges.

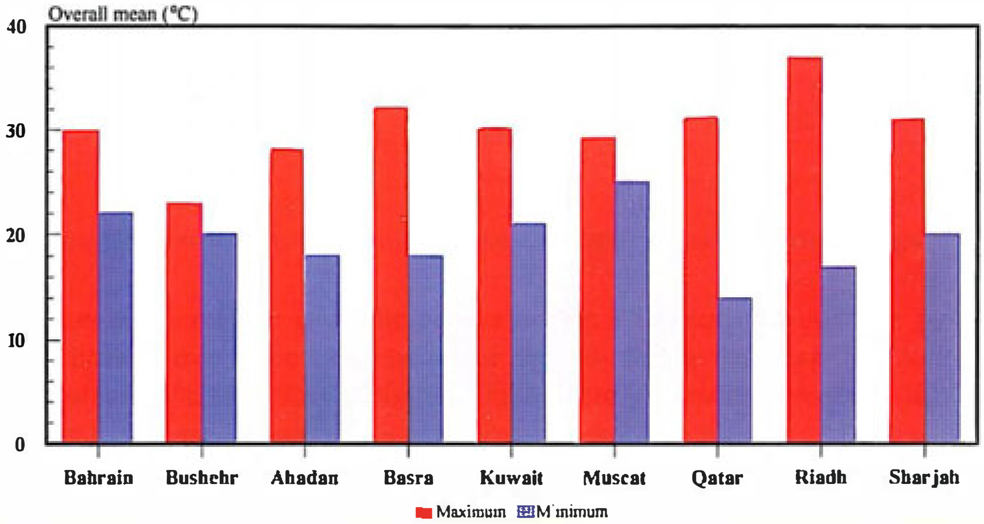
The RSA is therefore characterised by primarily dry climate that is associated with desert conditions. The general climate can be described as being very hot and dry in summer and relatively cool in winter with small amounts of rainfall in winter and spring (MEPA, 1989; Qatar, 1990). The winter and spring seasons in the region are very short, usually consisting of a two-month winter typically occurring in December and January, and often, only a single spring month typically occurring in March or April (Ali, 1994). The general climate for each Member State is summarised in Table (2.1)

**Table (2.1): The climate characteristics in ROPME Member States.**

| Member States | Type of Climate |
|---|---|
| Bahrain | Arid, mild, pleasant winters; very hot, humid summers |
| I.R. Iran | Mostly arid or semiarid, subtropical along Caspian Sea |
| Iraq | Mostly desert, mild to cool winters with dry, hot cloudless summers, northern mountainous regions along Iranian and Turkish borders experience cold winters with occasionally heavy snows that melt in early spring, sometimes causing extensive flooding in central and southern Iraq |
| Kuwait | Dry desert, intensely hot summers; short, cool winters |
| Oman | Dry desert; hot humid along coast; hot, dry interior; strong southwest summer monsoon (May to Sept.) in far south |
| Qatar | Desert; hot dry; humid and sultry in summer |
| Saudi Arabia | Harsh, dry desert with great extremes of temperature |
| U.A.E. | Desert; cooler in eastern mountains |

**Seasonality** in the RSA is closely correlated with air temperature. The temperature distribution of the RSA throughout the year shows a· range of values with the general pattern closely following topographic features and the local circulation. Winter is characterised by mean daily temperature below 20°C. The temperature in the northern part of the RSA is lower than in the southern part. In contrast to the cooler winter temperatures, the summer season is defined as the interval when mean daily air temperature is consistently greater than 30°C. The fluctuation between the temperature degrees during the year in some stations of Member States is very obvious as shown in Figure (2.1).

**Figure (2.1): Maximum and minimum mean temperature in ROPME Member States.**

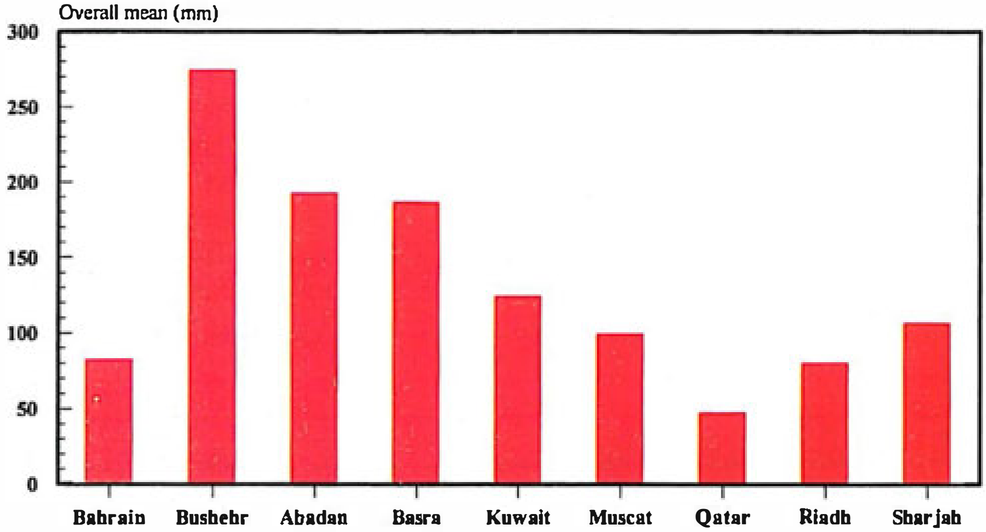



In general during the summer, air temperatures are extremely high. The Arabian Peninsula and the ROPME region are considered to be one of the hottest areas in the world (Takahasi and Arakawa, 1981). Temperatures in excess of 49°C have frequently been recorded at some stations in the region especially in the northern part of the RSA (Safar, 1985; MEPA, 1989; Qatar, 1990; Al-Kulaib, 1990). The climate changes over the past century in RSA had been studied by Nasrallah and Balling (1993). They observed 0.65°C increase in temperature and a small decline in precipitation. In 1997 a record temperature of 84°C in the sun and 52°C in the shade was reported in the open desert of Kuwait. While it is not unusual to record sub-zero temperatures in early morning of winter months of Kuwait. These large variations of temperatures require special adaptation capabilities in terrestrial and marine flora and fauna. Aksakal and Rehman (1999) during the period January studied the actual global solar radiation on a horizontal surface in the RSA coast near

Dhahran City–December 1999. They found that the highest daily and monthly mean solar radiation were 351 and 328 W/m$^2$ respectively where the highest one-minute solar radiation was 1183 W/m$^2$ which was reported in summer season.

The amount of **precipitation** in the region varies greatly, but a general trend of decreasing precipitation exists from north to south. The variability in rainfall is primarily due to the occurrence of thunderstorms, which in general do not have a well-defined pattern of occurrence on the Arabian Peninsula and the RSA. The overall mean in some stations of Member States is shown in Figure (2.2.1).

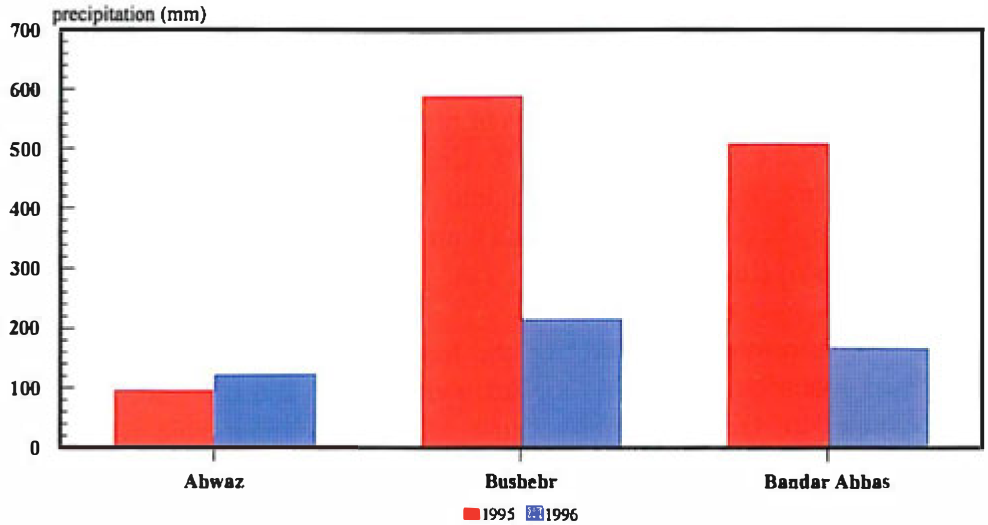
**Figure (2.2.1): The overall mean amount of rainfall in ROPME Member States.**




It is varied between 48 mm in Doha-Qatar to 275 mm in Bushehr – I.R. Iran. No values were reported for summer months (May–September) in those stations (OLI, 1999). Annual precipitation in the RSA averages 152 mm and is limited almost entirely to the winter months (Fouda, 1998). Hassan and Hassan (1989) gave an average precipitation value of 78 mm/yr. Here again, there is a large degree of variability from year to year, even within the same country. More detailed data from I.R.Iran showed that the annual precipitation reported the maximum (587.8 mm) in Bushehr city during 1995 while the minimum (94.1

mm) was reported in Ahwaz city during 1995 (Figure 2.2.2). The average precipitation during 1996 was 168 mm (LBA-I.R. Iran, 1999).

**Figure (2.2.2): Annual precipitation in I.R. Iran (1995-1996).**




**The wind regime** over the region of the RSA and the Arabian peninsula indicates that three types of wind prevail during the year: (i) Winter and summer Shamal (Shamal is an Arabic word that means "North"); (ii) Kaus (a local term used to describe a wind from the word southeast); and (iii) winds that prevail in coastal areas due to the sea breezes (Ali, 1994). However, the most prominent weather phenomenon in the RSA is the "Shamal" wind that blows down the axis of the RSA from the northwest in both summer and winter. The winter Shamal usually sets in with great abruptness and force between November and March, but seldom exceeds 10 meters/second. While a relatively rare event, the Shamal brings some of the strongest winds and highest seas of the season to the region.

The Kaus, on the other hand, blows from the south-southeast ahead of an approaching cold front. The Kaus winds increases in intensity as the front approaches, reaching to gale force. It should be noted that Shamal blow on the NW part of RSA and picks up humidity as it blows down the RSA axis. The Kaus increases in force as it blows towards the northwestern part, bringing more humidity in the summer months.

In the southern part of the RSA, winds are mostly westerly. Near the western side of the Strait of Hormuz, southwesterly winds are predominant. Wind patterns in the Gulf of Oman are strongly influenced by tropical circulation of the Arabian Sea with southwest monsoon winds during the summer and northwesterly in the winter months. A strong "sea breeze" occurs along the entire coastline, especially along the Arabian Peninsula. Driven by the intense temperature difference between the land and water surfaces, the sea breeze circulation adds a landward component to all winds. The effect of these winds is to drive floating pollutants to the beach much faster than they would move otherwise. Moreover, ground based thermal inversion is a common phenomenon, occurring up to 90% of nights over Kuwait mostly at 200 - 300 meters above the ground (EPC, 1992). Unlike sea breeze phenomenon, thermal inversion prevents plumes released into the air above the discontinuity layer from settling back on land. This had a profound affect on the behaviour of the oil well fires of Kuwait in 1991.

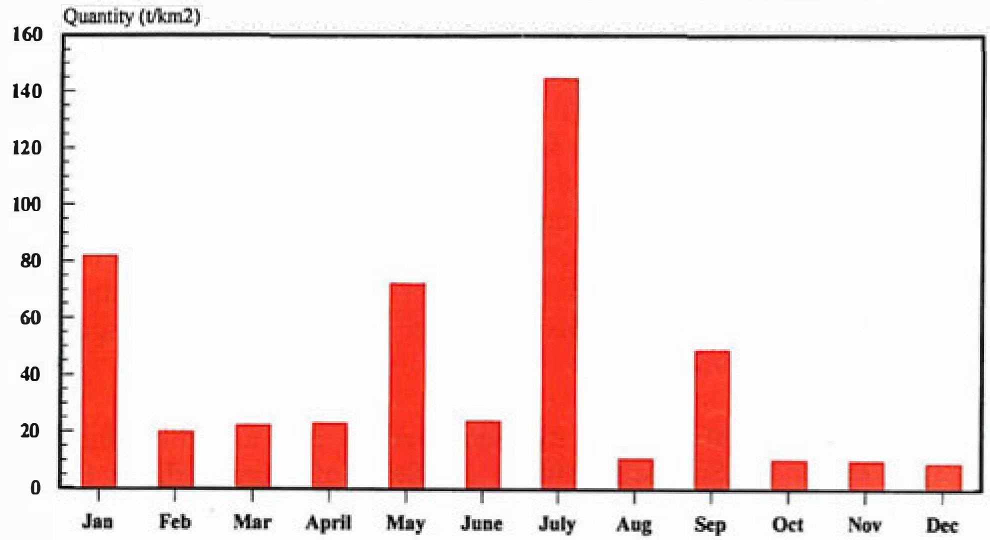
Dust and sandstorms are one of the important weather phenomena in the northern countries of the RSA: Kuwait, southern Iraq and I.R. Iran. This area is susceptible to these storms because of its low topographic relief, scanty vegetation cover, light-textured top soil and recurring strong and turbulent winds. These devastating phenomena have widespread adverse effects on the environment, the economy and the quality of life.

The dust storms passing over the northern part of the RSA are considered to be a major source of marine sediments (Khalaf *et al.*, 1982; Al-Bakri *et al.*, 1984). One interesting aspect of dust fallout in the area is its possible effects on the movement and fate of oil spills on the sea surface, acting as a sinking mechanism for oil droplets (Foda, 1984).


The amounts of dust fallout in the various dust storm regions have been discussed in Khalaf *et al.* (1980) who determined the monthly amounts of dust fallout along the coastal area of Kuwait for the period April 1979 – March 1980. They recorded the highest fallout in July (1002.7 t/km$^2$) and the lowest in November (9.8 t/km$^2$). The fluctuation of dust fallout during 1998 in Kuwait is shown in Figure (2.3). The concentration varied between 9.4 t/km$^2$ to145 t/km$^2$ with an overall mean of 40.2 ± 42.3 t/km$^2$ (EPA, 1999). Environment Public Authority in Kuwait (1996) used a high volume sampler in Shuwaikh Industrial

Area to monitor TSP. Samples were collected over a period of 48 hours, with TSP determined for the volume of air sampled. Results showed that the maximum concentration of 315 μg/m$^3$ was recorded in August while the minimum of 132.7 μg/m$^3$ was recorded in April. The overall mean was 207.8 μg/m$^3$ (EPD, 1996).

**Figure (2.3): Monthly mean dust fallout in the State of Kuwait, 1998.**




Dust can also act as a carrier for various types of pollutants, especially pesticides, by adsorbing them on the suspended particles and transporting them to remote areas (Risebrough *et al.*, 1968). Suspended dust can be transported over distances of up to several thousands of kilometers (Darwin, 1846, Delany *et al.*, 1967 and Prospero *et al.*, 1970) and eventually deposited partially in the Sea Area.

### 2.1.2 Physical characteristics, tidal movement, water circulation and water balance

#### 2.1.2.1 *Physical oceanographic characteristics*

General description of the hydrographic structure of the RSA has been reported by several authors, e.g. Grasshoff (1976), Brewer and Dyrssen (1985), Hunter (1986), Dorgham and El-Gindy (1991), El-Gindy and Dorgham (1992). A more comprehensive picture of the hydrographic structure of the RSA could be obtained from the results of three basin-wide studies carried out by different research vessels. Emery (1956) reported on a 1948 summer cruise by the German ship Meteor, Brewer and Dyrssen (1985) reported on the 1976 Winter-time Expedition of the Atlantis II from Woods Hole Oceanographic Institution

– USA, and Reynolds (1993) reported on a 1992 100-day Oceanographic Cruise by the NOAA Research Vessel Mt. Mitchell of USA. Several investigations of coastal water circulation patterns have also been carried out by individual countries.

**The surface water temperature** in RSA varies between 12°C in winter and >35°C in summer. The temperature difference between summer and winter is greatest (>20°C) in the northwestern part and least (<11°C) at Hormuz.

Due to high rate of evaporation in RSA, salinity increases gradually from southern to northern parts of the region with lower salinity along the Iranian side. In summer, the surface salinity varies from 34 ‰ off the Omani coast on the Arabian Sea, to 37‰ in the Gulf of Oman and up to 42‰ just off Bahrain. Salinity as high as 70‰ have been repeated in the Gulf of Salwah at its extreme southern extremity (Basson *et al.*, 1977). In winter, the salinity is somewhat higher than in early summer in the upper NW of RSA, apparently due to the variation of fresh water influx from Shatt Al-Arab and meteorological effects, particularly evaporation.

A surface flow of water of high temperature >28°C and low salinity of about 37‰ enters the Sea Area through the Strait of Hormuz during the summer season. This flow is also observed in the winter with temperature >20°C and salinity 39‰. The annual seawater temperature variations in the area, which reaches up to 20m depth in May and to deeper depths in February, might be related to air temperature and the vertical mixing intensity. The strong mixing in February leads to a vertical homogeneity and changes extended to deeper layers (Reynolds, 1993). In May, the thermocline acts as a barrier and limits the variation to the upper 20 meters (Reynolds, 1993).

According to the available data, the vertical thermal structure of the RSA has the following features:

a) In the winter time, north of Qatar, the water column is almost perfectly mixed top to bottom.
b) In the summer time, the northeastern end of the RSA becomes a two-layer system with a well-mixed surface layer and a well-mixed bottom layer that is a residual of the winter water.
c) At the extreme northern end, the depth becomes shallow enough that surface and bottom mixing can stir the water column over its full depth.
d) At the southern end of the RSA, the two-layer system persists year round. The upper layer of fresher water intruding from the Gulf of Oman to replace water lost by evaporation and the lower more saline water exits to complete the reverse-estuarine circulation.

2.1.2.2 *Tidal movement*

Tides in the RSA are complex and vary from semi-diurnal to diurnal. The tidal range is large with values greater than 1 m everywhere (Lehr, 1984). The dimensions of the Inner RSA are such that resonance amplification of the tides can occur and the result is that the semi-diurnal constituents have two amphidromic points while the diurnal constituents have one amphidromic point, in the centre near Bahrain. The tides in RSA are basically semi-diurnal. The tidal range is least in the central basin of the area, being about 1 to 2 meters in Bahrain. In the northwest, at Shatt Al-Arab delta, tides are normally about 2.5 meters, and in the South (in the Gulf of Oman), the range is about 2 meters. In Dubai (U.A.E.) and Lengeh (I.R. Iran) ranges of 3 to 4 meters are observed (Hartman *et al.*, 1971; Linden *et al.*, 1990).

The four main harmonic constituents of the tidal regime in the RSA as calculated by the British Admiralty (1976) were $M_2$, $S_2$, $O_1$ and $K_1$. Particular combination of the constituents to repeat itself requires about 19 years, although suitable approximation can construct an artificial tide cycle of about 24.8 hours which enables the main features of the Sea Area tides to be studied. The maximum amplitude of the four harmonic tidal components at the head of RSA and at the Strait of Hormuz is listed in Table (2.2).

**Table (2.2): Maximum amplitudes of the four harmonic tidal components.**

| Component | $M_2$ | $S_2$ | $K_1$ | $O_1$ |
|---|---|---|---|---|
| **Maximum Amplitude (in meters)** | **0.8, 0.9** | **0.25, 0.25** | **0.5, 0.3** | **0.3, 0.2** |
| **Location : 1st figure occurs at head of the RSA and second at the Strait of Hormuz** | | | | |

The tidal regime in the Omani coastal waters is predominantly of the mixed, prevailing semi-diurnal type i.e. there are two high waters and two low waters per day with a large diurnal inequality in high and low water levels. Average ranges around the Omani coast are between 1.5m and 2m, and maximum ranges are of the order of 3 m (WIMPOL, 1986). Another important and interesting feature observed at some locations of

the coast, for example in Kuwait, is that the semi – diurnal nature of tides may create a complex air exchange region as wind speed, wind direction and coastal morphology interact, affecting both the flow of air and seawater.

#### 2.1.2.3 *Water circulation*

Direct current measurements have not been made systematically in the RSA. Early hydrographic studies (Schott, 1918; Emery, 1956; Sugden, 1963; Brewer *et al.*, 1978) have indicated that the surface water movement is cyclonic inside the RSA. Evaporation and wind forcing have long been suggested as the major driving forces maintaining the RSA circulation. The former, i.e. evaporation has been emphasised by Sugden (1963) and Hunter (1982), while Wright (1974) and Hughes and Hunter (1979) argued for the importance of the latter.

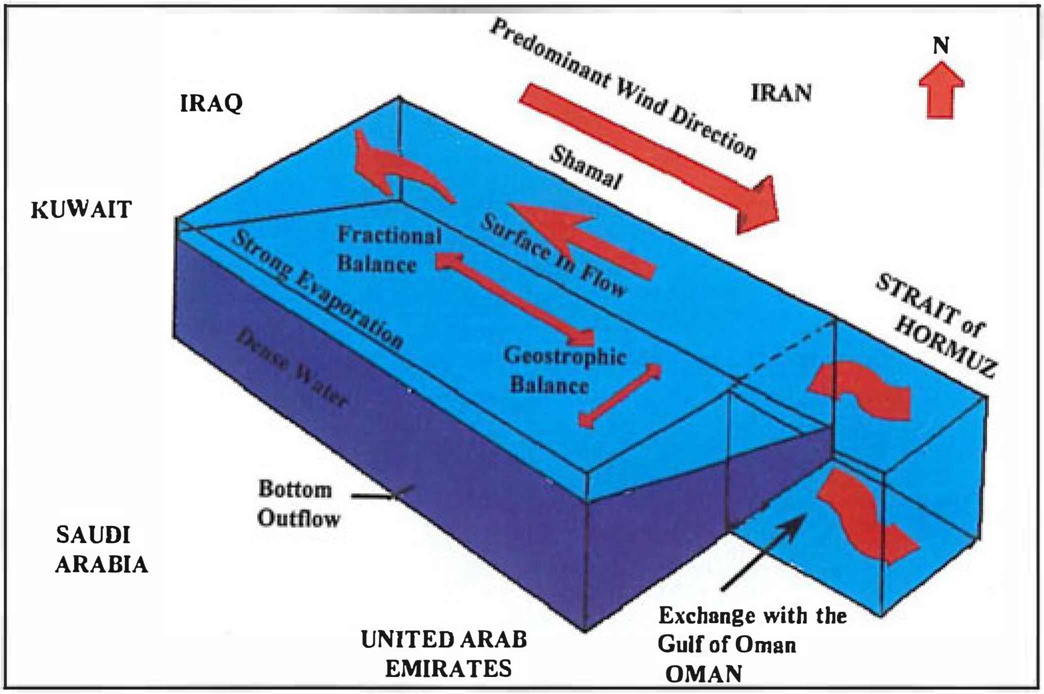
The early studies of the water circulation in the RSA suggest that the net freshwater loss to the atmosphere is replaced by a surface inflow in the Strait of Hormuz. Throughout the year and against prevailing Shamal winds, relatively low-salinity water enters the Inner Sea Area through the Strait of Hormuz freshening the hyper-saline Inner Sea water. As it enters, it undergoes evaporation, becomes more dense and sinks to exit the Inner Sea as a high-salinity undercurrent through the deeper portion of the Strait of Hormuz (Al-Hajri, 1990). This circulation is called “reverse estuary flow”.

Hunter (1982) made a quantitative assessment of surface currents using ship drift data collected by the British Meteorological Office up to 1981. The proposed surface current pattern in the four seasons and the all time mean flow field generally indicate a surface flow westward into the RSA along the Iranian coast (~10 cm/sec). The inflow from the Strait of Hormuz is quite evident and appears to be stronger (about 20 cm/sec) in summer and weakest (about 10 cm/sec) in spring and autumn. An early sketch by Hunter (1983) shows that the main features of the residual circulation in the RSA (Figure 2.4) are characterised by:

(a) High- and low-salinity water exchange in the Strait of Hormuz.
(b) Density-dominated circulation in the central and southern Inner Sea.
(c) Frictional balanced, wind-dominated regime in the NW Inner Sea.
(d) Evaporation-induced bottom flow.

The actual pattern of circulation is more complex than that shown in the sketch. Surface inflow occurs year round, but is more pronounced and extends deeper into the Inner Sea in the summer. However, in the winter the density difference is primarily due to the relatively low salinity water of the Gulf of Oman, where in summer both temperature and salinity strengthens the density difference. Reynolds (1993) used progressive vector diagrams (cumulative sums) of the filtered current vectors to study surface circulation in the RSA. The results substantiated the density-driven, reverse-estuary circulation pattern and clearly demonstrated the general pattern of in-flowing surface current and out-flowing bottom current. Overall mean currents were in the neighbourhood of 5 cm/sec., and a weak, cross-basin flow of about 2 cm/sec was evident in the records.

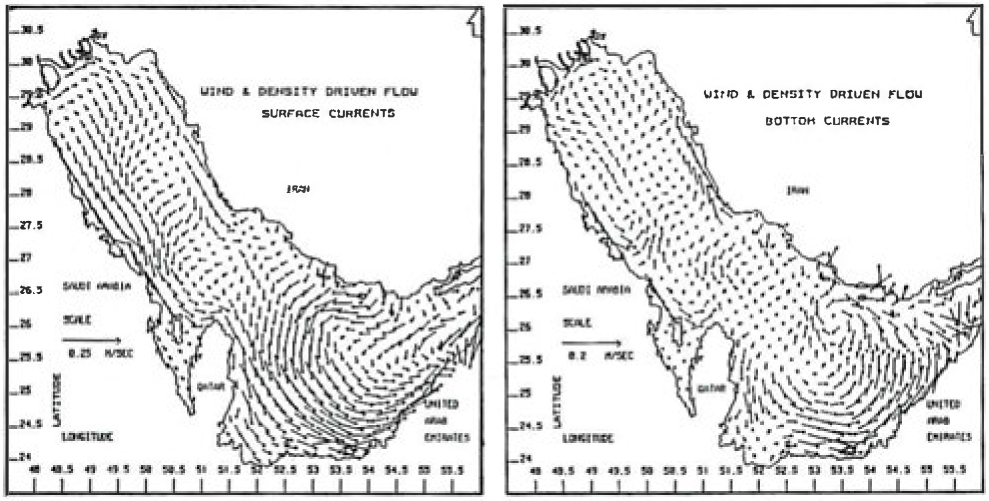
**Figure (2.4): Density-driven circulation of the RSA (Hunter, 1983).**




A three-dimensional hydrodynamic model was developed by Chao *et al.* (1992) to study the circulation in the inner RSA. The model contains realistic basin geometries and bathymetries of the inner RSA and a good portion of the Gulf of Oman and is driven by monthly climatological winds, evaporation and net heat gain by the Sea Area and the Shatt Al-Arab discharge. The model generates additional details of the circulation patterns that are otherwise unavailable from observations. The model succeeds in reproducing the seasonally varying cyclonic circulation in RSA. The cyclonic circulation is maintained by a surface geostrophic inflow and a bottom geostrophic outflow in the Strait of Hormuz. In the Gulf of Oman, the current toward the RSA tends to follow the southern boundary, accompanied by an anticyclonic eddy to the north.

The hydrodynamical models of the RSA developed at King Fahd University of Petroleum and Minerals-Research Institute (KFUPM/RI) have been used to compute the flows in the RSA driven by density gradient using the two sets of data collected on Legs 1 and 6 of the Mt. Mitchell cruise (Lardner *et al.*, 1993). The basic model in current use is called HYDRO1 (Version B). This model covers the whole RSA with a rectangular grid of approximately 10 km in size, the direction of the grid being chosen roughly parallel to the Saudi coast. The combined flow generated by the density gradients and the average winds for June are shown in Figure (2.5).

**Figure (2.5): Computed (a) surface (b) bottom follow driven by the average June wind combined with the density gradients from Leg 6 of Mt.Mitchell Cruise.**

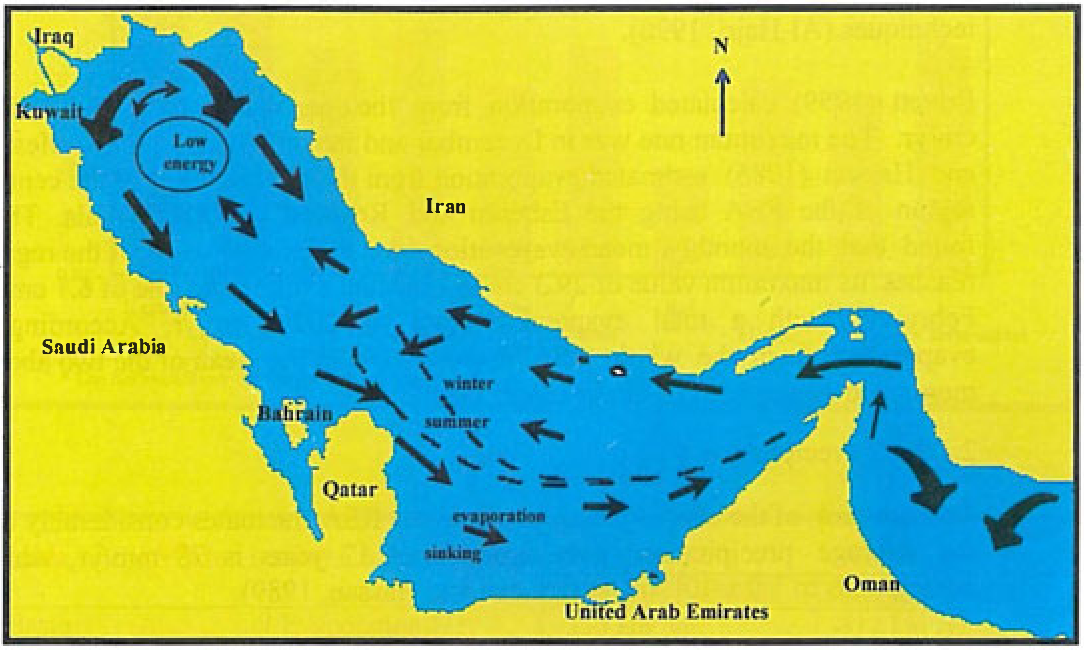



**(a)** **(b)**

In the Strait of Hormuz, there is a surface inflow with velocities reaching 15 cm/sec. The flow persists up the Iranian coast with the speed of 10 cm/sec almost as far as the Qatar peninsula. Near the bottom in this region, there is an opposite outflow towards the Strait. On the Emirates side of the RSA, the flow is strongly dominated by the wind, which generates an easterly surface flow of magnitude 12-15 cm/sec. This flow drags the bottom flow with it in the same direction (Lardner *et al.*, 1993). The pattern of surface velocities around the northern coast of Iran is anti-clockwise, however, being quite small (<4 cm/sec).

According to both Hunter's schematic circulation model described earlier [Hunter (1983), Figure (2.4)], and that proposed by Reynolds (1993) for the RSA (Figure 2.6), the flow is predominantly density driven with surface flow inward from the Strait of Hormuz and adjacent to the Iranian coast. A southward coastal flow is present along with entire southern coast of the RSA. The flow stagnates east of Qatar, where high evaporation and sinking forms a dense, bottom flow to the northeast and out of the Strait of Hormuz.

**Figure (2.6): Schematic of Surface Currents and Circulation Processes.**




(After Reynolds, 1993)

Circulation in the Gulf of Oman is dominated by a clockwise gyre in the west and a counter-clockwise gyre in the east. The interface between the two counter-rotating gyres is a region of upwelling along the Iranian coast. The circulation pattern seems to exist in winter and summer, but its strength and the upwelling depend on prevailing winds.

The only extensive set of current measurements were carried on the southeast coast of Oman in Al-Halaniiat Bay by Hunting Surveys Limited (1984-1985). The data shows a persistent westerly current set up in Al-Halaniiat Bay during the southwest monsoon at a time when offshore currents were set approximately northeast. Simultaneous wind measurements close to the mooring location show that wind direction was predominantly easterly, suggesting that local conditions here are considerably different from those further offshore. The data also suggests a dominance of wind driven currents over tidal currents. Current speeds throughout the year were <20 cm/sec, with maximum speed of 40 cm/sec, which is attained only occasionally.

### 2.1.2.4 *Water balance*

#### 2.1.2.4.1 Evaporation

Evaporation has a profound effect on the water and salt balances in the RSA and is one of the controlling factors in the process of water exchange with the Gulf of Oman through the Strait of Hormuz. Few attempts have been made to estimate evaporation from different zones of the RSA using different techniques (Al-Hajri, 1990).

Privett (1959) calculated evaporation from the open water of the RSA as 144 cm/yr. The maximum rate was in December and the minimum in May. Meshal and Hassan (1986) estimated evaporation from the coastal water of the central region of the RSA using the Esbesen and Reynold's (1981) formula. They found that the monthly mean evaporation from the coastal water of the region reaches its maximum value of 29.3 cm in June and a minimum one of 8.1 cm in February, with a total evaporation rate of 202.6 cm/yr. Accordingly, evaporation from the whole RSA may be taken as the mean of the two above mentioned values i.e. 172 cm/yr (Said, 1998).

#### 2.1.2.4.2 Precipitation

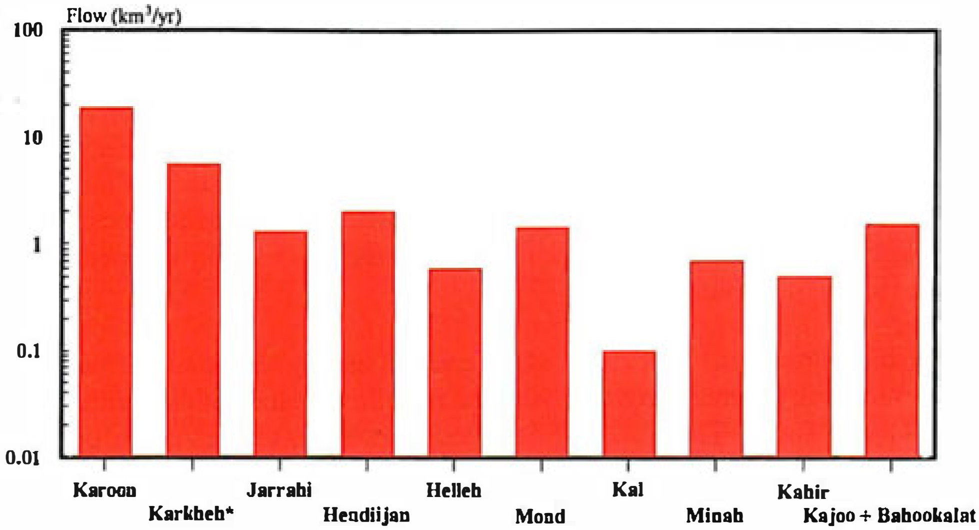
The amount of the annual precipitation on the RSA fluctuates considerably but the average precipitation over a period of 17 years is 78 mm/yr, which corresponds to $1.9 \times 10^{10}$ $m^3$/yr (Hassan and Hassan, 1989).

#### 2.1.2.4.3 Land run-off

Most river inflow into the RSA occurs in the north (Tigris, Euphrates and Karun) and primarily on the Iranian side. Records of mean annual flow measurements from the Iranian side are shown in Figure (2.8). Most of these rivers flow directly or indirectly through their tributaries to RSA. While Minab, Kahir, Kajoo and Bahookalat rivers flow to Gulf of Oman.

Based on available data and information on the three components of the water budget (evaporation, precipitation and run-off) such as those given above, attempts were made to calculate the water budget in the RSA and reach the water balance in the inner basin. Table (2.3) compares the results obtained by ROPME (1988) from the published Report of Linden *et al.*, 1990, and Reynolds (1993). Accordingly, renewal (residence) time, defined as the time it takes the water entering the inner RSA from the Gulf of Oman to completely flush the basin, is estimated at 3-5 years (ROPME) and 2.1 years (Reynolds). These values are important for consideration of the fate of contaminants. The two values are within the range suggested by Hughes and Hunter of 2-5 years (Hunter, 1985). However, without exact knowledge of the circulation in the Strait of Hormuz these values should be regarded as approximate.

## Figure (2.7): The annual mean flow of the Iranian Rivers.




* The Karkheh River discharges to Iraqi river system and eventually to RSA.

## Table (2.3): Water balance for the Inner RSA

| | | ROPME (1988) | Reynolds (1993) |
|---|---|---|---|
| Basin | Evaporation 1/<br>Precipitation 2/<br>Runoff 3/<br>Total loss | -350 $km^3/yr$<br>24 $km^3/yr$<br>5 $km^3/yr$<br>-321 $km^3/yr$ | -412 $km^3/yr$<br>19 $km^3/yr$<br>11 $km^3/yr$<br>-283 $km^3/yr$ |
| Strait of Hormuz | Inflow 4/<br>Outflow 4/<br>Total gain | 2696 $km^3/yr$<br>2375 $km^3/yr$<br>321 $km^3/yr$ | 10600 $km^3/yr$<br>10317 $km^3/yr$<br>283 $km^3/yr$ |
| | Volume of basin 8,400 $km^3$<br>Surface area of basin 240,000 $km^2$<br>Mean Depth 35 m | | |
| | Residence time | 3-5 yr | 2.1 yr. |

1/ A value of 0.4 $g/cm^2/day$ (equivalent to 1460 mm/yr) average those given by Privett (1959) has been used (compared with 100 mm/yr for the Mediterranean Sea).
2/ A precipitation of 100 mm/yr has been used.
3/ Average value given by Hartman *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.

### 2.1.3 Geological and sedimentological characteristics

#### 2.1.3.1 *Geology*

Geologically, the RSA has evolved by the interaction of the African and Eurasian plates. The Arabian Plate has been gradually moving northeastward, under thrusting Eurasia, for a considerable time. These movements have led to the slow closure of a vast waterway which once linked the Mediterranean and Indian Ocean, and in which a thick column of oil and gas bearing sediments, in excess of 10,000 m has accumulated.

In the northwest, the closure of the ancient seaway has been completed, and the former marine area is covered with the flat alluvial lands of the fertile crescent of Iraq and Iran. This lowland has been formed by the deposition of the load of sediment supplied by the Tigris-Euphrates-Karun luvial ystem ttracted o he low depression between the stable Arabian Shield and mobile fold belt of Iran, a composition for major river systems.

In the south, the history has been more complicated and the movements of the plates transporting Arabia and the adjacent Indian Ocean floor to the north-east has resulted in the anomalous Oman mountain range on the Arabian side of the depression.

The Inner Sea is a flooded-valley estuary. The evidence for the changing landscape of the region is provided by: drowned physiographic features obviously formed above or close to sea level such as valleys, coastal beach dune complexes, and abrasion platforms; and also by the presence of sediments with textural and compositional properties which indicate a shallow water origin (e.g., shallow water oolitic sands). Fauna found in the sediments show shallow-water characteristics at present depths well below their original levels of formation. The inner part can be considered to be geologically young in view of the fact that marine life started to be re-established only recently during the Holocene transgression (Sheppard, 1993). More details are also available in (SOMER, 1999).

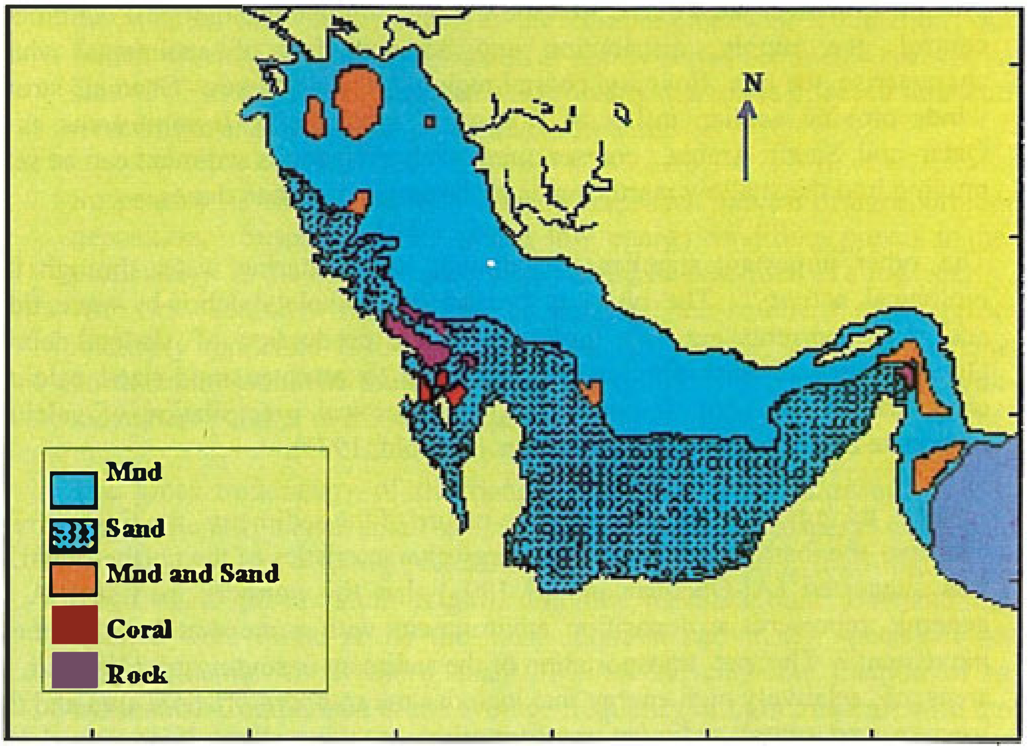
The western coast of RSA is generally low, flat and sandy. Beach sands may be cemented into beach rock. Often a sandbar overtopped by dunes isolates large lagoons flooded in winter but dry and covered by salt or gypsum for the rest of the year. Extensive algal and intertidal flats occur south of the Bahrain archipelago. The coast of the United Arab Emirates is characterised by a number of broad, sandy flats and lagoons and edges with barrier and fringing reefs. At the northern end of the RSA is the vast deltaic plain of the Euphrates, Tigris and Karun rivers that is formed of swamps, sandbars, spits and islands with fluctuating boundaries. The eastern coast is a region of extensive continental sedimentation. It is flat and low as far as Bushehr, then rocky and cliffed. In front of Ras Musandam the coast forms a large recess at the Strait of Hormuz, with two main islands, Qeshm and Hormuz. Along the north shore, cliffs and deltaic plains alternate (Chiffings, 1998).

The open, oceanic coast of Oman includes sandy and rocky stretches with ragged cliffs. The rocky shores are a major feature of the Gulf of Oman. The southern coast is composed of rocky headlands with cliffs alternating with shores of fine sands buffeted by oceanic swells (Chiffings, 1998). The sedimentological characteristics of the RSA as observed recently are discussed below.

2.1.3.2 *Sedimentological characteristics*

The RSA owes its sedimentary nature to the heavy rainfall during the Pleistocene which brought sediments from the Tigris and Euphrates rivers flowing through the marshes of Iraq and I.R. Iran (the Ahwar or Khors), the Karun and Karkha rivers from the Iranian Zagros mountains and the now extinct Al-Batin river from the highlands of the west central part of the Arabian Peninsula. The riverine input is reflected in the composition of bottom sediments (Figure 2.8).

**Figure (2.8): Sediment types in RSA.**




(After Carpenter *et al.*, 1997)

It can be seen that the fine (mud) sediments predominate the northwestern part of the RSA which could be attributed to the direct impact of the enhancement of aeolian action is represented by the increase in the rate of sediment transport. The transportation of fine-grained particles in suspension frequently occurs during dust storms usually initiated in southern Iraq. The particles migrate over Kuwait as thick dust clouds and finally settle in the northern part of RSA (Khalaf and Al-Ajmi, 1993). Also this could be reflecting the influence of the river inputs into the area. Much of the RSA floor is biogenic sediment, produced mainly from microorganisms, predominantly foraminifera. There is a wide range of other limestone-producing fauna and flora such as corals and some calcareous algae, though in terms of sediment production these are quantitatively unimportant. Carbonate sands are predominant in Saudi Arabia and the U.A.E. coast, whereas, on the Iranian side these are mixed with a greater proportion of terrigenous sediments from the wind, and numerous small riverine inputs (Purser and Seibold, 1973). It should also be noted that relatively large amounts of sand are deposited by the prevailing NW winds blowing across the axis of RSA. Khalaf *et al.* (1986) estimated that as much as 100 $t/km^2$ of sand are deposited annually in the inner RSA.

2.1.3.2.1 Sediment sources and processes

The unusual local climate of high aridity with evaporation in excess of precipitation over most of the area and the preventing oceanographic conditions control. the supply, distribution and accumulation of sediments which characterise the sea floor and coastal regions. The northwest "Shamal" strong winds provide aeolian influx of fine sand, silt and clay. In some areas, as of Qatar and Saudi Arabia, coarser quartz-rich terrigenous sediment can be seen moving into the shallow marine areas in the form of aeolian dunes.

The other important supplier of sediment is the marine water through the biological activity. The physical breakdown of skeletal debris by wave, tidal and storm currents are also important in the production of skeletal debris. Direct chemical precipitation of carbonate to produce mud-sized calcium carbonate is also of importance. Biochemical precipitation of calcium carbonate has been observed in the area (Seibold, 1973).

Finally, taking into consideration the nature of the sediments, the tidal current patterns, the bathymetry and low energy characteristics of the northern part, it was suggested (Al-Ghadban *et al.*, 1993) that the northern part of RSA, in general, represents a deposition environment with somewhat low sediment movement. The net transportation of the sediment is southward. However, in areas of relatively high energy that includes the southern offshore area and the western part, more sediment transportation is taking place. It is inferred that the sediments move N-S with a net sediment transport parallel to the axis of RSA.

2.1.3.2.2 Regional distribution of bottom sediments

The textural characteristics and regional grain-size distribution of bottom sediments in the RSA were discussed in detail by Al-Ghadban *et al.* (1996). Being subdivided originally into seven textural classes, the classification was simplified by grouping the sediments into four main classes: sand, muddy sand, sandy mud and mud. Data obtained from the grain-size analysis, simplified textural classification and lithologic description of the selected samples have been used to construct a map showing the regional distribution of the various textural classes of bottom sediments in the RSA (Al-Ghadban *et al.*, 1996).

Most of the area is covered with fine-grained sediments (mud and sandy mud) which occupy the deeper offshore areas as well as the sheltered depression in coastal areas. On the other hand, coarse-grained sediments (sand and muddy sand) occur mainly in the western area (offshore Bahrain, Qatar and U.A.E.) and as patches on and around islands and the rocky bottoms of the bathymetric highs.

The deposition of finer sediments along the eastern Iranian side compared with the western side is attributed to the counter-clockwise circulation from the Indian Ocean, whilst the deposition of poorly sorted sediments near the eastern side and in the northwestern area is probably due to the effect of tidal currents, river influx and deposition of aeolian sediments.

Suspension is thought to be the most important process of transportation and deposition. Suspension and hence low energy conditions prevail in the area, particularly in the northern part, which could be described as a low energy zone with low sediment movement. In contrast, the southern part represents a relatively moderate to high-energy zone with higher sediment movement. A north-south sediment transport from the northern part is inferred, with a net movement parallel to the axis of the region.

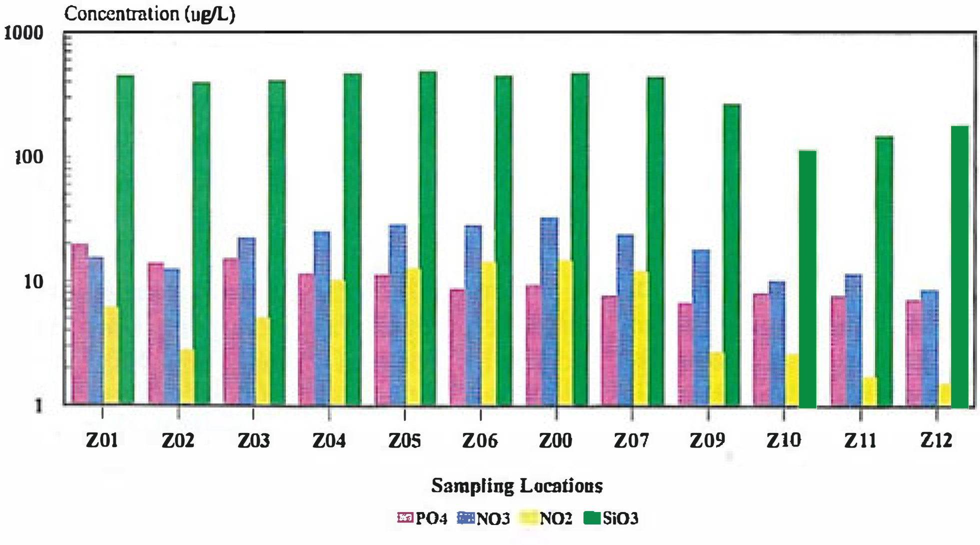
The gross mineralogy of the bottom sediments is biased towards carbonates, clay minerals, and a small amount of quartz and feldspars. Carbonates are represented by low-Mg calcites (of detrital origin), high-Mg calcite (of biochemical precipitation origin), dolomite, and aragonite. Low and high-Mg calcites were found to be the most common carbonates species in the area. Clay minerals form more than 70% of the clay-size fraction of marine sediments. Comparison of the average frequency of light minerals with those of the dust fallout and the Tigris-Euphrates basin sediments shows close resemblance in the light minerals constituents of the dust fallout and the RSA environment. This resemblance suggests that substantial quantities of the very fine sand and coarse silt fractions of the region are of detrital origin, derived from the dust fallout (Kukal and Saadallah, 1973; Al-Ghadban *et al.*, 1998).

### 2.1.4 Chemical oceanographic characteristics

Data on chemical characteristics of ROPME Sea Area have been increasing greatly since 1975, when a consultative meeting on marine sciences in the area was held in Paris (Grasshoff, 1976). However, comprehensive data that give a total view of the water chemistry of the area are still limited. In the literature one can find many good but sparse works that have been conducted in the area during the last few years as can be seen from the recent bibliography (Farmer and Docksey, 1983).

During the Umitaka-Maru Cruises (1993-1994) in RSA, measurements of oxygen, chlorophyll-*a*, ammonium, nitrates, phosphates and silicate were conducted along 5-7 transects between 28°N and the Strait of Hormuz, the results of this study were discussed in SOMER (1999). However data are available from some of the Member States as a part of their marine monitoring programme. In Kuwait a monthly sampling was conducted from 13 stations for the determination of nutrients, heavy metals, hydrocarbons as well as biological parameters. The reported mean concentrations were as follows: 7.1, 19.6, 4.9, 10.7 and 349 µg/L (Figure 2.9) for each of nitrites, nitrates, ammonia, phosphates and silicates, respectively (MNR-Kuwait, 1999).

**Figure (2.9): Concentration of nutrients in seawater, Kuwait 1998.**



In Bahrain, sampling was carried out twice a year (August and December) from 4 stations. The results showed that the concentrations of nitrites, nitrates, ammonia, phosphates and silicates ranged from 0.02-0.11, 0.38-0.77, 0.04-16.60, 0.04-0.23 and 0.8-64.7 μg/L, respectively (MNR- Bahrain, 1999).

In Qatar, sampling was carried out twice a year (May and September) from 21 stations. The results showed high concentrations range of most of the measured nutrients. For nitrites and nitrates where they are used to be determined as one parameter the concentration varied from 55.8-128.6 μg/L, silicates varied from 84.6-583.0 μg/L and ammonia varied from 67.4-127.2 μg/L. However, the concentrations of phosphates were almost the same in the two measuring periods (1.67 and 1.76 μg/L). The fluctuation in the nutrient concentrations could be attributed to the sampling locations, whereas the 21 stations are distributed over the long coastline of Qatar.

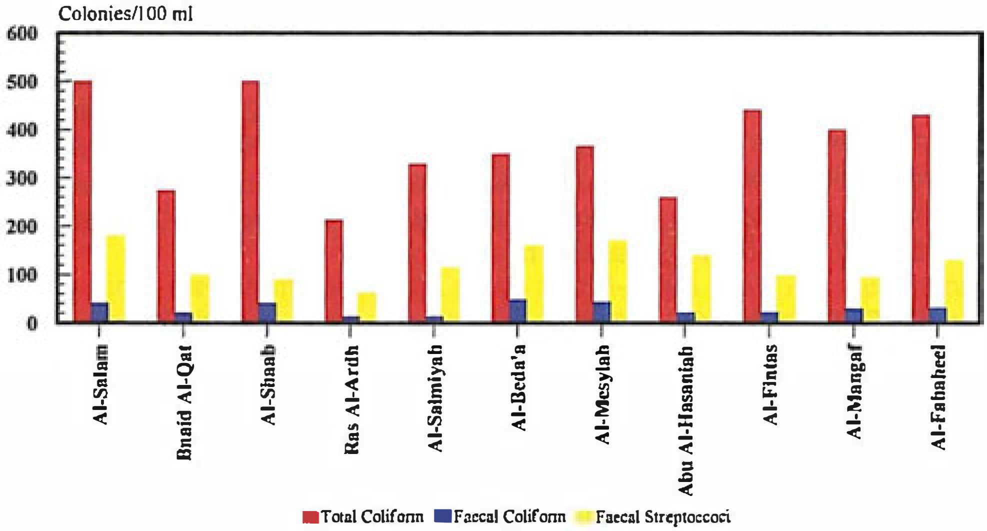
In UAE, Shriadah and Al-Ghais (1999) collected surface and bottom samples on monthly basis during the period of October 1993-September 1994 from twenty-four stations along the UAE coastline. The concentrations of the dissolved oxygen ranged from 3.63-9.02 mg/L, ammonia was from undetectable concentrations to 15.32 μg/L, nitrites also from undetectable concentration to 5.18 μg/L, nitrates varied between 0.07-14.32 μg/L, and silicates varied from 0.4-26.5 μg/L. The patterns of distribution indicated insignificant difference between surface and bottom layers due to the shallowness of the area, turbulence of the water column and the effect of sewage wastewater. Whereas the highest concentration were observed in the winter season with the exception for nitrates. At Sharjah, most of the nutrients decreased in a seaward direction due to the presence of the effective sewage pollution sources inside the creek. Shriadah and Al-Ghais (1999) concluded that the discharge of sewage and industrial wastes have affected the duality of seawater inside some semi-enclosed areas, especially Sharjah creek as indicated by the increase in the levels of BOD and the elevation in the concentrations of nutrients.

### 2.1.5 Microbiological and biological characteristics and major habitats

#### 2.1.5.1 *Microbiological characteristics*

The microbiological measurements are one of the indicators for sewage pollution in the marine environment. It has also been recommended in the list of parameters to be measured for any monitoring programme. However, the data are only available from Kuwait and can not reflect the status of marine environment in the ROPME Sea Area. The results as shown in Figure (2.10) show the median concentrations of total coliform, faecal coliform and faecal streptoccoci which were varied between 214-500, 12-47 and 63-180 colonies/100ml, respectively (MNR-Kuwait, 1999).

**Figure (2.10): Median concentrations of microbiological parameters of Kuwait coastal water, 1998.**

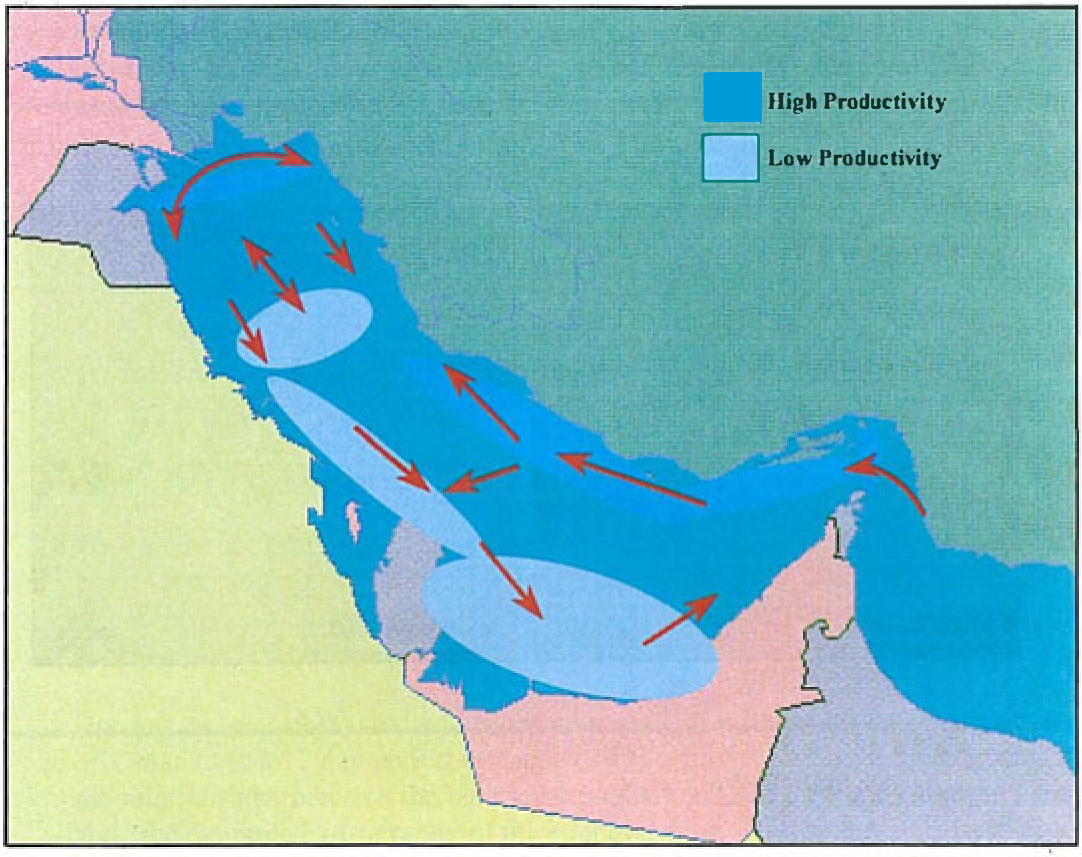



## 2.1.5.2 *Biological productivity*

### 2.1.5.2.1 Primary and secondary productivity

The productivity of the marine ecosystem of the RSA, particularly in the inner RSA and except at the mouth of rivers, is mostly associated with the mudflats. However, if compared with other seas, we find that water column primary productivity is still relatively higher than that of the Red Sea, but lower than that of the Arabian Sea (Sheppard, *et al.*, 1992). Evidence suggests the system is nutrient-limited (N-limited), which may explain the massive increase of productivity around river mouths and sewage outfalls. However, the ecosystem apparently has a limited capacity for high levels of nutrients, as oxygen levels become low during the summer months with temperatures exceeding 30°C. Measurement of chlorophyll-*a* ranging from 0.2 to 0.86 mg/m$^3$ have been reported in the ambient marine environment of the inner RSA (Sheppard, 1993) which is not particularly high, whereas values around 0.5 mg/m$^3$ and greater have been reported from the Arabian Sea waters. Measurements carried out during the R/V Umitaka-Maru cruises (January 1993, December 1993 and December 1994) ranged from 0.44-2.84 mg/m$^3$ in a homogenous vertical distribution (Hashimoto, *et al.*, 1995). The mean daily primary productivity in the area studied was estimated to be 0.51 g $C/m^2$/day (ranging from 0.12-1.27 g $C/m^2$/day (Hirawake *et al.*, 1998). Based on the data available, the distribution of productivity in the inner RSA is shown in Figure (2.11).

**Figure (2.11): Distribution of productivity in the inner RSA.**



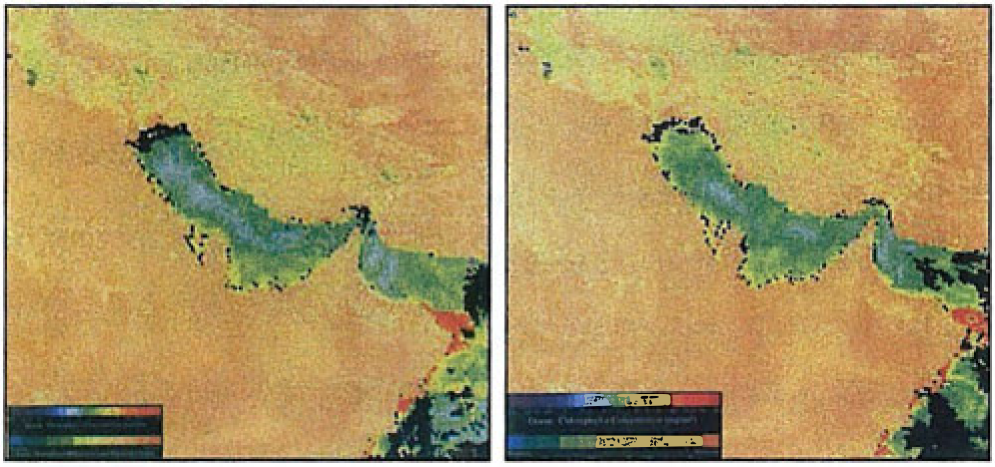

(After Hashimoto *et al.*, 1995)

Chlorophyll-*a* concentrations in Kuwait territorial waters ranged from 0.56 to 10.76 $mg/m^3$ with mean concentration of 2.23 $mg/m^3$ (MNR-Kuwait, 1999), whereas in Bahrain it varied within a very limited range of 4-6 $mg/m^3$ (MNR-Bahrain, 1999).

Barlow *et al.* (1999) found that the Gulf of Oman characterised by sub-surface chlorophyll maxima at 20-40 m during two seasons (SW monsoon in September 1994 and during the inter-monsoon period in November /December 1994). During the inter-monsoon season, total chlorophyll-*a* concentrations were generally half those measured in September and highest levels were found on the shelf (1.170 $mg/m^3$).

Utilising remote sensing analysis, chlorophyll concentrations were estimated in the RSA during two periods (7-13 September 1999 and 14-21 September 1999). Figure (2.12) indicates high concentration of chlorophyll in southern part of RSA (West Coast of Gulf of Oman) during the second period, ranging from 7.5-10 mg/m$^3$, which could be attributed to the upwelling phenomenon in this area. The figures also showed relatively higher concentrations in the shallow and coastal areas (4-5 mg/m$^3$) with the concentrations decreasing (0.2-0.3 mg/m$^3$) as the depth increased.

**Figure (2.12): Distribution of chlorophyll in RSA.**



2.1.5.2.2 Zooplankton

Zooplankton biomass in RSA varies both temporarily and spatially, as environmental factors vary from one to another and within seasons. Zooplankton derivative of up to about 2850 species/m$^3$ was reported by Basson *et al.* (1977) off coral islands. Price *et al.* (1993) compared abundance of zooplankton and penaeid shrimp larvae between the years 1975-1978 and 1992.

They found that total zooplankton biomass ranged between 0.85 ml/m$^3$ at Ras Tanura (1976) and 0.77 ml/m$^3$ at Safannia (1978) compared to 1.03 ml/m$^3$ and 0.24 ml/m$^3$ in 1992 respectively. Penaeid shrimp also showed a wide range from 6.77 nos/m$^3$ at Ras Tanura in 1976 and 16.704 nos/m$^3$ in 1978 at Safannia to 0.275 nos/m$^3$ and 0.009 nos/m$^3$ in 1992 respectively. Mean wet weight of total plankton and mean dry weight of dominant zooplankton including copepoda, ostracoda, chaetognatha and appendicularia were 14 g/m$^2$ and 526 mg/m$^2$, respectively. High biomass was observed in the northeast of the area where seawater with high temperature, low salinity and high concentrations of nutrient and chlorophyll-*a* was observed. Mean production in the area was 32 mg C/m$^2$/day. Large percentage in production by planktonic ostracoda next to that by copepoda is typical of this area. Secondary production in the area is comparable to those of upwelling areas, which have high productivity in the world oceans.

The major zooplankton groups were enumerated and identified during the Umitaka-Maru cruises (Al-Yamani *et al.*, 1998). Mean abundance of zooplankton was 20645±3282/m$^3$. Copepods were the most dominant group with a mean of 10680±1383/m$^3$. It was ranging from 41.3 to 62.7% composition of the total zooplankton abundance. *Calanoids* and *Cyclopoids* were equal abundant at all sampling stations, whereas *Ostracods* were more abundant along the eastern coast of RSA (Al-Yamani *et al.*, 1998).

In Kuwait the zooplankton biomass varied from 4.8 mg/m$^3$ (dry weight) in the inner part of Kuwait Bay to 288.0 mg/m$^3$ (dry weight) in the southern area of Kuwait territorial water (Ras Az-Zor) and the overall mean was 186.7 mg/m$^3$ (MNR-Kuwait, 1999). However, phytoplankton was varied from 2.7-4.9 g/m$^3$ (wet weight) with an overall mean of 4.9 g/m$^3$.

The plankton biomass in the northern, eastern and south eastern parts of Qatari waters were estimated at 100–500 mg/m$^3$, 200–500 mg/m$^3$ and 150–200 mg/m$^3$, respectively. These quantities indicate the high productivity of the water around Qatar (UN, 1997).

Herring *et al.* (1998) studied an area of some 120 x 70 km off the eastern coast of Oman over a 17 day period in August 1994 with the objective of determining the relationships between the biological populations, the oxygen minimum layer and the dynamic hydrography of the euphotic zone. Midwater trawls were used to sample the populations at three stations, oceanic, slope and shelf edge, respectively. Very marked changes took place in the hydrography and in the phytoplankton composition and abundance at the reference station at 19°N 59°E over the 16 day period between visits. The highest biomass of plankton and micronekton (expressed as wet volume or as carbon) occurred in the upper 100 m, closely correlated with the relatively high oxygen levels at these depths. Gelatinous animals predominated in these layers, with additional swarms of swimming crabs. Quite large populations of myctophid and photichthyid fishes and of decapod crustaceans were present below the oxycline by day. Most of these migrated into the surface layers at night, leaving minimal biomass behind, with the result that the ADCP backscatter data from beneath the oxycline at night were often below instrument resolution. Daytime ADCP data, on the other hand, showed multiple fine layering, some of which correlated with salinity differences. At the base of the oxygen minimum layer there was a large increase in biomass, marking the presence of a more typical bathypelagic fauna.


11

# Chapter 3

# Marine and Coastal Resources of ROPME Sea Area


The major habitats prevailing in the RSA are described in the first part of this chapter. In the second part, a brief account is given of the living and non-living resources of the RSA, which have been or are being exploited in the region, with a view to establishing the possible impact of development activities on the marine environment.

## 3.1 Major habitats

Deep and coastal habitats in the RSA are extremely variable and support a large variety of productive marine ecosystems. They range from exposed beaches to rocky highlands. Sand, mud and rock exist in both intertidal and sub littoral zones. Artificial structures (platform, jetties, etc.) and offshore islands play a considerable role in the variability of resources existing in the RSA. Sub littoral mud habitats are predominant in northern and eastern part of Inner RSA, while sand predominates in southern and western areas. Sub littoral rock exists in the Strait of Hormuz, in conjunction with islands and the southern coast of Oman.

Jones (1985) reviewed the coastal and marine habitats found in the RSA, categorising them into benthic deep and shallow subtidal habitats, intertidal habitats, rocky shores, sand shores and mud shores. He further indicated that the interaction of the physical factors in RSA produces a severe regime for the marine biota of the region, especially intertidally, so that diversity is lower within the inner part of the Sea Area than in the Gulf of Oman and the Indian Ocean in general. Although biological and ecological data on the marine biota of the region is dispersal available, with some coastal areas receiving more attention than others, at least four critical marine habitats, coral reefs, intertidal marshes, mangroves and seagrass beds, and kelp forest, have been recognised in the Region (Basson *et al.*, 1977; Barratt, 1984; Price, 1985). In addition, the importance of others such as intertidal sand and mud flats, algal dominated shores, and subtidal algal coral zones has been stressed (Price, 1985). In the pursuing paragraphs, a brief description is given of the major and critical habitats in the RSA.

### 3.1.1 Seagrass beds

Soft substrate seagrasses provide a mostly indirect food source and habitat for both resident fauna and temporary visitors, including commercially important fish and shrimps (e.g. *Penaeus semisulcatus*), pearl oysters and any other organisms. At least, four seagrass species are present in RSA, of which *Halodule uninervis* and *Halophila ovalis* are the most prevalent (Sheppard *et al.*, 1992). Their productivity is often enhanced by Cyanophya-dominated algal mats (Price, 1993). Further offshore, however, they appear to be patchy and less prevalent at least along the coast of Saudi Arabia. They occur along the coasts from Iraq, through Iran and Kuwait to beyond Bahrain and UAE. The distribution in Kuwait is limited. In Saudi Arabia, the greatest concentrations are between Safaniya and Manifa, in Musallamiyah and the south of Abu Ali, and in the Gulf of Bahrain (WCMC, 1991). In Bahrain, however, they are more extensive, though they do not generally extend deeper than 8 m (Price *et al.*, 1993). There appear to be more species at the Shatt Al-Arab entrance. This does not seem to be published description of seagrass associated with the Shatt Al-Arab. It is thought that there exist other species, which are unique in the area.

In the inner part of the RSA, more than 600 species of animals have been recorded among seagrasses (Basson *et al.*, 1977; McCain, 1984; Coles and McCain, 1990). Despite regional variation, available data suggest that both species richness and abundance of fauna are greater in the RSA than in Red Sea, at least in its northern parts (Biomass estimated at 0.05-0.24 g dry weight/$m^2$). Benthic fauna (within seagrasses and sand/silt) in the RSA are principally suspension feeders, which utilize more abundant organic particulate than occur in the clearer waters of the northern Red Sea.

Except for dugongs, green turtles, sea urchins and fish most species consume seagrass indirectly as detritus, after being broken down by mechanical and microbial action. To obtain an approximate qualification of productivity, Price and Coles (1992) have estimated that seagrass bed area as Tarut Bay (Saudi Arabia) could support production of 2 million kg of fish annually. The potential for sustainable development of commercial species of fish and shrimp is obvious.

Jupp *et al.* (1996) studied the seagrass communities at several locations on the coast of Oman. The main study site of their study was on the western side of Masirah Island on the Arabian Sea coast of Oman. This area is an important feeding ground for the green turtle, *Chelonia mydas L.*, and it is affected by upwelling of low temperature waters during the summer monsoon. They found that the depth distributions of Halodule uninervis (Forssk.) Aschers, and Halophila ovalis (R.Brown) Hook, f., the two most abundant seagrasses at this site, overlapped but were inversely related. Halodule dominated the intertidal zone and Halophila was more predominant in the deep subtidal, although total biomasses of the two seagrasses were similar in this depth zone. At all depths, biomass of Halophila was about equally distributed between leaves and roots and rhizomes. Leaf biomass of Halodule was only 7-20% of the total biomass and the highest below-ground biomass occurred in the intertidal zone. Their results showed that the reduced growth of seagrasses at Masirah Island seems to be due to stresses associated with the summer monsoon and grazing pressure, Survival of these populations is discussed in terms of seasonal growth and flowering.

### 3.1.2 Coral reefs

Hard bottom substrates include coral reefs and rock coastal formations. Their mix of colours and atmosphere tranquillity has fascinated divers in the RSA, some describing them as jewels of the sea. Historically, they were identified for their richness in fish and other marine life as well as the source for building material, and alter for ornament collectors. Although thought not to be present in such extreme conditions beyond the 23.5°C North and South of the equator, their presence in the RSA is a unique example of the adaptation by marine organisms. There are numerous patch reefs in the RSA, with coral islands representing the peak of their development. Because of scouring by loose sand in the water column, patch reefs support fewer and less dense communities than island coral reefs, which have extensive reef flats, which extend to depth of 10–20 m.

Given the extreme environmental conditions in the inner RSA, and the areas relatively short age in geological terms (<10,000 years), lack of opportunity resulting from absence of an intermediate platform in the Gulf of Oman, coral diversity is low in Indo-Pacific terms. About 55-60 zooxanthellate species have been identified in RSA (Sheppard and Sheppard, 1991). This is to be compared to about 200 species in the Red Sea and over 500 species (80 genera) from the western Pacific Ocean. Thus, given the protection and maintenance of the integrity of the ecosystem in the RSA, the potential for more species to drift from the Indian Ocean and settle in the RSA is one of the greatest gifts this generation can give to future generations.

The coral reefs in the inner part of the RSA occur in an environment with great extremes of temperature and salinity, as well as high turbidity. Normal winter temperature in the RSA is amongst the lowest at which coral reef exist (Downing, 1985). Both species diversity and percent coverage decrease approaching the shore, suggesting the coral survival is limited where physical conditions are more extreme. Only 57 hermatypic coral species occur on offshore island reefs, 24 of them are found on inshore reefs, and no corals are found where salinity exceed 46 (Fouda, 1997).

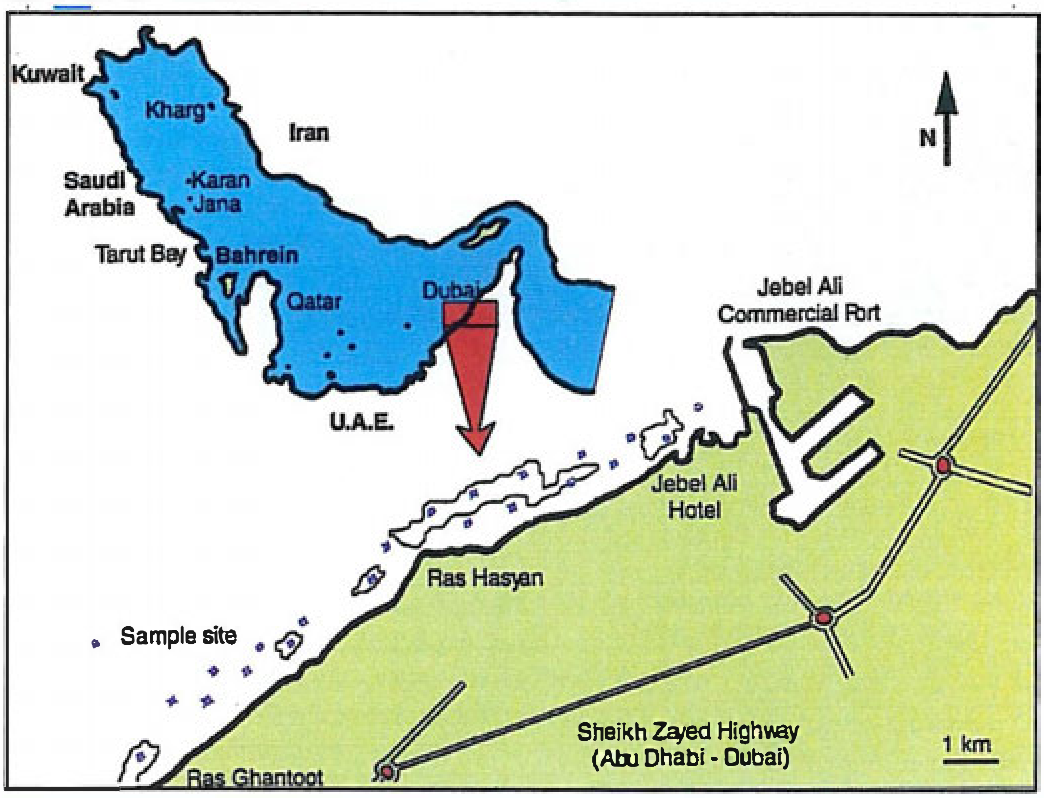
The most northerly reefs in the inner part of RSA lie around the coral islands off Kuwait where around 26 coral species are present, and like all known reefs in the RSA, they support insignificant coral growth below 15 m deep. Corals also occur in isolated colonies on rocky outcrops on the southern mainland of Kuwait. But towards the north of Kuwait, the influence of the Shatt Al-Arab's estuary conditions precludes corals. The Saudi Arabian islands have well developed reefs, with approximately 50 coral species occurring (Fouda, 1997). Patch reefs close to the mainland are much less diverse (McCain *et al.*, 1984; Coles, 1988).

Coral reefs in Bahrain and west of Qatar appear to be fairly representative of reefs located in the RSA near the mainland. Bahrain has numerous reefs along its northern and northeastern sides. The largest extent of patch reefs form a chain leading to deeper water north of Bahrain, estimated to provide a larger area of substrate than all coral islands of the Inner RSA combined (Price, 1993). Thirty-one coral species from 19 genera have been reported from Bahrain (Sheppard, 1985). Acropora of valenciennesi dominates cover > 80% over large areas at the 2-5 m depth around Fasht Adhm and other smaller northern reefs. *Porites compressa* co-dominates between 5 and 10 m depth at which diversity is greatest. *Porites nodifera* constructs substantial framework in higher salinity areas, and in these areas diversity is poor.

Water around Qatar is generally shallow which present major constraints against reef development. The west of the country borders the Gulf of Salwa where salinity is double that of oceanic water and thus, coral reefs are absent. On the northern and eastern coasts, salinity are less elevated and there is extensive coral growth. Coral reefs are shallow and are low in diversity but are well developed along the east coast. They are the central part of a long and broad line of reefs, which extend from Bahrain, down the east coast of Qatar and along the coast of the U.A.E. Shinn (1976) examined several transects leading out from the north and east coasts which crossed extensive reef areas consisting of many kilometers of *Acropora* thickets with some *Porites* and brain corals. A total of eight species of coral have been identified.

In U.A.E., Reef coral communities in a non-reef setting on shallow, flat hardgrounds were quantitatively sampled in Dubai (UAE) before and after a coral mass mortality in 1996 by Riegl (1999), Figure (3.1).

**Figure (3.1): Geographical location of sampled coral areas in Dubai-UAE.**




The coral fauna consisted of 34 scleractinian species (Table 3.1) before and 27 after the event, which removed virtually all *Acropora*. No alcyonacea were recorded. Five community types were identified and characterized by the dominant species: (A) a sparse *Porites lutea* community in sandy areas, (B) a dense *Acropora clathrata* community in areas with little sand, (C) a faviid community in muddy areas, (D) a *Siderastrea savignyana* community in sandy areas, and (E) a *Porites compressa* community, which built a framework in sandy areas. These communities are comparable to those described from other areas of the RSA, where a stable pattern of community differentiation appears to exist. The spatial distribution and dynamics of the coral communities appears to be strongly influenced by mass mortality events recurring every 15 to 20 y. A combination of extreme water temperatures and high sedimentation/turbidity appear to be the major cause of mortality (Riegl, 1999).

**Table (3.1): Coral species list of the st dy area in Dubai-UAE.**

| | |
|---|---|
| *Acropora clathrata* (Brook, 1891) | 1,2,3,4 |
| *Acropora pharaonis* (Edwards and Haime, 1860) | 1 |
| *Acropora horrida* (Dana, 1846) | 1,4 |
| ? *Acropora valenciennesi* (Edwards and Haime, 1860) | 1 |
| *Acropora arabensis* (Hodgson and Carpenter, 1994) | 2,3,4 |
| ? *Acropora florida* (Dana, 1846) | * |
| *Acropora valida* (Dana, 1846) | 3 |
| *Acropora tenuis* (Dana, 1846) | * |
| *Porites lutea* (Edwards and Haime, 1851) | 1,2,3,4 |
| *Porites solida* (Forskaal, 1775) | * |
| *Porites lobata* (Dana, 1846) | * |
| *Porites compressa* (Dana, 1846) | 1,2,3,4 |
| *Porites nodifera* (Klunzinger, 1879) | 1,2 |
| *Porites cf. Mayeri* (Vaughan, 1918) | * |
| *Siderastrea savignyana* (Edwards and Haime, 1850) | 1,2,3 |
| *Pseudosiderastrea tayamai* (Yabe and Sugyama, 1935) | 1 |
| *Coscinaraea monile* (Forskaal, 1775) | 1,2 |
| *Psammocora contigua* (Esper, 1795) | 1,2,3,4 |
| *Favia pallida* (Dana, 1846) | 1,2,3 |
| *Favia favus* (Forskaal, 1775) | 1,2,4 |
| *Favia cf. Rotumana* (Gardiner, 1898) | 1 |
| ? *Baarabattoia amicorum* (Edwards and Haime, 1850) | * |
| *Favites pentagona* (Esper, 1794) | 1,2,3,4 |
| *Platygyra daedalea* (Ellis and Solander, 1786) | 1,2,3,4 |
| *Platygyra lamellina* (Ehrenberg, 1834) | * |
| ? *Platygyra cf. Crosslandi* (Matthai, 1928) | * |
| *Plesiastrea versipora* (Lamarck, 1816) | 2,3 |
| *Cyphastrea microphthalma* (Lamarck, 1816) | 1,2,3,4 |
| *Cyphastrea serailia* (Forskaal, 1775) | 1,2,3 |
| *Leptastrea transversa* (Klunzinger, 1847) | 1,2,3 |
| *Turbinaria peltata* (Esper, 1794) | 2,3,4 |
| *Turbinaria reniformis* (Bernard, 1896) | 2 |
| *Stylophora pistillata* (Esper, 1797) | 1,2,3,4 |
| *Acanthastraea echinata* (Dana, 1846) | 1,3 |

Identification follows Sheppard and Sheppard (1991) and Riegl (1995) for Acropora. Previous published records from the RSA: 1, Sheppard and Sheppard (1991); 2, Fadlallah *et al.* (1993); 3, Hodgson and Carpenter (1995): 4, Vogt (1996), *, new record.

On the Iranian 2000 km long coast, Harrington (1976) identifies ten different habitats and describes eight islands extending from Asaluyeh to Bandar Abbas. The eastern most of these islands are surrounded by extensive coral reefs but no barrier reefs. Coral reefs in depths of 6 m have also been sighted in the area of Chah Bahar. However, except for the work of Harrington (1976) and Marini (1985) most of the published work on the ecology of the Iranian coastal areas is related to fisheries (IUCN/UNEP, 1988). Mergner (1984) reported 19 coral species from Hormuz Island, probably bearing great resemblance to those in the Omani side of the Strait.

In the Sultanate of Oman there are four regions which support coral growth (Salm, 1993): the Musandam Peninsula at the entrance of the RSA; the rocky shores, bay and islands adjacent to the capital area (Muscat, Gulf of Oman); the strait west and south of Masirah island; a number of sheltered bays along mainland Dhofar in the south and the Al-Halaniyat islands offshore (Arabian Sea). The other parts of the Oman coast either lack corals or support limited growth of small scattered colonies. This is because of absence of suitable stable substrate like in Al-Batinah coast or seasonal upwelling of cold water, vigorous algal growth and heavy wave action along most of the Arabian Sea coast (Fouda, 1997). There are 91 species of corals belonging to 53 genera and 18 families (Sheppard and Salm, 1988; Salm, 1993). Coral diversity increases south toward the equator with Musandam (41 genera), Muscat (42 genera) and Dhofar (48 genera). On Masirah island there are 27 genera which reflect the isolation of this island (Salm, 1993). The Fahal Island has the highest coral diversity in the Sultanate. The variety of substrate, depths and exposure to waves and currents in the vicinity of the island are the principal determinants of this high variety of corals (Fouda, 1997). *Porites* is the dominant builder of framework reefs through the Sultanate (Salm, 1993).

#### 3.1.2.1 *Coral reef bleaching*

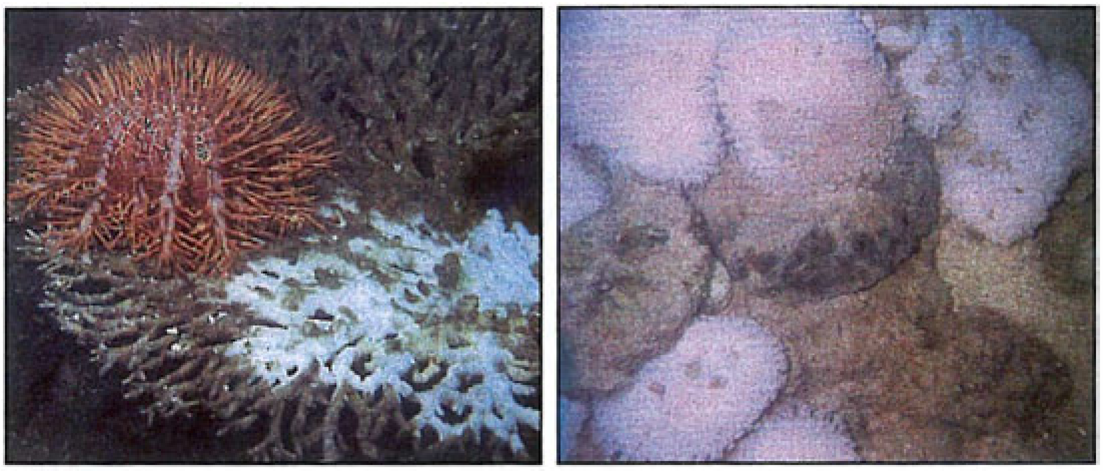
The Coral reefs in the ROPME Sea Area were subjected to a wide range of natural environmental stresses and human impacts (Figure 3.2). Crown of Thorns Starfish (COTS) have been reported from the Gulf of Oman over the last few decades, but reports from recent surveys indicated that the populations of these starfish have increased on some reefs (Harrison and Al-Hazeem, 1999). Coral bleaching was reported on some reefs in Bahrain, Oman, Saudi Arabia and UAE over the past few years with special reference to 1996 and 1998.

In Bahrain in 1996 a major bleaching was reported at Fasht Al Dibal where the temperature was 37.3°C, most corals on Fasht Al Adham bleached and then died. 20 miles north of Bahrain 100% coral reef bleaching was observed during August 1998 when the temperature increased from 34°C to 37°C in the deep water and 39°C in the shallow water in a week time and stayed on this level for few weeks. Another 50% bleaching was observed at 50 miles north of Bahrain (Wilkinson, 1998).

In Oman an extensive bleaching was reported during the end of May 1998 around Mirbat where the temperature ranged from 29.5-31.5°C. About 75-95% of *Stylophora* and 50% of large *Porites* colonies were bleached (Wilkinson, 1998).

In Saudi Arabia a severe bleaching was reported during 1996 which killed > 90% of *Acropora*. The dominated reefs in the northern part of Saudi Arabia *Porites* were also damaged. Another bleaching was during August 1998 when the sea temperature ranged from 35°C to 36°C. During that time high mortality of *Acropora* about (95%) and *Platygyma daedalea* were reported (Wilkinson, 1998).

**Figure (3.2): Monitoring of coral reef bleaching in RSA.**



(Harrison, 1999)

3.1.2.2 *Monitoring and assessment of coral reef*

Harrison and Al-Hazeem carried out an assessment of the health of coral reefs in Oman and UAE during November 1999. The study was initiated by ROPME and UNEP/ROWA to determine the extent of damage of coral reefs caused by the Crown of Thorns Starfish (COTS), and the mass coral bleaching. The long-term objective is to develop a plan of action for monitoring the status of coral reefs throughout the region. The findings from the survey are summarised below:

Significant numbers of COTS were recorded at most of the reefs examined. In Oman, two reefs at the Dimaniyat Islands were examined and ~25 COTS were observed or recorded at each reef. In some areas, COTS densities were up to $0.3/m^2$, and significant recent mortality of corals was evident. Ten COTS were also recorded at a popular dive site of Bandar Khayran in Oman.

At Khor Fakkan, UAE, 100 COTS were recorded at the island of Sirat al Khawr. Much of the southern area of the reef was severely impacted by COTS feeding, and no living branching corals were observed. Along the north-west area of this reef, a substantial aggregation of COTS were recorded, with a density of 0.3 COTS/$m^2$ counted in a transect area 30 m long and four m wide. This aggregation of COTS is ecologically significant and poses a threat to the viability of this small coral. Fifteen COTS were recorded at a mainland fringing reef adjacent to this island, and 13 COTS were recorded at Ra's Lulayyah. Two COTS were seen at the fringing reef at Jabal R'as, while no COTS or recent feeding scars were evident at reefs near Zubarah or Jazirat al Ghubbah.

In Abu Dhabi, UAE, however, rough weather prevented travel to the coral reef areas. Although the absolute numbers of COTS recorded at most of the reefs surveyed were relatively low compared with major COTS outbreaks recorded on other Indo-Pacific reefs in recent years, the COTS populations are regarded as ecologically significant because of the high densities of COTS present compared with the relatively small reef areas, and the substantial recent mortality of corals in these areas. Due to the comparatively small areas of coral reef present in these regions, the dense COTS aggregations, the high rates of feeding and recent coral death observed in some reef areas, it is concluded that these COTS aggregations pose a significant threat to the viability of some of these coral reefs. This is particularly true at Sirat al Khawr, where densities up to 0.3 COTS/ $m^2$ were recorded on the small fringing reef, and high rates of coral mortality were evident. In other regions, similar densities of COTS have been described as an outbreak, and COTS have been removed to maintain these reefs.

More than 1,000 COTS have been removed from the coral reefs in Oman and Khor Fakkan recently, and it is recommended that manual removal of COTS is continued at reefs where ecologically significant and potentially destructive populations of COTS exist. After COTS are removed from the reefs, they should be humanely destroyed, e.g. by crushing the centre of the disc area.

Other coral reef management issues encountered during this mission include problems with plastic and other litter, fishing nets abrading and smothering reef corals and other benthos, over-fishing, anchor damage to reef corals, coastal development burying nearshore fringing reefs, dredging causing increased sedimentation and decreased light, and chemical pollution. Some of these problems can be ameliorated effectively; for example, providing mooring buoys at popular anchor sites can prevent anchor damage.

### 3.1.3 Algal communities

There are several areas with hard substrate in the Omani coast which are not dominated by corals but by algae instead. This may occur in shallow coral reef areas, when algae tend to be filamentous greens and small browns which grow as "algal lawn" (Sheppard *et al.*, 1992). Algal communities in most of these areas are seasonal. Their seasonality is correlated with water temperatures where the inner part of the RSA is coldest in winter and the Arabian Sea is coldest during the summer upwelling. Brown algae in most depths are of small species, while large forms occur on reef crests and in the rocky platforms of stream where upwelling is important. Green and red algae are ubiquitous.

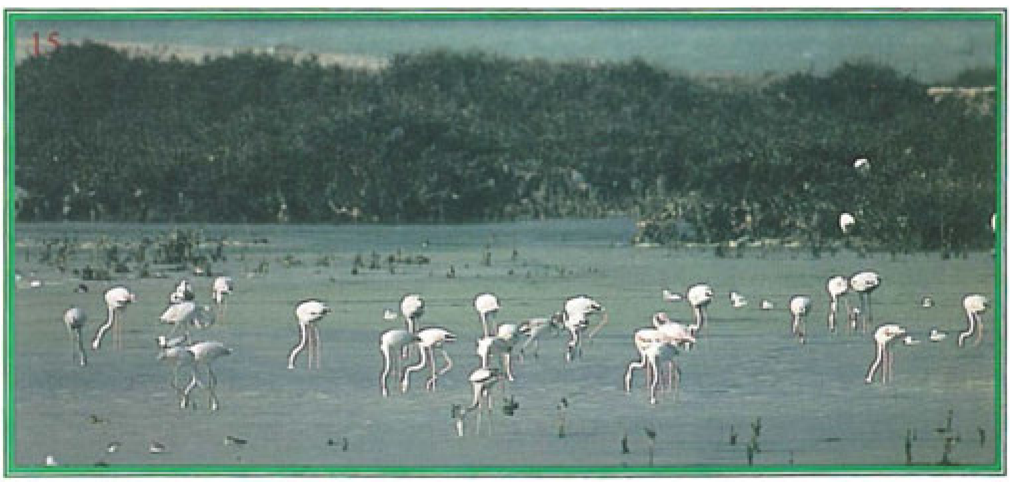
In I.R. Iran, extensive grass beds are found near the mouth of rivers and in the area of Chah Bahar (Harrington, 1976).


In Oman, growth of kelp and other brown algae is strongly seasonal. Maximum growth of *Sargassopsis zanardinii* occurs during the peak of the upwelling in August. By the end of September growth has almost completely stopped and blade decay has begun, although at the exposed site at Ras Sadha low level plant growth occur until mid-October, probably due to the higher nutrient levels (ROPME, 1988). Highest values of standing crop and biomass were obtained from inshore locations of moderate exposure and offshore locations. Dense population of mature *S. zanardinii* were found all along the rocky coast from Mirbat eastwards and northwards to Haik at 0-9 m (ROPME, 1988). Barratt, *et al.*, (1986) identified 204 algal species from the Ecklonia community (> 6.5m depth) and 206 species from the exposed rock platforms. The vegetation beneath the algal canopies includes at least 90 other species and many areas show algal lawns similar to those on reefs. The kelp community supports a large number of grazers and organisms at other trophic levels. Two major grazers of *Sargassopsis zanardinii*, are the green turtle *Chelonia mydas* and the rabbit fish *Sigenus oramin* that also feed to a lesser extent on *Ecklonia radiata.* Grazing and erosion of plants is high, with a significant part of the production entering the energy flow via detritus (Barratt *et. al.*, 1986).

Khoja (1998) studied 14 species of marine algae from the Anak and Al-Awamiyh mangrove swamps on the coast of Saudi Arabia. Eight Cyanophyta: *Chroococcus turgidus* var. *maximus, Merismopedia glauca, Pleurocapsa fuliginosa, Spirulina subtilissima, Hydrocoleum cantharidosmum, Nodularia spumigena* var. major; *Nostoc punctiforme* and *Homoeothrix varians*, and one *Chlorophyte*: *Gomontia polyrhiza* were reported to be new records for the RSA. Two Cyanophyta: *Gomphosphaeria aponina*, *Lyngbya majuscule*, and three Chlorophyta: *Enteromorpha intestinalis*, *Ulvn lactuca*, and *U. reticulata* have not yet been reported from the Saudi coastal zone. These species are additional floristic records to the existing checklist of the RSA.

### 3.1.4 Mangroves

Mangroves are salt-tolerant trees usually found in association with mudflats. Globally, mangrove ecosystems contain more than 60 species of trees and provide living space for more than 2000 species of fish, invertebrates and epiphytic plants (Clough, 1993). Scattered populations of Avicennia marina can be found in the RSA, occupying one of the driest mangrove habitats in the world, in which salt concentrations may reach levels that are beyond the physiological limit for other species.



Mangroves in the inner part of the RSA are much less extensive than before the era of intense development in the Region. Only about 125-130 $km^2$ of mangrove vegetation remain, 80% of which are on the Iranian side which have been estimated in 1970s to be 8900 hectares (Harrington, 1976). Due to the severe climatic conditions in conjunction with limited habitats and niches (Sheppard *et al*, 1992) only one *eurythermal* and *euryhaline* species, *Avicennia marina* occurs in the RSA. Since air temperature drops to freezing in winter over the extreme NW part of the Inner RSA, mangroves trees are not found in Kuwait and most of NE coasts of Saudi Arabia.

In Bushehr province (I.R. Iran), the mangroves have mainly expanded in the Nayband Bay and Dayer port area (Bardestan and Bardkhoon estuaries). Most of the mangroves are found in esuaries to which no fresh water flows. These mangroves are to some extent, exposed to gleyic solonchaks. Mangroves have formed assemblages with other halophylic flora. Sixteen species of these plants were identified within 8 botanical communities. In Bushehr the mangroves have created nursery grounds that are used for feeding, reproduction, growth and spending larval life by many aquatic animals (IFRO, 2000).

Along the Oman's coast and islands, mangroves are scattered upon more than 20 sites, Northern Batinah, Capital area extending to Sur, Gulf of Masirah and Bar Al-Hikman, and the Dhofar region (Fouda, 1995). Mangrove vegetation of *Avicennia marina* is varying from 2-6 m in height in the Gulf of Oman and up to 10m in the Arabian Sea (Fouda and Al-Muharrami, 1996), whereas in the inner part of RSA proper trees are poorly developed and often stunted (1-2 m) at least along western shores (Price *et al.*, 1993). Oman's mangrove communities include faunal assemblages of fish (more than 100 species), crabs, shrimps, *Penaeus indicus* and *P. semisulcatus*, shells and clams. Large wildlife includes over 200 bird species, three turtle species and four mammal species. Birds include cormorants, herons, egrets, spoonbills, flamingos, and many waders, gulls and terns. Mahout and Bar Al-Hikman (Oman) hold internationally important concentrations of shorebirds, notably crabplovers, sandplovers, demlins and redshank. Green turtles, loggerhead and hawksbill turtles are often seen nesting on sandy shores of mangrove areas. Gross primary productivity in Avicennia stands have been estimated to be $<1$ kg $C/m^2/yr$, however the value of mangrove is much more important biologically (IUCN, 1987).

In Qatar, mangroves occupy the area to the northeastern coast, where it intermingles with the Sabkha frontier vegetation. *Avicennia marina* (alqurm) is the only species present in Qatar (Sadooni and El-Kassas, 1998).

Hegazy (1998) conducted a study on a naturally growing population in Al-Khor mangrove swamps in Qatar during the years 1993-1995. Avicennia marina is the only mangrove species growing in Qatar and the ROPME Region. The phenological cycle indicated that the reproductive period extends from April to October, while vegetative activity occurs throughout the year with minimum growth during late autumn and early winter. Total litter fall decreased from a maximum of 188 g/m$^2$/month to a minimum of 80 g/m$^2$/month. Litter decomposition was lower in winter than in the summer months. Calorific content of the decomposing litter was consistent with over 90% of litter energy lost over l-year period. The calorific content of buried leaves decreased from 6.85 kcal/g dry weight to 0.32 kcal/g dry weight after 1 year.

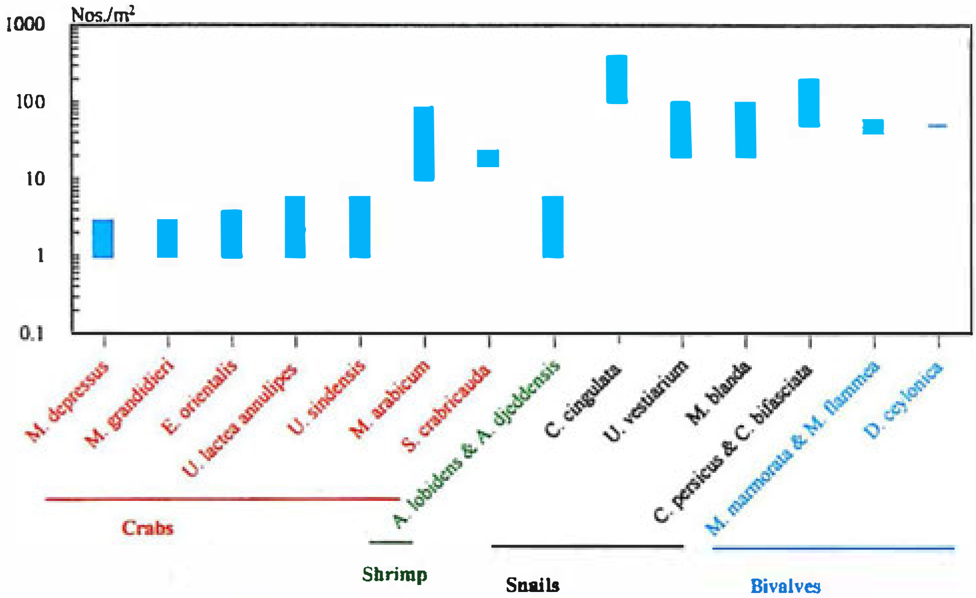
In UAE, Dodd *et al.* (1999) estimated standing biomass varying between 70 and 110 t/ha for the tallest stands and between 14 and 65 t/ha for shortest stands. The estimates for litterfall are 7.4-8.5 t/ha/yr in the tallest stands and 5.1-6.9 t/ha/yr in the shortest stands. These values of biomass are intermediate between levels reported for the same species in New Zealand and in Australia and the estimate of litterfall is comparable with that obtained from stands in Australia. Thus, despite the harsh ecological conditions, A. marina forms highly productive stands.

### 3.1.5 Tidal mud flats


Tidal mud flats represent the greatest contributions to primary production in the RSA (Price *et al.*,1993). This habitat constitutes a major part of the coastal areas in Kuwait. The most extensive mud flat systems are located in the NW of RSA in the approximity of the Shatt Al-Arab delta (Jones, 1986). Detailed studies of mud flats have been carried out in Saudi Arabia (McCain, 1989; Feltkemp *et al.*, 1994) and in Kuwait (Halwagy and Halwagy, 1977; Jones, 1988; Al-Bakri *et al.*, 1989). Those studies show that the cyanophyta-dominated algal mats covering mud flats, account for most of the productivity in RSA, providing a major feeding area for wintering waders and passage migrants which fertilise these flats as they feed during their brief stay (Zwart *et al.*, 1991).

Tidal mud flats also provide a good ecosystem for a variety of benthic communities (crabs, snails, bivalves, polychaetes, sea stars and sea urchins), (MNR-EPA, 1999). Tidal mudflats also include sabkahs that also support mats of cynophyta, diatoms and bacteria, e.g. nitrogen fixing bacteria which also contribute to the overall productivity of tidal mudflats. McCain (1984) identified 624 species of organisms in tidal flats, compared to 452 in the sand biotope and 360 in the seagrass beds of the eastern coast of Saudi Arabia.

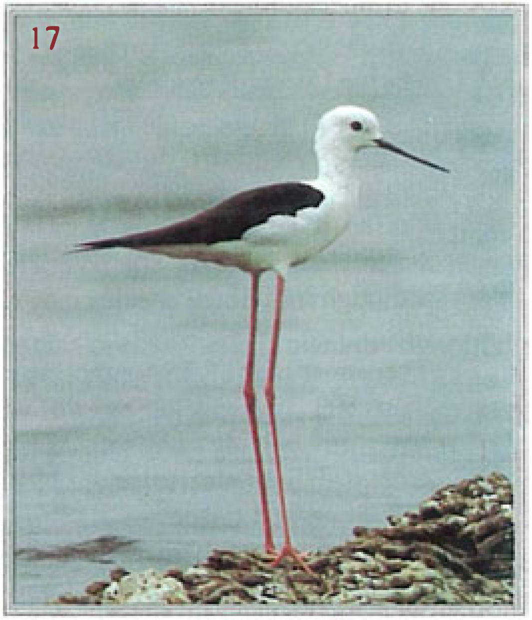
**Figure (3.3): Density of benthic organisms in mud flat (Northern Kuwaiti waters, 1999).**




In Bahrain, the mud flats are found on the north eastern sides of the island in bays relatively sheltered from the prevailing wind and wave action and thus their sediments are stable. At low tide shorebirds feed on the mud flats while at high tide their richness is exploited by many species of fish. Much of the natural production of mud flats is carried by these feeders into other areas of the coastal ecosystem. Several of these prime habitats have been and continue to be lost or degraded by infilling (Nightingale and Hill, 1993).

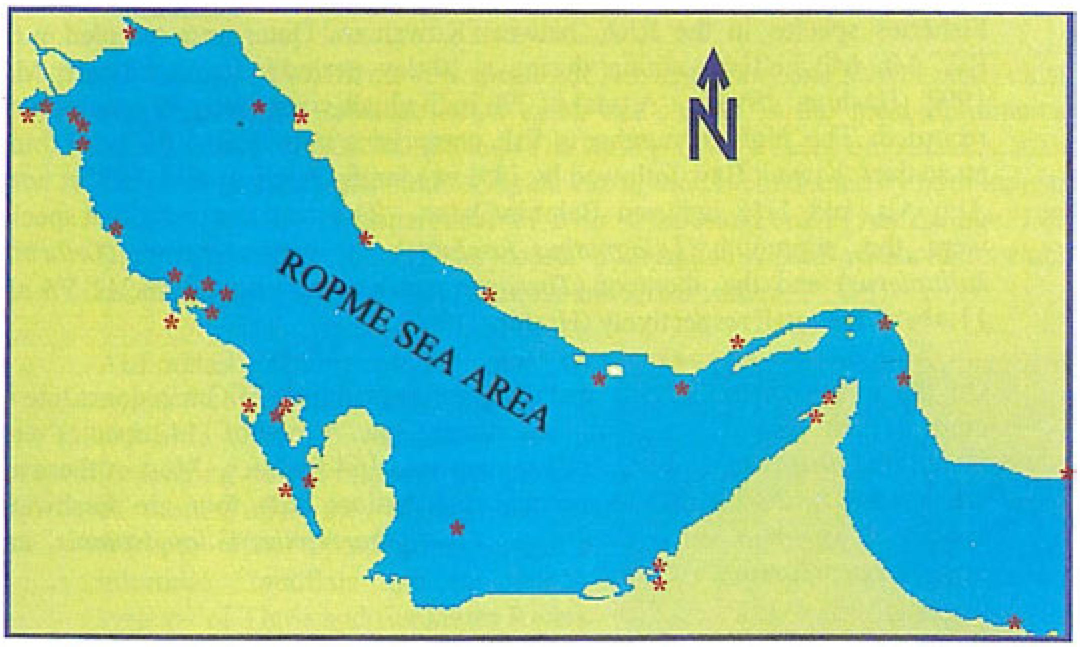
### 3.1.6 Protected areas

There are eight parks and reserves already established along the coasts of the region, and over 56 sites have been recommended for protection. Some areas are also covered by international conventions and programmes. One site is listed under the international MAB Unesco Biosphere Reserve Programme, Hara Protected Area in Iran, while four sites are recognised as wetlands of international importance under the Ramsar Convention, the Shadegan marshes and mudflats of Khore al Amaya, the Khuran Straits, the deltas of Rud e Shur and the deltas of Rud e Gaz (WCMC, 1991).




Iraq has a series of protected areas, which it classes, as Breeding Stations. The authorities establish additional two stations per year, and there are also proposed game parks, nature reserves and bird sanctuaries. Most of the important nature conservation areas in the country are unprotected although many have been recommended for future protection as national parks or reserves. The coastline of Iraq is restricted to an area next to Faw by the mouth of the River Shatt Al-Arab (Tigris/Euphrates). Little-developed areas recommended for protection include the mudflats near Al Faw, and Khor Zubair/Khor Abduallah (WCMC, 1991).

**Figure (3.4): Proposed and established protected areas in ROPME Region.**




Note: Data confirmed with Member States.

## 3.2 Living and Non-Living Resources

### 3.2.1 Marine Living Resources

#### 3.2.1.1 *Fishes*

Unlike the more stable tropical marine environment, the predominantly arid, subtropical RSA is characterised by a generally low diversity of fish species, although individual species may occur in high numbers (Fouda, 1997).

The inner part of RSA supports more than 500 fish species, most of which live in pelagic or soft substrate demersal habitats (Price *et al.*, 1993) and at least 125 species are found on the reefs (Sheppard *et al.*, 1992), about 130 fish species are known to occur in Kuwait (Mubarak *et al.*, 1999), 71 species from Bahrain (Smith *et al.*, 1987), 106 species from reefs in Saudi Arabia (McCain *et al.*, 1984; Coles and Tarr, 1990; Krupp and Muller, 1994).


Fisheries species in the RSA between Kuwait and Qatar were sampled in the R/V Mt. Mitchell expedition during a 10-day period in late April-early May 1992 (Hashim, 1993). A total of 790 individuals comprising 45 species were recorded. The highest number of fish, comprising more than 40%, were found at station Kuwait Bay, followed by 18% at Manifa-Saudi Arabia, 15% at north Abu Ali, and 11% between Bahrain/Qatar. The most dominant fish species were the slipmouth (*Leiognathus fasciatus*), the pigface bream (*Lethrinus kallopterus*) and the therapon (*Therapon puta*), comprising 27.4%, 11.5% and 11.4% of the total, respectively (Hashim, 1993).

On the other hand, the rich and diverse fish resources of Oman constitute its main natural resource after oil and natural gas. A total of 1142 species were identified, distributed among 520 genera and 164 families. Most of these are the marine with broad geographical distribution; only four are freshwater species (*Cyprinion micropthalmum*, *Garra barreimie*, G.*longispinnis*, and *Oreochromis aureus*).

Oman is characterised by large number of species in 21 families, comprising 92.6% of the estimated total number of marine families of the whole Indo-Pacific region, and 49.9% of the world's marine families (Fouda *et al.*, 1998).

The Arabian Sea and Gulf of Oman are more diverse in fish species (similar to 1000 fish species) than the inner RSA (>500 fish species). More than 400 species are demersal, 511 species inhabit coral reefs and coastal lagoons, two are mesopelagic species, and the remainders are pelagic (157), bathypelagic (30), and bathydemersal (7 species) (Fouda *et al.*, 1998). Current fishing effort levels on some target species are either close to maximum sustainable yield or exceed it. A shift in species composition has resulted in declining landings of some high value fishes.

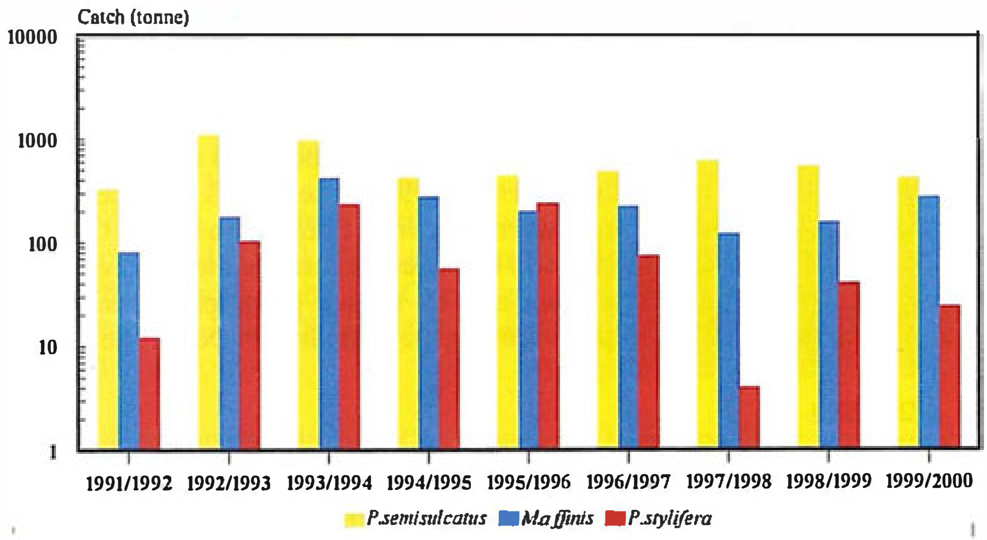
Environmental extremes in the inner part of RSA have limited the distribution of many species (Coles and Tarr, 1990; Price *et al.*, 1993). Peak fish species diversity and population densities of the dominant species are attained on the well-developed offshore reefs of Saudi Arabia while seasonal variation in these parameters is particularly high at the nearshore reefs (Coles and Tarr, 1990; Krupp and Muller, 1994). Fish diversity falls off moving northwards and southwards of Saudi Arabia, as environmental conditions become more extreme. Probably the richest reef fish fauna will be found on the Iranian reefs, near the Strait of Hormuz (Price *et al.*, 1993). These reefs lie in deeper waters and are supplied with oceanic water in-flowing through the Strait. On the other side, the high diversity of Oman's fish fauna is attributed to the diverse coastal habitats, wide climatic spectrum and its unique geographic location in the upwelling region of the northwestern region of the Indian Ocean (Fouda, 1997).

3.2.1.2 *Crustacea*

As mentioned earlier, a few species of lobsters (spiny and shovel nose) exist in the RSA. Other crustacea also exist, but shrimp is the most dominant and commercially important species. The shrimp fishery based on penaeids, mainly *Penaeus semisulcatus* and *Metapenaeus affinis*, is conducted by both industrial trawlers and an artisanal fleet of over a thousand boats (van Zalinge, 1984). Richest resources are off the coasts of Iran and Kuwait with smaller catches taken from the Saudi Arabia, Bahrain and Qatar waters.


Al-Foudari (2000) found that *M. affinis* contributes subsequently to Kuwait's total shrimp catch. Depending on the season, their percent of contribution may be as much as 40% to 50%. In addition, Kuwait's intertidal mudflats and the marsh system of Tigris and Euphrates Rivers in Iraq had served as nursery habitat for *M. affinis.* Although, there is no direct evidence of shrimp migrating from Iraq's inland waters to the northern RSA, but it is thought that Kuwait's population of *M. affinis* has been enhanced by recruites from the Iraqi marshes. After the destruction of tens of thousands of hectars of marsh habitat above Basrah, the volume of *M. affinis* will likely decrease. However, *P. semisulcatus* species was found in the southern part of Kuwaiti's waters. Throughout their range, the nursery habitat of juvenile *P. semisulcatus* is characterized by benthic vegetation (Al-Foudari, 2000). *Parapenaeopsis stylifera* was also found in low percent among the landed shrimp of Kuwait (Figure 3.5).

**Figure (3.5): Catch of Kuwait's shrimp landed by dhow boat fishery through the seasons 1991/1992-1999/2000.**



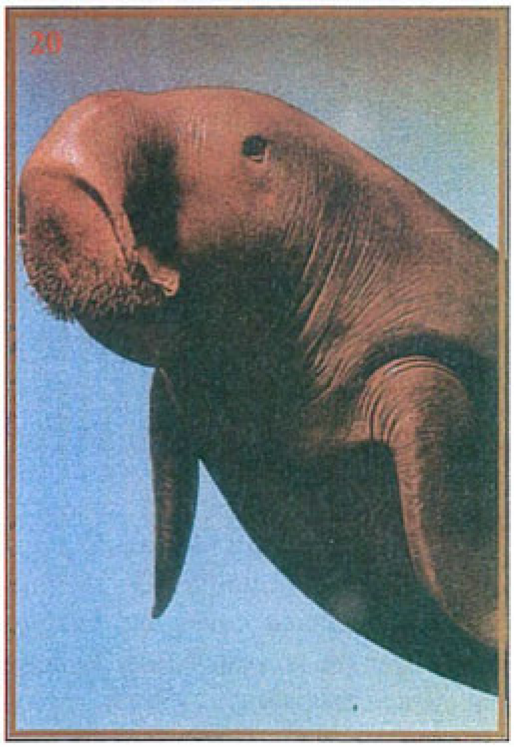

(Al-Foudari, 2000)

Tubli Bay and shallow areas south of 'Fasht Al-Adhom' are known for their importance to Bahrain penaeid shrimps. In Bahrain seven penaeid species were found (Abdulqader, 1999). Commercial shrimp landings are mainly from single species, *P. semisulcatus*. The six other remaining species makes about 5% of the annual shrimp landings. Two species *P.latisulcatus* and *Metapenaeus kutchensis* grow to good size. The remaining four species *M.stebbingi*, *Trachypenaeus curvirostris*, *Metapenaeopsis stridulans* and *M.mogiensis* are smaller and are usually partially or entirely discarded. Catches of small sized shrimp frequently exceed the amount of big shrimp catches at the end of the season (February and March), (Abdulqader, 1999). Shrimp trawlers are causing recruitment over-fishing of the main shrimp species, *P. semisulcatus*. This is suggested by low catch rates and smaller shrimp sizes observed from the on-going GCC survey. Trawlers are likely to have less impact on the spawning stock of this species. Ban area regulation may prevent fishing at shrimp nursery grounds. Small boats can be excluded from the shrimping fleet, which could provide further protection to shrimp recruits.

The shovelnose lobster, *Thynus orientalis*, is common in shrimp by-catch in Bahrain (Abdulqader, 1999). This species was found in fish trawls in good quantities during October to January. Up to almost 200 tons of shovelnose were landed in a year (FSS, 1998).

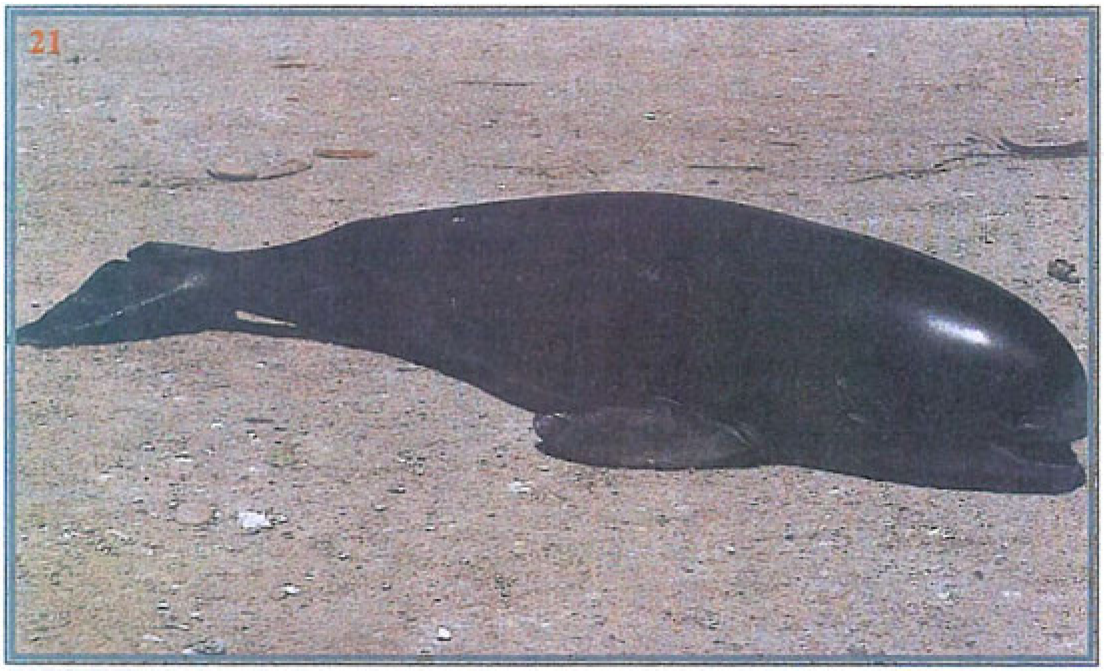
Brachyuran decapods of the families Grapsidae and Ocypodidae are a dominant faunal element of intertidal flats and mangroves in the RSA and the Gulf of Oman (Apel and Turkay, 1999). Recent collections along the coasts of the U.A.E. and Saudi Arabia and examination of material from other parts of RSA revealed in total six species of grapsid and 21 taxa (species and subspecies) of ocypodid crabs occurring in these habitats within the RSA. Great differences in species diversity and composition exist between the different parts of RSA. Maximum diversity was observed for the easternmost part of the U.A.E. (Ras al Khaimah, Umm AlQuwain) and for Kuwait. Highly reduced species numbers were found along the shorelines of Abu Dhabi and Saudi Arabia. The most likely factor causing this pattern is salinity. Zoogeographically it appears that most of the RSA species are of an 'eastern' (Indian) origin. 'Western' (East African and Red Sea) elements are restricted to the south-eastern part of the RSA (coast of the U.A.E.) and to the Gulf of Oman (Apel and Turkay, 1999).

#### 3.2.1.3 <u>*Marine mammals*</u>




Dugongs or sea cows are strictly herbivorous. Seagrasses form their staple diet. In the inner part of the RSA, some herds of these marine mammals were discovered for the first time in 1980s. The largest ever record herd of over 600 individuals was observed in the Gulf of Salwah between Bahrain and Qatar peninsula (Preen, 1989). In Oman, there have been no confirmed sightings of dugong. The estimated RSA population is 7310 about 1300 individuals, making the RSA the most important area for these species in western part of its range, and second in global importance only to Australia (Preen, 1989). Other marine mammals of interest include whales and dolphins, i.e. Brydes whale and the Humpback whale, Bottlenose dolphin (*Tursiops truncatus*) and Indo-Pacific humpbacked dolphin. Other dolphins and whales known to inhabit adjacent parts of the Indian Ocean are also likely to occur in inner part of the RSA.

Basson *et al.* (1977) reported several species of dolphin in RSA. For small cetacean species are known to be seen in RSA, including the finless porpose (*Neophocaena phocanoldes*). Three to four of great whales have also been recorded, although it is probable that these animals are not resident but strand after becoming trapped (Chiffings, 1998).

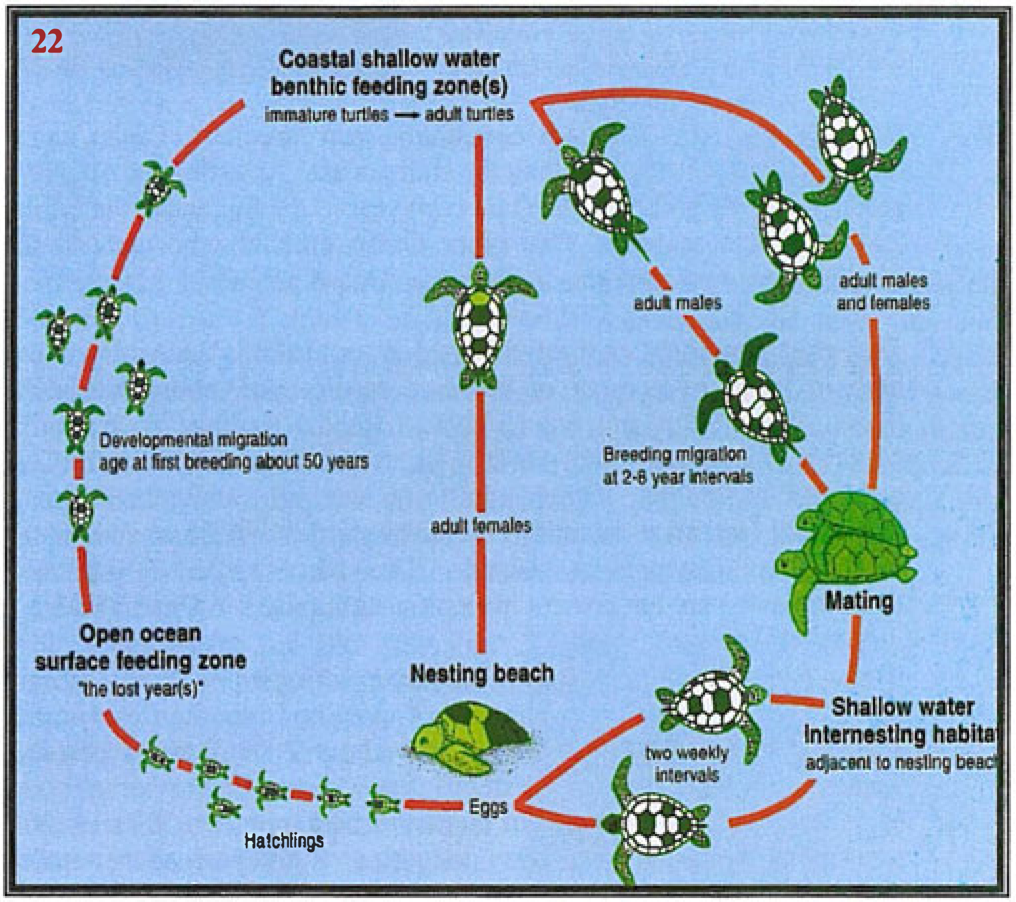


About 20 dolphins and whales species exist in Oman's open waters, representing 25% of all known species in the world (Bladwin and Salm, 1994). They vary greatly in size from the slender agile spinner dolphins (< 2 m in length) to the huge sperm whales (> 20 m in lengths). The Indo-Pacific humpback dolphin, common dolphin, spinner dolphins, pan-tropical spotted dolphin and Bottlenose dolphin are the most common dolphins in Oman. Some dolphins occur in very shallow water (Indo-Pacific humpback dolphin), others in sheltered coves and bays (e.g. Bottlenose dolphin), and still others can be seen in groups of 10 to 20 individuals (common dolphin) or mixed with others, chasing fishes.

3.2.1.4 *Marine reptiles*

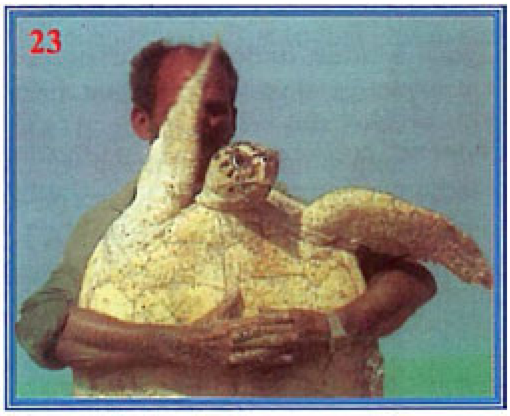
3.2.1.4.1 Turtles

Marine turtles form a prominent part of the fauna of the RSA, which contains some globally important nesting beaches. In RSA, marine turtle populations have two components: (i) a small resident population, individuals of which are sometimes encountered in seagrass areas; (ii) a much larger migratory population, which breed on offshore coral islands, including Karan and Jana islands in Saudi Arabia. All the five-pantropical species are known in the region: Hawksbill, Greens, Leatherbacks, Loggerheads and Oliver Ridley.




In Bahrain, the Green Turtle, Hawksbill, Leatherback and Loggerhead (*Chelonia myda, Eretmochelys imbricata, Dermochelys coriacea* and *Caretta caretta*) have been reported.

In Qatar, the island of Sharaawh has nesting populations of Hawksbill Turtles (*Eretmochelys imbricata)*; hatchlings are seen in early July but nesting numbers are reportedly very low (Ross and Barwani, 1981). The *Chelonia mydas* species were also reported in Qatari water (WCMC, 1997)




In I.R. Iran, Green Turtles (*Chelonia mydas)* nest in small numbers at Bushehr, Bandar Abbas and Ras Beris. Hawksbill Turtles (*Eretmochelys imbricata)* occur in significant numbers in the area from Taheri (Siraf) to Bandar-e-Lengeh, at Qeshm Island and from Tang (Bandar Tang) to the Pakistani border (Ross and Barwani, 1981; Groombridge, 1982).

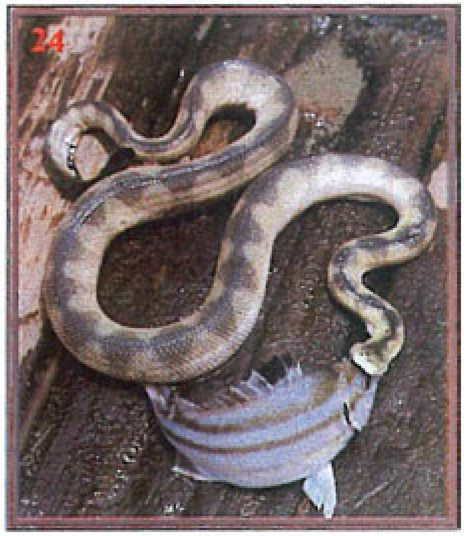
Green Turtles are the most commonly seen species in Oman, and nest on at least 275 beaches spread along the entire coast. An estimated 50,000 to 60,000 green turtle egg clutches are laid each year in the Sultanate, the effort of about 20,000 turtles or more. This gives Oman probably the greatest number of nesting green turtles of any single Indian Ocean nations.

The most important part of the region for turtles is the Arabian Sea (Oman), both in terms of number of breeding species and abundance of individuals (Ross, 1979; Salm and Salm, 1991). Recent findings have confirmed that Maṣirah Island holds the world's largest nesting population of Loggerhead, estimated at 30,000. Other significant sites are along the Dhofar coast and around Al-Halaniyat Islands. Hawksbill turtles exist in considerable numbers notably at Daymaniyat Island. The other turtles (Olive Ridley and Leatherhawks) are not present in significant numbers in Oman (Fouda, 1997).

Karan (primary site), Kurayn, Jana, Harqus, Jurayd in Saudi Arabia were also reported to support large numbers of nesting Green Turtles. Estimates made during the early 1980s suggested that about 2000 females nested on these islands each season, which extends from May to September; subsequent data suggest a downward revision of this estimate, to between 500 and 1000 females per season. Females nest every second or third year, so the total number of females using the area will be two to three times these figures (which do not include males or immature turtles), (WCMC, 1991).

3.2.1.4.2 Sea snakes

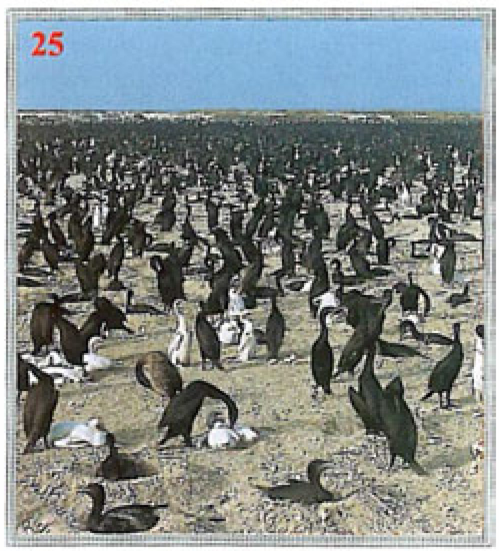
Other marine reptiles of scientific interest include sea snakes. At least nine species of sea snake (Hydrophiidae) occur in RSA including *Enhydrina schistosa*, *Hydrophis cyanocinctus*, *H. lapemoides*, *H. ornatus*, *H. spiralis*, *Lapemis curtus*, *L. viperina* (= *Praescutata viperina*), *Microcephalophis gracilis* (= *Hydrophis gracilis*), *Pelamis platurus* (WCMC, 1991).




In general, very little is known about the population status of sea snakes, and virtually nothing about their status in the RSA. The *Hydrophis* is the most popular species. The group generally are found in muddy, warm waters, and their preferred habitat is relatively abundant in the inner part of the RSA, whose soft substrate habitats are contiguous with other sea snake-rich areas in the Arabian Sea and around India (Gasperetti, 1988; Sheppard *et al.*, 1992).

3.2.1.5 <u>Birds</u>

The RSA supports a diverse marine bird community of great international importance. Huge numbers of seabirds breed on the offshore islands, especially Socotra Cormorant (most of the world population) and terns *Sterninae* (Gallagher *et al.*, 1984) (e.g. Bridled Tern, White-cheeked Tern, Lesser Crested Tern). The intertidal zone is estimated to support up to four million waders Charadrii in winter, making the RSA as one of the five most important regions of the world for wintering waders (Zwarts *et al*, 1991). The intertidal and shallow subtidal zones are also internationally important in winter and during migration seasons for populations of about 20 other waterbirds species including grebes, cormorants, herons, flamingos, gulls and terns.




The inner part of the RSA is particularly important for wintering waders, passage migrants and breeding seabirds. Pre-war (1991) surveys have been undertaken during winter along the western RSA (Zwarts *et al.*, 1991). During the winter survey, a total of 21 wader species represented by nearly 30,000 individuals were recorded. Important species included oystercatchers, ringed plovers, lesser sandplover, little stint, dunlin and others. Mud flats were found to support greater wader feeding densities than either rock flats or sand flats. Extensive mud flats occur along the shores of most, if not all, the inner part of the RSA. Highest wintering wader counts in Saudi Arabia were found on the intertidal mudflats of Tarut Bay, Dawhat and Dafi and the northwestern part of Musallamiya. Each year an estimated quarter of a million waders winter in the Saudi Arabian part of the RSA, and for the whole inner part of RSA the number may be as high as 1-2 million.

The inner part of the RSA is also an important feeding area for passage migrants which winter further south, and which breed up to 15,000 km away in the far north. Over the spring, these supplement the numbers of wintering birds. Waders are the most important migrants in the RSA, occurring in even larger numbers than during winter. Evidence has now accumulated showing that intertidal flats function as vital feeding areas for many migrating waders, and clearly play an essential role in the life cycle of these bird species.

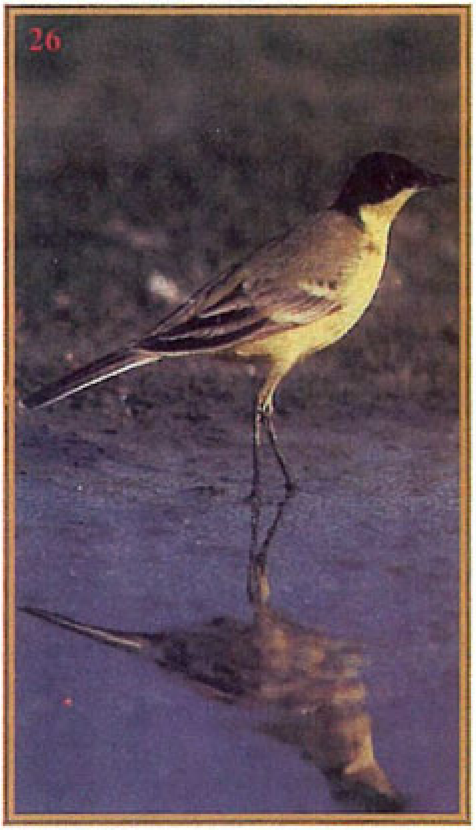
Offshore islands provide major nesting sites for at least three different terns. The commonest is the lesser-crested tern, with an estimated 25,000 pairs nesting on five Saudi Arabian islands. It appears that the inner part of the RSA represents the breeding area for a large part of the world's population. Other seabirds, such as Socotra cormorant, a species confined to the Arabian Peninsula also breed along parts of western RSA coast.

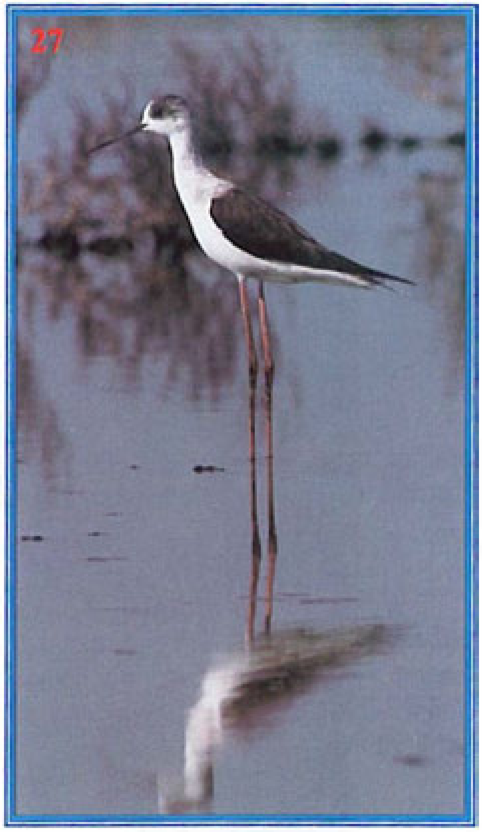
In the northern parts of RSA, along the coasts of I.R. Iran, about 88 species of birds are recorded. Among them 19 species are resident and 69 species are wintering either passage migrants (46 species) or breeding sea birds (23 species).

In Bahrain, the islands are of international importance on account of a small colony of breeding Sooty Falcon (*Falco concloor)* and a large proportion of the world population of Socotra Cormorants (*Phalacrocorax nigrogularis)*. The flamingo (*Phoenicopterus ruber)* is present throughout the year, and the Osprey (*Pandion haliaetus)* breeds there as well.

Gallagher *et al.* (1984) described the status of breeding colonies of seabirds from several localities around the coast of Qatar and on its islands. These include at least four species of terns (*Sterna* spp.) and occasionally the Socotra Cormorant (*Phalacrocorax nigrogularis)*.

The avifaunal assemblage of U.A.E. mangroves is a biogeographical combination of Paleartic and Indo-Malaysian bird communities with some unique elements, for example, the endemic Kalbaensis subspecies of White-collared Kingfisher *Halcyon chloris* breeds at the single type locality - Khor Kalba, Sharjah, with a total (world) population of only 44 pairs (Aspinall, 1996). Other ornithological interest includes: Booted Warbler *Hippolais caligata*, breeding at Khor Kalba and nowhere else in Saudi Arabia, two colonies of Crab Plover *Dromas ardeola* in Abu Dhabi Emirate, sustained by mangrove-dwelling crabs and being the only known examples in the Western RSA, as well as regionally important breeding or wintering populations of Indian Pond Heron *Ardeola grayti*, Western Reef Heron *Egretta gularis* and Clamorous Reed Warbler *Acrocephalus stentoreus*. In addition, the invertebrate productivity of U.A.E. mudflats supports 1-3 million visiting waterfowl annually and is doubtless attributable, in part, to the continuous (leaf) litter input from mangrove.

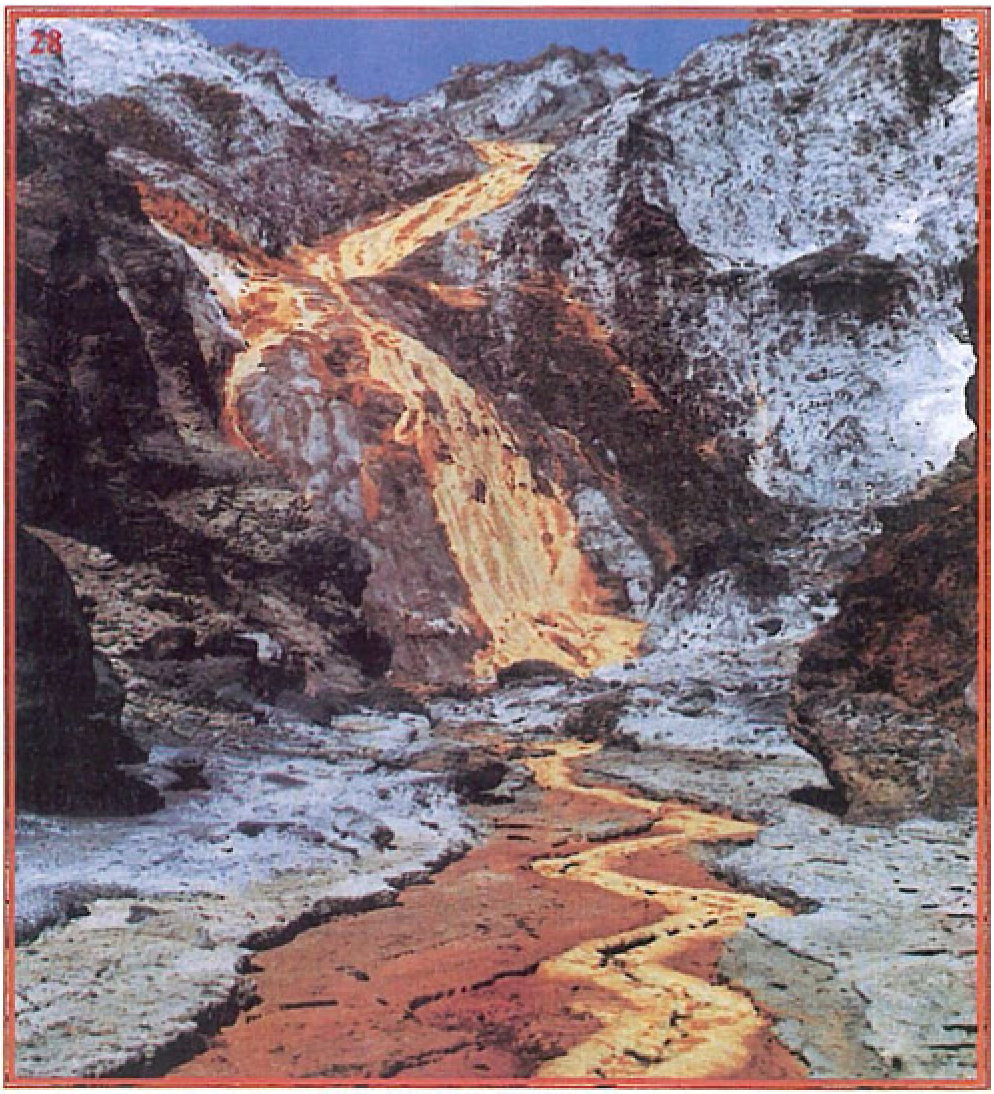



The major coastal bird habitats in Oman include: offshore waters, islands and islets, coastal cliffs, rocky shores (e.g. Musandam), sandy beaches (e.g. Batinah Coast), tidal flats (e.g. Bar Al-Hikman), Khawr environment and mangroves (e.g. Qurm in Muscat). Examples of birds include cormorants, herons, egrets, spoonbills, flamingos, many waders, gulls and terns. Bar Al Hikman and the surrounding areas, including Mahout Island, hold internationally important concentrations of shore birds, notably crabploves, sandploves, dunlies and redshank.

3.2.2 Non-Living resources

Before the petroleum era in the Region, the small coastal communities relied on the sea, not only for food but also for building materials, especially sand and coral rocks. Wood from mangrove trees and other coastal plants were harvested for firewood. The dawning of the petroleum era (1950s) witnessed the introduction of desalination plants that converted seawater into steam and brine. The steam is used to run electricity turbines and produce potable water by mixing with ~10% brackish water (mined from the aquifers). The brines are used to produce salt, chlorine and caustic soda. Desalination and power plant stations are run by oil and/or gas, as the most easily available source of energy. However, oil and gas remain the dominant non-living resource exploited in the coastal and marine areas of the RSA.



# Chapter 4

# Socio-Economic Activities and Structures Affecting ROPME Sea Area

The state of the marine and coastal environment is largely dependent on the human, social and economic activities that take place both on land, particularly in the coastal zone, and at sea. It is of prime importance, therefore, to focus on those activities that are likely to affect the marine and coastal environment in the RSA. In this context, this chapter of the report will briefly review both the land-based and the sea-based activities that represent potential sources of pollution in the RSA.

## 4.1 Land-Based Activities

### 4.1.1 Industrial development

The RSA has witnessed an unprecedented growth in the industrial sector over the past 30 years. The most common heavy industries in the region include petroleum refineries, petrochemical industry and desalination and power plants.

#### 4.1.1.1 *Major Industries*

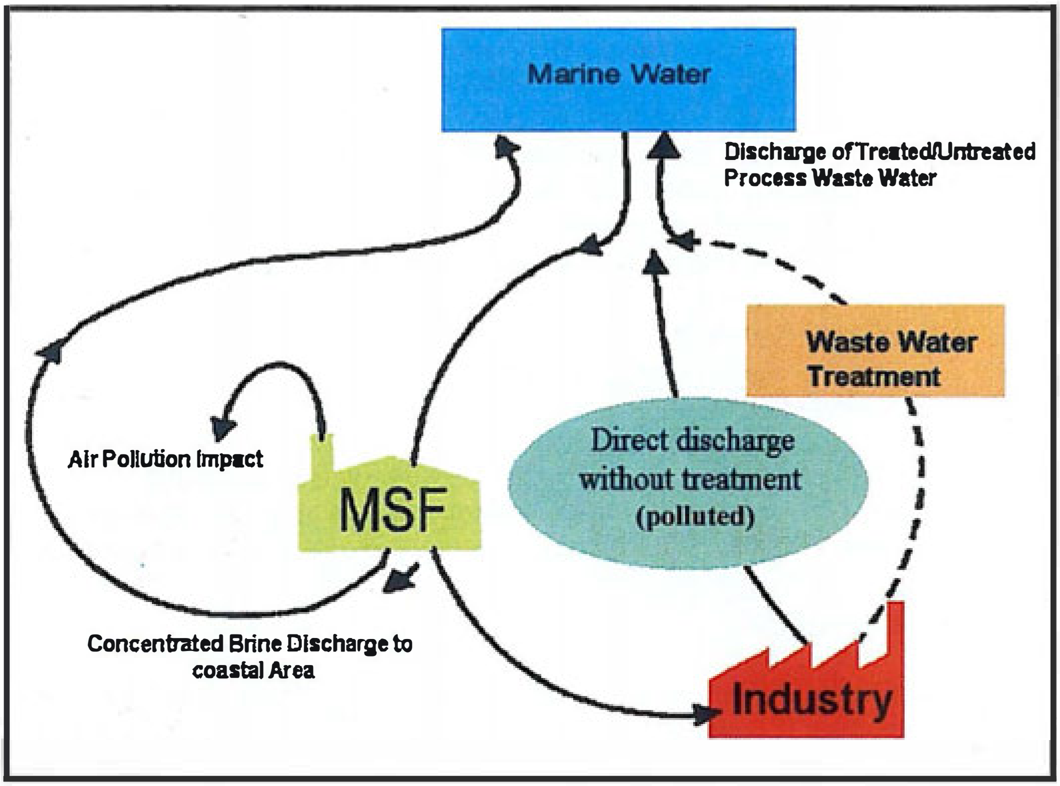
Heavy industries are major contributors to the pollution load into the marine environment (Figure 4.1) and the main source of the chemical oxygen demand (COD) pollution load. Light industries include agricultural and livestock productions and food and beverages which are generally contributing to the bio-chemical oxygen demand (BOD) loads.

The main industry-related waste source categories that are of potential effect on the marine environment in the RSA are addressed in this chapter. Most of the data in the chapter were updated based on the Land-Based Assessment Reports provided by Member States.

For Bahrain, daily production of 1,700 tons of granulated urea and 500,000 tons/yr of high-grade aluminium are reported. Wastes of these industries are gases, liquids and solid wastes with considerably high amounts (UNEP, 1999).

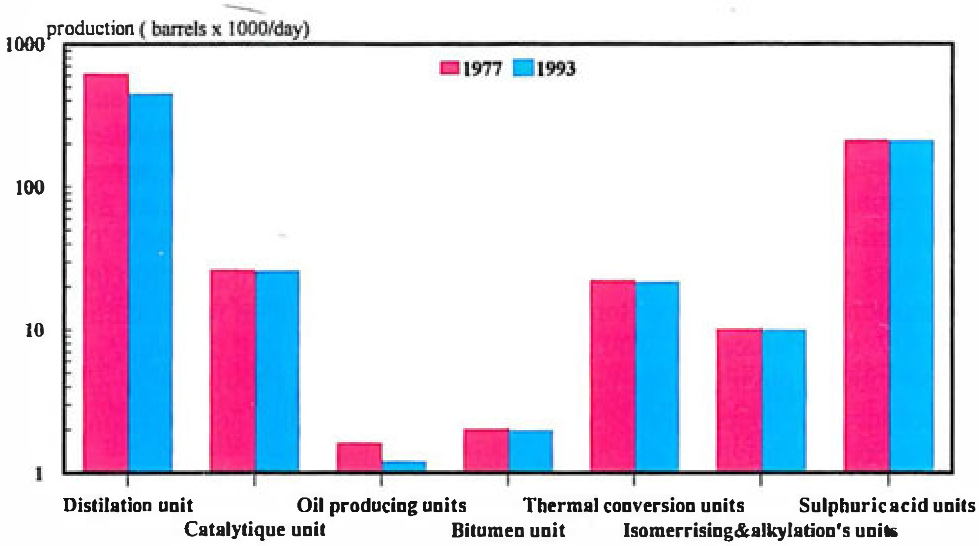
For I.R. Iran, the refinery in Bandar Abbas is known to be the largest refinery in the world (UNEP, 1999), started working in early 1998. Many oil refineries in I.R. Iran were damaged during the Iraq/Iran War, some renovated and others under construction. The total production of Abadan refinery was 2,500 barrels/day in 1912 (LBA-I.R. Iran, 1999), increased to 610,000 barrels/day in 1977 (pre Iraq-Iran War) and maintained 450,000 barrels/day due to reconstruction of the system in 1993, Figure (4.2).

**Figure (4.1): The desalinated water cycle (LBA-Qatar, 1999).**



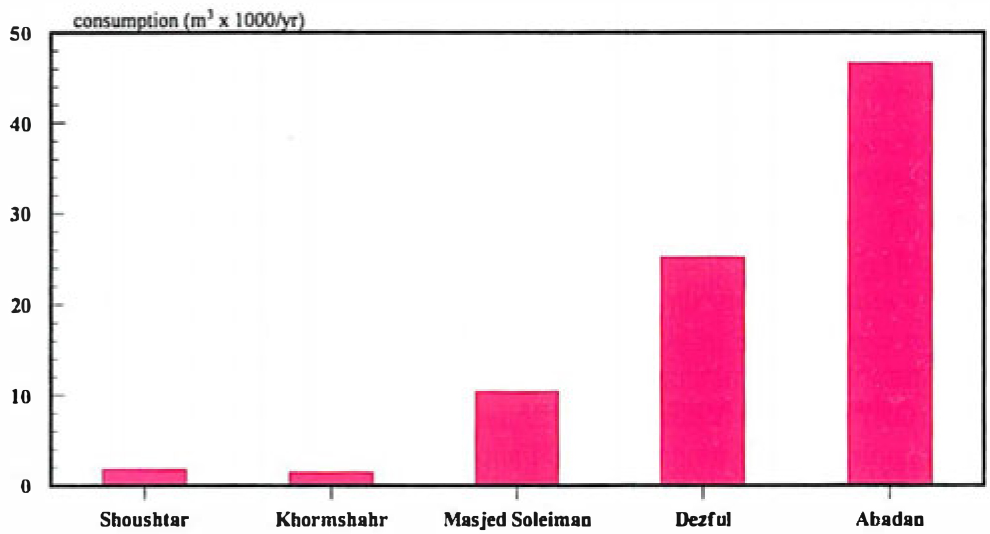

Some of the largest heavy industries plants of I.R. Iran are located in five industrial complexes and five cities in Karun basin (LBA-I.R. Iran, 1999). The water consumption of each town is shown in Figure (4.3). The amount of industrial effluent discharge varies from 0.03 $m^3$/hr for Fakhr Khorramshahr chemical company to 14640 $m^3$/hr for Abadan refinery, which discharge the waste into Arvand River (LBA-I.R. Iran, 1999). The most polluting industries in terms of quantity of industrial sewage discharging into the Karun basin are cellulose-processing industries, then chemical and petrochemical plants followed by food processing and steel industries.

Figure (4.2): The production of Abadan refinery before and after the Iraq- Iran War.




(LBA-I.R. Iran. 1999)

Figure (4.3): The water consumption in the Iranian industrial towns within the Karun basin.



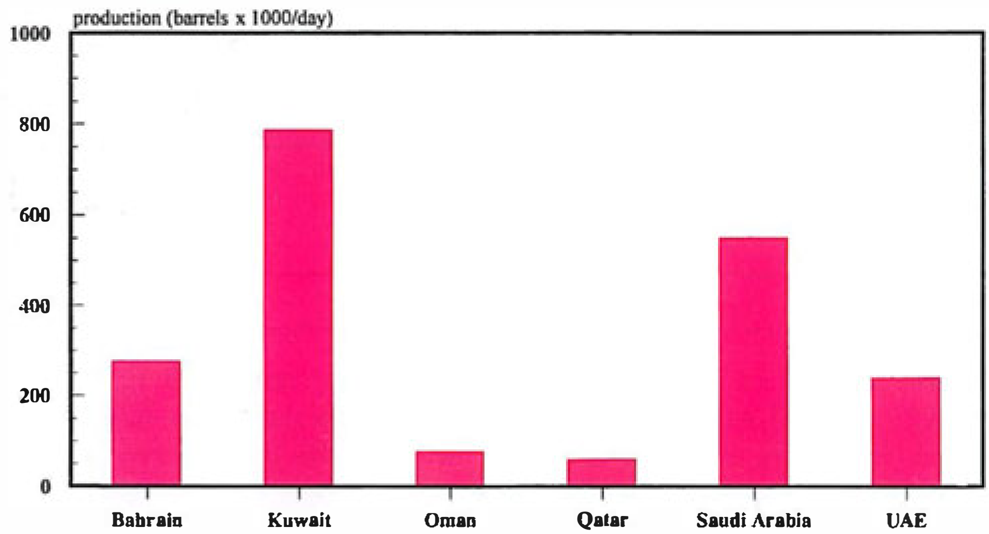

(LBA-I.R. Iran, 1999)

In Kuwait, the output of the oil refineries was 790,000 barrels/day, representing 39.5% of 1995 oil production (ESCWA, 1997). This figure is expected to increase in the next few years to 44.5% (UNEP, 1999).

In Qatar, the refinery of General Petroleum Company is known as the National Oil Distribution Company (NODCO). It processes 62,000 barrels/day of crude oil and is presently going through an expansion process to increase the crude refining capacity to 82,000 barrels/day in addition to processing 27,000 barrels of stabilised condensate from the North field (LBA-Qatar, 1999). Two identical plants were established in 1973 and 1979 is Qatar to produce 800,000 tons/yr of ammonia and 900,000 tons/yr of urea. A third plant was established later in 1997 to produce 547,500 tons/yr of ammonia and 730,000 tons/yr of urea and the fourth plant is under construction (LBA-Qatar, 1999). Other petrochemical products of Qatar are 525,000 tons/yr of ethylene, 360,000 tons/yr of low density polyethylene and 70,000 tons/yr of sulphur.

In Saudi Arabia, the estimated production of the three refineries namely; Jubail, Ras Tanura and Ras Al-Khafji was 551,351 barrels/day Figure (4.4). (LBA-S.Arabia, 1999).

**Figure (4.4): The estimated production of oil refineries in some ROPME Member States.**




(ESCWA, 1997; LBA-Qatar, 1999; LBA-U.A.E., 1999; LBA-S.Arabia)

Petrochemical industry in the eastern part of Saudi Arabia is situated in Jubail Industrial City. Nine primary petrochemical plants producing 7.32 million tons annually of a wide range of petrochemical products such as methanol, ethanol, ethylene chloride, ethylbenzene, styrene, chloride, caustic soda, fromaldehyde, MTBE, polyethylene, urethane, ethylene, nitrogen, oxygen gases, monoethylene glycol, etc. (LBA-S.Arabia, 1999).

In the U.A.E., the total production of oil refineries has increased from 180,000 barrels/day in 1986 to 240,000 barrels/day in 1997, representing 12% of UAE oil production. About 50% of this amount is consumed locally (LBA-U.A.E., 1999).

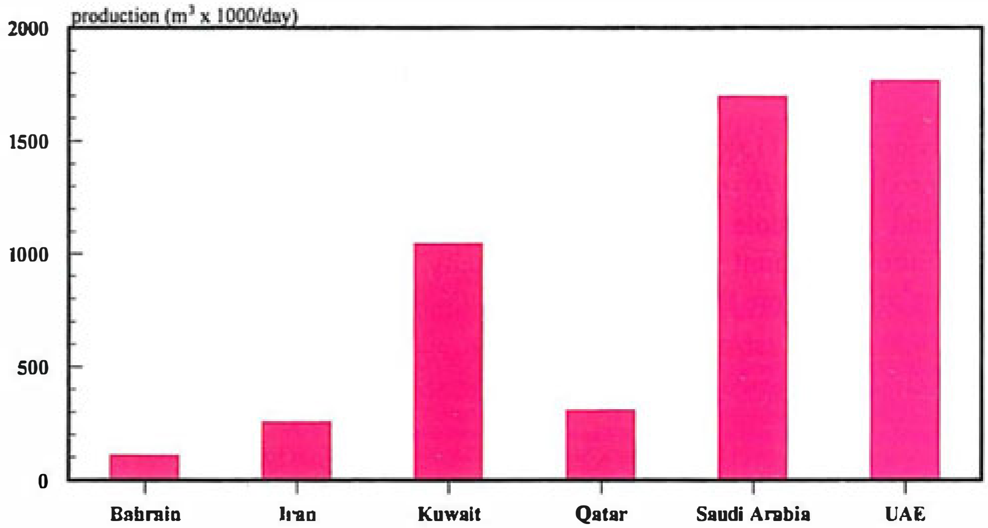
4.1.1.2 *Desalination and Power Plants*

More than 11,000 desalination plants are in operation throughout the world producing ~20 million $m^3$/day. About 65% of the capacity exist in West Asia and the Middle East. North America has about 11% and North Africa and Europe account for ~7% each capacity. Plant sizes and designs range from 20 $m^3$/day to more than 500,000 $m^3$/day (WHO, 2000).


About 68 power and desalination plants exist on the coastal line of RSA. The production capacity of desalination plants varies between ROPME Member States according to the population and the demand for freshwater. For example, an estimation of the production capacity of the Multi Stage Flash (MSF) which is the main technique for desalination used in all Member States varied from 113,650 $m^3$/day in Bahrain to 1698,874 $m^3$/day in Saudi Arabia as shown in Figure (4.5). Additional desalination plants exist in ROPME Member States using other methods of desalination e.g. Reverse Osmosis (RO), Electro-dialysis (ED), Thermal Compression (TC) and Vapour Compression (VC).

The heated brine (salt water) is discharged back to the sea as by-product, which will lead to changes to the physical characteristics of sea water mostly in terms of temperature and salinity (UNEP, 1999). Sea and brine water can contain micro-organisms that could be pathogenic bacteria, protoza and possibly virus (WHO, 2000). Although, heated brine is likely to disturb the balance of marine ecosystem, its impacts on the marine environment are not yet well established (LBA-S.Arabia, 1999).

**Figure (4.5): The production capacities of MSF desalination plants in ROPME Member States.**




(Al-Hajr & Ahmed, 1997)

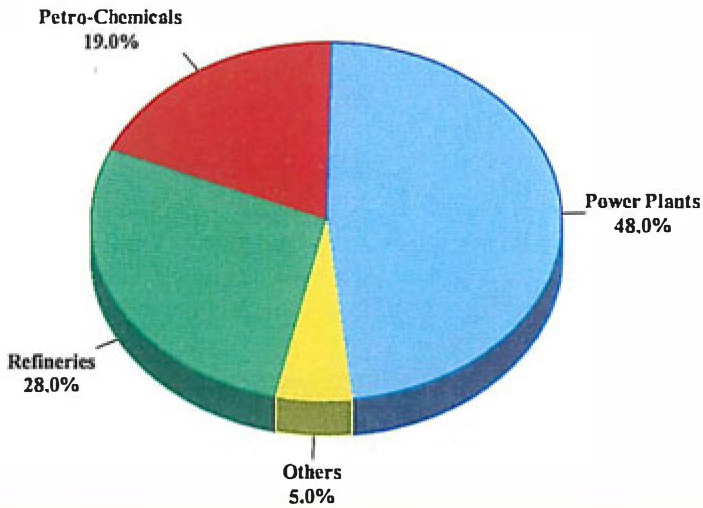
4.1.1.3 *Liquid industrial wastes*

Industries, which are mostly, located on the coast usually discharge their effluents to the sea. According to ROPME reports, the desalination and power plants are discharging the maximum percentage of effluent volume estimated at 48% of the total effluent discharges and account to some of the BOD, COD and SS (Suspended Solids) loading. Next to the desalination and power plants, the petroleum refineries have been reported to contribute 28 % of the total waste volume to the RSA and are major contributor to the COD, oil and metals load. Petrochemical and other industries contribute only 19 % and 5 %, of the total discharge to the RSA, respectively Figure (4.6). Power and desalination plants also contribute to the oil loading produced by oil export, which are responsible for the high load of oil contaminants in the RSA.

The amount of oily liquid wastes in Bahrain during the period (1996-1998) varied according to the type of waste. The highest oily waste is tarry pitch which amounted to1,500,000 tons/yr followed by oil sludge, which varied from

3,000-10,600 tons/yr and waste oil of 12 tons/yr (LBA-Bahrain, 1999). This is an increase of 14.5% compared with the data of mid 1980's. Most of these liquid wastes are transferred for recycling whereas the rest are incinerated to reduce volume and weight, which also reduce the potential to pollute. The residues from incineration processes can be land-filled (LBA-Bahrain, 1999). However, no data are available about the contaminant load to the RSA from these processes.

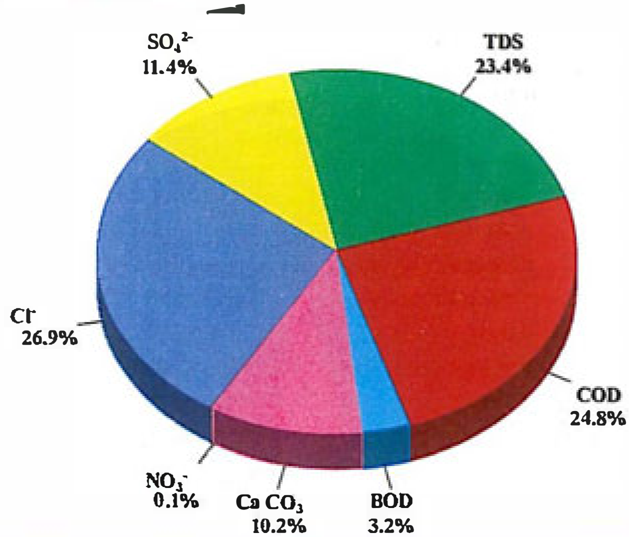
**Figure (4.6): Discharge of wastewater into the coastal zone of RSA.**




The total pollution load entered the Karun-Dez basin in I.R. Iran is summarised in Figure (4.7). The amounts of the pollutants are as follows 28,156 tons/yr BOD, 218,081 tons/yr COD, 205,939 tons/yr TDS, 100,498 tons/yr $SO_4^{2-}$, 23,635 tons/yr $Cl^-$, 477 tons/yr $NO_3^-$ and 89,808 tons/yr $CaCO_3$. The highest load was related to $Cl^-$, which represented 26.9% of the total amount of pollutants load followed by 24.8% for COD (LBA-I.R. Iran, 1999).

In Qatar, the amount of cooling water and brine discharge from the power and desalination plants varies between 25,000 and 124,800 $m^3$/hr (219-1093 million $m^3$/yr). The pollutants are only residual chlorine of 0.1 ppm (equivalent to 21,900-109,300 tons/yr of chlorine) and the thermal load. About 5-10 tons/yr of oil and chemicals are generated from the power and desalination plants. These are proposed to be disposed of by incineration (LBA-Qatar, 1999). However, for the oil refinery the main effluents consist of liquid hydrocarbon as discharged from the pressure relief valves. The effluents may also contain phenol, sulphides and dissolved solids. The process wastewater has been estimated at 800 $m^3$/day with oil content of 103.2 $m^3$/day. This is mixed with the cooling water rated at 4.8 million $m^3$/day and discharged to the sea. The main pollutant in this process is the oil contamination (LBA-Qatar, 1999). Another load is also possible from the fertilisers and petrochemical industries, in addition to the gas and fuel production.

**Figure (4.7): Contaminant load percentage of liquid discharge into Karun-Dez basin - I.R. Iran.**




In Saudi Arabia, the liquid industrial discharge was mainly from sewage treatment plants, which include domestic and industrial wastes. The total generated amount is 736,500 $m^3$/day and the discharged amount is 600,00 $m^3$/day (LBA-S.Arabia, 1999). The contaminant loads of the discharged waste are shown in Figure (4.8). The Figure indicated that the highest load was 12,801 tons/yr reported for COD/TOC followed by 7,062 and 6,374 tons/yr for TSS and BOD, respectively. The lowest amount was 220 tons/yr for total chlorine ($T\text{-}Cl_2$). However, the liquid wastes discharge to the sea were through the cooling canal at Jubail Industrial City with BOD 8,211 tons/yr, TSS 2,377 tons/yr and oil 384 tons/yr. Saudi Aramco has four industrial facilities discharging treated wastewater to the sea after partial use for landscape activities. However, the data on volumes discharged to the sea from these facilities and the volume for irrigation are not provided (LBA-S.Arabia, 1999).

The amount of the industrial liquid waste in UAE was estimated at 37 million $m^3$ in the year 1998. The BOD, TSS and oil pollution loads were 11,082; 29,727 and 20,140 tons/yr respectively. In Abu Dhabi, the BOD, TSS and oil loads are

3,018; 10,330 and 6,748 tons/yr, respectively. The main sources of BOD in Abu Dhabi are: dairy farms and dairy industry, layer houses, petroleum refinery and slaughter houses that account for 44%, 27%, 20% and 9% of the total load, respectively. Whereas the major sources of TSS loads are dairy farm and dairy industry, layer houses and power plant as shown in Figure (4.9) (LBA-U.A.E., 1999).

**Figure (4.8): Contaminant load percentage of liquid discharge from municipal and industrial facilities in Saudi Arabia to RSA.**

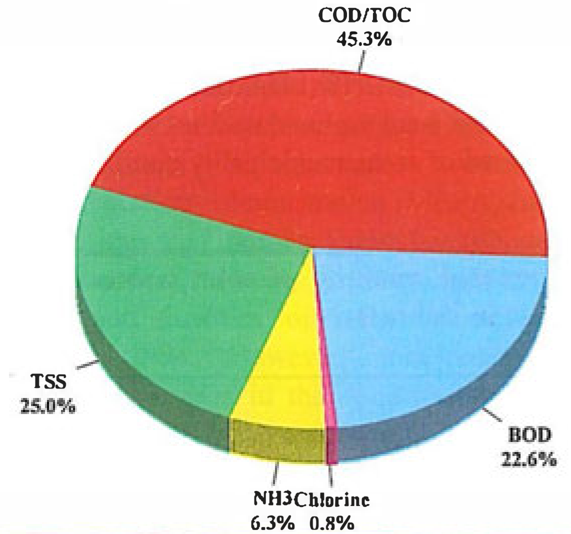
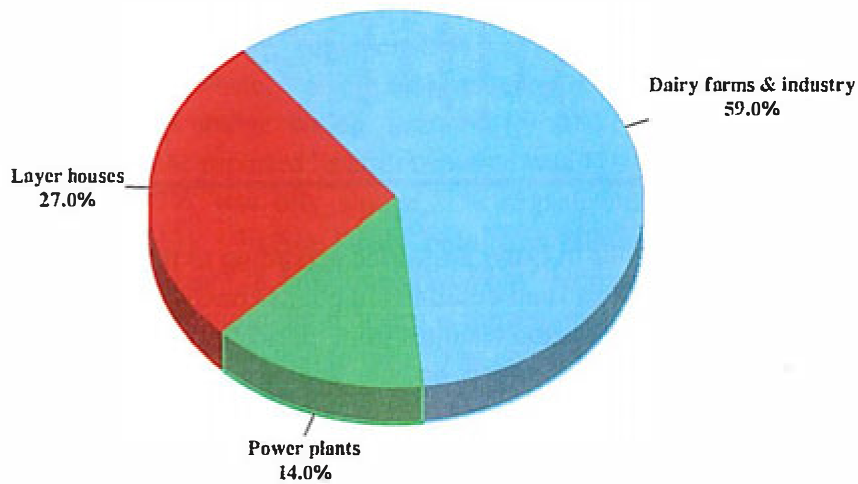



**Figure (4.9): Major sources of TSS of industrial liquid waste generated in Abu Dhabi, 1998.**

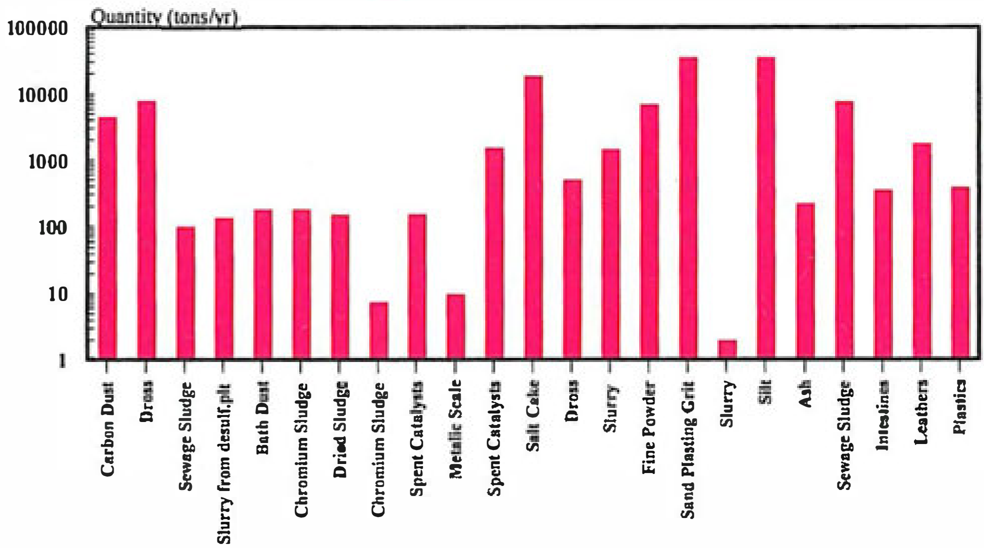


For Dubai Emirate, the liquid wastes load of BOD, TSS and oil were 5,973; 13,897 and 9,487 tons/yr respectively. Paper mill, dairy industry, edible oil refinery and aluminium industry are the main sources of BOD load and account for 40%, 29%, 17% and 14% of the total load, respectively.

4.1.1.4 *Solid industrial wastes*

Solid wastes are generated by various industries in the region and may affect the RSA if not properly managed and handled. In Bahrain, the major industrial solid wastes are sand plasting grit and silt which amounted to 35,000 tons/yr for each and both account for 57% of the total industrial solid wastes in Bahrain during the period from 1996-1998 (LBA-Bahrain 1999), Figure (4.10). The data are 20% less than what were accumulated in 1990. It also worth noting that all the wastes are disposed of at the municipality dump in Askar.

**Figure (4.10): The estimated quantity of solid wastes generated by large scale industries in Bahrain.**



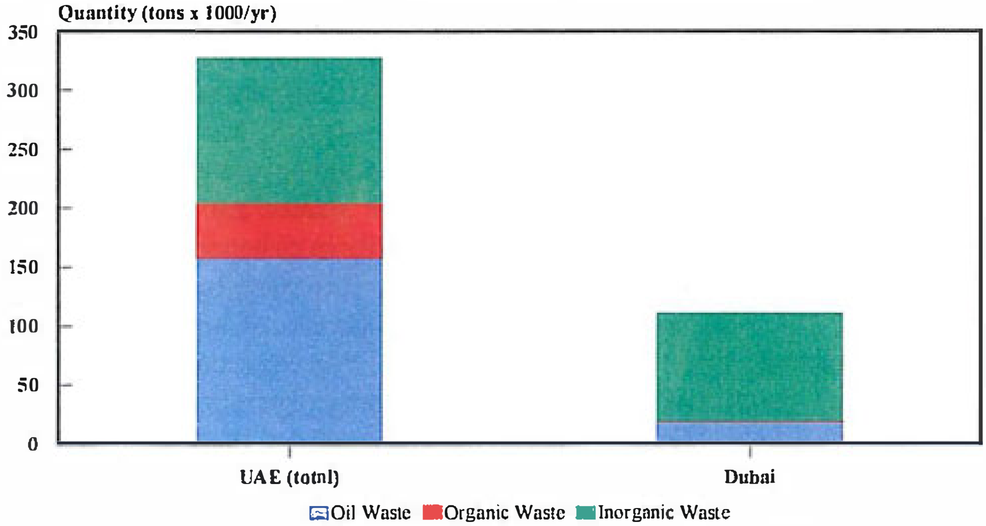

The solid wastes in Qatar are varied according to the industrial type. The solid waste from power and desalination plants consist of residues from tank farms, oil water separation and residues from lubricating oils which add up to about 10 tons/yr. These are stored on site and are proposed to be disposed of by incineration (LBA-Qatar, 1999). Oil refinery generates a total of 16.2 tons/yr of solid wastes consisting of catalysts, molecular sieves and sludge, and are disposed of in the landfill at Messai'eed. Urea and Ammonia plants generate another 100 tons/yr of catalyst waste. This waste is used to be recycled. However, no estimation is given for the quantity of the petrochemical waste. About 150 tons/yr of hydrocarbon wastes is generated from the liquefied natural gas in addition to small quantities of filters and catalysts produced. These solid wastes are planned to be discharged in a dumpsite currently being established within Ras Laffan Industrial City. Fuel additives industry also generates solid wastes, which are classified as non-hazardous wastes. The quantity varies from 3 $m^3$/yr for spent filter cartridges to 352 $m^3$/yr for spent catalysts (LBA-Qatar, 1999).

Approximately 1.2 million tons/yr of solid wastes are generated from the municipal, commercial and industrial activities in eastern part of Saudi Arabia. The municipalities of eastern province have constructed municipal landfills to receive and discharge the generated wastes. The Meteorology and Environmental Protection Administration (MEPA) has estimated the quantity of industrial (hazardous and non-hazardous) waste generated by the industry, including petrochemical, cement, fertiliser, iron and steel, small & medium scale industries, port facilities, oil refineries etc., in the eastern province at 106,700 tons/yr in 1994. However, more recent estimation (LBA-S.Arabia, 1999) indicated an increase in the solid waste up to 199,366 tons/yr which is almost 87 % more than the previous estimate by MEPA (1994). The latest estimation included the solid wastes generated by petrochemical industries, cements plants and oil refineries. It also worth noting that the solid hazardous wastes are not allowed to be dumped at the sea. The Kingdom has various licensed companies having landfill, land-farm, chemical treatment, encapsulation, stabilisation and incineration facilities for environmental management of industrial waste (LBA-S.Arabia, 1999).

The estimated industrial hazardous solid waste generated in UAE for the year 1998 was 327,086 tons/yr, of which 48% was oily wastes, 14% organic waste and 37% inorganic waste. Spent oil processing is one of the major industrial sources at the oily sludge which accounts for 80% of the total produced oily sludge. In Dubai the reported hazardous waste was 110,650 tons/yr for the year 1997 of which 17% was oily sludge, 1% organic sludge and 82% inorganic sludge (Figure 4.11). In Abu Dhabi, petroleum refinery is the main industrial source of oily sludge (28,413 tons/yr) which represent 20% of the total oily sludge in UAE. Aluminium industry is the major source of organic sludge in UAE estimated at ~1,000,000 tons/yr. The actual data provided by the factory indicated that the inorganic sludge generated by the factory represent 90% (109,896 tons/yr) of the total inorganic waste generated in UAE. The oil sludge at oil export terminals was estimated at 130,000 tons/yr (LBA-UAE, 1999).

Generally, according to ROPME's rapid assessment data and the 1999 country reports, oil sludge represents the main industrial solid waste in the RSA.

**Figure (4.11): Hazardous solid wastes loads in the U.A.E., 1998.**




4.1.1.5 *Atmospheric industrial emissions*

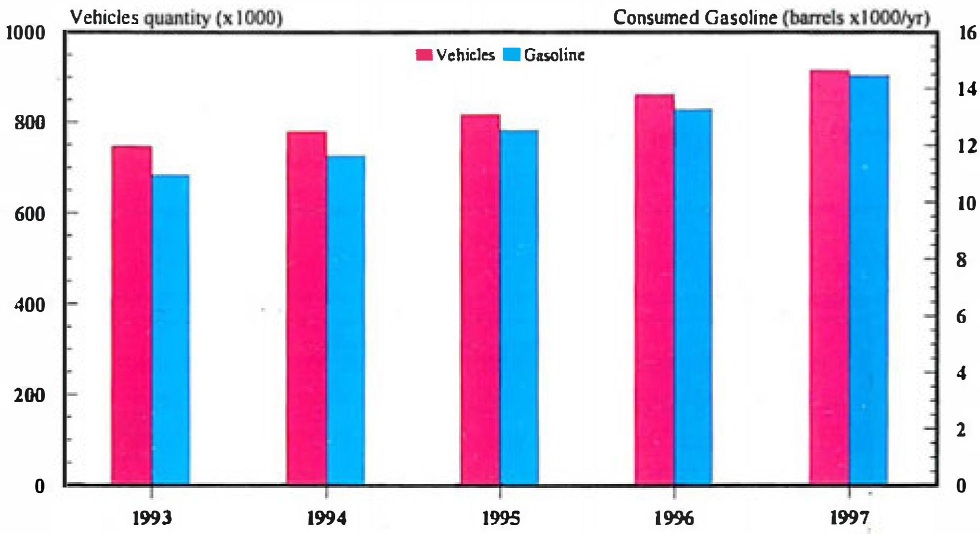
The third category of pollution loads resulting from land-based industrial processes is the atmospheric emissions that may eventually reach the marine environment by deposition (Figure 4.1). Major sources of air pollution in the RSA, particularly the more industrialised centres, include oil refineries, oil gathering centres, oil platforms, petrochemical and fertiliser plants, power plants and motor traffic.

There is an increase demand on the new and used motors in some ROPME Member States. It may be added that smoke from the incomplete combustion of fuel is currently a serious environmental problem in the region due to the existence of the polycyclic aromatic hydrocarbons (PAHs) that is of great risk to the environment and health. The atmospheric deposition would contribute to the load on a regional scale.

In Bahrain the number of motor vehicles increased from 120,000 in 1990 to 185,000 in 1998, which has become a tremendous source of atmospheric pollution. The waste oil from motor vehicles during the period 1996-1998 was 3,000 tons/yr (LBA-Bahrain, 1999).

For Kuwait the motor vehicles increased from 746,994 in 1993 to 914,274 in 1997 (ASA, 1998). This also led to an increase in the consumed gasoline from 10,923 barrels/yr in 1993 to 14,445 barrels/yr in 1997 (ASA, 1998) as shown in Figure (4.12).

**Figure (4.12): The relationship between the increase in number of vehicles and the consumed gasoline in Kuwait, 1993-1997.**

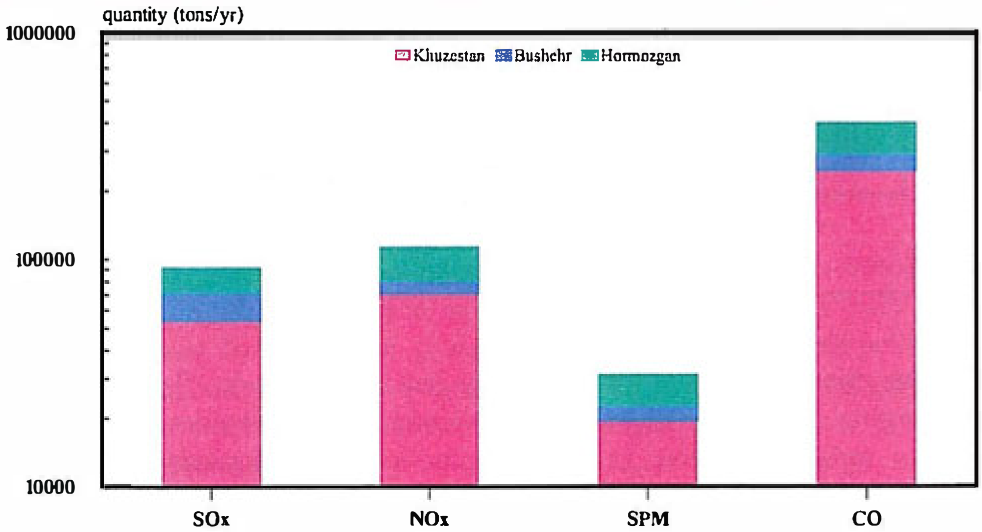



The primary emission sources from industries include: flaring, venting and purging gases; combustion processes such as diesel engines, plant exhaust and gas turbines; fugitive gases from pits, loading operations and tankage and loosed from process equipment; airborne particulate from soil disturbance during construction and from vehicle traffic; particulate from other burning processes such as garbage/sludge burning.

The principal emitted gases include sulphur dioxides and hydrogen sulphide that are produced and depend upon the sulphur content of the hydrocarbon and diesel fuel, particularly when used as a power source. In Kuwait, for example, the sulphur content of fuel used as power source is around 2.4% (McKenna *et al*., 1995) while in Qatar the sulphur content is 1.25% (LBA-Qatar, 1999). Higher sulphur content can lead to odour production. Particulate from stocks is the second atmospheric industrial emissions of significance and may lead to more stress towards the marine environment. Nitrogen oxides, carbon monoxide, methane and volatile organic carbons also exist in appreciable amounts. The air emission estimates do not emphasise the source but combine several sources together (ROPME, 1997).

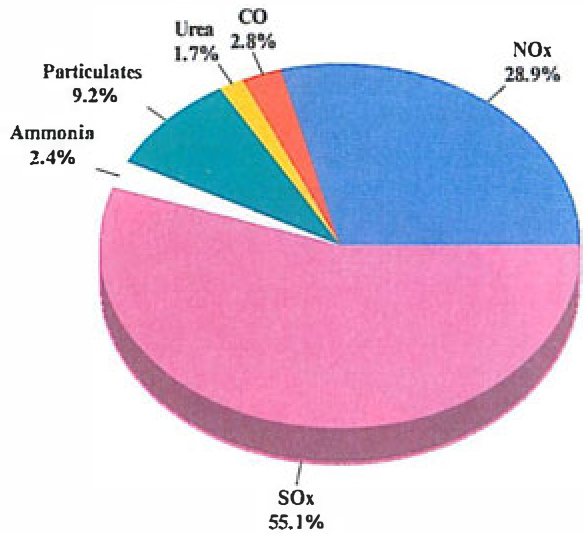
The emission load of pollutants from domestic, commercial and industrial activities, transportation, agriculture and power stations in three provinces of I.R. Iran during 1996 is shown in Figure (4.13). The Figure indicates the major load of pollutant as the carbon monoxide (CO) which amounts to 397,737 tons/yr. The second load is attributed to nitrogen oxides ($NO_x$) that amount to 113,757 tons/yr, followed by 92,089 tons/yr of sulphur oxides ($SO_x$) and 31,227 tons/yr of SPM. About 62% (390,891 tons/yr) of the total pollutants load (634,810 tons/yr) were emitted to the atmosphere from Khuzestan activities followed by 26 % (166,400 tons/yr) from Hormozgan and 12% (77,519 tons/yr) from Bushehr (LBA-I.R. Iran, 1999).

**Figure (4.13): Atmospheric emission load in different provinces in IR.Iran, 1996.**




The estimated total emission load of pollutants in Qatar from different industrial activities is 186,812 tons/yr (LBA-Qatar, 1999). More than 55% (102,873 tons/yr) was as sulphur oxides resulted from petrochemical industries. The $NO_x$ represent 28.9% (53,977 tons/yr) of the total pollutants load. However, the remaining percentage is distributed between particulate (9.2%), CO (2.8%), ammonia (2.4%), urea (1.7%) and volatile organic carbon (VOC) which is < 1.0% (Figure 4.14).

**Figure (4.14): Estimated atmospheric emission load in Qatar.**




The emission load of the pollutants from the eastern province of Saudi Arabia varied between 2 tons/yr vanadium emitted from the power plants to 166,750 tons/yr $NO_x$ emitted from different industrial facilities. Sulphur dioxides (32,1.52 tons/yr), particulate (5,248 tons/yr), VOC (84,395 tons/yr), ammonia (1,870 tons/yr) and urea (380 tons/yr) are also emitted into the atmosphere (Figure 4.15). About 66% of the $NO_x$ are emitted from the power and desalination plants and 98% of VOC is attributed to the oil refineries (LBA-S.Arabia, 1999).

The overall atmospheric pollution loads of $SO_x$, $NO_x$, particulate, CO and VOC in UAE for 1998 were 57,933, 159,093, 60,000, 303,854 and 71,452 tons/yr. The main load was attributed to CO, which represents 46.6% of the total pollutant loads (Figure 4.16.1). The gasoline and powered cars and trucks are the main sources of CO emission to the atmosphere in UAE (LBA-UAE, 1999). Power plant represents 51% of the emitted $NO_x$ while 37% is related to the industrial process and 12% is attributed to the traffic loads. 62% of Sulphur oxides ($SO_x$) was related to the industrial process, 26% to power plants and 12.5% to the traffic load. The particulate load was mainly related to the emission from industrial process (90%), and the remaining 10% were distributed between traffic and power plants (6 % and 4% respectively). The pollution loads were reported the highest value in Abu Dhabi with 311,416 tons/yr (47.7%), followed by Dubai of 133,391 tons/yr (20.4%) as shown in Figure (4.16.2). However, the remaining Emirates showed the following values: Sharjah 94,084 tons/yr (14.4%), Ras Al-Khaimah 60,952 tons/yr

(9.3%), Ajman 23,225 tons/yr (3.8%), Fujairah 20,200 tons/yr (3.1%), and Umm AlQuwain 9,064 tons/yr (1.4%) (LBA-UAE, 1999).

**Figure (4.15): Estimated atmospheric emission load in the eastern province of Saudi Arabia.**

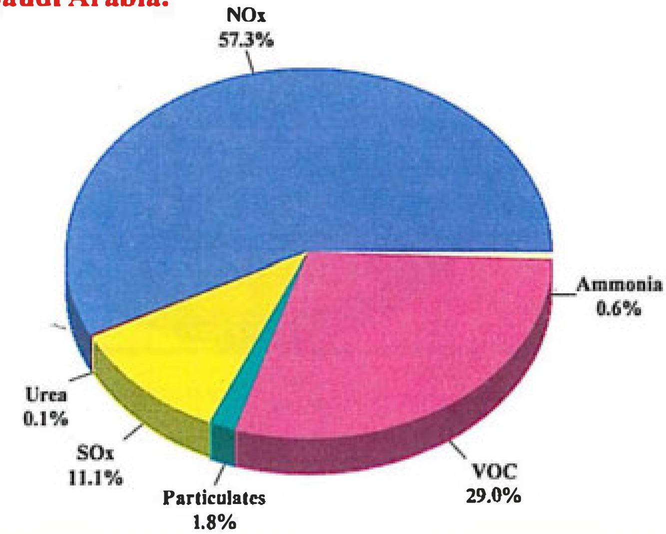



**Figure (4.16.1): The distribution of atmospheric pollutants load in UAE, 1998.**

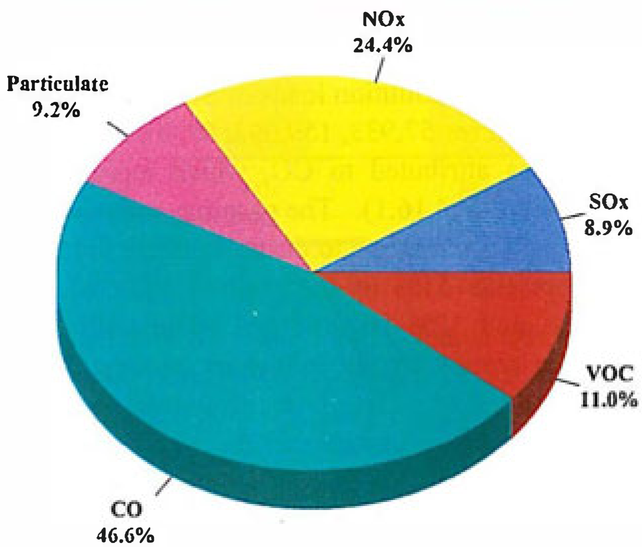
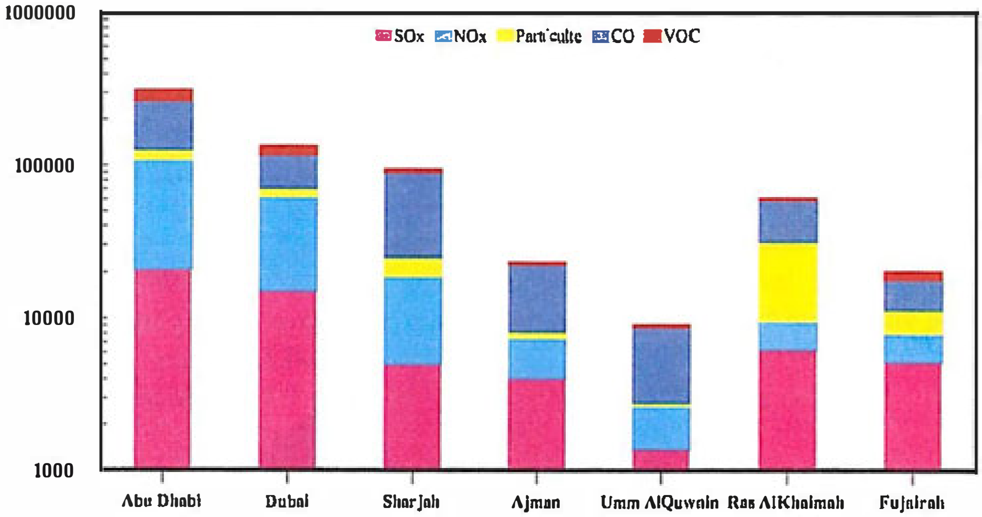


**Figure (4.16.2): The distribution of atmospheric emission load between the United Arab Emirates, 1998.**



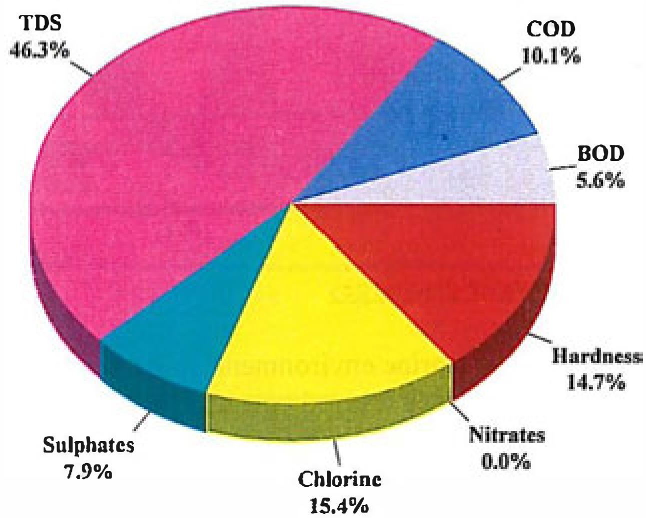

4.1.2 Domestic wastewater discharges

The coastal and the marine environments in RSA are influenced by the sewage discharges from urban and rural areas. The wastewater is either partially treated or untreated with characteristics, which vary according to the type, source and the degree of treatment of the wastewater. The early studies undertaken by ROPME Group of Consultants in 1986 showed that the total volume of treated and untreated sewage discharged into the RSA at that time was about 157.236-million $m^3$/yr. A more recent estimate of sewage treatment plants in the RSA gives the combined capacity of more than 2-million $m^3$/day, out of which 35% is treated wastewater (Abu-Ghararah and Abdulraheem, 1999).

In Bahrain, the main wastewater treatment facility receives 150,000 $m^3$/day of municipal wastewater from all parts of Bahrain, in addition to ~15,000 $m^3$/day received from small plants distributed within the country. About 130,000 $m^3$/day of the wastewater are dumped into the sea. The total dissolved solids in wastewater ranged from 12,500 –35,000 ppm. The domestic wastes collected from the residential area has increased by 37% during the last 10 years which is not compatible with the 15% increase in population for the same period. In 1998 the domestic wastes amounted to 2.880-million tons/yr (LBA-Bahrain, 1999).

In the I.R. Iran, about 151.7-million $m^3$/day of sewage is entering the Karun and Dez Rivers by cities. The contamination load varied from 277.3 tons/yr for nitrates to 448,492 tons/yr for total dissolved solids. The loads for other contaminants were for BOD (53,954 tons/yr), COD (97,300 tons/yr), sulphates (76,380 tons/yr), chlorine (149,099 tons/yr) and calcium carbonates (142,344 tons/yr); the percentage of distribution is shown in Figure (4.17). The main load was entering from Ahwaz and Khoramshahr cities (LBA-I.R. Iran, 1999).

**Figure (4.17): Total contaminants percentage load entered Karun and Dez Rivers, I.R. Iran.**




In Kuwait, there are three major sewage treatment plants. The total daily volume of received sewage was 275,000 $m^3$. About 70% of the received sewage was from Kuwait's coastal population and 14.6% of wastewater from the industrial sources (UNEP, 1999). However, no recent data are available for the quantity of the discharged contaminants to RSA.

In Oman, a total of 250,000 $m^3$/yr of treated effluents are discharged to the sea from six coastal sewage treatment plants in Muscat and two plants in the remote Region of Musandam. Additional quantity of 1,500 $m^3$/yr is discharged from Bukha as a result of overflow drainage and 27,000 $m^3$/yr is also discharged to the sea during emergencies (LBA-Oman, 1999).

In Qatar, thirteen sewage treatment plants are operated with a total capacity of 33.0 million $m^3$/yr (LBA-Qatar, 1999). However, the quantity and the quality of the contaminants discharged to the RSA are not available.

In Saudi Arabia, there are seven sewage treatment plants operating in the eastern province. Most of them are secondary level aerobic biological treatment plants while the others (Jubail and Saudi Aramco) are advanced tertiary plants (LBA-S.Arabia, 1999). Their load of pollutants has been discussed above (4.1.1.3).

In UAE, there are four large sewage treatment plants with a total operation capacity of 461,000 $m^3$/day. About 60% of the tertiary treated effluents is used for irrigation and the remaining 40% is discharged to the RSA (LBA-UAE, 1999). However no data are available about the constituents of this discharge.

### 4.1.3 Management and discharges of river basins

Human activities along river basins as well as the engineering works and structures such as man-induced alterations and dams built on rivers have significant effects on the marine and coastal ecosystems associated with these rivers. The effect will be both on the hydrological and biological cycles, through changing the pattern of river flows and on the quality of water discharged into the marine environment, which usually carries large amounts of dissolved and particulate material to the sea. As stated earlier, most river inflow in the RSA occur in the northwestern end of the Sea Area, primarily from Shatt Al-Arab system and Iranian side rivers. The Shatt Al-Arab is a nexus of three major rivers, Tigris, Euphrates and Karun (Figure 2.7).

On the other hand, several dams have been constructed on the major tributaries of Shatt Al-Arab. According to Linden *et al.* (1990), five major dams in Turkey, Syria and Iraq have been built on the Tigris and Euphrates and are controlling the river flow. On the third main tributary of Shatt Al-Arab, the Karun in Iran, there are two major dams. In addition, there are plans for construction of more dams in the future. Recent information indicates that these dams have reduced the flow of water through Shatt Al-Arab drastically, enough to allow extensive drainage operations to be carried out in the

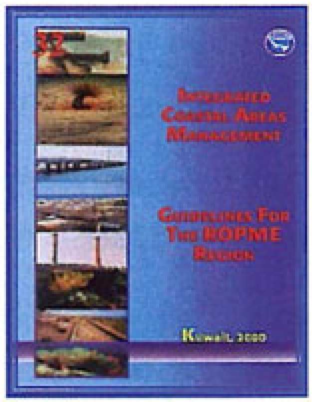
"Alahwar" area (wetland) of Iraq in recent years. With the filtering role of the Iraqi wetlands being eliminated and the newly constructed drainage channel discharging river water into Khor Al-Zubair (at the Iraq–Kuwait border, around Warba Island), has resulted in reduction of the salinity, increased nutrients input and likely to bring more agriculture drainage into the area (Al-Yamani, 1997).

It should be noted that the issue of the dams on the Shatt Al-Arab is not only a water issue for the countries in which the major rivers run through. The levels of fresh water and nutrients provided by these rivers significantly affect fisheries resources in the NW part of the RSA. Thus, reduction of river discharge into the RSA is of a wider regional significance than what is given to it now.

In view of the above activities in the largest river basin in the RSA, it becomes essential that the impact of these activities on the coastal and marine ecosystems in the northern part of the RSA be carefully monitored and studied. Initiating river basin management arrangements for the major rivers should be high on the regional agenda.

### 4.1.4 Coastal development and physical alterations

The coastal zone of the RSA is becoming, like any other coastal area world-wide, under increasing pressure resulting from the high pace of development and the extensive economic activities that take place there. By the early 1990's, some countries of the region, have already developed >40% of the coastline (Price and Robinson, 1993), and recent reports indicate that coastal investment in the region is estimated to be worth between 20-40 million US$/km of the coast (Fouda, 1998).




Most of the coastal development projects require extensive dredging and land reclamation operations to be undertaken in the coastal zone. Several such projects have been or are being implemented in ROPME Member States. For example, in Bahrain such activities have considerably increased in the 1970s, serving both industrial and residential purposes. Some reclamation operations involved large areas for constructing industrial complexes and for building the King Fahd Causeway connecting Bahrain to Saudi Arabia. The reclaimed land in Bahrain increased the surface area of Bahrain from 661.87 $km^2$ in 1975 to 700 $km^2$ in 1994, thus changing the area of the coastal zone by adding about 39 km$^2$ to its area in less than 20 years. Ten km of Oman coastline covering an area of about 3.6 km$^2$ has been reclaimed with 1,625 tonnes of quarry and/or beach sand material. Such magnitude of physical alteration in the coastline has had several adverse environmental effects on the coastal environment including damage to the spawning ground of various marine species and to seagrass beds, removal or alteration of the benthos that form the main source of food for many commercial fish species, increase in siltation due to the outslip of fine sediments, release of fine material during dredging operations resulting in increase of water turbidity that may irritate or clog fish gills, interfere with visual feeding and inhibit photosynthesis.

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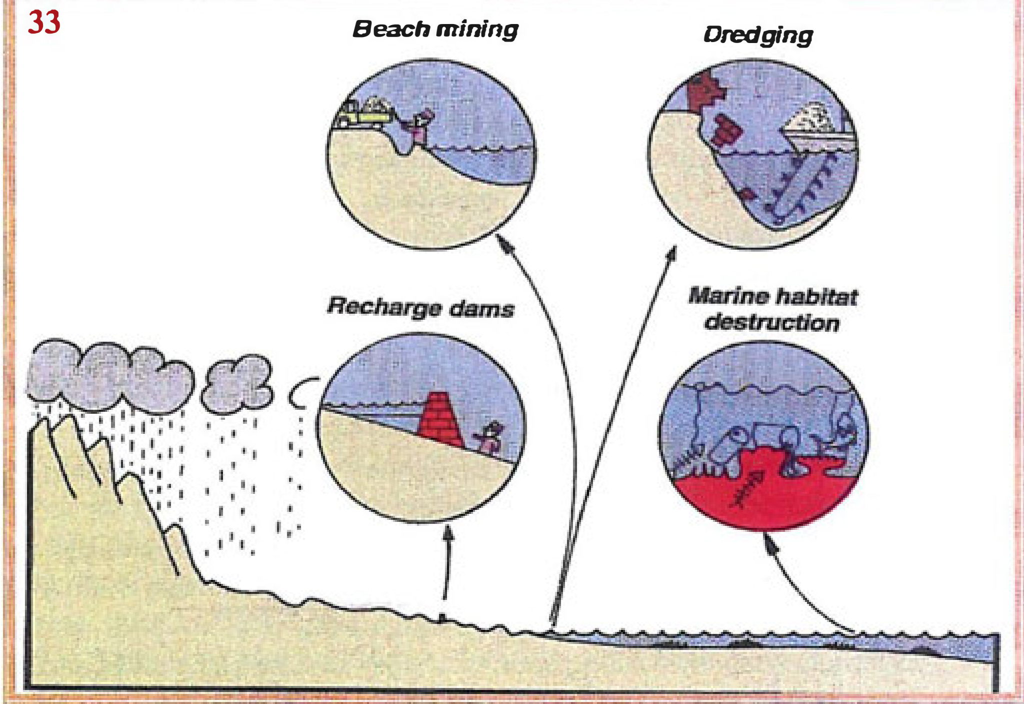



In Kuwait, considerable parts of the intertidal areas along Kuwait City and some sections along the southern coast have been reclaimed. Land reclamation disturbed the natural hydrodynamic conditions of the coastal water and the fill material is not stable under local beach processes, so significant erosion problems have developed along most of the fill edge of the reclaimed areas. Al-Bakri *et al.* (1985) indicated that the effect of these reclamation activities is not only the partial or total loss of the upper intertidal areas but also the modification of the physical nature of the adjacent tidal flats. Loss of the ecosystem and death or migration of the marine inhabitants of the affected areas would naturally accompany such modification.

In Saudi Arabia much of the commercial and residential development along the coast has taken place in coastal cities, particularly around Jubail and further south around Tarut Bay, Dammam and Khobar. Particularly around Tarut Bay, there have been major land-filling activities in the coastal areas. There, land-filling not only causes permanent destruction of coastal habitat, it also can have indirect environmental impacts such as sedimentation, which has been just as severe. Changes in water circulation in the vicinity can alter the structure of the resident plant and animal community. Land-filling activities are routine in coastal development projects. The Saudi Arabian coast has experienced causeways, ports, residential and commercial areas, industrial facilities and roads on land-filled areas (LBA-S.Arabia, 1999).

Likewise, in other ROPME Member States, coastal development projects are taking place at a high pace, such as the development and establishment of aquaculture facilities in Iran, high density single-family dwellings in Oman and modern urban centres, industrial complexes and desalination plants in U.A.E. (Fouda, 1998). Additionally, in some cases, construction of causeways or other structures that block the flow of water and slow down the natural flushing action can make the area around the construction more susceptible to water pollution.

### 4.1.5 Recreation and tourism facilities

Recreation and tourism facilities are developing at a fast rate in many countries of the region. These include building of marinas, facilities for water sports, fishing, marine parks, archeological siting and other recreational activities. Such facilities are expanding and developing considerably well in Bahrain, Oman and U.A.E. where they are extensively used by both nationals and expatriates and by visiting tourists. They are also being established in Saudi Arabia at Jurayd and Jana Islands, Jubail, Muntazah, Dawhat As'sayh and Zalum and Al-Khobar; in Iran at Kish and Qeshm Islands and in Kuwait at the waterfront and Al-Khiran recreational areas.

Along with the development of recreation and tourism facilities in the coastal area as an important industry for the diversification of national economies, a number of luxury modern hotels and furnished holiday apartments and extensive range of restaurants have been built with the necessary coastal roads and other infrastructures to cater for the diverse needs of individual travelers and tourist groups. These installations, when built haphazardly or not managed in an environmentally sound manner could have adverse effects on the marine and coastal environment. Thus, they should be carefully monitored and regulated with a view to protecting the coastal area against degradation, damage and misuse.

## 4.2 Exploration and Exploitation of the Living Marine Resources

Although the region is quite rich in terms of commercial finfish and shellfish species, the fisheries sector plays only a minor role in national economies. In most Member States of ROPME, the contribution of the fisheries sector to the gross domestic product (GDP) is less than one percent. For example, it is 0.3% for Bahrain while in Kuwait the fisheries and aquaculture activities represent together 0.1% and in Qatar the fisheries and agriculture represent together 1.0% of the GDP. However, it has been indicated that in the Sultanate of Oman revenue from fish was 36.5% of the total oil export revenue for 1984 and it is still the most important export product after petroleum. The Islamic Republic of Iran has also intensified efforts to develop its fisheries resources in recent years.

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), (FAO, 1997).

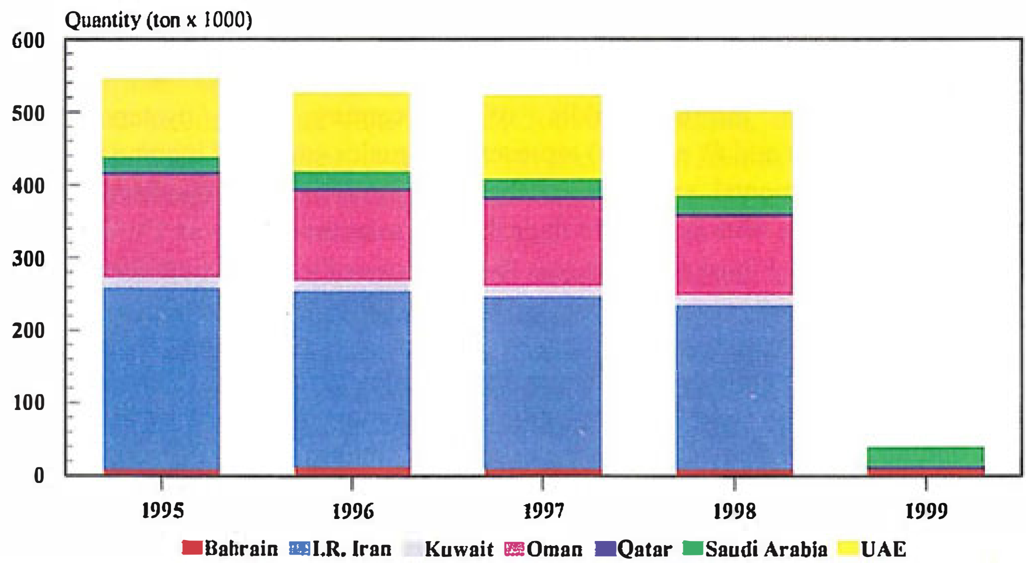
Over 1,000 fish species, six species of shrimp (*Penaeus semisulcatus, P. indicus, Metapenaeus affinis, M. stebbingi, M. monoceros, Parapenaeopsis stylifera*), two species of spiny lobsters (*Panulirus homarus homarus, P. versicolor*), one species of shovel nose lobster (*Thenus orientalis*), one species of cuttlefish (*Sepia pharaonis*), one species of abalone (*Haliotis mariae*), one species of crab (*Portunus pelagicus*) support the commercial fisheries in this region (Mohammed *et al.*, 1981; Johnson *et al.*, 1992; Fouda and Hermosa, 1993; Krupp and Muller, 1994; Abdulqadar, 1994; Siddeek *et al.*, 1997; Fouda, 1997). Until almost middle of the century, pearl oysters (*Pinctada margaritifera* and *P. radiata*) represented a major source of income in the RSA. The environmental extremes of the area has limited the distribution of many species, some live as close to their thermal tolerance limits as 1°C during some parts of year. Figure (4.18) shows the locations of trawling grounds in the inner RSA.

The overall landings in Member States for the period 1995-1999 are shown in Figure (4.19). The highest landing was reported for I.R. Iran followed by Oman, which showed a decrease in fish landing from 1995 to 1999. UAE reported almost close quantities to those quantities of Oman while Qatar reported the minimum quantities during the same period. Bahrain and Kuwait were almost within the same range.

**Figure (4.18): Productive trawling grounds in RSA.**


(After Sheppard *et al.*, 1993; Mathews *et al.*, 1993)

**Figure (4.19): Fish landings in ROPME Member States during 1995 – 1999.**



The demersal fisheries of the inner RSA, Gulf of Oman and the Arabian Sea were reviewed recently by Siddeek *et al.* (1999). Over 350 commercial fish species, eight shrimp species, two spiny lobster species, one shovel nose lobster species, one cuttlefish species, one crab species, and one abalone species support the demersal fisheries in the continental shelves of the three regions. Artisanal and industrial vessels with over 120 000 fishermen were involved in demersal fisheries. Fishing boats include fish and shrimp trawlers (wooden and steel hulled), large wooden boats (dhow) with inboard engines, small dhows with outboard engines, and fibreglass boats. Fishing gear consists of trawls, bottom gill nets, traps (wire mesh and plastic types), barrier traps, hand lines, bare hands and knives (to dislodge abalone). Demersal fish (primarily *Lethrinidae, Sparidae, Serranidae, Siganidae, Sciaenidae, Stromateidae, Lutjanidae, Trichiuridae*, and *Nemipteridae*) and shrimp (*primarily Penaeus semisulcatus, Metapenaeus affinis, Parapenaeopsis stylifera,* and *Penaeus merguiensis*) were the two commercial demersal resources. Approximately 198,000-214,000 tons of demersals were landed annually during 1988-1993, accounting for nearly 40% of the total marine landings (475,000-552,000 ton). This percentage however varied among countries. 25% in Oman, 32% in U.A.E., 71% in Qatar, 52% in Saudi Arabia, 56% in Bahrain, 55% in Kuwait, close to 100% in Iraq, and 41% in Iran (Siddeek *et al.*, 1999).

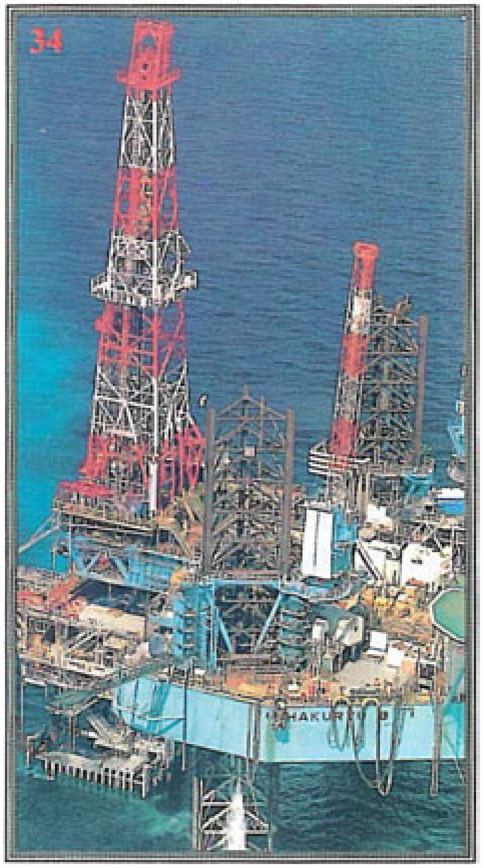
Environmental degradation, e.g. from land reclamation has also led to the elimination of nursery areas for shrimps. Furthermore, the reduced rate of outflow from Shatt Al-Arab may have had quite significant negative effects on the reproduction. To these factors could be added the effects of bottom trawling and the destruction it causes to benthic communities. It should also be pointed out that the years of war in the region had contributed significantly to the decline of fisheries, particularly in the northwestern 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 decreasing of fishing efforts (no new licenses are issued and a limit is imposed on the size of the fishing boats).

Fishing effort on certain stocks may have been below the optimum level (e.g. certain Omani demersal fish), near the optimum level (e.g. Omani shrimp), or above the optimum level (e.g. RSA shrimp and demersal fish). Overexploitation led to restriction of fishing effort by limiting fishing licences, regulating fishing gear (mesh size) and capture size, closing fishing areas, restricting fishing season, and banning certain fisheries. However, fisheries management was hampered by lack of appropriate management regulations, enforcement and data on most stocks. Pollution and degradation of nursery areas were also affecting the productivity of fisheries resources. To achieve sustainable demersal fisheries, we need to maintain a healthy marine environment, reduce fishing effort, and strictly enforce closed seasons and closed areas. These measures are being implemented with varying degrees of success by all the countries (Siddeek *et al.*, 1999).

## 4.3 Exploitation of Non-Living Marine Resources--Sea Based Industrial Activities

Oil and gas are produced from offshore fields deposits by almost all of the countries of the region. In addition, seawater is extracted for desalination and steam production to generate electricity. Seawater is also used for cooling purposes in large industries, e.g. refineries.




There are approximately 34 offshore gas and oil fields in the region with additional fields waiting exploitation. There are over 800 producing offshore oil wells with the largest numbers being in Saudi Arabia, Iran and the United Arab Emirates. As many as 50 wells can be drilled from a single platform (Ryan and Brown, 1985). The major hazard of offshore drilling is well blowout. For example, in the six years period between 1993 and 1998 two major spills have been caused by well blowouts as listed in Table (4.1).

Environmental impacts are possible at all stages of offshore oil exploration and production activities. In particular, the impacts of produced water on the marine environment especially in shallow waters or near to ecologically sensitive areas are more noticeable. The magnitude of environmental impacts is also subject to the volume of produced water and the composition of discharge (i.e. oil, production chemicals, NORM, solids, inorganic and metal salts). Such operational discharges are for the most part regulated by international agreements and ROPME Protocol. In addition to these environmental effects, offshore oil exploitation has other impacts. The presence of rigs and pipelines create exclusion zones for fishing vessels and other shipping, while the debris associated with offshore oil operations can damage fishing gear or entangle ships' propellers. Also, offshore wells can be a target for military action, as shown by several events in the RSA, or sabotage, with consequent pollution of the neighbouring waters (SOMER, 1999).

**Table (4.1): Major oil spill incidents due to well blowouts during 1993-1998.**

| | **Incidents** | |
|---|---|---|
| | **1** | **2** |
| **Date** | 23/11/93 | 08/08/98 |
| **Location** | Bahrain (Bahrain-Saudi Causeway) | Kuwait/ Al-Ahmadi |
| **Source** | A-B Pipline (Saudi-Bahrain) | Al-Ahmadi Refinery Pipeline |
| **Type of Oil** | Crude Oil | Crude Oil |
| **Amount of Oil Spilled** | Just over 4000 bbls | 650 bbls |
| **Cause of the Incident** | Pipeline was hit by a barge | Leakage of old pipeline |

In I.R. Iran, there are different locations for exploration, exploitation and export of crude oil from offshore fields in RSA (Figure 4.20). The volume of produced water varied from 200 barrels/day in Nowruz field to 115,000 barrels/day in Salman field and the oil contents varied from 25 mg/L in Sirri district to 270 mg/L in Reshadat field (Figure 4.21), (SBA-I.R. Iran, 2000).

The estimated average discharges of chemicals from offshore activities for Qatar during 1999 were 31.5 tons/month as detailed in Figure (4.22). The chemicals used by offshore operations were mainly corrosion inhibitors, scale inhibitor, anti foams, demulsifier/oil dispersant, biocides and water clarrifier. It is also worth noting that all drilling mud used are water based and pH balance and none of the drilling mud chemicals used contain toxic or hazardous constituents as specifically listed by ROPME (SBA-Qatar, 2000).

In 1989, ROPME Member States adopted the Protocol concerning Marine Pollution resulting from Exploration and Exploitation of the Continental Shelf (ROPME, 1993). The Protocol and its Guidelines aim at controlling the pollution resulting from all types of offshore operations including exploration and exploitation of resources, conduct of seismic operations, use of E & P chemicals and the disposal of drill cuttings on the seabed. With the implementation of this protocol it is expected to achieve proper regional co-ordination for sound environmental practices in offshore oil and gas exploration and production activities.

effort, and strictly enforce closed seasons and closed areas. These measures are being implemented with varying degrees of success by all the countries (Siddeek *et al.*, 1999).

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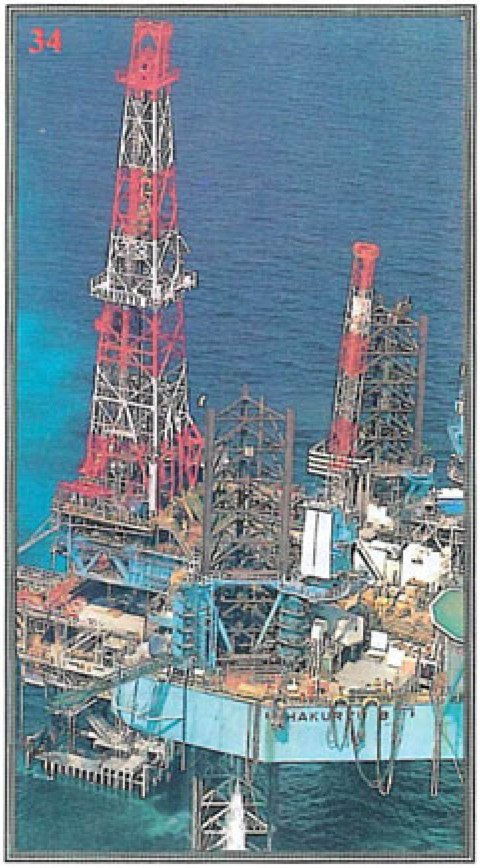



There are approximately 34 offshore gas and oil fields in the region with additional fields waiting exploitation. There are over 800 producing offshore oil wells with the largest numbers being in Saudi Arabia, Iran and the United Arab Emirates. As many as 50 wells can be drilled from a single platform (Ryan and Brown, 1985). The major hazard of offshore drilling is well blowout. For example, in the six years period between 1993 and 1998 two major spills have been caused by well blowouts as listed in Table (4.1).

Environmental impacts are possible at all stages of offshore oil exploration and production activities. In particular, the impacts of produced water on the marine environment especially in shallow waters or near to ecologically sensitive areas are more noticeable. The magnitude of environmental impacts is also subject to the volume of produced water and the composition of discharge (i.e. oil, production chemicals, NORM, solids, inorganic and metal salts). Such operational discharges are for the most part regulated by international agreements and ROPME Protocol. In addition to these environmental effects, offshore oil exploitation has other impacts. The presence of rigs and pipelines create exclusion zones for fishing vessels and other shipping, while the debris associated with offshore oil operations can damage fishing gear or entangle ships' propellers. Also, offshore wells can be a target for military action, as shown by several events in the RSA, or sabotage, with consequent pollution of the neighbouring waters (SOMER, 1999).

**Table (4.1): Major oil spill incidents due to well blowouts during 1993-1998.**

| | Incidents | |
|---|---|---|
| | 1 | 2 |
| **Date** | 23/11/93 | 08/08/98 |
| **Location** | Bahrain (Bahrain-Saudi Causeway) | Kuwait/ Al-Ahmadi |
| **Source** | A-B Pipline (Saudi-Bahrain) | Al-Ahmadi Refinery Pipeline |
| **Type of Oil** | Crude Oil | Crude Oil |
| **Amount of Oil Spilled** | Just over 4000 bbls | 650 bbls |
| **Cause of the Incident** | Pipeline was hit by a barge | Leakage of old pipeline |

In I.R. Iran, there are different locations for exploration, exploitation and export of crude oil from offshore fields in RSA (Figure 4.20). The volume of produced water varied from 200 barrels/day in Nowruz field to 115,000 barrels/day in Salman field and the oil contents varied from 25 mg/L in Sirri district to 270 mg/L in Reshadat field (Figure 4.21), (SBA-I.R. Iran, 2000).

The estimated average discharges of chemicals from offshore activities for Qatar during 1999 were 31.5 tons/month as detailed in Figure (4.22). The chemicals used by offshore operations were mainly corrosion inhibitors, scale inhibitor, anti foams, demulsifier/oil dispersant, biocides and water clarrifier. It is also worth noting that all drilling mud used are water based and pH balance and none of the drilling mud chemicals used contain toxic or hazardous constituents as specifically listed by ROPME (SBA-Qatar, 2000).

In 1989, ROPME Member States adopted the Protocol concerning Marine Pollution resulting from Exploration and Exploitation of the Continental Shelf (ROPME, 1993). The Protocol and its Guidelines aim at controlling the pollution resulting from all types of offshore operations including exploration and exploitation of resources, conduct of seismic operations, use of E & P chemicals and the disposal of drill cuttings on the seabed. With the implementation of this protocol it is expected to achieve proper regional co-ordination for sound environmental practices in offshore oil and gas exploration and production activities.

**Figure (4.20): Location of offshore oil fields in I.R. Iran.**

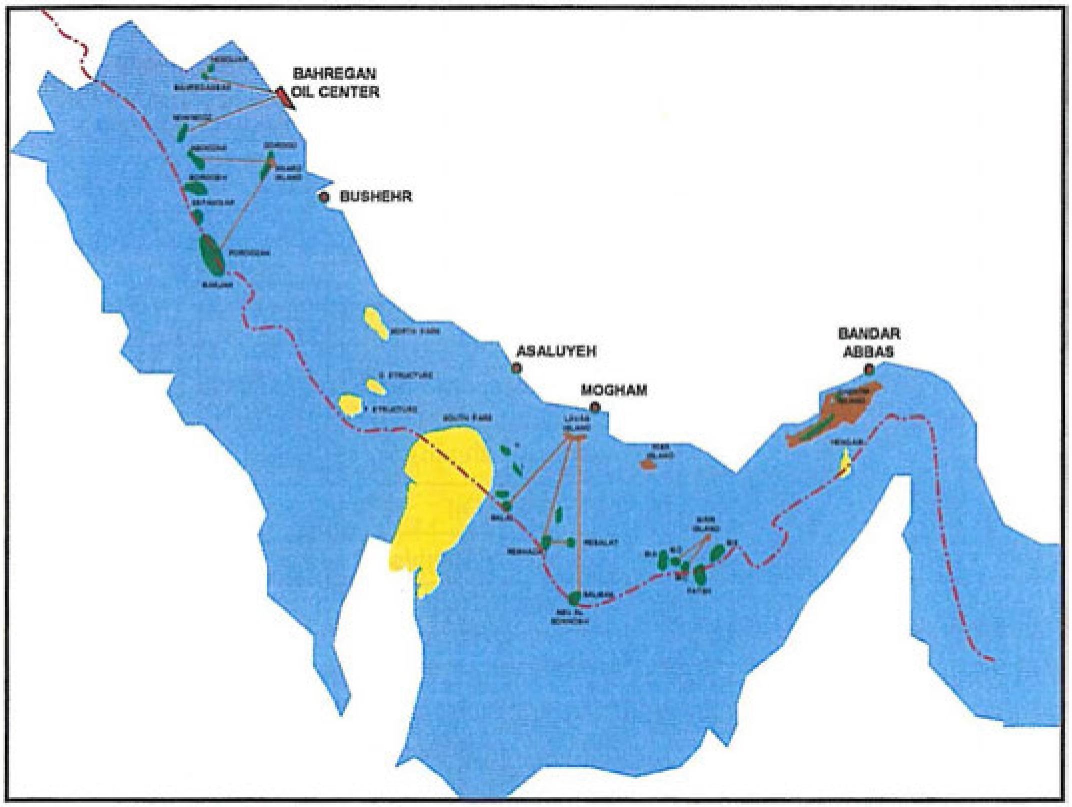



**Figure (4.21): The quantity of produced water and oil content resulted from offshore activities in I.R. Iran.**

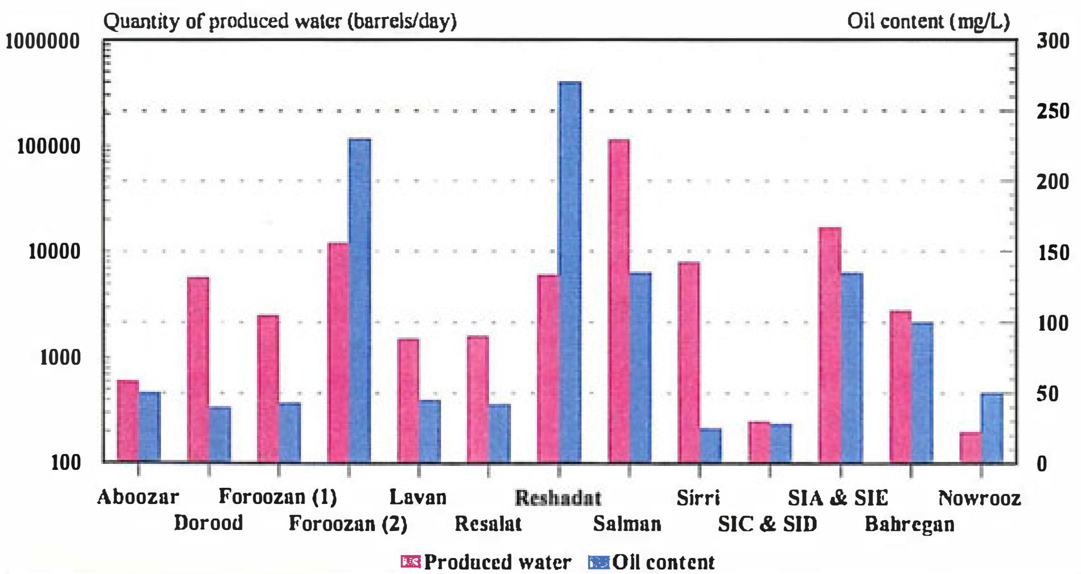
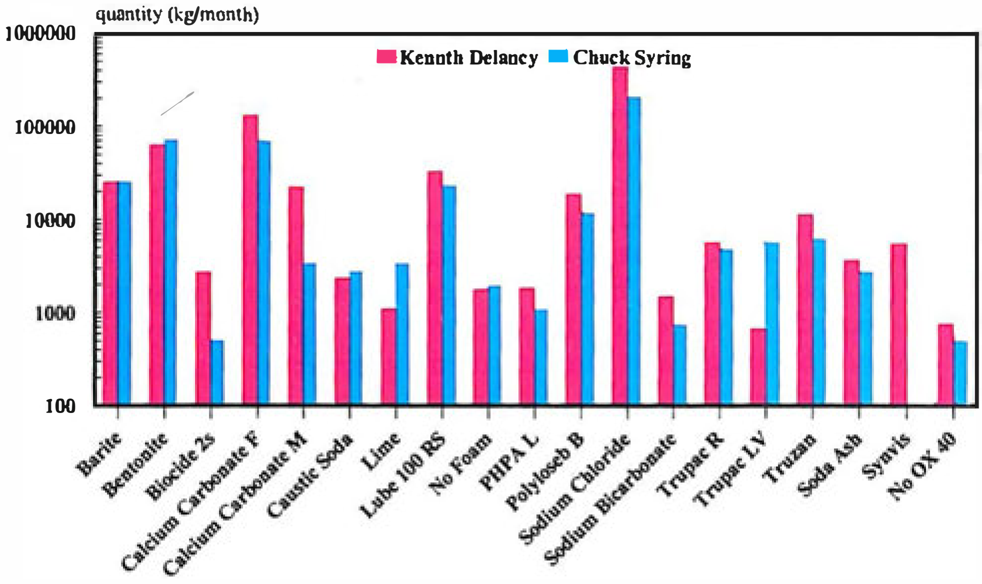


**Figure (4.22): Average monthly discharge of chemicals from offshore activities, Qatar-98/ 99.**




The utilisation 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‰. The effluents also contain residual chlorine (mainly as brominated, iodated and chlorinated organic), 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 the nearshore shallow areas may be considerable (Ali and Riley, 1986).

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.

### 4.3.1 Dredging

As mentioned earlier, wide-scale dredging activities are taking place in most of the coastal areas of the RSA, particularly in countries undertaking land reclamation operations. Regular dredging operations may also be carried out to keep harbours, rivers and other waterways from silting up, or in association with new construction and engineering works offshore.

Uncontaminated dredged material, if properly handled, causes few problems in the long term, and indeed can serve a variety of useful purposes, including land-fill, building of artificial reefs and reclamation of previously damaged coastal sites. If dumped at sea, its physical impact must be taken into account and careful selection and management of the dumpsites is important.

About 10% of dredged materials are contaminated from a variety of sources, including shipping, industrial and municipal discharges, and land run-off. Typical contaminants include oil, heavy metals, nutrients and organochlorine compounds. Dumped dredged material has liquid and suspended particulate phases, but the greatest potential for impact generally lies with the settleable or solid-phase material which may affect benthic organisms by smothering and physical disruption of habitats; bioaccumulation and toxicity from both soluble and suspended phases may also occur.

Contaminated dredged material may slowly release its adsorbed burden and result in long-term exposure of local habitats to one or more contaminants. However, laboratory and field studies show that leaching into the water column of chlorinated hydrocarbons, petroleum and metals is slight. Nutrients are released at concentrations much greater than background but mixing processes tend to mitigate effects. The major impact at disposal sites with small current velocity and low wave-energy is the physical mounding of the material. Benthic recolonisation of these mounds is relatively rapid on fine-grained sediments and slower on coarse-grained material.

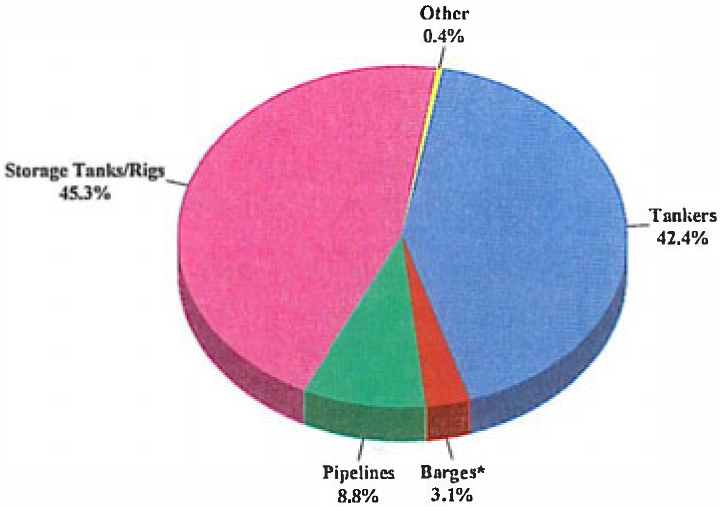
No single method of sea disposal, or category of sea disposal site, is suitable for every type of dredged material or industrial waste. All alternatives need consideration at the planning stage to ensure that the waste has the smallest possible environmental impact (GESAMP, 1990).

### 4.3.2 Maritime transport

The global marine transportation during the period of 1978-1996 showed that about 45% of the spilled oil entered the marine environment by storage tanks and almost the same amount (42.4%) from tankers accidents (MEMAC, 2000). However the remaining quantity is related to the pipelines, barges and other sources as shown in Figure (4.23).

About 25,000 tankers navigate through the Strait of Hormuz in which they are carrying about 60% of the total oil exports to the world. The oil is exported from 34 major oil terminals in the region (UNEP, 1999). About 2 million barrels of oil are spilled in the region every year (Hinrichsen, 1996) from the routine discharge of dirty ballast water (UNEP, 1999). Besides the dirty ballast water, ships also generate other types of waste. All ships produce bilge water, oily slops from centrifugation of bunker oil, as well as leakage and from washing of engine rooms. These are much smaller amounts, but with a higher content of oil. Ships also produce sewage and garbage as all other households. Garbage is estimated at 8.3 metric tons/yr (Abdulraheem, 1997). However, in order for ships to deliver their waste, adequate reception facilities must be provided.

**Figure (4.23): Percentage of globally spilled oil from different sources, 1978-1996.**



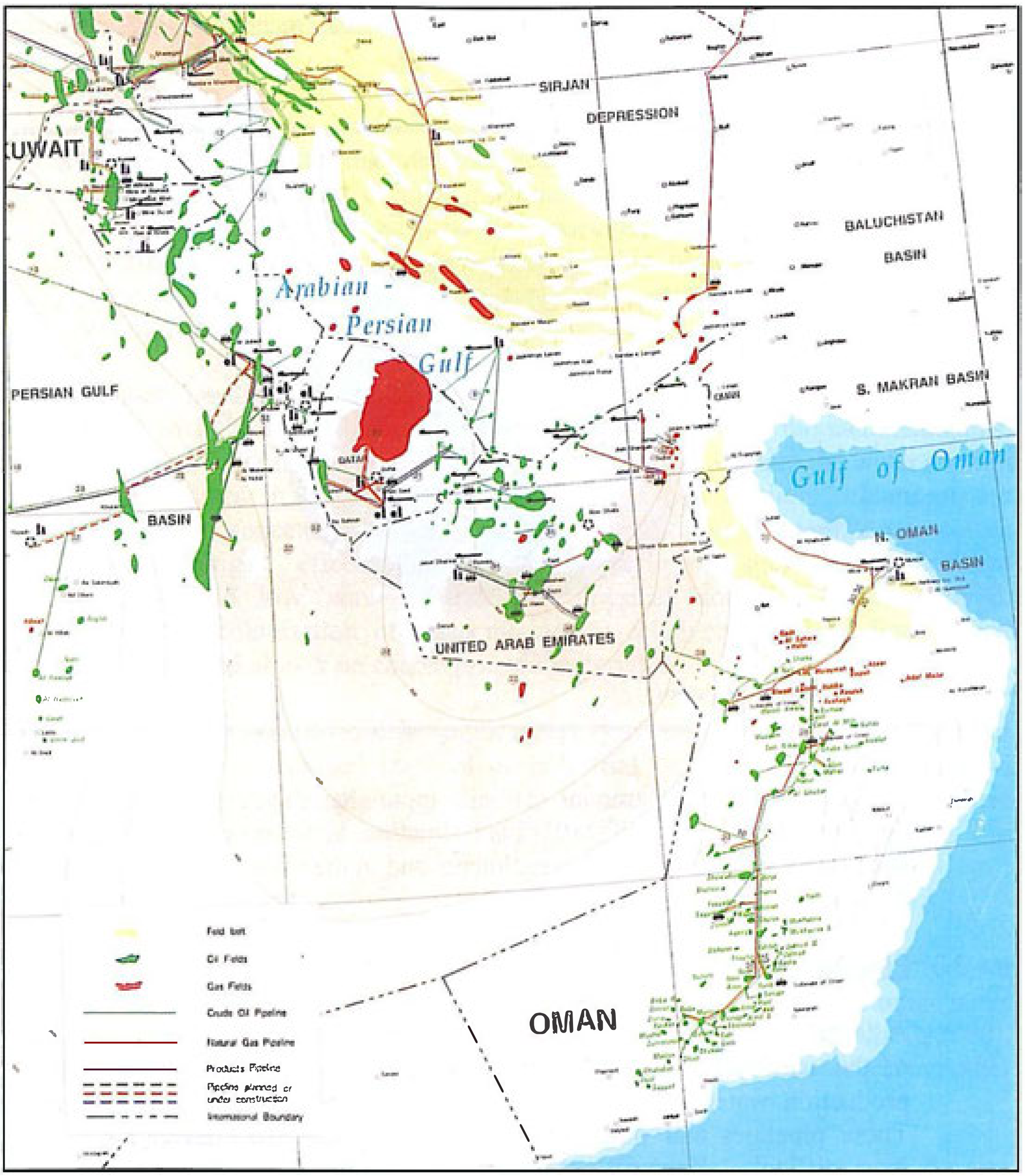

*Barges/other vessels except tankers

Although the total amount of oil input has reduced, the geographical distribution is not uniform. This situation is reflected by the amount of hydrocarbons found in marine sediments and in the wide distribution of tar balls on beaches, especially in Oman.

### 4.3.3 Pipeline networks

A large network of thousands of kilometres of pipelines is lying on the bottom of the sea in the region (Figure 4.24). 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 is available to evaluate the quantities of oil releases from such accidents, as they are often not reported. The practice of burying pipelines in coastal areas is rarely followed because of the high cost involved. Sediment entrapment techniques around pipelines have also been used to provide protection from anchoring ship and dredging vessels.

**Figure (4.24): Distribution of oil and gas field and pipeline in RSA.**




(PennWell Maps, Middle East Oil & Gas 4[th] Edition, Map Editor Alan Petzet, Exploration Editor, Oil & Gas Journal)

# Chapter 5

# Major Contaminants of the Marine Environment and their Effects

The focus of this Chapter is on specific groups of contaminants whose observed levels and distribution in the water column, sediments and biota are being used as indicators of the health of the marine environment. Biological indicators, i.e. population assemblages, diversity indices and other ecological relationships have not been used by government agencies in the Region as part of their marine pollution monitoring programmes. The principal marine contaminants in the RSA are from land-based, offshore oil operations and shipping activities, which contribute significantly to the overall impact of human activities on the marine environment.

This Chapter also has the focus on the results of the ROPME–IAEA Contaminant Screening Project. The survey in Kuwait and Saudi Arabia took place in October 1998 and the survey in Qatar and UAE during March 2000. Selected locations along the coastline of these countries were sampled for sediments, biota and seawater. The sampling were carried on in order to determine the impact of 1991 oil spill.

## 5.1 Distribution and effects of Trace Metals

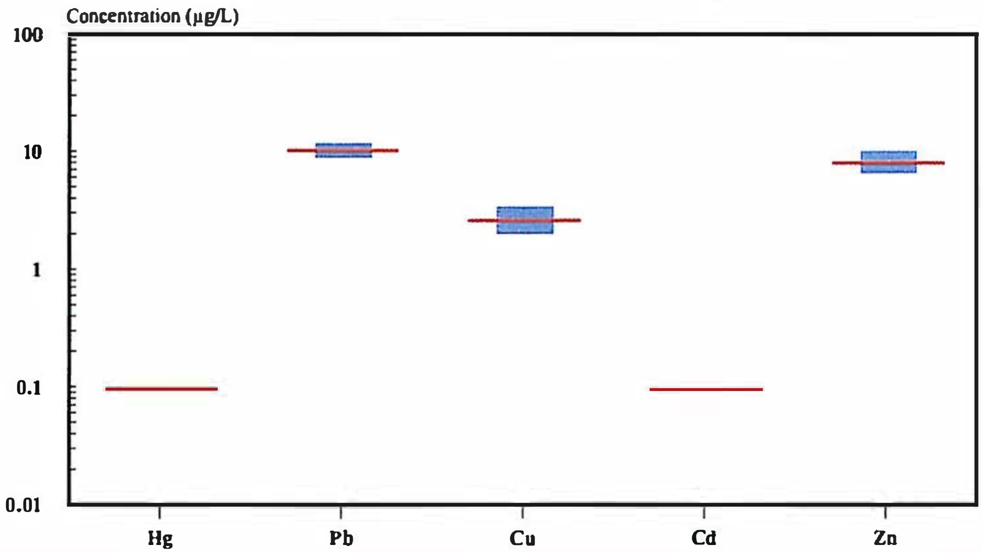
Metals occur naturally in the environment and are present in rocks, soil, plants, and animals. Metals occur in different forms: as ions dissolved in water, as vapours, or as salts or minerals in rock, sand, and soil. They can also be bound in organic or inorganic molecules, or attached to particles in the air. Both natural and anthropogenic processes and sources emit metals into air and water. Trace metals are found in seawater, marine organisms and sediments. Therefore, it is essential to find out their natural background levels in the marine environment.

### 5.1.1 Trace metals in seawater

As a part of the marine monitoring programme, some Member States have determined the concentrations of trace metals in seawater in their dissolved form. In Bahrain the samples were collected from four stations, the concentrations of Hg and Cd were found constant (0.1 µg/L during 1998

(MNR-Bahrain, 2000). Other metals, i.e. Pb, Cu and Zn fluctuated within a narrow range which indicated a constant situation in Bahrain (Figure 5.1).

**Figure (5.1): Concentrations of trace metals in seawater of Bahrain, 1998.**




In Kuwait the sampling is carried on from 13 locations each two months to determine the concentration of Hg, Pb, Cu, Ni, V, and Fe (MNR-Kuwait, 1999). The results as summarised in Figure (5.2) indicated that Hg and Fe concentrations varied within a wide range (0.036-0.113 µg/L, 13.2-55.3 µg/L respectively) which could be attributed to the differences in sampling locations. Where the inner stations in Kuwait Bay reported higher values than the outer stations. The concentrations of Ni also showed a wide range (1.25-11.1 µg/L), but there was no obvious reason for this result.

In Qatar, the samples were collected from 29 stations, the results of the two periods of May and September 1998 are summarised in Figure (5.3). There has been no significant difference in the measured concentrations for the two periods (MNR-Qatar, 1999). The overall mean of Pb, Cu, Fe, Zn and Cd was 6.2, 39.5, 26.7, 39.9 and 0.8 µg/L for the first period (May 1998) and 4.18, 20.1, 28.1, 40.4 and 0.8 µg/L respectively for the second period (September 1998). However, the range within the same parameter was so obvious. For example, the concentration of Pb ranged from 0.1-15.6µg/L in May 1998 and from 0.3-12.3 µg/L in September 1998, and Zn varied from 0.9-130.3 µg/L (September 1998). These results could be attributed to the different activities and sources of pollution in each of the sampling location. In general most of the high concentration of trace metals for the second period were reported for Mesaieed.

**Figure (5.2): Concentrations of trace metals in seawater of Kuwait, 1998.**

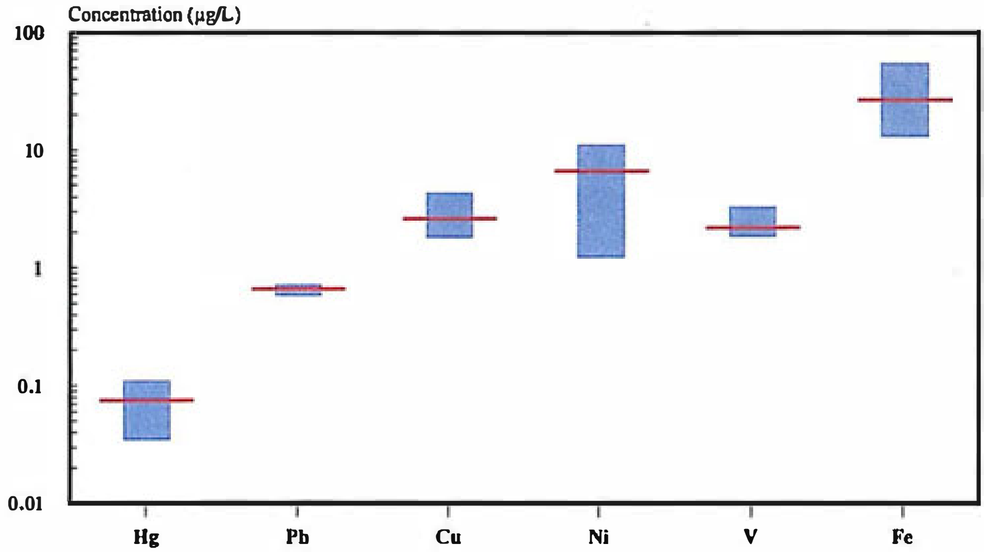
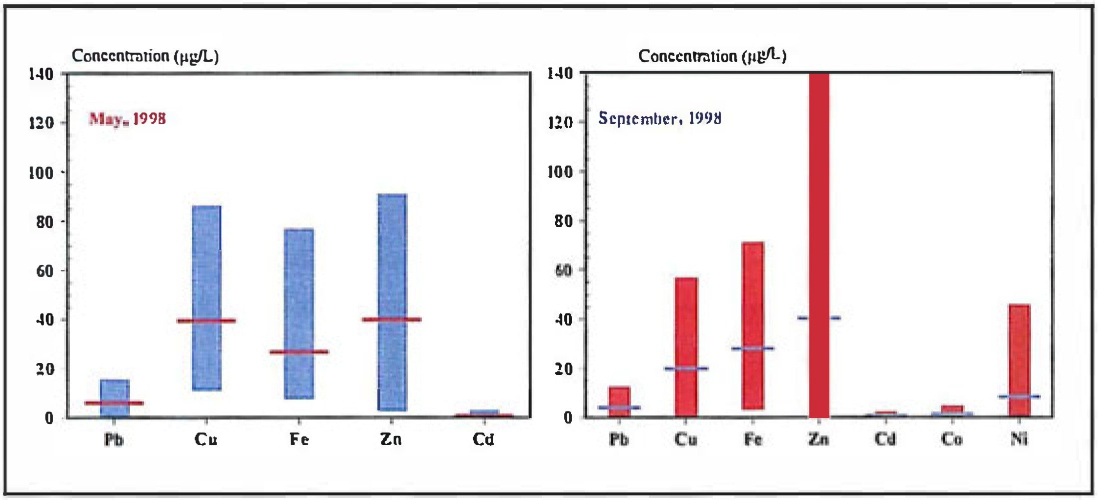


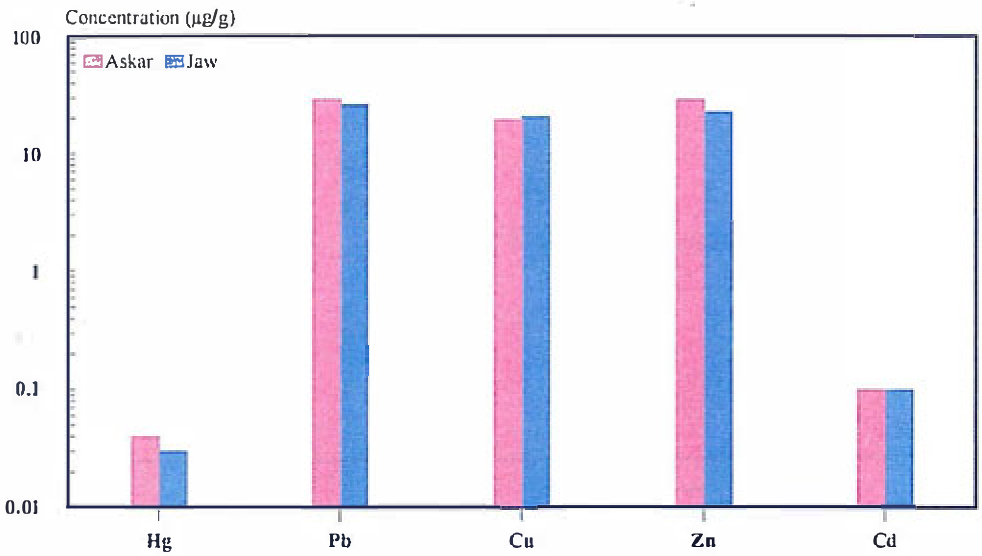

**Figure (5.3): Concentrations of trace metals in seawater of Qatar, 1998.**




## 5.1.2 Trace metals in sediment

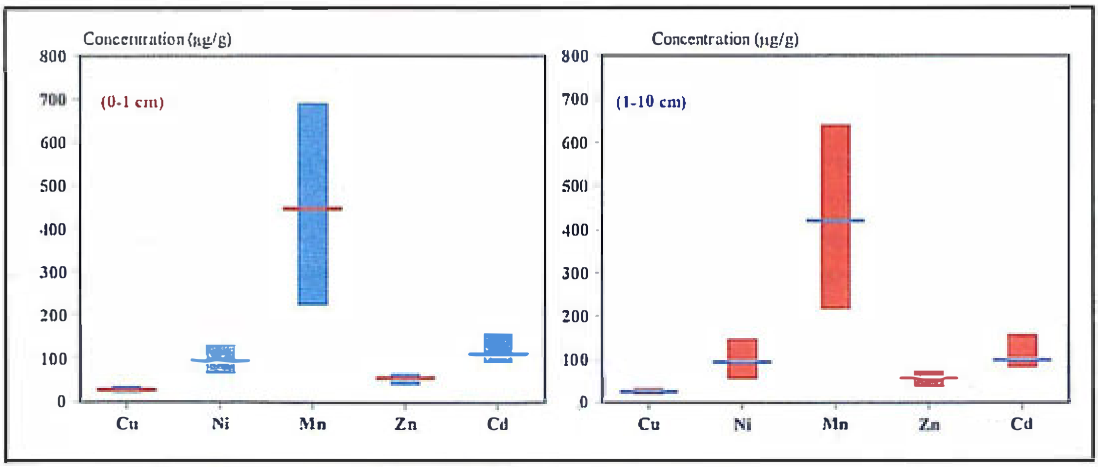
The concentrations of trace metals in sediments were also considered within the monitoring programme of ROPME Member States. In Bahrain, the results of 1994 (Figure 5.4) for Hg, Pb, Cu, Zn and Cd indicated that there are no significant difference between the two sampling stations, Askar and Jaw (MNR-Bahrain, 2000).

**Figure (5.4): Concentrations of trace metals in sediment of Bahrain, 1994.**



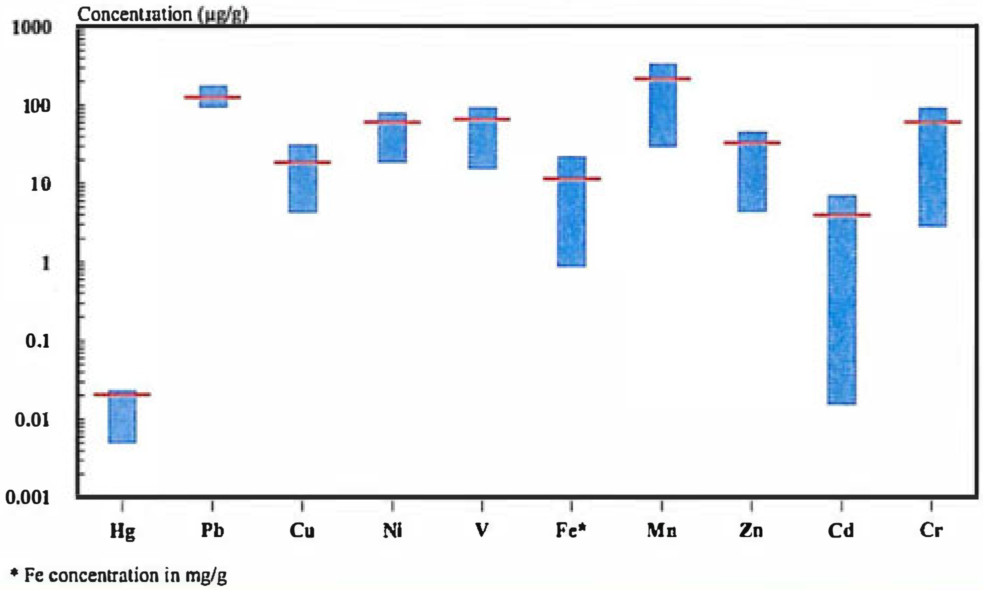

In I.R. Iran, the results of Ghods Cruise which was carried on during 1996 (DOE, 1996) are summarised in Figure (5.5). Samples were collected from 9 transacts along the Iranian coastline from Khor Mosa north of the Hormuz Island. No significant difference with 95% confidence interval was found for the mean concentration of Cu, Ni, Fe, Mn, Zn, Cd in several depths (the upper 1 cm and in the lower part up to 10 cm depth).

**Figure (5.5): Concentrations of trace metals in sediment of I.R.Iran, 1996.**



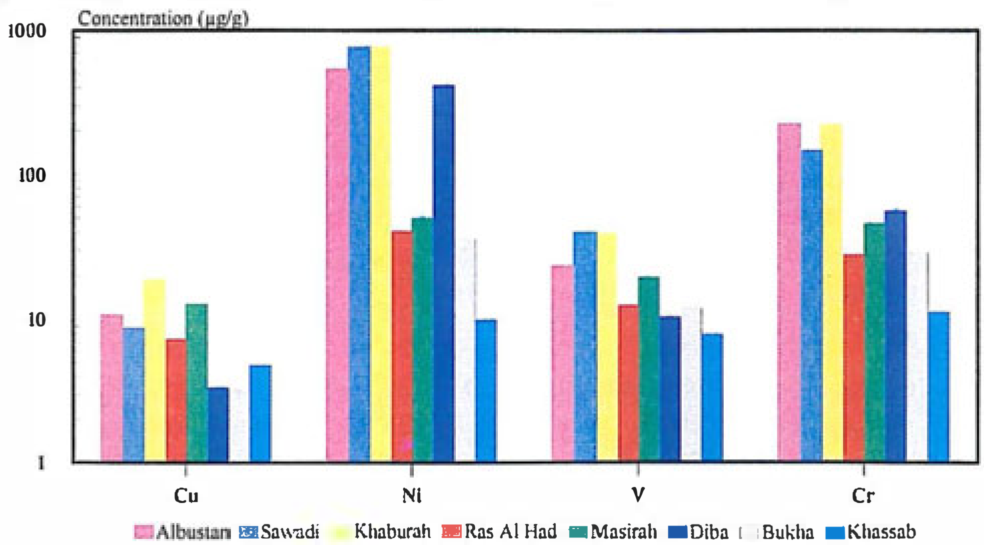
In Kuwait, the overall mean concentrations during 1998 for Hg, Pb, Cu, Ni, V, Mn, Zn, Cd and Cr was 0.02,122, 17.9, 58.5, 64.3, 214.5, 32.5, 3.9 and 59.9 µg/g and 11.23 mg/g for Fe (MNR-Kuwait, 1999). Most of the high concentrations of trace metals were reported in Kuwait Bay. The results are summarised in Figure (5.6).

**Figure (5.6): Concentrations of trace metals in sediment of Kuwait, 1998.**




In Oman, 8 stations were covered during 1997/1998 to measure Cu, Ni, V and Cr, their overall mean concentrations as shown in Figure (5.7) were 8.7, 329.5, 20.7 and 95.4 µg/g (MNR-Oman, 1999).

**Figure (5.7): Concentrations of trace metals in sediment of Oman, 1997/1998.**



High concentrations were reported for Khaburah followed by Sawadi and Albustan and the lowest concentrations of trace metals were reported for Kassab and Bukha.

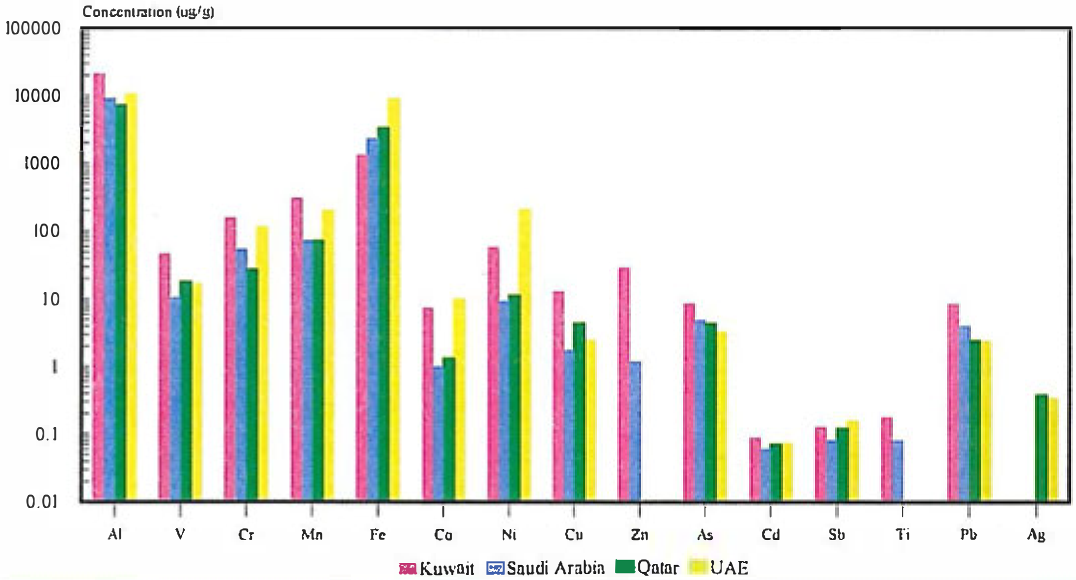
Trace metals determination was also covered during the contaminant screening surveys of IAEA during 1998-2000. The sampling locations and dates for Saudi Arabia, Kuwait, Qatar and UAE are summarised in Table (5.1).

**Table (5.1): Sampling locations for the contaminant screening project (1998-2000).**

| Country | Station | Location | | Date |
|---|---|---|---|---|
| | | Lat. (N) | Long. (E) | |
| **SAUDI ARABIA** | Ras Al-Qurrahya (Aziziyah) | 26°05.05 | 50°09.27 | 15.10.98 |
| | Jubail (Industrial Port) | 27°03.73 | 49°37.60 | 16.10.98 |
| | Abu Ali | 27°19.77 | 49°28.44 | 16.10.98 |
| | Ras Al-Ghar | 27°32.60 | 49°12.68 | 16.10.98 |
| | Manifa Bay | 27°35.78 | 48°55.10 | 18.10.98 |
| | Ras Tanajib | 27°45.85 | 48°53.27 | 18.10.98 |
| | Ras Mishab | 28°10.69 | 48°36.81 | 17.10.98 |
| | Ras Al-Khafji | 28°30.00 | 48°28.83 | 17.10.98 |
| **KUWAIT** | Khiran (Back Bay) | 28°40.09 | 48°22.92 | 20.10.98 |
| | Ras Az-Zor | 28°44.54 | 48°22.74 | 20.10.98 |
| | Fahaheel | 29°05.08 | 48°08.39 | 22.10.98 |
| | Al-Bida'a | 29°16.76 | 48°05.34 | 21.10.98 |
| | Sulaibikhat | 29°19.30 | 47°50.69 | 22.10.98 |
| | Doha Bay | 29°22.48 | 47°49.00 | 22.10.98 |
| | Khor Sabiyah (near bridge) | 29°37.17 | 48°09.07 | 22.10.98 |
| | North Kuwait Bay | 29°31.00 | 48°16.00 | 21.10.98 |
| | South of Bubiyan Island | 29°33.49 | 48°22.48 | 21.10.98 |
| | South of Falaika Island | 29°21.41 | 48°17.44 | 21.10.98 |
| **QATAR** | Mesaieed | 24°56.398 | 51°37.709 | 28.03.00 |
| | Dukham | 25°21.069 | 50°45.718 | 29.03.00 |
| | Doha | 24°20.257 | 51°34.456 | 29.03.00 |
| | Ras Laffan | 25°47.000 | 51°35.775 | 30.03.00 |
| | Ras Al Nouf | 25°37.427 | 51°32.889 | 30.03.00 |
| **U.A.E.** | Jebel Ali | 25°04.518 | 54°58.611 | 31.03.00 |
| | Abu Dhabi | 24°29.917 | 54°21.668 | 01.04.00 |
| | Abu Dhabi (Port Zayad) | 24°32.609 | 54°23.815 | 01.04.00 |
| | Al Marfa | 24°06.200 | 53°29.207 | 02.04.00 |
| | Al Ruweis (Jebel Dhannah) | 24°09.842 | 52°38.887 | 02.04.00 |
| | Akkah Head | 25°28.977 | 56°21.940 | 04.04.00 |
| | Akkah Head Beach | 25°28.721 | 56°21.770 | 04.04.00 |

The overall mean concentration of Al, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, , As, Cd, Sb, Ti, Pb and Ag are summarised in Figure (5.8).

**Figure (5.8): The mean concentrations of trace metals in sediment collected from RSA, 1998 & 2000.**

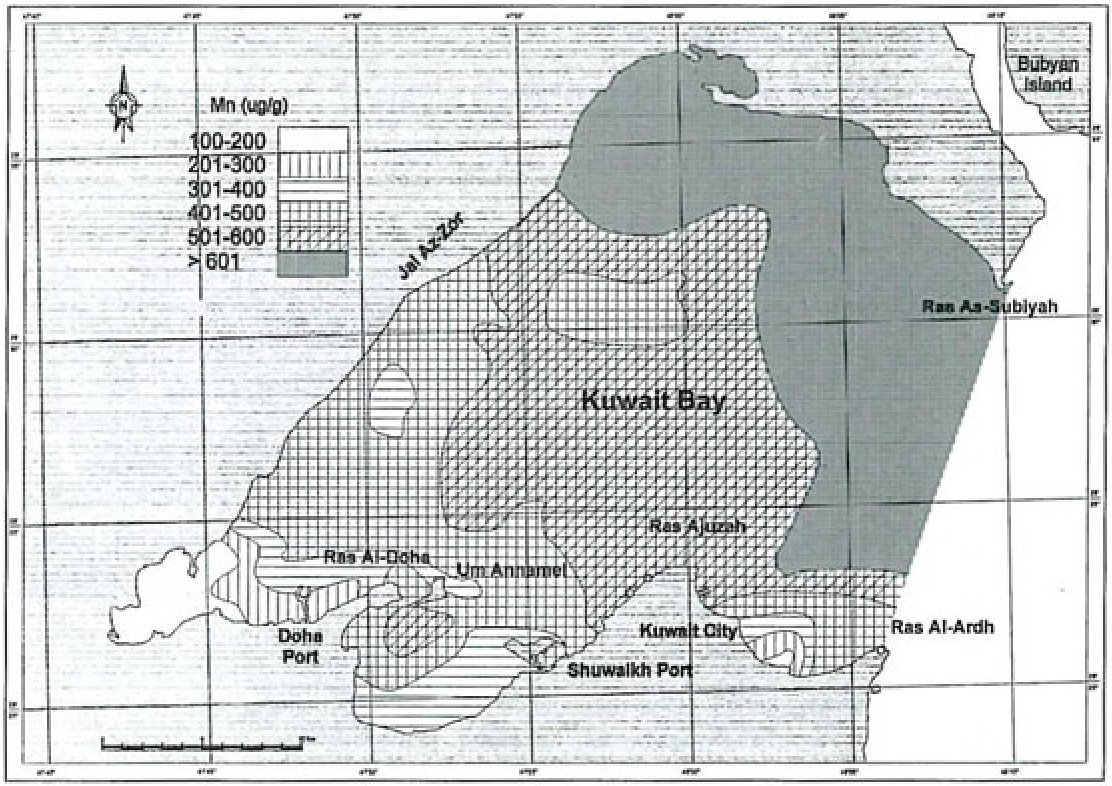



In general, sediment samples collected from Kuwait showed higher overall mean concentration for most of the trace metals than those collected from Saudi Arabia, Qatar and UAE. This result could be attributed to the discharge of Shatt Al-Arab. It would normally be reflected in elevated levels at stations in the immediate proximity to the Shatt Al-Arab outflow. This was certainly evident with Mn in which concentrations were particularly in order of magnitude greater than corresponding levels in Saudi Arabia, Qatar and UAE. Such a conclusion could also be supported by the results reported by Al-Majed (2000) as shown in Figure (5.9).

In Saudi Arabia, the maximum concentrations of V, Fe, Co, Ni, Cu, As and Pb were noted at Jubail which was the only station located near a highly industrialised urban area. In Qatar, high concentrations of trace metals were reported for Mesaieed, Dukhan and Doha while lower concentrations were reported for Ras Laffan and Ras Al-Nouf. In UAE, the high concentrations of trace metals in general were reported for Al-Ruweis and Al-Marfa. However, the maximum Ni and Fe concentrations (1010 and 29600 µg/g) were measured in Akkah Head Beach.

The mercury concentrations in sediments were very low (Figure 5.10) particularly those from UAE (0.6–2.2 ng/g). In Saudi Arabia the highest concentration (5.4 ng/g) was found near the highly industrialised port of Jubail.

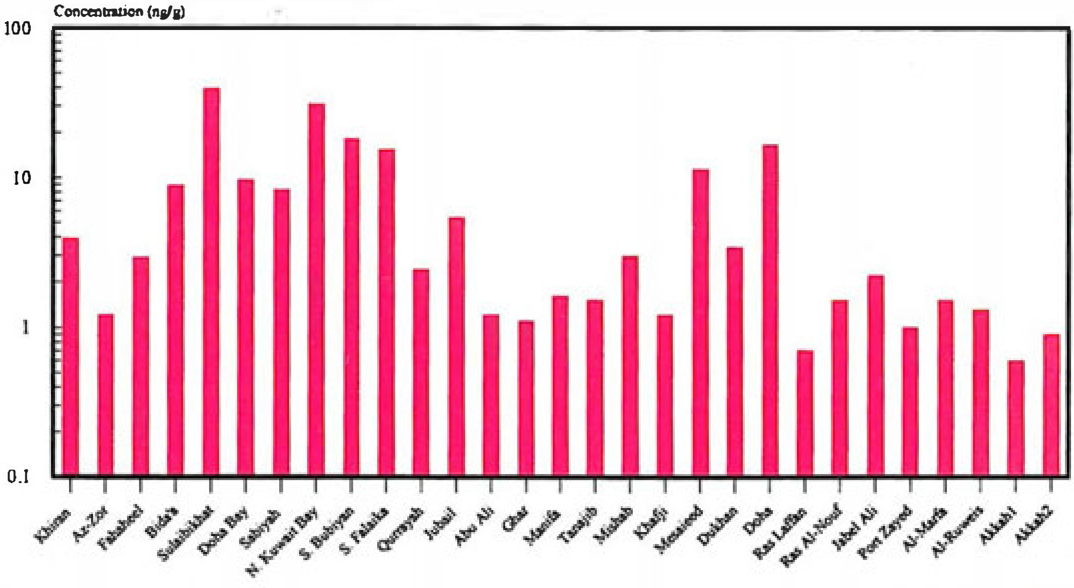
**Figure (5.9): Distribution of Mn in the upper layer (1-15 cm) of sediment samples collected from Kuwait Bay, 1996-1998.**




In Qatar, the concentration of Hg varied from 0.7-16.7 ng/g, where the maximum was reported for Doha followed by 11.4 ng/g in Mesaieed. The minimum concentration was reported for Ras Laffan. In Kuwait, levels were somewhat higher ranging from 1.2–39.4 ng/g with the maximum concentration recorded at Sulaibikhat, an area suspected to be directly contaminated by land-based runoff. Nevertheless, mercury concentration of 30 ng/g is quite low by most standards and falls in the lower end of the range of values (<100ng/g) typical for uncontaminated nearshore and offshore sediments (IAEA, 1990, 1996, 1998; Kureishy and Ahmed, 1994; Al Majed *et al.*, 1998).

Shriadah (1999) also studied the distribution of eight heavy metals in the sediments of four mangrove areas, namely Abu Dhabi, Umm al-Quwain, Ras al-Khaimah, and Khor Khuwair along the shoreline of the United Arab Emirates (U.A.E.). The metal concentration in different mangrove areas were scattered in the ranges of 3.12-6.94 µg/g for Cd (mean 4.82 µg/g), 5.70-14.0 µg/g for Co (mean 10.2 µg/g), 8.28-18.9 µg/g for Cr (mean 11.9 µg/g), 5.31-29.4 µg/g for copper (mean 7.21 µg/g), 28.8-169 µg/g for Mn (mean 84.1 µg/g), 14.8-109 µg/g for Ni (mean 36.4 µg/g), 13.2-49.8 µg/g for Pb (mean 28.1 µg/g), 4.59-22.4 µg/g for Zn (mean 11.3 µg/g), and ND-2.13% for organic carbon (mean 0.63%). Significant variations in the levels of these metals were considered due to: organic carbon content; presence of well developed mangrove forests; and anthropogenic inputs such as discarded automobiles, transformers, batteries, tires and spilled crude oil, atmospheric fallout as well as wastewater disposal. In addition, recreational activities cause negative effects. Concentrations of Mn, Ni and Pb were significantly higher than the other metals. The high concentrations of Mn and Ni were due to non-anthropogenic sources (the geological nature formations and the presence of high mountains of basic igneous rocks), whereas the high levels of Pb were due to inputs from oil spills, discarded solid wastes such as automobiles, batteries and the prior high rate of petrol combustion lead.

**Figure (5.10): The mean concentrations of mercury in sediment collected from RSA, 1998 & 2000.**

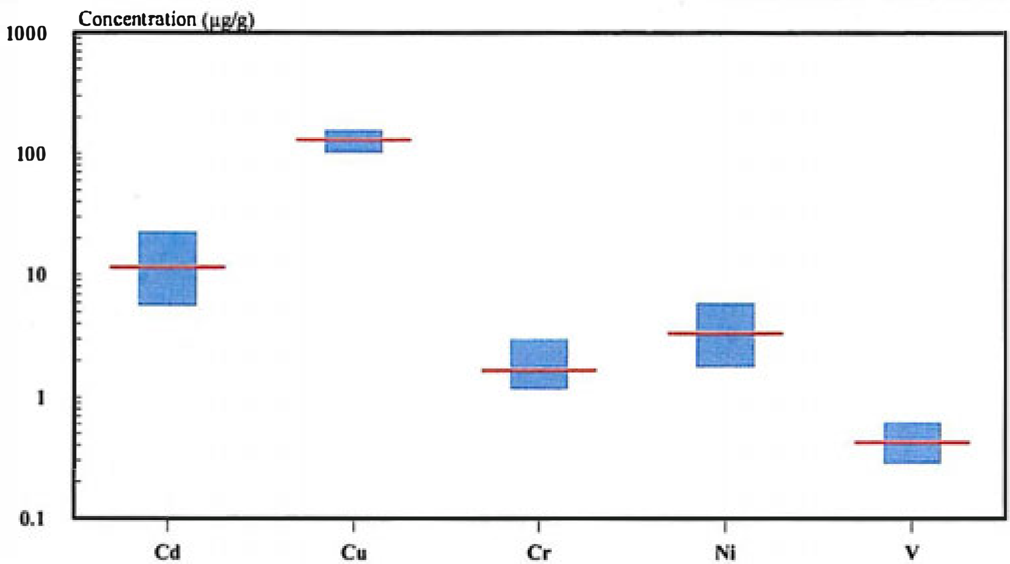



## 5.1.3 Trace metals in biota

A total of 162 fish and shellfish samples representing important species have been collected from different coastal areas of Bahrain (Madany *et al.*, 1996), and analysed for Pb, Cd, Hg, and As. The overall mean levels for Pb, Cd, Hg and As in fish samples were 0.132, 0.032, 0.084 and 1.7 µg/g wet weight, respectively, whereas for shellfish they were 0.149, 0.045, 0.042 and 3.61 µg/g wet weight. These values indicate higher levels of metals in shellfish when compared with fish, except for mercury, and reveal that generally the levels of metals in these organisms are lower than the existing guidelines, except for arsenic. The provisional tolerable weekly intake of Pb, Cd, Hg and As through fish was estimated to be 0.7, 0.17, 0.45 and 9 µg/kg bodyweight, respectively. The results did not reveal a clear pattern regarding variations of metals concentration between areas and species (Madany *et al.*, 1996).

The concentration of Cd, Cu, Cr, Ni and V were determined in oyster tissue collected from some Omani stations during the period 1997-1998, the results are shown in Figure (5.11). The concentration of Cd varied from 5.8 µg/g reported for Bustan to 22.7 µg/g to 22.7 reported for Masira and Ni concentration varied from 1.81µg/g in Bukha to 5.9 in Bustan station with no obvious reason for these variations (NMR-Oman, 1999). The variation of the other metals was very limited as can be seen in Figure (5.11).

**Figure (5.11): Concentrations of trace metals in oyster tissue, Oman 1997-1998.**

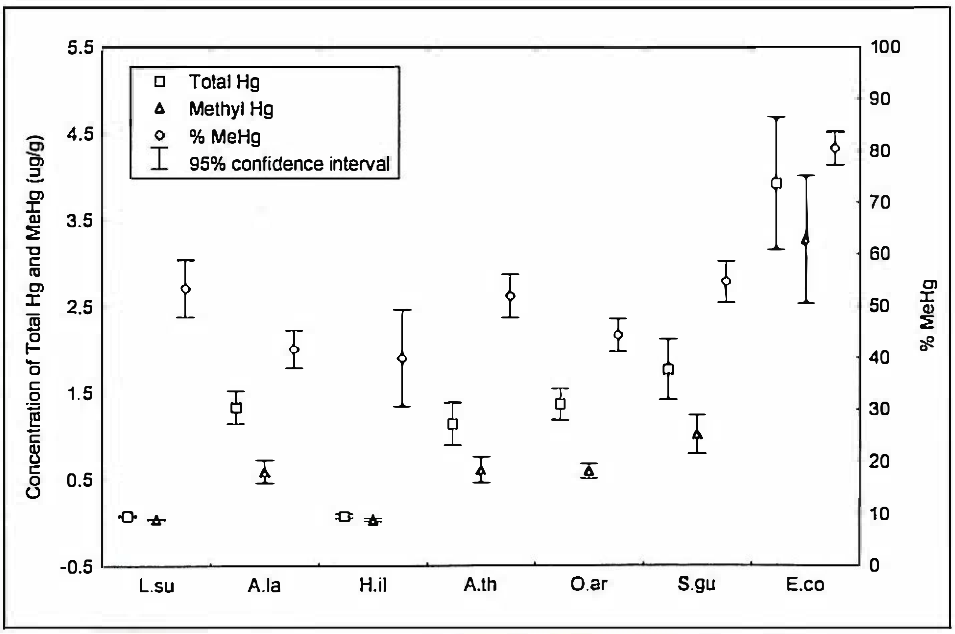



Bu-Olayan and Subrahmanyam (1996) reported the concentrations of Cr, Fe, Co, Ni, Pb, V, and Zn in fish to assess the impact of petroleum-refining activities and the 1991 War. Twenty-eight species of fish from the Kuwait coast were collected 50 m apart. Results show that fish samples contain 6.2-6.8 µg/g Cr, 4.2-96.2 µg/g Cu, 0.5-20.4 µg/g Ni, 0.2-14.6 µg/g Pb, 0.02-15.6 µg/g V, and 7.6-81.3 µg/g Zn. Cu, Ni, and Zn in station covering the Kuwait City were often greatly in excess of those present in station covering the Al-Ahmadi area, while Cr, Pb, and V were greater in station covering Al-Ahmadi area. Significant correlations were observed between some trace metals in fishes, indicating their common association.

Bu-Olayan and Subrahmanyam (1998) determined Cu, Ni, Pb, V and Zn concentrations in marine crab, *viz. Macrophthalmus depressus* (Crustacea: Decapoda) in order to assess the impact of petroleum-refining activities and the 1991 War. Results as expressed by µg/g showed that crab samples contain 16.2-172.6 Cu, 0.52-1.68 Ni, 0.66-2.07 Pb, 0.52-2.30 V, and 168.80-268.80 Zn respectively. All the trace metals analysed in stations covering the Kuwait City were often greatly in excess of those present in the remaining stations.

Al-Majed and Preston (2000a) studied the total mercury (T-Hg) and methyl mercury (MeHg) concentrations in zooplankton and various fish species (N=330) collected from Kuwait Bay and the northern area of Kuwait (Figure 5.12). The T-Hg concentrations in zooplankton ranged from 0.004-0.035 µg/g (dry weight) with MeHg representing <25% of the T-Hg. Total and MeHg concentrations in fish differed between species and ranged from 0.073 µg/g (*Liza subviridis*) to 3.923 µg/g (*Epinephelus coiodes*). T-Hg and MeHg in fish tissue were significantly correlated at 0.01 level. They were also correlated with length and weight of the analysed species. The mean percentage of MeHg ranged from 40.1% (*Hilsha ilisha*) to 80% (*Epinephelus coiodes*) of the T-Hg. The relationships between observed concentration, habitat and feeding habits were examined. Of the fish analysed 20.6% were greater than or equal to 0.500 µg/g (wet weight) T-Hg, and exceeded the WHO limit. For MeHg, 20.6% were greater than or equal to 0.300 µg/g (wet weight). It is estimated that similar to 3.2 kg of T-Hg and similar to 1.9 kg of MeHg are being removed yearly by fish landings from Kuwait territorial waters and introduced to the local food supply.

**Figure (5.12): The overall mean of T-Hg, MeHg and MeHg% for the different species with 95%CI.**



A seawater pollution assessment program was carried out in the liver, skin and muscle tissues of the localised *Lethrinus lentjan* fish species (Al-Yousuf *et al*., 2000). Monitoring the concentration of the major heavy metals at different sites along the western coast of the United Arab Emirates was studied. The concentrations of Zn, Cu and Mn were found to follow the order: liver > skin > muscle while the Cd concentration follows the sequence: liver > muscle > skin. The influence of fish sex and body length on the metal accumulation of those metals in the tested fish organs was critically investigated. The average metal concentrations in liver, skin and muscle of female fish were found to be higher than those found in the male fish. The detected metal levels were generally similar to previous pre-war, 1991 levels. The study concluded that the marine fish from RSA are comparatively clean and do not constitute a risk for human health.

The trace metals concentrations from the contaminant screening project were also measured and the range in the muscle of the different fish species are shown in Table (5.2).

**Table (5.2): Concentrations of trace metals in fish tissue collected from RSA, 1998 & 2000.**

| Metals | Kuwait | Saudi Arabia | Qatar | UAE |
|---|---|---|---|---|
| | N=5 | N=5 | N=4 | N=4 |
| V (µg/g) | <0.10 | <0.1 | 0.03-0.04 | <0.01-0.04 |
| Cr (µg/g) | <0.1-0.214 | <0.1-0.163 | <0.01-0.05 | <0.01-0.05 |
| Mn (µg/g) | 0.168-1.18 | 0.041-0.225 | 0.18-0.35 | 0.063-0.14 |
| Fe (µg/g) | 3.13-11.2 | 3.59-8.48 | 2.4-21.7 | 23.3-203 |
| Co (µg/g) | <0.05 | <0.05 | <0.005-0.013 | <0.005-0.014 |
| Ni (µg/g) | <0.1-0.476 | 0.147-0.753 | 0.03-0.09 | <0.01 |
| Cu (µg/g) | <0.05-0.99 | <0.05-0.59 | 0.49-0.59 | 0.37-19.5 |
| Zn (µg/g) | 7.62-18.5 | 10.3-25.6 | 5.8-67.3 | 1.82-23.3 |
| As (µg/g) | 0.447-7.76 | 0.731-8.13 | 2.2-10.0 | 1.9-5.0 |
| Ag (µg/g) | <0.01-0.065 | <0.01-0.014 | 0.002-0.005 | <0.001-0.002 |
| Cd (µg/g) | <0.01-0.075 | <0.01-0.063 | 0.001-0.013 | <0.001-0.001 |
| Sb (µg/g) | 0.005-0.008 | 0.005 | <0.001 | <0.001 |
| Ti (µg/g) | <0.005 | <0.005 | - | - |
| Pb (µg/g) | <0.01-0.142 | 0.051-0.561 | 0.108-0.551 | <0.01-1.28 |
| Bi (µg/g) | 0.005-0.008 | <0.005-0.016 | - | - |
| T-Hg (ng/g) | 55-1400 | 38-1260 | 343-1042 | 509-2345 |
| MeHg (ng/g) | 42.3-1290 | 28-1300 | - | - |

In general, the concentrations of trace metals in fish tissue were not exceptional and almost within the same concentrations for the previous studies of the same species; *Hilsha ilisha, Epinephelus coiodes, Cephalopholis hemistikotos* and *Scomberomorus commmerson* (Fowler *et al*., 1993; IAEA, 1996). Interestingly, the values for Mn, Fe, Ni, Cu, Zn, Cd and Pb tended to fall in lower range of concentrations reported for some 26 fish species collected throughout the RSA during the Umitaka-Maru cruises (Al-Majed *et al*., 1998). Likewise, Cd, Pb, Zn, Ni and Cu concentrations were reported by Kureishy (1993) for fish collected from Qatar.

Bivalves were also considered during the contaminant screening survey and the results as shown in Table (5.3) indicated that the concentrations of trace metals varied within the same country.

**Table (5.3): Concentrations of trace metals in bivalves collected from RSA, 1998 & 2000.**

| Metals | Kuwait | Saudi Arabia | Qatar | UAE |
|---|---|---|---|---|
| | N=3 | N=4 | N=1 | N=6 |
| V (µg/g) | 1.19-1.94 | 1.29-3.68 | 0.76 | 0.28-3.23 |
| Cr (µg/g) | 1.94-2.21 | 0.514-1.15 | 0.97 | <0.01-3.41 |
| Mn (µg/g) | 13.3-98.2 | 12.6-853 | 17.7 | 5.36-1110 |
| Fe (mg/g) | 307-677 | 155-463 | 517 | 89.9-501 |
| Co (µg/g) | 2.57-4.41 | 0.176-4.78 | 4.45 | 0.117-12.9 |
| Ni (µg/g) | 6.38-12.8 | 2.08-23.0 | 23.9 | 0.07-35.8 |
| Cu (µg/g) | 3.61-7.12 | 0.847-58.3 | 8.35 | 4.61-63.8 |
| Zn (µg/g) | 41.5-92.2 | 16.4-640 | 69.1 | 159-1830 |
| As (µg/g) | 19.6-56.3 | 19.8-100 | 156 | 16.2-153 |
| Ag (µg/g) | 0.827-3.34 | 0.037-2.39 | 3.03 | 0.017-1.92 |
| Cd (µg/g) | 0.333-0.862 | 0.235-3.91 | 1.17 | 2.73-10.7 |
| Sb (µg/g) | <0.005-0.016 | 0.005-0.030 | 0.027 | <0.001-0.013 |
| Ti (µg/g) | <0.005-0.005 | <0.005-0.009 | - | - |
| Pb (µg/g) | 1.50-5.62 | 0.885-5.32 | 1.45 | 0.098-2.29 |
| Bi (µg/g) | 0.005-0.046 | 0.009-0.029 | - | - |
| T-Hg (ng/g) | 80.9-136 | 37-505 | 315 | 9-207 |
| MeHg (ng/g) | 44.8 (N=1) | 11.4-45 | - | - |

### 5.1.4 Effect of trace metals

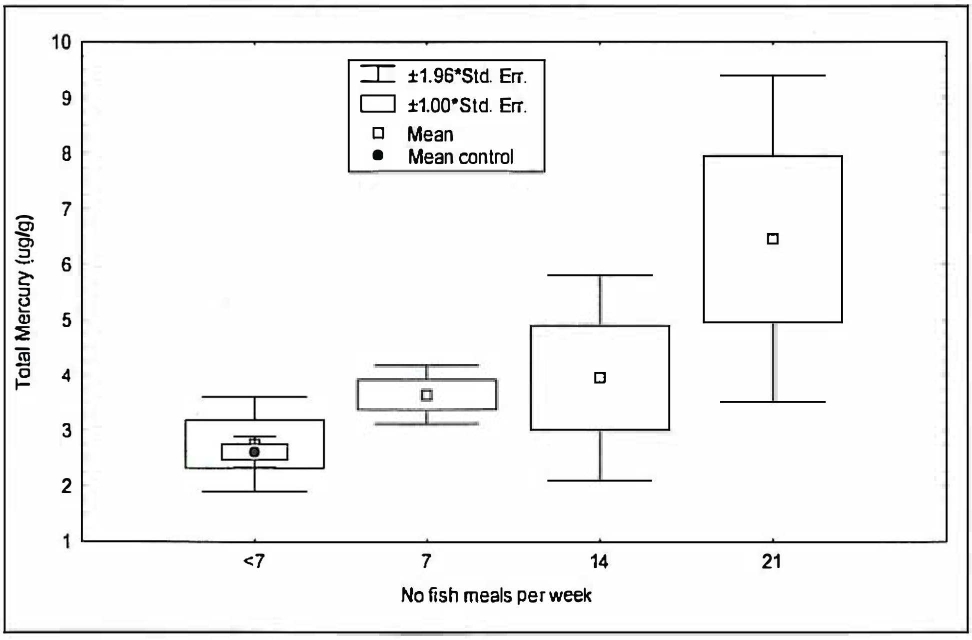
Total and methyl mercury concentrations in the hair of fishermen are described anticipating that they represent the critical group for dietary exposure (Al-

Majed and Preston, 2000b). One hundred human hair samples were collected from fishermen. Thirty-five additional samples were taken from a control group working in a local construction company. The levels of T-Hg and MeHg in the hair of about 78% of the fishermen and 63% of the control population exceeded 2.0 µg/g.

In general, the mean concentrations of T-Hg and MeHg are around twice the WHO "normal" level (2.0 µg/g) but are still less than the WHO threshold level (10.0 µg/g). However, it should be noted that levels are for fishermen who eat at least one meal of fresh fish per day, which is not the case for the general population. It may be added the health risk of eating fresh fish may be less than that associated with eating canned tuna fish. This may be concluded by comparing those eating two meals per week of canned tuna fish (4.304±0.708 µg/g and 4.224±0.696 µg/g for T-Hg and MeHg respectively). However, with those who eat 7 meals of fresh fish per week (Figure 5.13) exhibited mean concentrations of 3.658±2.271 µg/g and 3.522±2.210 µg/g for T-Hg and MeHg respectively (Al-Majed and Preston, 2000b).

In accordance to the obtained strong correlation (r = 0.999) between T-Hg and MeHg, one of these determinations can be used for human hair samples to reflect the body content, and preferably the MeHg due to its higher toxicity (WHO, 1990). A positive relationship is found between the fish intake quantity and with the edible parts of fish.

**Figure (5.13): Total mercury concentrations in the hair of fishermen and controls as a function of the number of fish meals consumed/week.**



## 5.2 Hydrocarbons Distribution

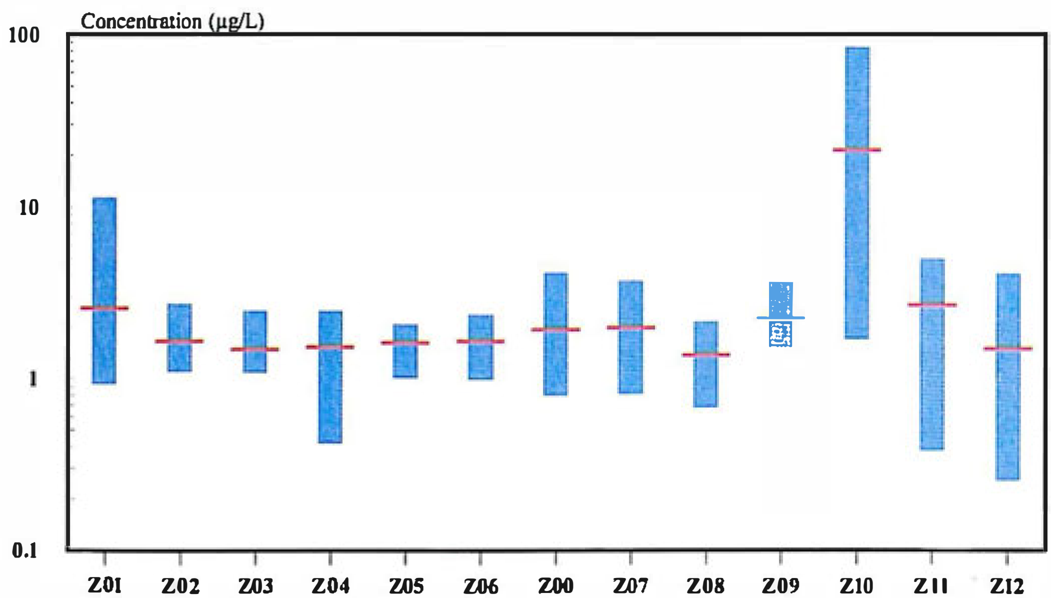
### 5.2.1 Petroleum hydrocarbons

Hydrocarbons are organic compounds made primarily of carbon and hydrogen atoms arranged in aliphatic and/or aromatic configurations. Polycyclic aromatic hydrocarbons are a group of contaminants related to oil exploration and extraction that also have other sources. In areas of high concentration, such as oil spills, they can be acutely toxic. The main environmental concern is that some of the compounds can cause mutations and cancer at low concentrations. Spilled petroleum products are the largest single source of PAHs. Produced water from both oil and gas platforms contains PAHs. Taking into account the large volumes of produced water discharged from oil production, the yearly input of PAHs into the environment, even from a single offshore oil field, may be significant (Stone *et al.*, 1997).

#### 5.2.1.1 *Petroleum hydrocarbons in seawater*

Petroleum hydrocarbons (PHCs) concentration in seawater in the northwestern region have been reported to be in the range of 0.3–89.1 µg/L (MNR-Kuwait, 1999). The overall mean of PHCs for 1998 were slightly higher than the overall mean of 1997 (2.773 µg/L). The concentrations of PHCs from Kuwait Bay to the southern locations are shown in Figure (5.14).

**Figure (5.14): Concentration of petroleum hydrocarbons in seawater, Kuwait 1998.**

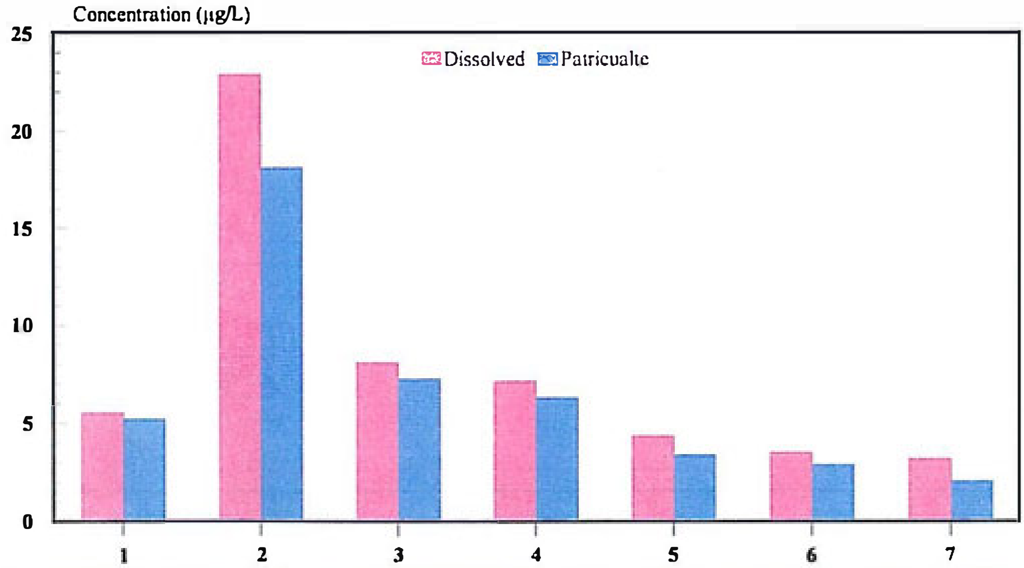


In Bahrain the concentration of PHCs in seawater varied within a limited range of 1.1–1.6 μg/L in 1994 (MNR–Bahrain, 2000).

Madany *et al.* (1998) measured the levels of petroleum hydrocarbons in the coastal seawaters of Bahrain in two stations during the period October 1993 to December 1996. The two stations were located in the northeastern and northern part of Bahrain, and were similar in terms of their use and possible sources of oil pollution. The overall mean concentration of petroleum hydrocarbon in station 1 was 43.3 and 30.6 μg/L expressed as equivalent concentration of chrysene and crude oil, respectively, whereas in station 2 the mean was 22.4 and 23.0 μg/L, respectively. The results showed no significant variations in the concentrations of petroleum hydrocarbons between the two stations. Also, the results did not reveal significant temporal differences in both areas. Generally, levels of petroleum hydrocarbons were relatively high in both areas compared to other coastal areas of the region suggesting a chronic oil pollution problem.

Al-Saad *et al.* (1998) conducted a study to determine the distribution of dissolved and particulate petroleum hydrocarbons in Shatt al-Arab Estuary and the northwertern part of RSA. Seven sampling stations were selected from and the sampling programme was completed between June 1993 and July 1994. The overall mean concentration of PHC was 7.8 μg/L for the dissolve phase and 6.4 μg/L for the particulate form. The distributions of PHC between the seven stations are shown in Figure (5.15).

**Figure (5.15): Distribution of dissolved and particulate phase petroleum hydrocarbons in water samples collected from Shatt Al-Arab and the northwestern part of RSA.**



Shriadah (1999) collected monthly seawater samples during 1993-1994 at 24 sampling stations. Oil concentrations in seawater were below 13 μg/L and ranged from 0.19 to 12.95 μg/L. Comparatively higher concentration levels (5.97 μg/L) were recorded at offshore stations which are located close to oil tankers' routes in the RSA. The other stations, on the other hand, which represent coastal waters of the United Arab Emirates showed lower concentration levels (4.18 μg/L). Oil pollution levels were also higher at surface layers (4.91 μg/L) as compared with bottom layers (3.70 μg/L) reflecting higher rate of oil dissolution at surface layers. The presence of oil pollution, on the other hand, at bottom layers was probably due to:

i. The role of bottom sediments on the enrichment of overlying water layers by hydrocarbons.
ii. The role of precipitation of thick residual oils after evaporation of lower-boiling-point components of the oil and the turbulence of water column.

The study revealed comparatively lower levels (3.93 μg/L) and lower vertical gradients (1.17 μg/L) for the whole area in the summer season compared to the winter season (4.18 and 1.64 μg/L, respectively) as a result of a maximum rate of evaporation of lower boiling-point components of the oil and sinking of thick residual oils during summer months in addition to the intensity of tanker traffic at the time of sampling.

5.2.1.2 *Petroleum hydrocarbons in sediment*

Metwally *et al.* (1997) determined the concentrations of total petroleum hydrocarbons in sediment samples collected from eight stations along the coastal area in Kuwait. The TPH concentrations were variable and ranged from 7.43-458.61 μg/g dry sediment. The highest TPH concentrations were found near the Shuaiba Industrial Area and in the Shuwaikh Port where both industrial and boating activities and land-based wastewater discharges are most common.

Al-Lihaibi and Ghazi (1997) collected surface sediments from RSA during the Umitaka-Matu Cruises to determine total petroleum hydrocarbons and specific aliphatic hydrocarbon components in order to provide information on the extent of oil contamination and the degree of weathering of the spilled oil following the 1991 War. The concentration of petroleum hydrocarbons in the sediments ranged from 5.4-92.0 μg/g with an average of 32.6 μg/g. The surface distribution of the petroleum hydrocarbons showed an increasing trend towards the northeast of RSA, and among the individual transacts there was a pronounced increasing trend towards the northwest direction of RSA. Despite offshore oil-related activities as well as a potential impact from the 1991 oil spill, the concentrations of petroleum hydrocarbons in the study area were relatively low. This finding may be attributed to the effectiveness of weathering processes. The distribution of the saturated hydrocarbon fractions exhibited, principally, the following:

i. The presence of n-alkanes between C-15 and C-33 in nearly all samples with a lack of predominance of odd/ even carbon numbers.
ii. The presence of an Unresolved Complex Mixture (UCM) in most of the samples.
iii. The n-C-18/phytane ratios reflect the limited influence of microbial degradation.
iv. A relative distribution of the saturated hydrocarbons indicating weathering classification equivalent to stage I.

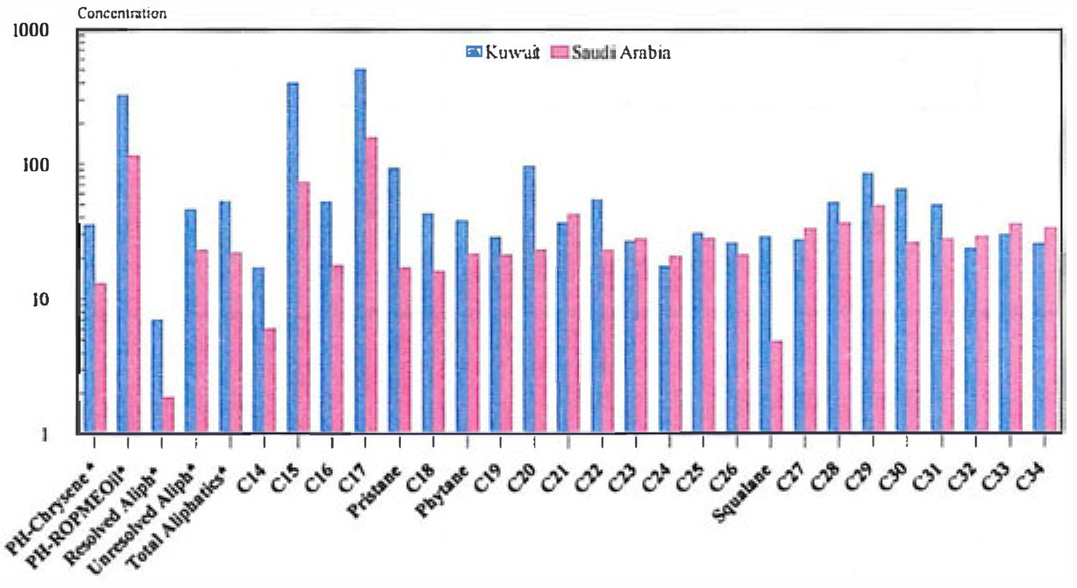
Shriadah (1999) analysed sediment samples collected from UAE for determination of the petroleum hydrocarbons. The results showed that offshore areas were with a mean concentration of 7.0 µg/g. However, the levels reported in this study and in particular those for coastal areas (6.5 µg/g) were below 10 µg/g of dry weight which correspond to hydrocarbon concentrations in coastal areas considered unpolluted.

An assessment was made of the nature and distribution of hydrocarbons in, and the impact of the 1990/91 War Oil Spill on, the RSA (Al-Omran and Rao, 1999). Core sediments samples were collected during the Umitaka-Maru Cruises (1993-1994) from the inner part of the RSA were analysed for aliphatic and polycyclic aromatic hydrocarbons, and selected triterpanes. The area is characterised by background levels of natural hydrocarbons derived from mixed autochthonous and terrestrial origin, with low levels of anthropogenic input of degraded petroleum hydrocarbons. The total aliphatic hydrocarbons ($C_{17}$-$C_{34}$) varied from 0.1-93 µg/g, pristane varied from < 2.0-15 ng/g and phytane varied from <2.0-71 ng/g. The biodegradation plays a major role in the depletion of short-chain hydrocarbons derived mostly from marine plankton and bacteria. Also, a reduction of petroleum hydrocarbons was suggested by the dominance of an unresolved complex mixture in the aliphatic hydrocarbon composition. The results indicated that the area under investigation was not impacted by the 1991 War Oil Spill. However, different petrochemical sources like tanker deballasting and/or offshore operations may have been the major contributors to the observed materials. A minor contribution of Arabian light crude oil to the sediments of the southern area was observed in the deeper sediments of RSA (Al-Omran and Rao, 1999).

As a part of the contaminant screening project sediment samples were collected for the determination of petroleum hydrocarbons. The result of sediment collected from Kuwait and Saudi Arabia indicated that the total aliphatics in all sediments ranged from < 1-300 µg/g. The highest values of total aliphitics in Saudi Arabia were noted at Manifa Bay and Ras Al Ghar, two areas that were heavily impacted by the oil spill in 1991 (Readman *et al.*, 1992; Fowler *et al.*, 1993). It is evident that residual oil from the spill, highly degraded as noted by the low sum n-alkanes, is still present along the impacted portion of the Saudi Arabian coastline. For Manifa Bay, Ras Al Ghar and Khafji, petroleum hydrocarbon concentrations at all other sites were quite low. The very low levels of total aliphatics at Ras Al Qurrayah suggest that this station can still be considered as an adequate control site for the portions of the RSA coast impacted by the oil spill.

Along the Kuwaiti coast, only the sites at Khiran and Ras Az-Zor and possibly Fahaheel, were heavily impacted by the 1991 oil spill. Total hydrocarbons and aliphatic fractions were relatively high at those sites, but were not as high as the measured concentrations neither in Doha Bay sediments nor far from the desalination plant. The overall mean concentration of petroleum and aliphatic hydrocarbons in sediments are summarised in Figure (5.16).

**Figure (5.16): Mean concentrations of petroleum hydrocarbons in sediment of Kuwait and Saudi Arabia, 1998.**

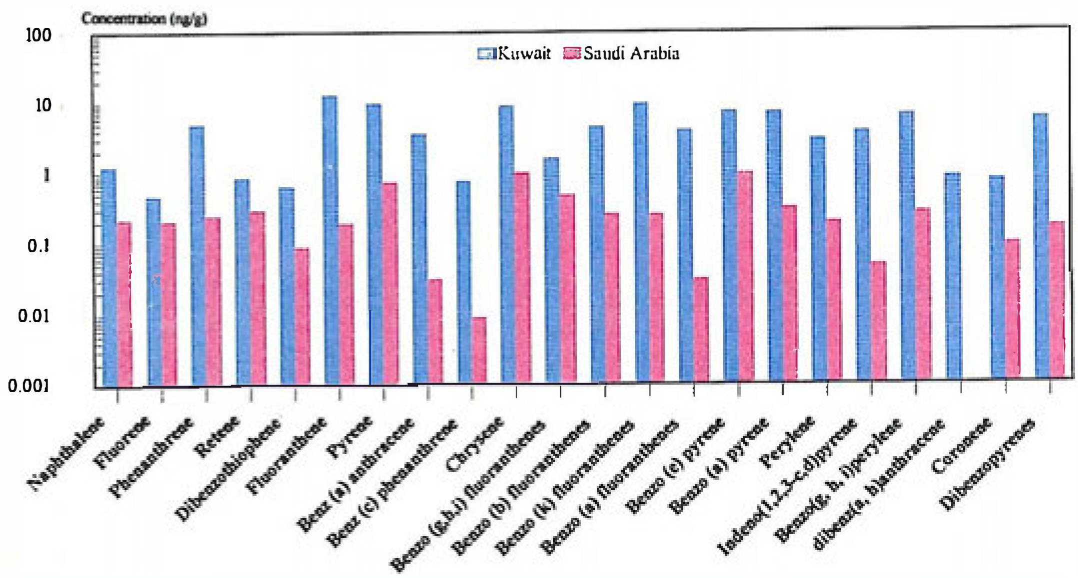



* concentration in µg/g while for the rest it is in ng/g

The highest levels of primarily oil-derived, were recorded at Ras Al Ghar and Manifa Bay. This was the case for the parent compound such as phenanthrene, fluoranthrene and pyrene. It is noteworthy that with the exception of those two stations, the PAH levels were generally much lower than has been measured in earlier surveys.

In Kuwait, high PAH concentrations were noted at Doha Bay, Sulaibikhat and Fahaheel. Phenanthrene, fluoranthene and pyrene were particularly high at Doha, the site that visually appeared to be the most polluted. The very high benzo(a)pyrene concentrations was found at Sulaibikhat and Doha Bay (17 and 44 ng/g, respectively). They are some of the highest reported to date and warrant continued monitoring. The overall mean concentrations of aromatic hydrocarbons in sediment are summarised in Figure (5.17).

**Figure (5.17): Mean concentrations of aromatic hydrocarbons in sediment of Kuwait and Saudi Arabia, 1998.**




5.2.1.3 *Petroleum hydrocarbons in biota*

The concentration of total aliphatic and aromatic hydrocarbons were assessed in rock oyster tissue collected from seven locations in Oman during 1997–1998 (MRME--Oman, 1999). The results varied from 37.0–383.1 µg/g (dry weight) for total aliphatics and from 27.0–170.7 µg/g (dry weight) for total aromatics (Figure 5.18).

Vazquez *et al.* (2000) measured the hydrocarbon concentrations in the clam *Meretrix meretrix* at selected locations along the Saudi Arabian RSA coastline for the period 1981-90 (prior to the 1991 War) and compared them to those from the, war and post-war periods. Five of the nine sites in the study were affected by the war oil spill (Figure 5.19). There was no significant impact in the n-alkane levels. However dibenzothiophenes and phenanthrenes increased significantly in the clam tissue during the war period (Figure 5.20). These values returned to pre-war levels after a short period of time (within two years). The data from the sites affected by the oil spill are compared with data from the other four unaffected sites in the study that are located further to the south.

**Figure (5.18): Mean concentration of hydrocarbons in oyster tissue, Oman 1997-1998.**

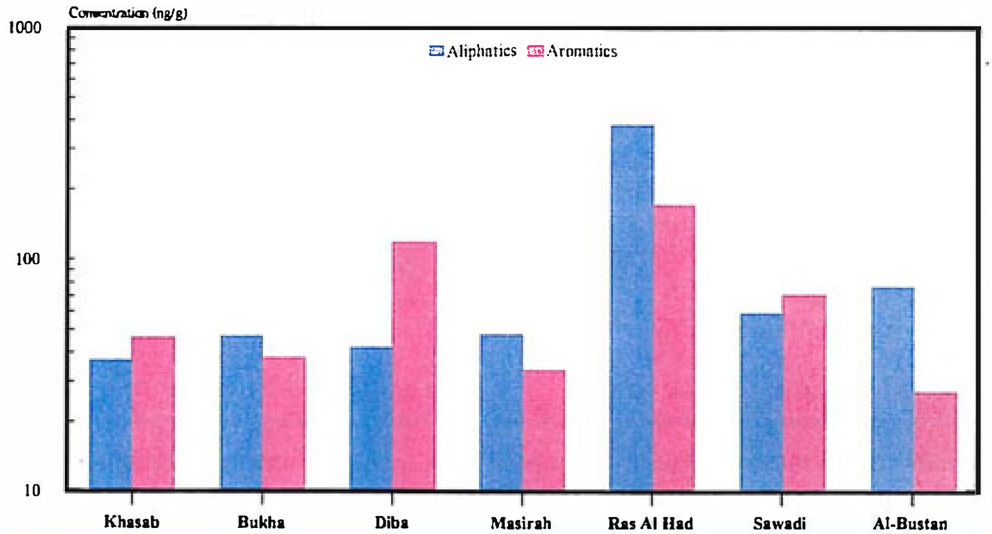
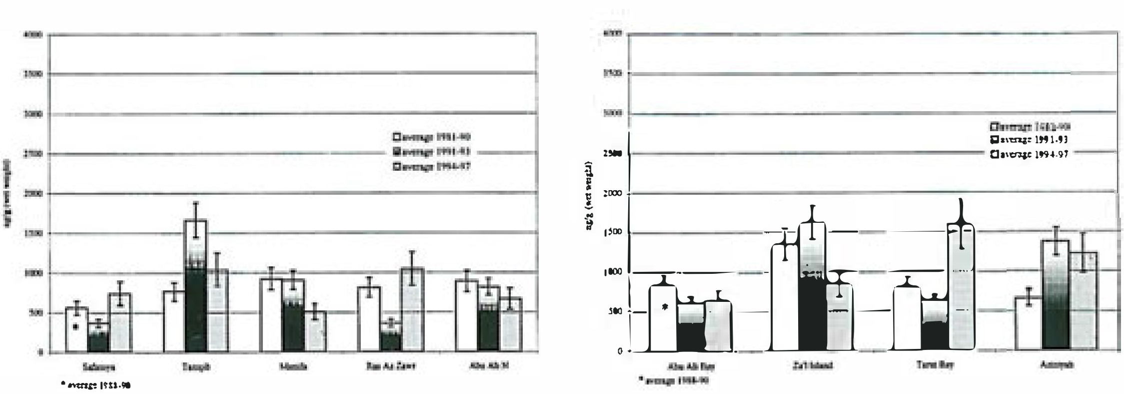
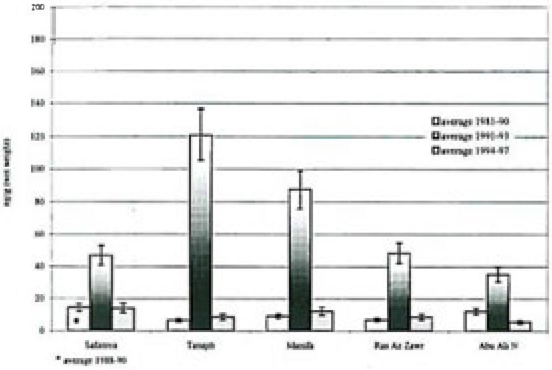



**Figure (5.19): Total n-alkanes and their relative standard deviation in clams collected from different sites in Saudi Arabia.**

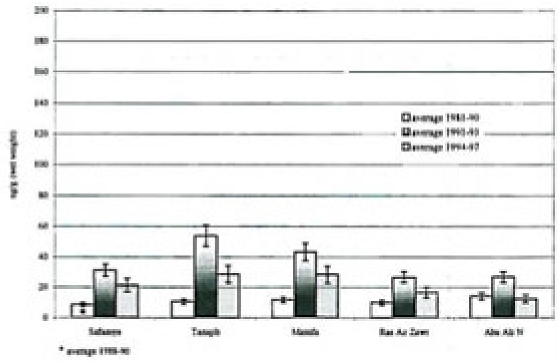


Sites affected by the 1991 War oil spill | Sites not affected by the 1991 War oil spill

**Figure (5.20): Total dibenzothiophens and phenanthrene and their relative standard deviation in clams collected from different sites in Saudi Arabia.**



Sites affected by the 1991 War oil spill



Sites not affected by the 1991 War oil spill

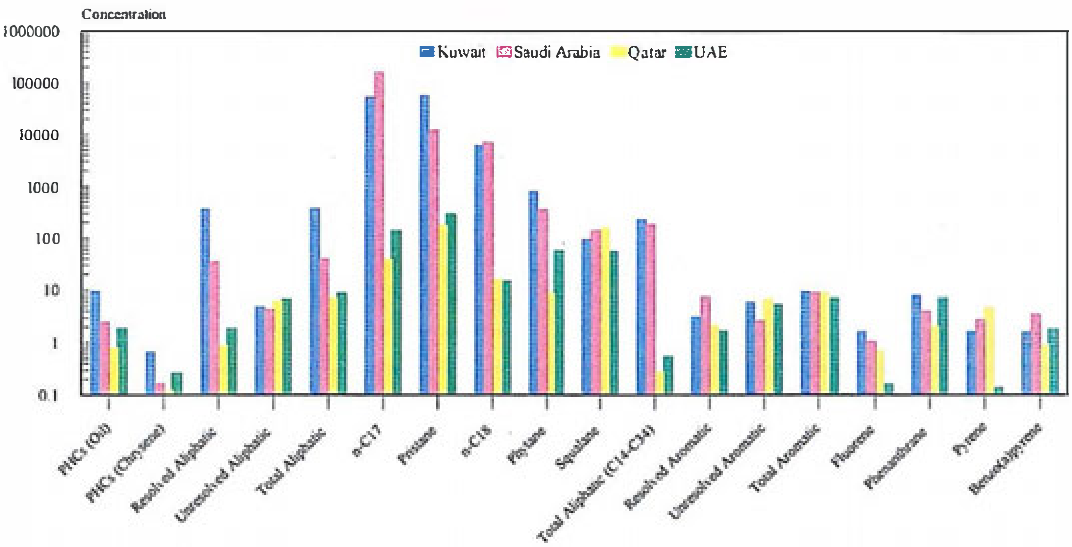
Fish muscles and bivalves were analysed, as part of the contaminant screening survey, for monitoring the concentration of petroleum hydrocarbons. The results as summarised in Table (5.4) showed that the total PHCs in fish muscles ranged from 0.18-9.8 µg/g, total aliphatic ($C_{14}$-$C_{34}$) ranged from 0.11-240 µg/g and benzo (a) pyrene ranged from 0.15-3.7 µg/g.

**Table (5.4): Concentrations of petroleum hydrocarbons in biota, RSA 1998&2000.**

| Compounds | Kuwait | | Saudi Arabia | | Qatar | | U.A.E. | |
|---|---|---|---|---|---|---|---|---|
| | Fish Muscles N=5 | Bivalves N=3 | Fish Muscles N=5 | Bivalves N=4 | Fish Muscles N=4 | Bivalves N=1 | Fish Muscles N=4 | Bivalves N-6 |
| PHCs (ROPME Oil equivalent) | 1.2-9.8 | 22-57 | 0.39-2.6 | 12.0-72.0 | 0.18 - 0.79 | 0.86 | 0.20-1.9 | 5.4-289 |
| PHCs (Chrysene) µg/g | 0.076-0.68 | 1.8-5.2 | 0.034-0.17 | 1.3-7.8 | 0.054-0.12 | 0.19 | 0.029-0.26 | 0.71-35 |
| Resolved Aliphatic (µg/g) | 2.2-380 | 4.5-13 | 3.1-36 | 6.5-20 | 0.41-0.9 | 8.9 | 0.4-1.9 | 1.1-21 |
| Unresolved Aliphatic (µg/g) | 1.8-5.1 | 41-83 | 1.3-4.5 | 14-41 | 2.8-6.4 | 21 | 0.77-6.9 | 12-130 |
| Total Aliphatic (µg/g) | 12-390 | 45-92 | 4.8-41 | 23-57 | 3.2-7.2 | 30 | 1.4-8.8 | 18-150 |
| n-C17 (ng/g) | 920-54000 | 1200-2600 | 490-160000 | 485-5000 | 20-39 | 570 | 49-140 | 150-540 |
| Pristane (ng/g) | 310-58000 | 300-420 | 160-12000 | 98-580 | 25-180 | 67 | 18-295 | 66-300 |
| n-C18 (ng/g) | 50-6300 | 46-100 | 24-7000 | 25-110 | 4.2-16 | 29 | 4.5-15 | 29-48 |
| Phytane (ng/g) | 30-830 | 41-150 | 16-360 | 12-640 | 1.1-8.9 | 59 | 7.7-59 | 23-160 |
| Squalone (ng/g) | 0.54-98 | 270-465 | 36-145 | 51-125 | 45-160 | 280 | 1.6-56 | 69-210 |
| Total Aliphatic (C14-C34) (µg/g) | 1.7-240 | 3.0-4.5 | 0.85-190 | 1.4-7.6 | 0.11-0.28 | 1.2 | 0.17-0.56 | 0.81-5.3 |
| Resolved Aromatic (µg/g) | 0.52-3.3 | 3.0-3.9 | 0.68-7.8 | 6.9-9.9 | 0.54-2.2 | 4.4 | 0.27-1.7 | 1.1-13 |
| Unresolved Aromatic (µg/g) | 1.0-6.4 | 11.0-21.0 | 0.69-2.8 | 7.2-16 | <1.0-7 | 5.1 | 1.4-5.6 | <1.0-103 |
| Total Aromatic (µg/g) | 1.5-9.8 | 14-25 | 1.9-9.4 | 14-24 | 0.81-9.2 | 9.5 | 0.27-7.3 | 1.1-107 |
| Fluorene (ng/g) | 0.31-1.7 | 0.18-0.47 | 0.091-1.1 | <0.045-0.27 | 0.16-0.71 | 0.48 | <0.030-0.16 | <0.030-2.1 |
| Phenanthrane (ng/g) | 3.4-8.4 | 5.8-7.9 | 1.6-4.2 | 3.1-7.5 | 0.27-2.1 | 3.1 | 1.3-7.4 | 2.2-25 |
| Pyrene (ng/g) | <0.03-1.7 | 4.3-10 | 0.43-2.9 | 0.72-2.1 | 0.16-4.9 | 1.4 | 0.026-0.14 | 0.22-15 |
| Benzo(a)pyrene (ng/g) | 1.0-1.7 | 0.83-4.9 | 0.77-3.7 | <0.14-7 | 0.15-0.94 | < 0.072 | 0.15-1.9 | 0.39-12 |

In general, most of the maximum concentrations of PHC in fish were reported for samples collected from Kuwait followed by Saudi Arabia, which could be attributed to the 1991-oil spill. However, the lowest maximum concentrations of PHCs were reported for samples collected from Qatar and UAE (Figure 5.21.1). For Bivalves most of the maximum concentrations of PHCs were reported for samples collected from UAE where those samples were mostly rock and pearl oysters. However, Kuwait and Saudi Arabia samples were almost within the same level (Figure 5.21.2).

**Figure (5.21.1): Maximum concentrations of petroleum hydrocarbons in fish muscle, RSA 1998&2000.**




Concentration unit as indicated in Table (5.4)

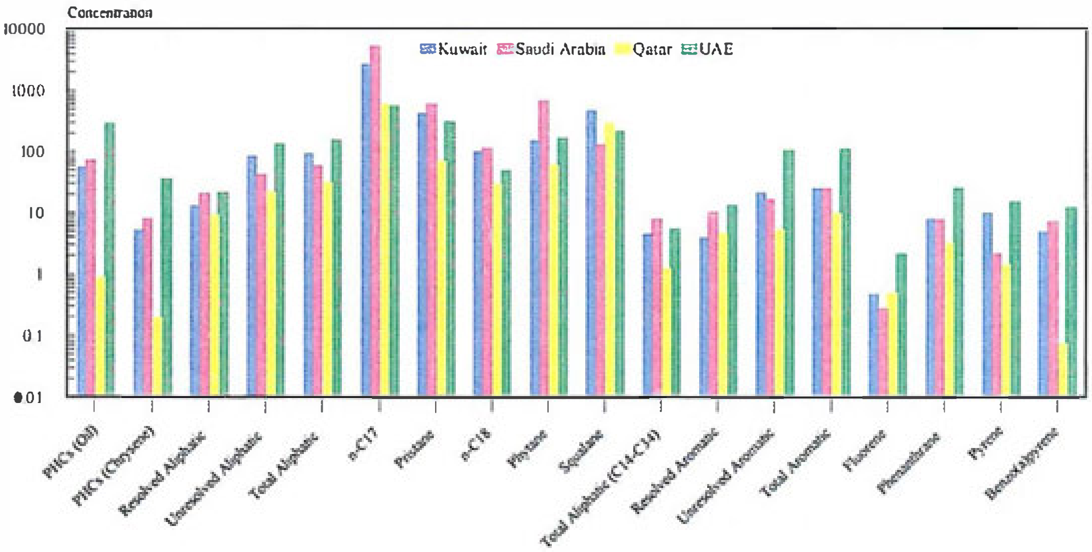
## 5.2.2 Halogenated hydrocarbons

Halogenated hydrocarbons are hydrocarbon compounds in which various numbers of hydrogen atoms have been replaced by Cl, Br or I atom.

### 5.2.2.1 *Halogenated hydrocarbons in seawater*

Halogenated hydrocarbons that may be of interest in the marine environment 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. The significance of bromoform in the environment may attributed to the sensitivity of embryonic and larval stages of marine organisms and to the possibility of mimicking hormones released by marine organisms and thus interfere with the chemical communication system of these organisms causing disruption of their life cycle.

**Figure (5.21.2): Maximum concentrations of petroleum hydrocarbons in bivalves, RSA 1998&2000.**




Concentration unit as indicated in Table (5.4)

5.2.2.2 *Halogenated hydrocarbons in sediment*

Generally the data of halogenated hydrocarbons in the Region could be considered low as illustrated by several scientists (see SOMER, 1999). These compounds are still not included in the marine monitoring programme of Member States which could be due to the non existence of the origin of those compounds and their low concentrations. A more recent data are available through the contaminant screening survey, the results are shown in Figures (5.22.1) and (5.22.2).

In Kuwait, high concentrations of DDE were found at Bida'a, Doha Bay and Sulaibikhat. The highest lindane concentrations were also recorded at the latter two stations. It is of interest that endosulfan sulfate concentrations were very low at all coastal stations and ranged from 1.22 pg/g reported for Kuwait samples to 2.88 pg/g in UAE samples. The mean concentrations of DDT were almost within the same level in all Member states (6.2-8.9 pg/g), however, somewhat higher levels were found in sediments from Sulibikhat (Kuwait) and Mesaieed (Qatar), (29 and 19 pg/g respectively).

The results showed high concentration of organochlorine and PCBs in Kuwait than in the other three countries. The Aroclor 1254 in Kuwait sediment range from 50–24500 pg/g with the two highest values (3300 and 24500 pg/g dry) noted at Sulaibikhat and Doha Bay, respectively. In Saudi Arabia Aroclor 1254 ranged from <7.8–190 pg/g with the maximum concentration recorded at Manifa Bay. In Qatar, it ranged from 20 pg/g in Ras Laffan to 290 pg/g in Doha. For UAE, it was varied between 13 pg/g in Al-Marfa to130 pg/g in Akkah.

**Figure (5.22.1): Mean concentration of organochlorine pesticides in sediment from RSA, 1998 & 2000.**

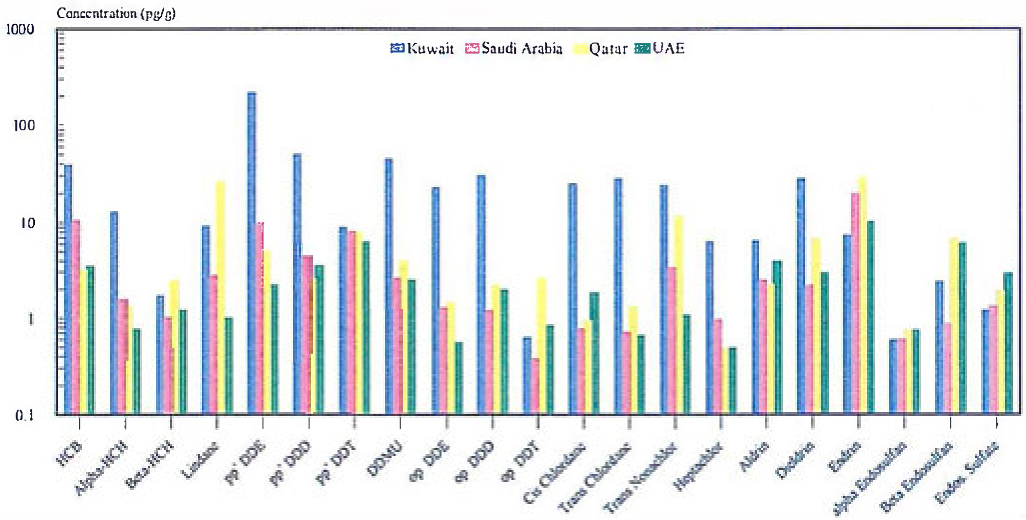
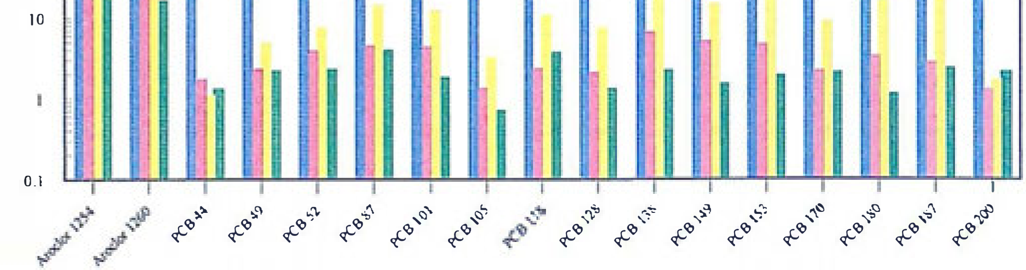



**Figure (5.22.2): Mean concentration of polychlorinated pesticides in sediment from RSA, 1998 & 2000.**



### 5.2.2.3 *Halogenated hydrocarbons in biota*

Usually the concentration of the organochlorine in the fat of the animal is higher than that in the feed by a factor of 10 to 15which could be referred to as biomagnification. Their persistence in the environment is expressed in terms of "Half-life". The recent available data from the contaminant screening survey are summarised in Table (5.5) and expressed as ng/g dry weight. The overall means of chlorinated hydrocarbons in fish muscles are shown in Figure (5.23.1) and for bivalve the means are shown in Figure (5.23.2).

**Table (5.5): Concentrations of chlorinated pesticides in biota, RSA 1998&2000.**

| Compounds | Kuwait | | Saudi Arabia | | Qatar | | U.A.E. | |
|---|---|---|---|---|---|---|---|---|
| | Fish Muscles N=5 | Bivalves N=3 | FishMuscles N=5 | Bivalves N=4 | Fish Muscles N=4 | Bivalves N=1 | Fish Muscles N=4 | Bivalves N=6 |
| HCB | 0.017-0.47 | 0.019-0.062 | <0.004-0.18 | <0.005-0.009 | 0.006-0.013 | 0.057 | 0.014-0.062 | 0.013-0.29 |
| Alpha HCH | <0.003-0.13 | <0.003-0.033 | <0.003 | <0.003-0.026 | <0.005-0.008 | 0.17 | <0.005-0.016 | <0005-0.083 |
| Beta HCH | 0.028-0.68 | 0.03-0.24 | 0.037-0.41 | 0.034-0.073 | 0.016-0.066 | 0.23 | 0.032-0.091 | 0.021-0.24 |
| Lindane | 0.006-0.24 | 0.03-0.26 | <0.003 | <0.003-0.027 | <0.006 | 0.15 | <0.004-0.02 | |
| pp' DDE | 1.6-26 | 0.14-2.4 | 0.4-3.4 | 0.18-0.38 | 0.064-0.14 | 0.014 | 0.057-0.71 | <0.004-3.3 |
| pp' DDD | 0.21-7 | 0.036-0.31 | 0.04-0.35 | 0.036-0.089 | <0.013 | <0.01 | <0.01-0.037 | <0.01-0.86 |
| pp' DDT | 0.03-2.3 | 0.065-0.38 | <0.007-0.17 | 0.49-1.2 | 0.015-0.033 | 0.14 | <0.014-0.09 | 0.026-0.54 |
| DDMU | 0.28-2.9 | 0.045-0.18 | 0.061-0.45 | <0.021-0.036 | 0.023-0.044 | <0.007 | 0.008-0.057 | <0.007-0.32 |
| op DDE | 0.028-0.98 | 0.01-0.069 | 0.008-0.042 | 0.013-0.022 | <0.004 | <0.003 | <0.003-0.005 | <0.003-0.061 |
| op DDD | 0.01-0.52 | 0.07-0.11 | <0.003-0.43 | 0.02-0.059 | <0.011 | <0.007 | <0.007 | <0.007-0.6 |
| op DDT | <0.003-0.033 | <0.005 | <0.003-0.31 | <0.003 | <0.01 | <0.007 | <0.007-0.023 | <0.007-0.65 |
| Cis chlordane | 0.018-0.56 | 0.056-0.17 | 0.016-0.046 | 0.029-0.14 | <0.008 | N.A | <0.006-0.036 | <0.006-0.47 |
| Trans Chlordane | 0.007-0.28 | 0.005-0.16 | <0.003-0.031 | <0.003-0.64 | <0.008 | <0.006 | <0.006-0.008 | <0.006-0.078 |
| Trans Nonachlor | 0.044-0.94 | 0.008-0.06 | 0.033-0.11 | <0.01-0.095 | <0.004-0.026 | <0.004 | 0.005-0.09 | <0.004-0.015 |
| Heptachlor | <0.005 | <0.006 | <0.005 | <0.008 | <0.005 | <0.003 | <0.003-0.009 | <0.003-0.06 |
| Aldrin | <0.005-0.11 | 0.007-0.02 | <0.005-0.059 | 0.013-0.05 | <0.004 | <0.003 | <0.003-0.017 | <0.003-0.11 |
| Dieldrin | 0.11-0.44 | 0.15-0.23 | 0.045-0.23 | <0.01-0.3 | 0.013-0.03 | 0.006 | 0.035-0.14 | 0.016-1.2 |
| Endrin | 0.07-0.27 | 1.1-3.3 | 0.088-0.17 | 0.94-6 | <0.017 | <0.013 | <0.013-0.067 | <0.013-0.38 |
| Alpha Endosulfan | <0.006 | <0.005 | <0.006-0.007 | <0.006 | <0.004-<0.007 | <0.004 | <0.004 | <0.004-0.004 |
| Beta Endosulfan | <0.007 | <0.008-0.011 | <0.007-0.012 | <0.007 | <0.005-0.027 | <0.005 | <0.005-0.033 | <0.005-0.094 |
| Endosulfan Sulfate | <0.009 | <0.009-0.015 | <0.009-0.052 | <0.009 | <0.006-0.022 | <0.006 | 0.006-0.067 | <0.006-0.016 |
| Aroclor 1254 | 1.7-58 | 0.5-3.8 | 0.37-1.5 | <0.18-1.1 | 0.38-0.65 | 1.3 | 0.12-2.1 | 0.078-3.7 |
| Aroclor 1260 | 1.5-25 | 0.62-2.7 | 0.27-1.3 | 0.3-0.57 | 0.23-1.3 | 0.11 | 0.14-3.8 | 0.062-3 |
| PCB44 | <0.001-2.3 | <0.011-0.044 | <0.01 | <0.012-0.024 | <0.008-<0.012 | <0.008 | <0.008 | <0.008-0.095 |
| PCB49 | 0.11-3.1 | 0.014-0.12 | 0.058-0.096 | 0.025-0.075 | <0.011-0.059 | 0.056 | <0.01-0.031 | <0.01-0.12 |
| PCB 52 | 0.046-4 | 0.044-0.2 | 0.016-0.13 | 0.079-0.1 | 0.021-0.029 | N.A | <0.01-0.13 | <0.01-0.31 |
| PCB87 | 0.012-2 | 0.013-0.16 | <0.008-0.019 | <0.01 | <0.005-0.026 | <0.005 | <0.005-0.089 | <0.005-0.12 |
| PCB 101 | 0.21-5.4 | 0.026-0.38 | 0.02-0.14 | 0.015-0.09 | 0.04-0.13 | 0.054 | 0.02-0.36 | <0.007-0.24 |
| PCB 105 | 0.042-1.3 | 0.022-0.19 | <0.007-0.043 | <0.013-0.034 | 0.014-0.028 | 0.006 | 0.006-0.16 | <0.005-0.094 |
| PCB 118 | 0.1-3.2 | 0.011-0.49 | 0.013-0.1 | <0.01-0.076 | 0.053-0.11 | 0.015 | 0.021-0.35 | <0.006-0.11 |
| PCB 128 | 0.059-1.4 | 0.018-0.27 | 0.059-0.18 | <0.009-0.041 | 0.01-0.029 | <0.005 | 0.01-0.28 | <0.005-0.084 |
| PCB 138 | 0.5-6.3 | 0.23-1.1 | 0.071-0.43 | 0.033-0.28 | 0.07-0.26 | 0.025 | 0.061-1 | 0.023-0.48 |
| PCB 149 | 0.25-5 | 0.039-0.28 | <0.012-0.22 | <0.013-0.098 | 0.02-0.073 | 0.022 | 0.009-0.099 | <0.008-0.27 |
| PCB 153 | 0.89-8.2 | 0.29-1.6 | 0.093-0.76 | 0.07-0.56 | 0.11-0.44 | 0.047 | 0.065-0.9 | 0.072-0.78 |
| PCB 170 | 0.12-1.4 | 0.013-0.2 | 0.01-0.074 | <0.009-0.042 | 0.016-0.078 | <0.005 | 0.008-0.33 | <0.005-0.14 |
| PCB 180 | 0.064-2.3 | 0.06-0.29 | 0.031-0.14 | <0.01-0.037 | 0.028-0.15 | 0.010 | 0.01-0.64 | <0.005-0.25 |
| PCB 187 | 0.29-2.7 | 0.058-0.25 | 0.03-0.24 | 0.016-0.089 | 0.029-0.17 | 0.010 | 0.029-0.32 | <0.006-0.45 |
| PCB 201 | 0.008-0.25 | 0.008-0.051 | 0.01-0.015 | <0.012-0.11 | <0.006-0.011 | <0.006 | <0.006-0.037 | <0.006-0.048 |

N.A. = Not Analysed

The results indicated high concentrations of the organochlorine in samples collected from Kuwait. Five different species of fish were collected in Kuwait and analysed for chlorinated hydrocarbons, their range varied from 1.6-26 ng/g for DDE, 0.03-2.3 ng/g DDT and 1.7-58 ng/g Aroclor 1254. UAE samples almost have the same trend of Kuwait samples with lower concentrations for most of the measured organochlorine in fish muscles. However, for the bivalve from UAE the overall mean concentrations were almost close to the overall mean reported for samples collected from Kuwait.

**Figure (5.23.1): The overall mean concentrations of chlorinated pesticides in fish muscles, RSA 1998 & 2000.**

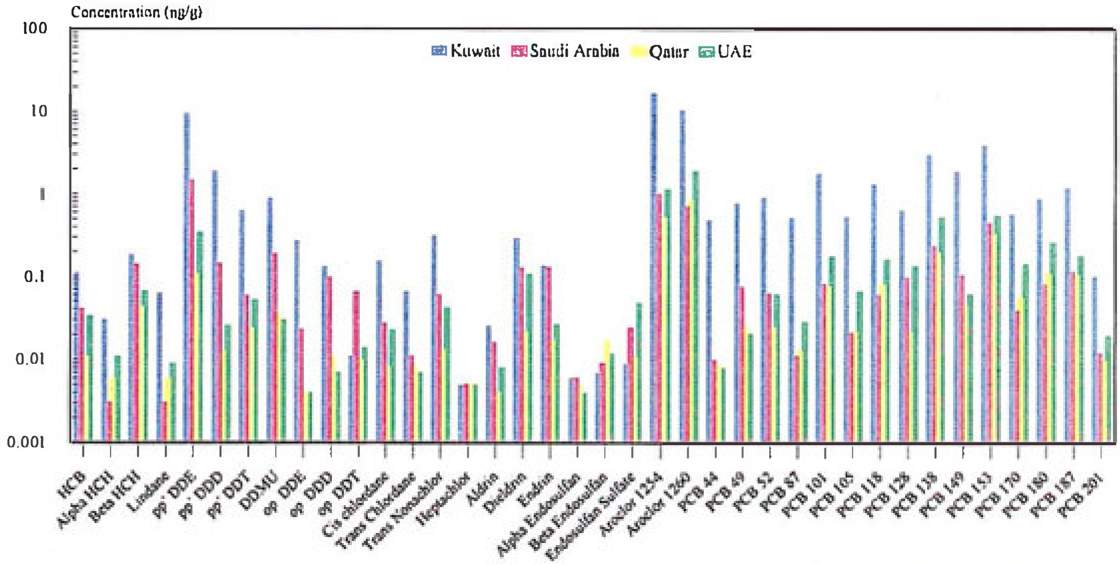
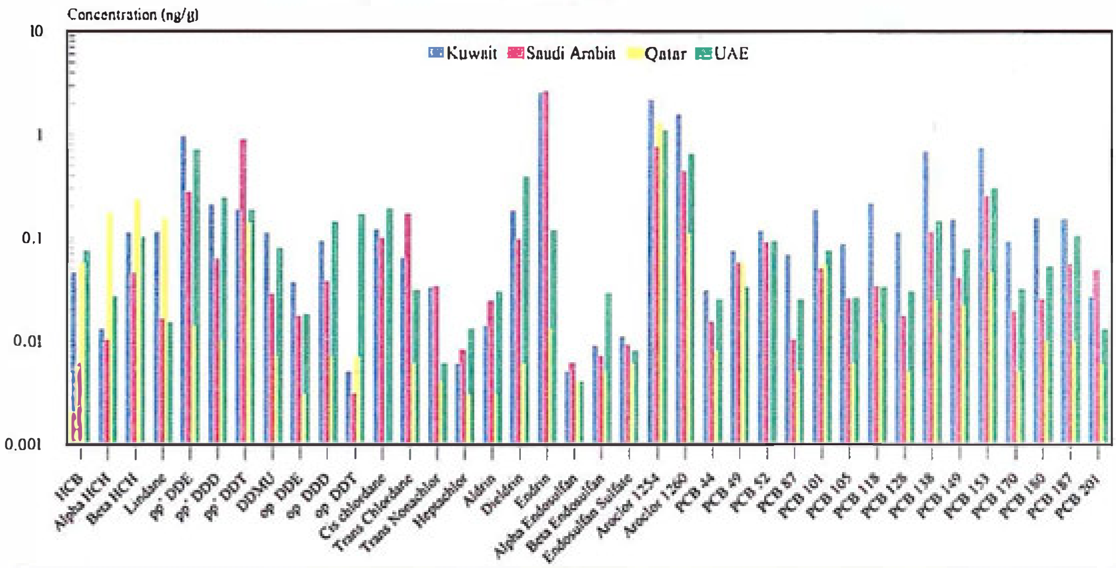



**Figure (5.23.2): The overall mean concentrations of chlorinated pesticides in bivalves, RSA 1998 & 2000.**



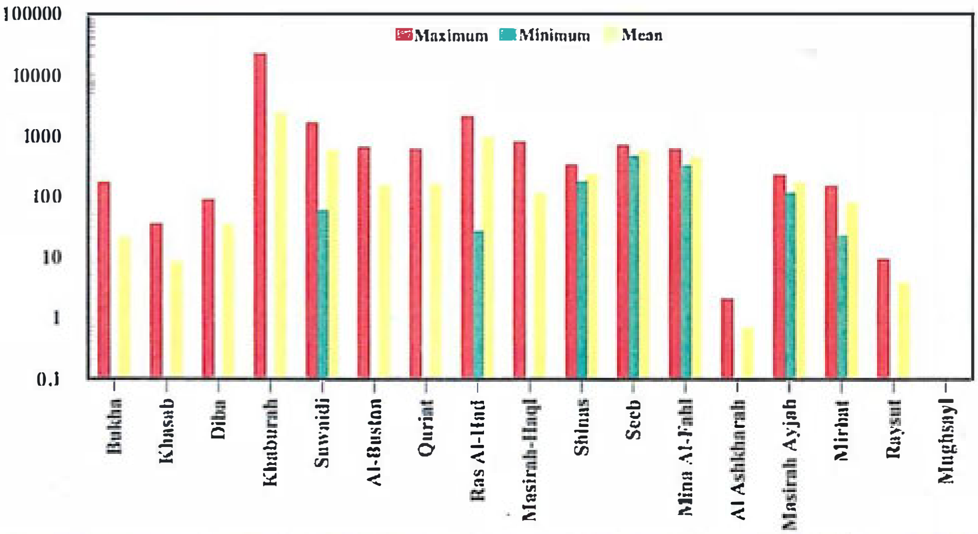
5.2.3 Tar balls

Coastal ecosystems in the RSA have been under increasing pressures from hostilities and other developmental activities. The region has a long history of crude-oil pollution. Because of the high ambient temperature, oil deposited along the coastline or inland evaporates, leaving a semi-solid tar (Hegazy, 1997).

Al-Madfa *et al.* (1999) determined beach tar concentrations along the Qatari coastlines. Tar concentrations, collected from 11 locations, varied in space and time with values ranging between 2 and 1132 g/m (average 290 g/m) of beachfront. Tar deposition was at maximum following the 1991 War oil spill, especially along the northwestern (average 723 g/m) and northern coasts (average 620 g/m). With the exception of higher levels off Saudi Arabia and Oman, the levels of beach tar around Qatar appear to be within the range of previously recorded RSA values. The eastern coast appears to be receiving fresh tar in lower amounts (average 150 g/m) than the western coast (average 304 g/m), where older tar from earlier spills still persists in large quantities. The application of strict regulations on ballast water disposal in the RSA led to a clear declination in tar deposition since 1993, reaching baseline limits in some locations.

In Oman, the overall mean concentration ranged from 0 g/transact in Mughsayl to 895 g/transact in Ras Al-Had for the period 1997-1998 (MNR-Oman, 1999). Other high means were reported in Suwaidi (552 g/transact) and Seeb (548 g/transact). The results are summarised in Figure (5.24).

**Figure (5.24): Concentration of tar ball deposited on the coastal area of Omani beaches, 1997-1998.**



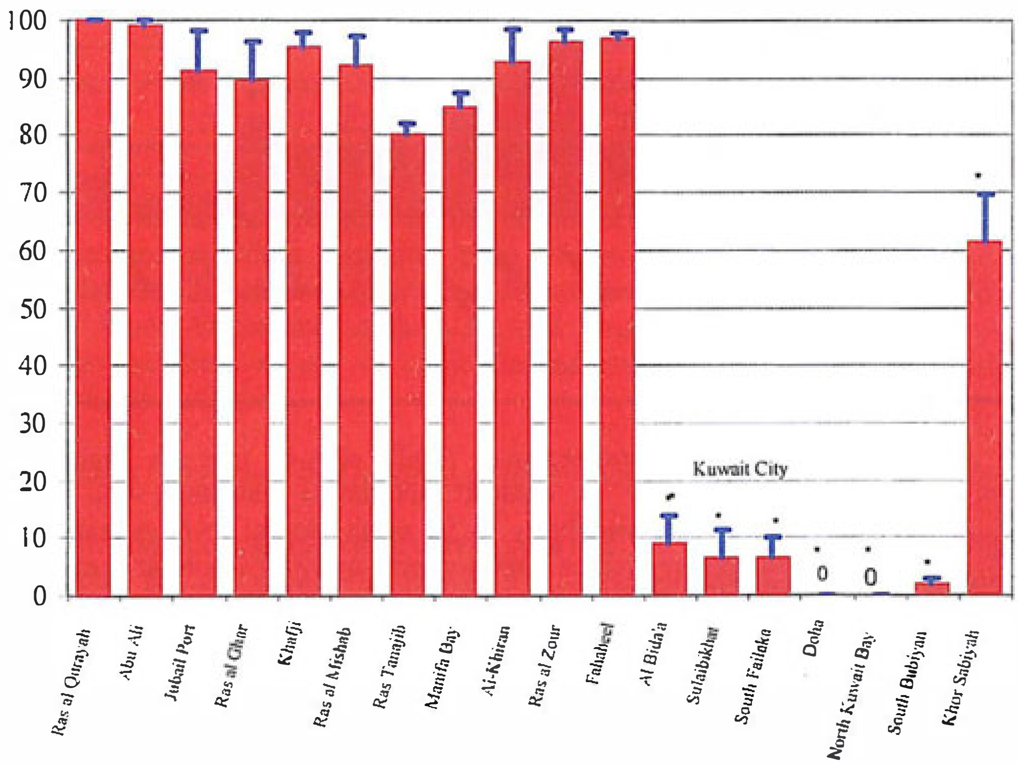
5.2.4 Effect of pollution on the marine environment

5.2.4.1 *Toxicity test*

Toxicity of marine sediment and surface water was carried out as a part of the contaminant screening survey. Samples were collected from 18 intertidal and near shore sites between Bubiyan Island in the north of Kuwait and Ras Al-Qurayah in Saudi Arabia. Fertilised eggs of Kuwait urchins (*Echinomtra mathaei*) were exposed to seawater extracts of sediment as well as sub-surface water and the surface film of the water (microlayer).

The sediment results indicated that when fertilised sea urchin eggs were exposed to water-soluble extracts of marine sediment the percentage completing development to normal live larvae (late gatrula or pluteus stage) differed greatly according to the site from which the sediment was collected. In Saudi Arabia most coastal sites showed little or no toxicity, i.e. had greater than 90% normal larval development (Figure 5.25).

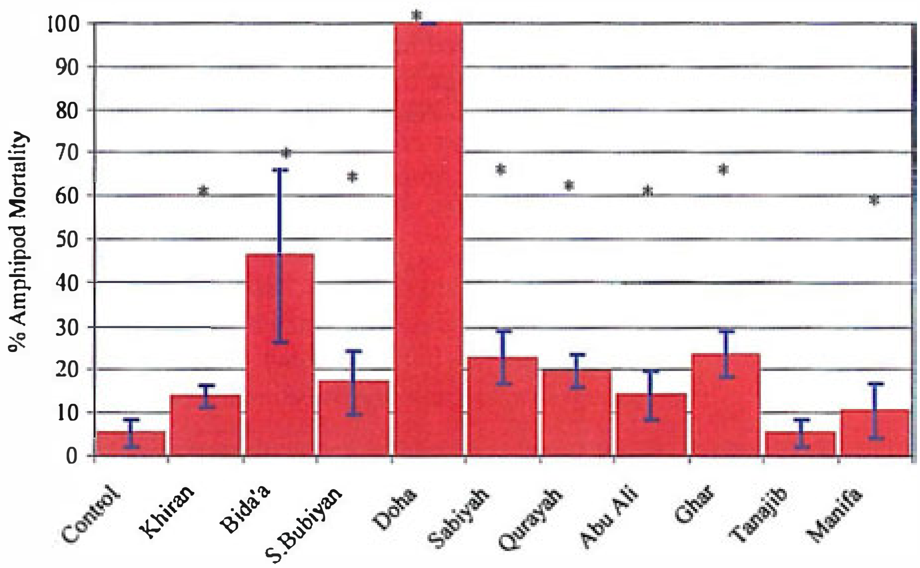
**Figure (5.25): Toxicity of RSA beach sediments**




(* = toxic)

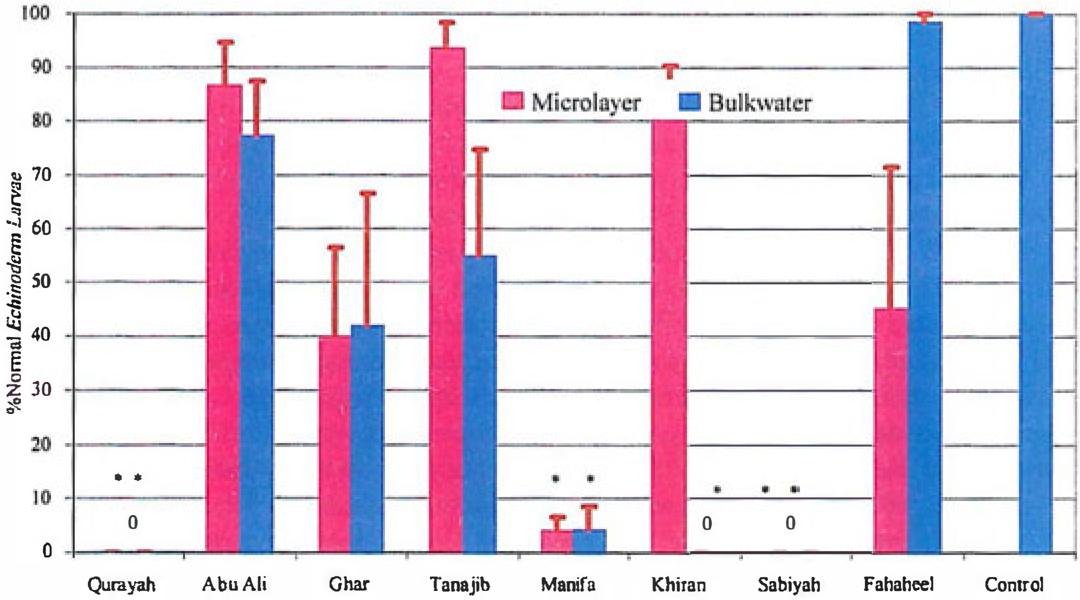
Abundant tar (smooth flat plaques) was found along the beach at the Manifa Bay site (S8). Manifa Bay (S8) as well as Ras Tanajib (S7) sediments showed some moderate, but not significant, toxicity (i.e. 80 to 85% normal larval developments). In Kuwait, sediments from the southern stations (Al Khiran (K1), Ras al Zour (K2) and Fahaheel (K10) were not toxic, but all stations from Al Bida'a northward were significantly toxic. The amphipod mortality test indicated significantly toxicity at all sites examined except Ras Tanajib (S7). Doha (K7) sediment was extremely toxic, causing 100% amphipod mortality (Figure 5.26).

**Figure (5.26): Toxicity of RSA beach sediments (Amphipod mortality%).**




The surface microlayer and seawater results showed that sea urchin larvae developed 100% normally in control (laboratory) seawater (36‰ salinity). There was considerable variability in % normal larval development between samples and sample replicates. Development was >80% normal in microlayer samples from Abu Ali, Ras Tanajib and Al Khiran and bulkwater samples from Fahaheel (Figure 5.27). However, significantly toxicity occurred both in microlayer and bulkwater samples from Ras al Qurayah, Manifa Bay (S8) and Khor Sabiyah (K8) and in the bulkwater only at Al Khiran (K1). Salinity at most stations were less than 45‰ and collected water and microlayer samples were not adjusted for salinity differences. The low (0) normal development at Ras Al Qurayah, could be due to the high salinity (35‰) of the samples adversely affecting E. mathaei larval development. However, small tar balls were observed rolling in near the water line at Ras al Qurayah. Also, the amphipod test (above) indicated significant toxicity that cannot be explained by high salinity since it was conducted with added 32‰ salinity seawater.

**Figure (5.27): Toxicity of RSA nearshore surface water.**




In general, the recovery of the oil impacted areas of the northwest RSA coastline continues at a slow pace. Approximately 7½ years after the war-related spill, elevated oil residues are still present at several contaminated sites in Saudi Arabia and southern Kuwait. Organisms exposed to sediments and seawater from several of those sites indicate toxicity in the form of sub-lethal and lethal effects.

5.2.4.2 *Status of pollution and its effect on the marine environment*

Oil may pose a problem at certain sites near urban centres such as Sulaibikhat, Doha Bay and Fahaheel, however, it is not completely clear if the main sources for the observed levels are marine (e.g., tanker activities) or land-based. At most of the sites in the industrialised areas around northern Kuwait, the problems of ecological health may arise from a mixture of diverse organic contaminants (POPs) derived from industrial and agricultural inputs. The sites at Sulaibikhat and Doha Bay were high in most all of the trace organic contaminants analysed, and the latter site was so badly polluted that the local intertidal ecology appeared to be severely disrupted. These potential problems of high levels of mixed contaminants were underscored by the toxicity results, which suggest widespread sublethal and lethal toxicity to certain marine species in the area of northern Kuwait. In this area as well as at the sites examined in Saudi Arabia, organic contaminants (oil and POPs) are highly suspect as the causative agents since heavy metal levels are not particularly high outside certain localised point sources. Furthermore, toxic metal concentrations have not fluctuated significantly over the last two decades and probably, for the most part, reflect baseline levels of these trace elements in the RSA.

Local point sources of contamination, possibly of a transient nature, still may pose local problems. One example in this study was the relatively high levels of DDT found at Qurrayah coupled with the observed toxicity in both sediments and seawater from this site. Because of its relative remoteness from industrial and urban activities, Qurrayah (Al-Aziziyah area) has been selected as a control site for the surveys of oil and non-oil pollution in this region. Hence, the finding of elevated pesticide contamination and concomitant toxicity at Qurrayah was unexpected and highlights the episodic and transient nature of pollution events in the RSA. As the surface microlayer appears to be a critical site for contaminant concentration and resultant toxicity, a greater effort should be made to better characterise the mix of contaminants in this portion of the water column. Likewise, the sediments which eventually integrate all the contaminants are also toxic at many sites in this northwestern region, and it would be important to better understand the extent of these observed effects within the RSA. Thus, increased effort to characterise all toxic agents in sediment samples and discern their effects is highly recommended.

Bioindicators such as bivalves and fish continue to be useful tools in pinpointing areas where contaminants are bioavailable and persistent in the biota. However, to properly interpret sources of possible metal contamination, it is imperative to understand the natural bioaccumulation potential and natural background levels of metals in the species under study since content and ratios of heavy metals vary greatly among the bioindicator species (particularly bivalves) used in the RSA.

Aside from the above aspects, which should be given attention in future monitoring work, we still have gaps in our knowledge of the spatial (and local) distributions of some of these key contaminants in the RSA. Most existing reliable data have been obtained for the northwestern region of the RSA. Areas around the northeastern Shatt Al-Arab have been little surveyed as well as many locations along the eastern and southeastern shores of the RSA. Because the Shatt Al- Arab drainage system is the most likely source for the large-scale input of agrochemicals and many other industrial and urban contaminants to the RSA, this is a critical area to screen for POPs as well as other potential contaminants originating from land-based sources.

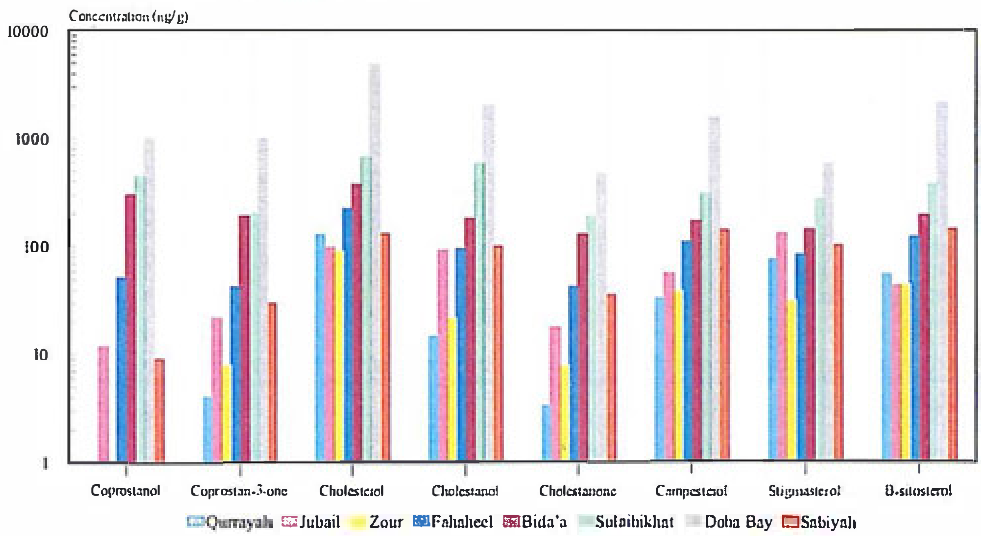
## 5.3 Faecal Sterols in sediment

Coperstanol (5β-chloestan 3β-ol), a motabolic byproduct of cholesterol, is one of the principal sterols found in human and animal faeces, and thus a useful indicator of sewage pollution in the coastal zone (Redman *et al.*, 1986 a&b). The composition of sewage effluents depends strongly on the input streams and the provided level of treatment (Al-Omran, 1998).

The concentrations of sterols were measured in the intertidal surface sediments collected from the vicinity of coastal effluents and bathing beaches along Kuwait coastline (Al-Omran, 1998). The sediments were characterised for their sterol composition. The results indicated that the faecal coprostanol varied between 0.55-45.1 μg/g, which amounted to 9.9-49.5% of the total sedimentary measured sterols. Shuwaikh area in Kuwait Bay showed the highest impact, which is attributed to the continuous sewage discharge, slow speed tidal currents and the nature of sediments. The overall patterns of distribution indicate that physical processes constraining the area affect the sewage-derived material discharged from coastal effluent. The prevailing tidal currents contribute to faecal contamination of bathing beaches. The sterols composition, other than the faecal inputs indicates the contribution of both terrigenous and biogenic inputs to sedimentary organic matter (Al-Omran, 1998).

As a part of the contaminant screening survey, the concentration of sterols in selected sediments from the Kuwait and Saudi Arabia were measured, the results are shown in Figure (5.28).

**Figure (5.28): Concentration of sterols in sediments collected from Kuwait and Saudi Arabia, 1998.**



In Saudi Arabia, Jubail was the only site samples, which was located adjacent to a heavily populated and urbanised area. Nevertheless, coprostanol concentrations were very low (12 ng/g) and typical of those encountered in open coastal areas (IAEA, 1996, 1998). On the other hand, those stations situated near Kuwait city were an order of magnitude or more higher and demonstrate the presence of domestic pollution. The 1000 ng/g coprostanol concentration measured at Doha again signals the generally contaminated nature of this Bay.

## 5.4 Radioactive substances in sediment and biota

Radioactive substances (i.e., materials containing radionuclides) have entered and/or are entering the marine and coastal environment, directly or indirectly, as a result of a variety of human activities and practices. As the offshore drilling activities expand in the Region, concern over disposal of material in the associated waters in the marine environment is also growing.

The available data on the radioactive substances in the Region are limited to the radioanalyses carried out by IAEA in the Region. In fact in 1994 a series of cesium, plutonium and polonium measurements in sediments were made in Kuwait, Bahrain and UAE (Fowler, personal communication, 2000), the results of which are summarised in Table (5.6).

**Table (5.6): Concentration of radionuclides in RSA sediments, 1994.**

| Location | $^{137}$Cs | | $^{239+240}$Pu | | $^{238}$Pu | | $^{238}$Pu/$^{239+240}$Pu | $^{210}$Po | |
|---|---|---|---|---|---|---|---|---|---|
| | Bq/Kg | Error | Bq/Kg | Error | Bq/Kg | Error | Ratio | Bq/Kg | Error |
| ***Kuwait*** | | | | | | | | | |
| Shuwaikh Port | 14.97 | 1.482 | 0.181 | 0.017 | 0.0031 | 0.0012 | 0.02 | 37.95 | 1.5 |
| N. Kuwait Bay | <1.255 | | 0.113 | 0.012 | 0.0013 | 0.0013 | 0.01 | 26.43 | 0.65 |
| NW Khor Bubiyan | 5.261 | 1.001 | 0.034 | 0.003 | 0.0007 | 0.0009 | 0.02 | 23.56 | 0.8 |
| Shuaiba | <1.386 | | 0.055 | 0.005 | 0.0017 | 0.0014 | 0.03 | 12.32 | 0.42 |
| S. Bubiyan | 5.804 | 1.178 | 0.083 | 0.009 | 0.0012 | 0.0012 | 0.01 | 26.95 | 0.88 |
| ***Bahrain*** | | | | | | | | | |
| W. Fasht Al Jarim | 4.979 | 1.168 | | | | | | | |
| Askar | <1.471 | | | | | | | | |
| Jasrah | <1.250 | | | | | | | | |
| ***UAE*** | | | | | | | | | |
| Jebel Ali | <1.400 | | | | | | | | |
| Off Al Abyad Island | <1.462 | | | | | | | | |
| Off Al Abyad Island | <1.155 | | | | | | | | |
| Bidy'a | <1.365 | | | | | | | | |

The $^{137}$Cs and plutonium values are quite low and are typical of those originating from atmospheric fallout from earlier nuclear testing. For example, typical values in Mediterranean sediment range from 3.2 - 36.1 Bq/Kg $^{137}$Cs, 0.044-0.667 Bq/Kg $^{239+240}$Pu, and 0.0012 - 0.027 Bq/Kg $^{238}$Pu with the higher values found near river outflows, which focus runoff from land (*ibid.*). Furthermore, the average $^{238}Pu/^{239+240}Pu$ ratios of approximately 0.02 are consistent with those in atmospheric fallout. The lowest $^{137}Cs$ concentrations are found further down the RSA in UAE at a greater distance from the Shatt Al-Arab outflow. Interestingly, the Shuwaikh port area contained the highest Cs and Pu levels measured in the study. Nevertheless this site appears to be a focal point (in the "sedimentary" sense) for wide variety of contaminants which have been measured previously, and perhaps the higher radionuclide concentrations are related to the nature of the specific sedimentary regime in that area of Kuwait Bay. For comparison, some recent measurements in Mururoa Atoll where underground tests were carried out by the French showed sediments containing about 600 Bq/Kg $^{239+240}Pu$ (*ibid.*), i.e. some 3 orders of magnitude higher than the maximum concentrations measured in the RSA or Mediterranean Sea. The concentrations of the natural radionuclide $^{210}Po$ (not anthropogenically introduced) are possibly indicative of the carbonaceous nature of these coarse-grained, sandy sediments since fine-grained sediments typically contain somewhat higher concentrations of around 60-70 Bq/Kg $^{210}Po$. In general, it appears that the RSA sediments tested display concentrations of these anthropogenic radionuclides which are indicative of world-wide fallout as a source-term (*ibid.*).

Uranium was included in the trace element scan as a part of the contaminant screening survey because of the general interest in this element in the RSA environment following the use of depleted uranium in ordnance during the 1991 War. The results given in Figure (5.29) show that the highest uranium concentration in sediments was found at Doha Bay (3.04 μg/g) followed by Ras Mishab in Saudi Arabia (3.01 μg/g). Corresponding concentrations in clams from those two sites were also found to be correlated with ambient uranium concentrations in their surrounding sediments.

The concentration of uranium in fish muscle ranged from 0.005-0.022 μg/g in Kuwait, 0.005 μg/g in Saudi Arabia, 0.005-0.009 μg/g in Qatar and 0.007-0.035 in UAE. However concentrations of uranium in the bivalves collected from Kuwait, Saudi Arabia, Qatar and UAE were uniformly higher and ranged from 0.198-1.12 μg/g, 0.12-0.770 μg/g, 0.390 μg/g (N=1), and 0.010-0.498 μg/g, respectively, in those countries.

## 5.5 Litter

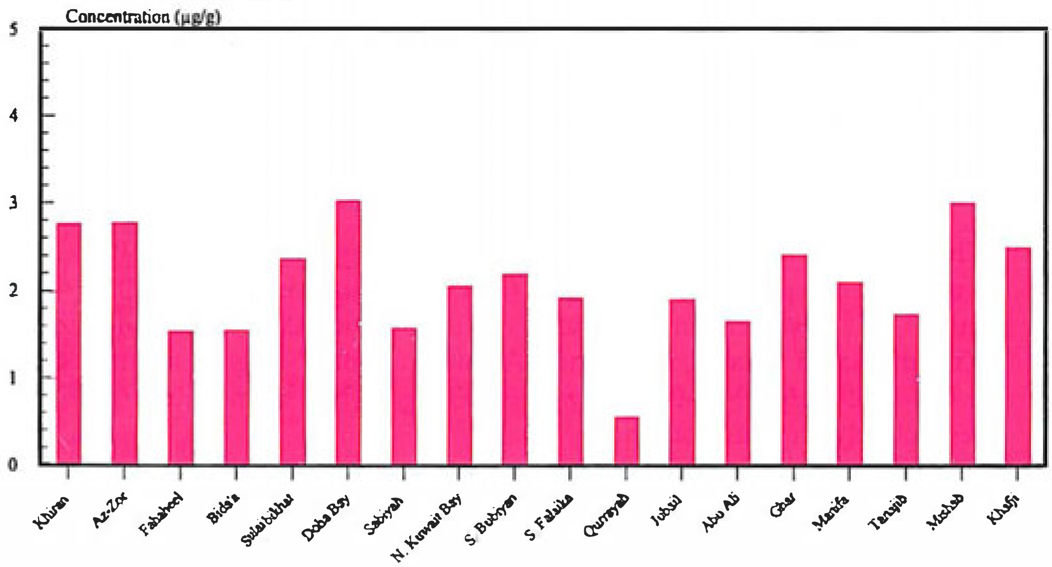
Litter is an increasing problem in the RSA from mainland, shores and ships. It is estimated that 1.2-2.6 kg/person/day of plastic waste is generated on ships, much of which is thrown overboard (Anbar, 1996).

The ROPME's shallow coastal areas are now being used as repositories for large quantities of industrial, commercial and residential trash and other solid waste. Often this takes the form of plastics, metal containers, wood, tyres and even the entire scrapped automobiles at some localities. Oil sludge constitutes, in terms of quantity, is the most important type of solid waste (Linden *et al.*, 1990). Much of the lighter debris has become spread along widespread tracts of shoreline through wind and water movements.

Littering of the shoreline is a very obvious sign of environmental deterioration in many parts of the region. This situation has rendered many beaches unsuitable for recreation particularly near more densely populated areas. Visitors have probably in most cases left the litter on the beaches. Even in very remote areas, the beaches are found to be severely contaminated by litter, probably transferred by the sea to the shore.

Hegazy (1998) conducted a study on a naturally growing population in Al-Khor mangrove swamps in Qatar during the years 1993-1995. Total litter fall decreased from a maximum of 188 $g/m^2$/ month to a minimum of 80 $g/m^2$/ month. Litter decomposition was lower in winter than in the summer months.

**Figure (5.29): Concentration of uranium in sediments from Kuwait and Saudi Arabia, 1998.**



CHAPTER 6

# MAJOR ACCIDENTS AND EPISODIC EVENTS

The region is hosting over 65% of the world oil reserves and 30% of the world gas reserves. In which over 76 billion metric tons of recoverable oil lies under and around the RSA while the national gas reserves amounted to 32.4 trillion cubic meters as estimated earlier by Hinrichsen (1996). The marine environmental operations in the area acquire special importance being a main source of food, potable water and the national income. In addition, this marine body is characterised by a unique ecosystem that forms part of the natural heritage. This region, with its diversified oil operations, has the most crowded shipping routes in the world, where tankers and ships carry about 60% of the world's total crude oil exports (UNEP, 1999). Accordingly, effective management for safety operations is critical for protection of the marine environment of the region.

About 1.2 million barrels of oil are spilled into ROPME Sea Area annually (GEO, 2000). The level of petroleum hydrocarbons in the area exceeds that in the North Sea. Oil pollution may be encountered anywhere in the marine environment and results from operational discharges of shipping, river run-off, natural seeps, atmospheric inputs, coastal refineries, petrochemical industry, offshore operations and tanker accidents. Such inputs are of a great threat to the marine environment.

Natural seeps have occurred over thousands of years and cannot be controlled. They are found in various parts of the world including the ROPME Sea Area and are impossible to measure accurately but are thought to account for between 0.02 and 2.0 million tonnes per year of hydrocarbon input to the marine environment (McDonagh, 1998).

Accidental spills of hydrocarbons are among the most spectacular accidents an area can be faced with. These spills represent in some estimate less than 15% of the total amount of hydrocarbons discharged every year into the marine environment (Tramier, 1999). Natural seepage, atmospheric fall out, urban run out, transportation (other than accidents) are the main origins of the input of hydrocarbons into the sea.

Operational inputs occur particularly during production, transportation and processing of oils. They are reducing as awareness of and concern about environmental issue increases. For example, there are pressures to reduce the concentration of oil in produced water, to eliminate the use of oil-based drilling mud and to avoid the discharge of oily water from oil tankers by the use of segregated ballast tanks. Nevertheless, operational inputs probably exceed accidental inputs by a considerable margin. Whereas operational discharges tend to result in chronic environmental impact, accidental inputs have the potential to result in acute damage to the environment of the affected area with relatively long-term impact in some circumstances. Major accidents tend to attract considerable media, public and political attention. Various measures have been introduced in recent years to try to reduce the number of shipping accidents resulting in releases of oil and to ensure procedures are in place to deal with spills once they have occurred (MEMAC, 1998).



## 6.1 War-related Oil Spills

The ROPME region was most unfortunate to witness the consequences of two wars in one decade. The war between Iraq and Iran started in 1980 and lasted for eight years and the 1991 War, which lasted for 35 days.

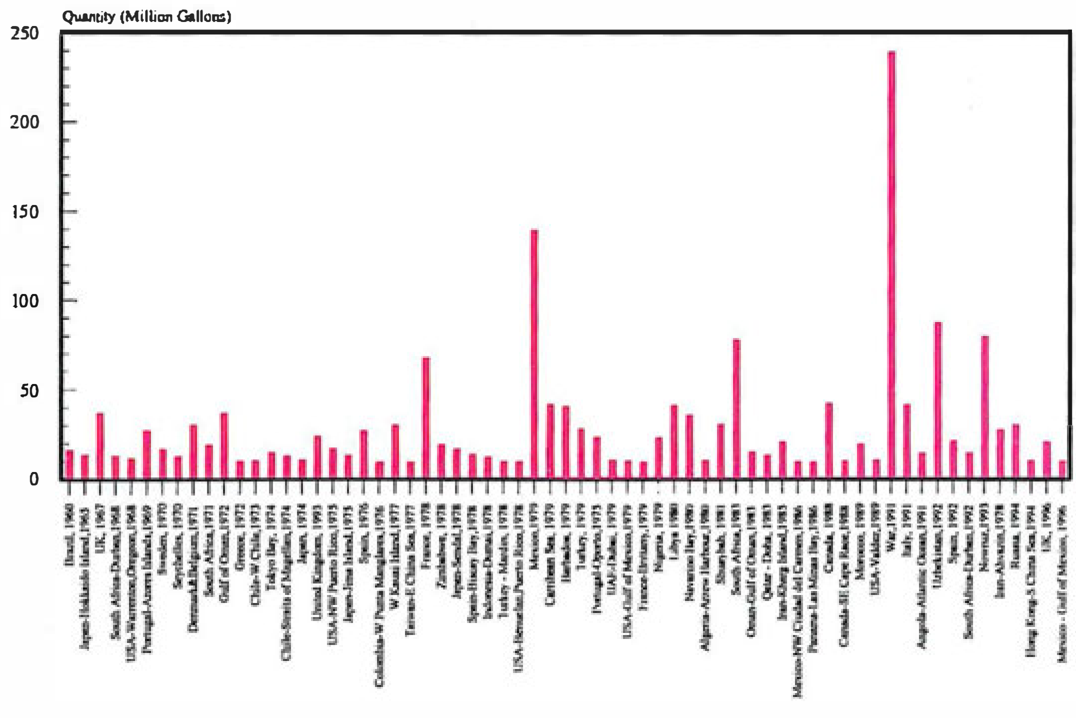
### 6.1.1 The Iraq-Iran War (1980–1988)

The most dramatic environmental episode of this war that had direct effect on the RSA was the blow-out of the Nowruz offshore oil wells off the Iranian coast. Consequently, an estimated amount of one million barrels of crude oil was spilled in the marine environment throughout the 16-month period (Olfat, 1984). This makes the Nowruz oil spill the longest recorded spill in the region. Other estimates indicate that the oil spilled during this period amounted to 2-4 million barrels (Reynolds, 1993). The extent, fate and effects of Nowruz oil spill was fully addressed in the first Regional Report of the State of the Marine Environment by ROPME (SOMER, 1999).

### 6.1.2 The 1991 Oil Spill

An estimated 6–8 million barrels of oil were spilled into the RSA from two major sources: four sunken and leaking vessels, including Iraqi oil tankers, and release of oil from the Kuwaiti Mina Al-Ahmadi Sea Island terminal and the Iraqi Mina Al-Bakr loading terminal. Additional sporadic discharges occurred from these and other sources through June 1991. Several hundred thousand barrels of oil seeped from damaged Kuwaiti and Iraqi oil facilities and several small Iraqi sunken tankers in the northern part of the Sea Area contributed additional pollution through the spring and early summer of 1997. This oil spill is by far the largest spill in the marine environment ever recorded Figure (6.1). However, the final official estimate of the oil spill as claimed by Kuwaiti authorities indicates that the total amount of oil discharge and spilled from various sources into the RSA is in excess of 9 million barrels (PAAC, 1999).

**Figure (6.1): Oil Spills involving more than 10 million gallons.**




(International Oil Spill Statistics, 1997)

For the purpose of preparing a contingency plan for oil combating, Al-Hajri, (1999a) has suggested spill size thresholds (tons/yr) for several kinds of operations. In his study, more than 500 tons/yr is considered as high rating from the environmental consequence point of view (Table 6.1). As such the 1991 spill is a tremendous environmental stress to the entire ecosystem. Such unprecedental oil spill has impacted the onshore areas of Kuwait and Saudi Arabia and the offshore areas, as well. Therefore, many studies are still needed for better environmental assessment of this catastrophe.

**Table (6.1): Suggested Thresholds of Spill Size Consequence.**

| Nature of Operations | Spill Size Thresholds (tons/yr.) | Environmental Consequence Rating |
|---|---|---|
| 1. Offshore | <100 | Low |
| | 100-500 | Moderate |
| | >500 | High |
| 2. Coastal Zone | 1 | Low |
| | 1-100 | Moderate |
| | >100 | High |
| 3. Onshore | <500 | Low |
| | 500-5000 | Moderate |
| | >5000 | High |

The international and regional efforts to assess the state of the marine environment culminated in launching, in late February 1992, of a 100-day research cruise in the RSA by the Research Vessel Mt. Mitchell of the U.S. National Oceanic and Atmospheric Administration (NOAA), under the auspices of ROPME and IOC of UNESCO. The findings and conclusions drawn on the basis of Mt. Mitchell Cruise results were given in several papers published in a special issue of the Marine Pollution Bulletin (1993).

Following the Mt. Mitchell cruise, three cruises were carried out by the Tokyo University School of Fisheries research vessel, Umitaka-Maru during 1993-

1994. The findings and conclusions drawn from these cruises were given in several papers published in a special proceeding (Otsuki *et al.*, 1998).

The Open Sea Cruises of the Mt. Mitchell and Umitaka-Maru in addition to the coastal surveys and national monitoring activities represent the extent of efforts made to assess the impacts of war on the marine environment of the RSA. The extent, fate and effects of the 1991 Oil Spill were fully addressed in SOMER 1999.


A more recent survey was carried out for ROPME under an agreement with NFP-I.R. Iran. ROPME convened two scientific committee meetings and prepared the cruise plan and I.R. Iran hired a training vessel named "Ghods" and mde arrangements for the study. The cruise was carried out in the Iranian and Kuwaiti waters from 14 August to 4 September 2000.

### 6.1.3 Other Military Activities

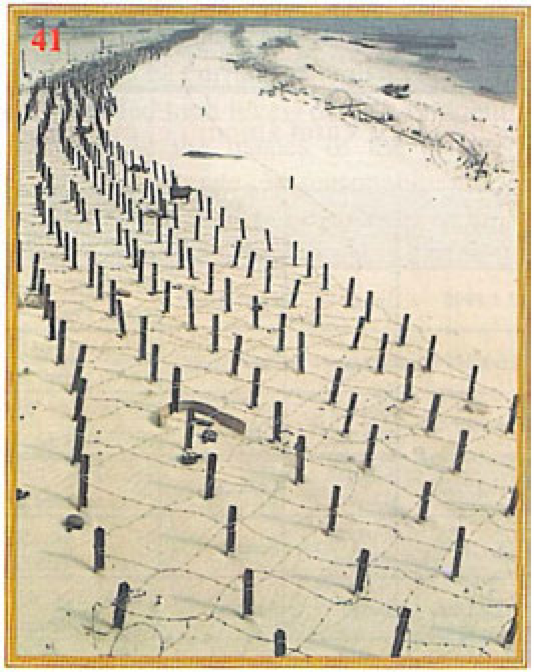
Other military activities imply for the oil well fires and their impacts as well as the destruction of coastal infrastructures and habitats. Setting fire to the Kuwait oil wells is another episodic event of the 1991 War that had significant environmental impact and adverse effects on the surrounding atmosphere and the marine and terrestrial ecosystems.

Several reports indicate that out of the 943 Kuwait oil wells, at least 700 wells were either set on fire or damaged (UN, 1991; Al-Besharah, 1992; Tawfiq, 1992). The official Kuwaiti reports indicate that from the 798 oil wells at which explosives were detonated, 604 wells caught fire and an additional 45 wells only gushed oil to the desert surface (PACC, 1999). The Ministry of Oil in Kuwait makes an estimate of oil and gas fire based on a field survey of the oil wells on fire, the gushing and the damaged wells, the extent of the oil pools formed in the desert, and the previous information about the pressure inside the wells.

This estimate puts the quantity of oil and gas burnt at 6 million barrels and 100 million $m^3$/day, respectively, generating substantial emissions of sulphur dioxide, hydrogen sulphide and oxides of nitrogen. In addition, incomplete combustion products including carbon monoxide, polycyclic aromatic and other volatile organic hydrocarbons were generated by the fires. Secondary formation of acid aerosols such as sulphuric acid may have also taken place in the atmosphere, although in most cases sulphates were formed instead due to the presence of salt in the aerosols resulting from the release of associated brines and use of seawater in fire fighting (Steven *et al.*, 1992).

The impacts of the Kuwaiti oil well fires on the marine environment are quite evident from both physical and visual observations at the time of burning and from the analysis of remote sensing data and field observations by several investigators. Particulate from the fires was deposited on both land and sea over wide areas.

As a defensive measure, the Iraqi military occupying Kuwait laid extensive mine fields all along the coasts, on the intertidal zone and in the deep sea channel approaches to Kuwait. In addition, numerous trenches were dug along the coast and damage was inflicted on all coastal installations, facilities and infrastructure. These destructive activities in the coastal zone have negative impact on the marine and coastal environment and will impose serious threat to beach users and fisherman for years to come (SOMER, 1999).




Another major coastal activity observed in the north-western part of the RSA in the aftermath of the war and which will have negative consequences on the fisheries and the ecology of the area is the drainage of Iraqi marshes. Iraq has reduced the marshes (with an estimated area of about 0.5 million hectares Maltby, 1994) to water channels delivering river water directly into the RSA, with all its sediment loads, agrochemicals, sewage and industrial wastes. This action has deprived the area of a giant "Kidney" that acted as a self sustained mega waste treatment facility and is likely to affect the spawning grounds of shrimp and migratory fish at the Shatt Al-Arab delta and the Kuwait Bay.

## 6.2 Tanker Accidents

Tanker accidents represent a major source of oil spills. Fortunately, for many years, the RSA has been saved from major accidents involving super tankers. However, a few incidents mainly by sub-standard barges have taken place in the Sea Area resulting in oil spills of varied magnitudes between 1998 and 2000 as shown in Table (6.2). These incidents resulted in a total of 9,000 metric tons of spilled oil in the marine environment (MEMAC, 2000).

Evidently, oil spills of appreciable magnitude would require immediate action on the part of the State concerned. In case of a major oil spill, the resources of a single State may not prove to be sufficient to handle the situation alone. It will therefore require increased regional co-operation to maximise the utilisation of resources that can be made available in the region under an effective regional response mechanisms.

**Table (6.2): Total amount of oil spilled in RSA*.**

| Date of Incident | Type | Type of Incident | Location | Type of Oil | Amount Spilled | |
|---|---|---|---|---|---|---|
| | | | | | Metric tons | US Gallons |
| 7.1.1998 | Barge | Partly sank | 25° 30'N, 055° 23'.4E Ajman Coast | Mix of refined black oil | 6000 | 1,764,705.80 |
| 15.1.1998 | Barge | Partly Sank | 27° 36'N, 051° 26'.2E Ras Al Motaf, I.R. Iran | Refined fuel oil | 2000 | 588,235.29 |
| 14.2.1998 | Coastal Tanker | Sank | 25° 56'.2N, 055° 21'.5E 23' East of Abu Musa Island | Gas oil | 700 | 205,882.35 |
| 5.3.1998 | Coastal Tanker | Leakage | 26° 37'N, 050° 57'E Close to Bahrain | Refined black oil | Few Gallons | Few Gallons |
| 24.1.2000 | Coastal Tanker | Sank | 24° 38.3'N, 054° 0 24'.3E 6'NE of Mina Zayed | Black Fuel Oil | 300 | 88,235 |
| 23.2.2000 | Barge | Sank | 27° 43'6'N, 052° 01'E East of Bushehr | Black Oil | – | – |
| | | | | Total Spilled | 9,000 | 2,647,058.44 |

*Period January 1998 - February 2000

All figures given to the very best estimation and specific gravity for conversion to US Gallon used 0.0034

(MEMAC, 2000)

In the absence of a regional oil spill contingency plan, the threat of a major oil spill is overwhelming the limited resources of any State in the region. Moreover, without adequate reception facilities to receive wastes from tankers, a port state control scheme to co-ordinate regional activities and a legal system to provide a deterrent against oil pollution, the input of oily wastes and other wastes into the RSA will continue.

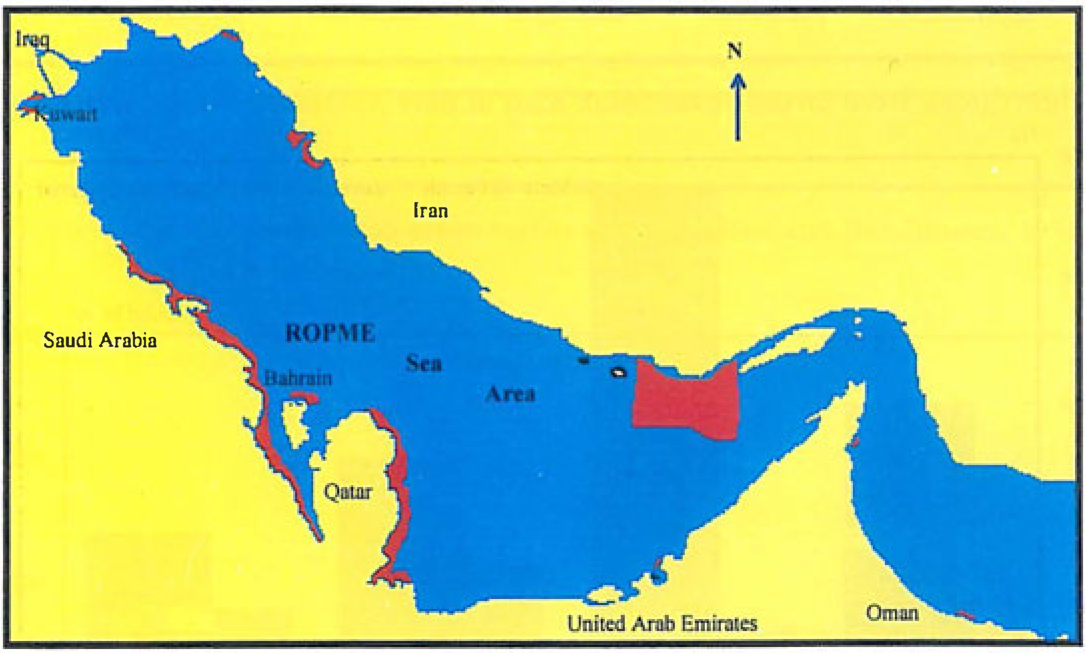
## 6.3 Mass Mortality of Marine Organisms

In recent years there has been an increasing number of unusual environmental events in marine ecosystems. These have included a number of large-scale disease events and die-off of a variety of marine and coastal organisms, unprecedented occurrence and proliferation of certain algal species (ROPME, 1999).

These repeated mass mortality and fish kill phenomena have also caused economic losses in the fisheries sector and anxiety among fish consumers in the affected State or States in the region.

Marine mortality often coincides and appears to be correlated with a variety of environmental factors. These factors have included high levels of anthropogenic contaminants in the affected ecosystems or in the tissues of the affected organisms, oxygen depletion (anoxia), climate change, unseasonably warm temperatures, novel disease agents, biotoxins (red tide) and changes in food supply. Several major incidents were reported in the region during the period of 1986-2000 (Figure 6.2).

**Figure (6.2): Locations of marine mortality in RSA, 1986-2000.**

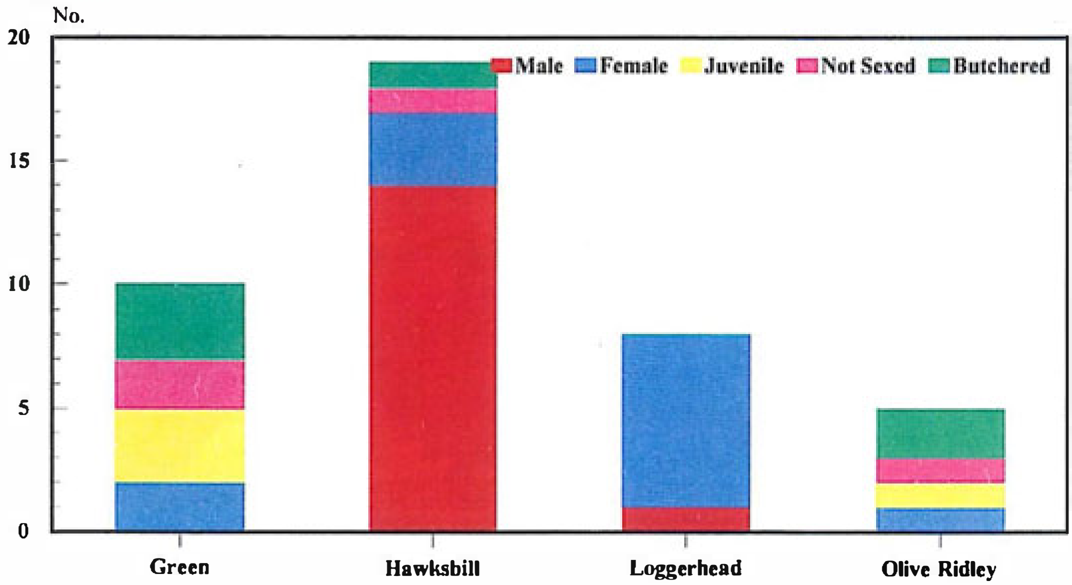



In 1986, during the period between 23 August and 30 October, dolphins, dugongs, fishes and turtles were found dead on the western and eastern shores of RSA. The heaviest mortality occurred between late August and late September 1986, resulting in the death of a large number of dolphins and fishes in Mesaieed area on the eastern coast of Qatar and the eastern coast of Saudi

Arabia (ROPME, 1997). The extensive surveys carried out on the Saudi and Qatari coasts as well as in other ROPME Member States showed that this mortality incident included marine mammals, fishes, turtles, invertebrates and birds. In the marine mammals category: a total of 527 dolphins, on the coasts of Qatar (358), Saudi Arabia (141), Bahrain (18), Iran (6), Kuwait (2), and U.A.E. (2); 7 dugongs (Dugong) and one whale of unknown species (20 feet long) were reported dead. In the fish category, the estimated number was 4000-8000 fishes of different species and lengths (generally greater than 60 cm). In addition, 58 dead marine turtles, about 10,000 or more cuttle fish, a small number of dead crabs and a few dead birds were recorded. Subsequent to this event and on 10 November 1986, up to 2000 terns were found dead off the Saudi Coast.

In Oman, during May 1990, 19 dead hawksbill turtles were found at Barr Al-Hikman of the Arabian Sea coast during their way for nesting. The details of this incident are shown in Figure (6.3). Another incident was also reported in Oman during March 1991 where a total of 118 dead turtles were found in Ras Qumaylah to Ras Sirab (Figure 6.4), (Al-Hajri, 1999b).

**Figure (6.3): Dead turtles on the south coast of Barr Al-Hikman – Oman, 1990.**




Records on the mortality of marine mammals and turtles in Omani waters were continued up to 1998 as shown in Figure (6.5). All of these green turtles died due to dehydration or human interruption at the time of their way back to the sea after laying eggs (Al-Hajri, 1999b)

**Figure (6.4): Dead turtles on Ras Qumaylah to Ras Sirab– Oman, 1991.**

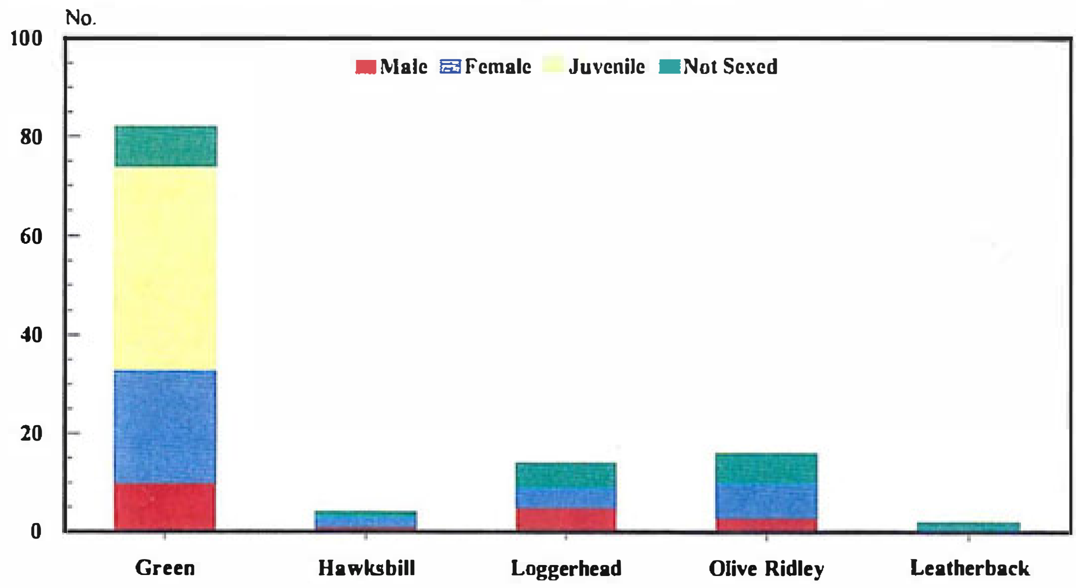
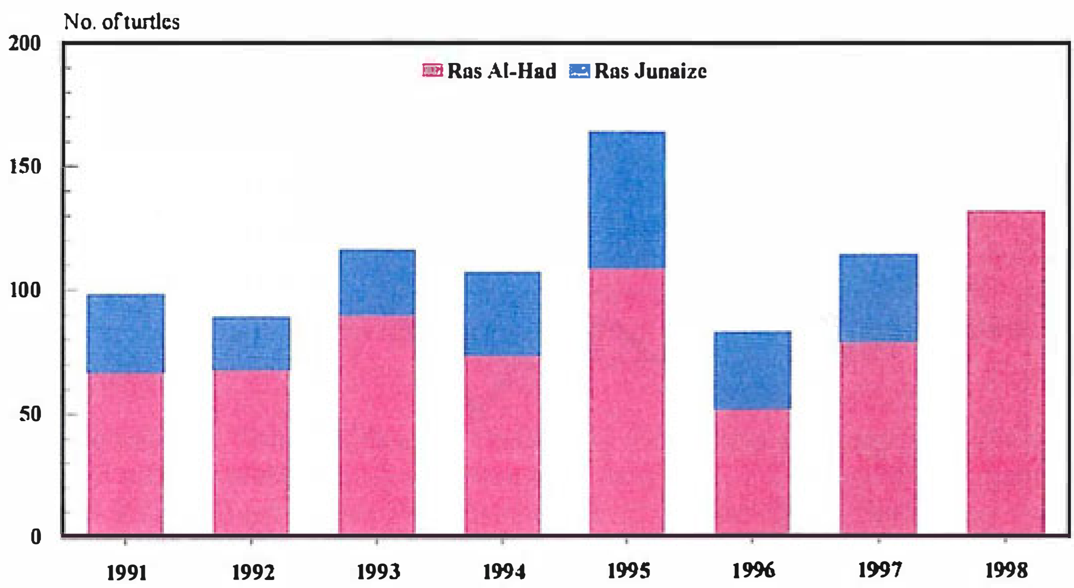



**Figure (6.5): Number of dead green turtles at Ras Al-Had and Ras Junaize, 1991-1998.**



A large scale fish kill was reported in the Iranian coastal waters of the RSA between 15 August and 30 September 1993. This took place less than two months after sinking of the Russian merchant ship, Captain Sakharov offshore to the Southwest of Lavan Island with its cargo of 40 containers spilling chemical substances. This resulted in the immediate mortality of large schools of pelagic fishes (Indian oil-sardine) in the offshore waters of Lavan and Kish Islands, followed by high mortality of demersal and benthic fishes (catfish, silver seabream, yellow fin seabream and flathead) in August-September 1993 (DOE, 1998).

During 1993, 1994 and August-September 1996 similar phenomena were observed in several locations in the RSA, namely Bahrain, Iran, Kuwait, Oman, Qatar, Saudi Arabia and U.A.E. where thousands of fishes of many species, some dolphins and turtles were found dead on the coast of these countries. Reports on mortality in the Iranian coastal water alone indicate that in this period (1993-1994) a total of 22 dolphins, 3 whales, 2 whale sharks and many turtles were found dead on the shores of Bushehr Province (DOE, 1998). During the period 22 July–7 September 1996, a large-scale fish kill of demersal fishes (silver seabream, yellow fin seabream and flat head) was observed in the Iranian coastal waters of Bushehr. This event was attributed to unusually high water temperature and low dissolved oxygen content (Figure 6.6) of Bushehr coastal waters at the time of the fish mortality (Valavi, 1998). Also the density of phytoplankton was measured during this incident and the results as shown in Figure (6.7) indicated that the densities of phytoplankton is hundred times higher than the normal conditions in previous years.

**Figure (6.6): Dissolved oxygen and temperatures recorded in coastal water of Bushehr during first and second September 1996.**

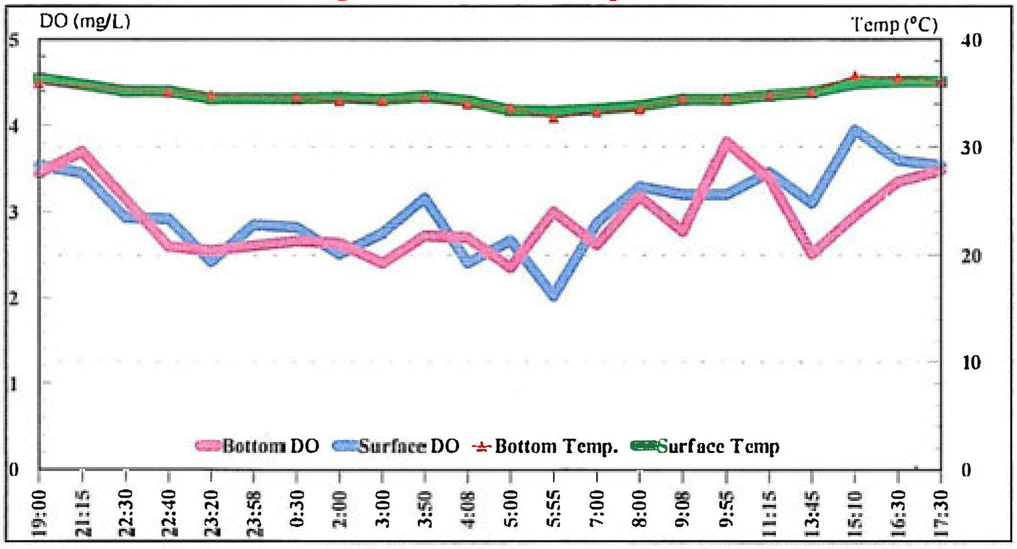
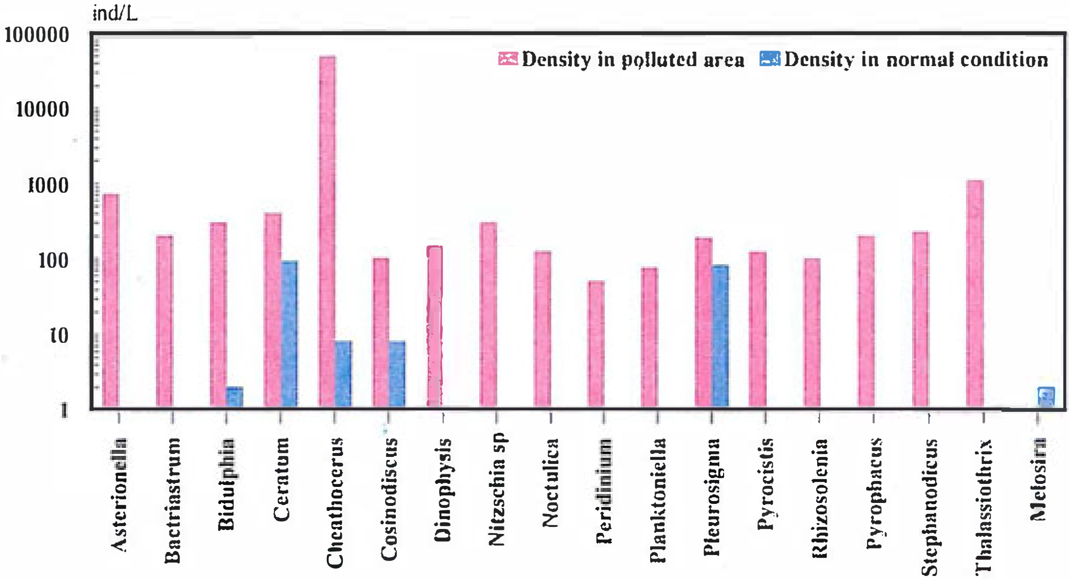


**Figure (6.7): Phytoplankton densities in polluted area with high fish mortality (September 1996) and in normal condition (September 1993).**

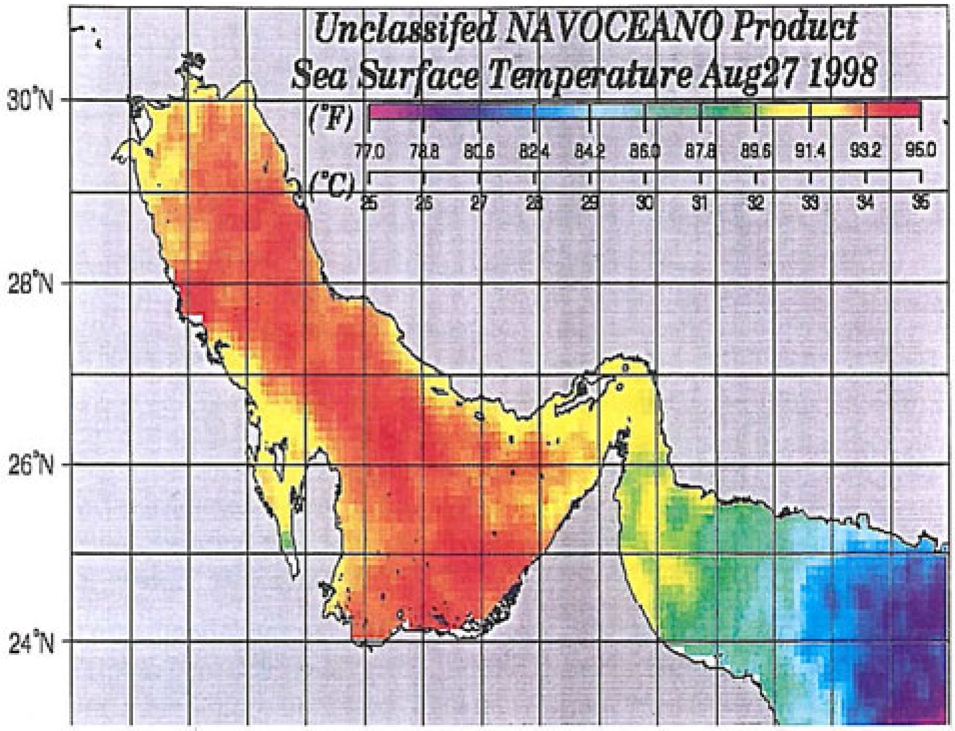



In 1997, fishermen observed dead fish (mainly sardines) floating in the offshore area near Abu Moosa Island. Similar observation was also reported in Ajman coast and Umm Al-Qaiwain. The high temperature (33.5-34°C) was reported the main reason for the fish kill in that area.

A fish kill incident was observed in the month of August 1998 in the coastal areas of Bahrain. Investigating the possible reasons for this phenomenon, satellite images of the actual sea surface temperatures in the RSA were obtained and specimens of the dead fish were analysed. The conclusion was that given the reported increase of water temperature in the Sea Area and the fact that the fish examined tend to congregate mainly in the shallow waters, thermal shock/lack of oxygen seems to be the most likely possible cause of fish death. Figure (6.8) illustrates the high sea surface temperature (35°C) observed in August 1998.

A massive fish kill (about 60 tons of grey mullet *Liza macrolepis* and 150 tons of sobaity seabream, *Sparidentex hata*, from the fish farm cages) was reported in Kuwait Bay between 19 September and 25 October 1999. Similar event was reported by I.R. Iran. These incidents were also associated with unusual blooms of marine organisms (Harmful Algal Bloom (HAB) so called red tides and other algal blooms). These algal blooms of dinoflagellates (phytoplankton with greater than one million cell/litre of Gymnodinium mikimotoi-like species) were observed to be the dominant species in the studied samples (EPA, 1999).

**Figure (6.8): Sea surface temperature in the RSA as observed by satellite in August 1998.**




Increase of nutrients from land-based sources was reported to be a major cause related to this massive kill. Figure (2.13) shows the high density of chlorophyll-*a* as observed during the period of fish morality in Kuwait, and I.R. Iran. The frequent occurrence of such incidents infers the deterioration of water quality in the region. Therefore, great care should be taken to minimise the input of pollution from land-based sources to maintain adequate levels of nutrients in the area. Other water quality parameters such as water temperature, salinity and dissolved oxygen should also be monitored to maintain acceptable levels and to ensure the availability of good ecosystem in ROPME Sea Area.

A large number of dead fish from different species was observed on the coast of Wilayat Baraka in Oman on 2nd September 2000. The investigations are still on-going to reveal the cause of this phenomenon by the Ministry of Regional Municipalities and Environment in co-ordination with the Ministry of Agriculture and Fisheries and the Sultan Qaboos University.

## 6.4 Eutrophication

The process of fertilisation that causes high productivity and increased biomass of filamentous algae and others in an aquatic system is called eutrophication. The addition of nutrients, such as phosphorous, nitrogen, and potassium, results in rapid growth of algae in the same way shown in fertilisers fuel green growth.

The rate of nitrogen and phosphorus is crucial and any shift could affect the phytoplankton community and have far reaching effects on food web dynamics. If phosphorous is reduced and relaxed, excess nitrogen in the system could initiate another round of serious eutrophication. In principle, the entire process of fertilisation or phosphorus/nitrogen enrichment represents a simple stress-response mechanism, where the chemical stress and subsequent biological response can be clearly identified.

Eutrophication generally occurs as a result of discharging excessive amounts of nutrient-rich wastes into the marine environment. Sources of nutrients are diverse including industry, agriculture and sewage disposal. A number of industrial processes contribute to the problem such as methanol/ammonia production, oil refinery, slaughter-house and livestock industry, sewage treatment plants, as well as the release of untreated wastewater. In addition, intensive blooms of pelagic algae in offshore areas appear to become more frequent. This may be a sign of a more large-scale eutrophication in offshore areas.

Rivers provide a major input of nutrients to the sea, but such materials remain largely within the shelf areas and only a small fraction of the nutrients ultimately reach the open ocean, which remains oligotrophic. Over the past few decades increased discharges of nutrients to the coastal zone have occurred worldwide. In some locations, the increases in concentrations of dissolved nitrate and phosphate and of organic carbon, together with organic accumulations in sediments, have brought about changes in the structure of planktonic and benthic communities, often with substantial ecological and economic consequences. There have also been increases in the number and extent of episodic events, such as exceptional plankton blooms, which alter natural ecosystems and threaten the mariculture industry and coastal amenities. Algal blooms have also been associated with some of the frequent episodes of seafood contamination by biotoxins, sometimes with very serious consequences for human health. It is seldom possible to connect with certainty unusual algal blooms to enhanced nutrient levels and detailed studies of some recent cases have not shown convincing cause-effect relationships. There is clearly a need for a better understanding of the dynamics of phytoplankton growth in coastal waters and it is recommended that appropriate studies be undertaken (GESAMP, 1990).

In spite of the limited scientific data available on the biological effects of the contamination by sewage and nutrients in the marine and coastal environment of the RSA, there seems to be enough evidence that eutrophication occurs or may occur in certain locations in the region particularly close to the urban and industrialised areas.

Linden *et al.* (1990) indicated some signs of eutrophication on the northern coast of Bahrain where dense mats of filamentous green algae were observed in the intertidal zone giving obvious signs of organic pollution and increased levels of nutrients in the water.

Similar pollution problems from sewage and agro-based industries caused increase growth of benthic algae in the north-west RSA off Shatt Al-Arab and signs of eutrophication were also observed in Kuwait Bay and in the coastal waters of Dhahran (Saudi Arabia), Abu Dhabi (U.A.E.) and Muscat (Oman).


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 (Linden *et al.*, 1990).

Current anthropogenic inputs of nutrients are at least comparable to those from natural sources and that these inputs are related to present population densities in coastal regions and their hinterland. Within the next 20 to 30 years a near doubling in human population is projected and even greater rates of increase are expected in some coastal areas. Such changes will inevitably be accompanied by increases in agriculture and livestock production and by further expansion of mariculture. Thus, anthropogenic inputs could then be on larger scale.

Given that these increases occur predominantly in coastal areas where waste treatment facilities are few and population growth is most rapid, it is therefore expected that the most severe effects will be found in areas with dense and increasing coastal populations and on coasts with restricted water circulation. Studies have therefore been encouraged by ROPME, as part of the LBA Regional Plan of Action, to estimate the scale and severity of these potential effects and to encourage appropriate and effective action, which might include radical changes in techniques for sewage disposal, and other land-based activities.

# CHAPTER 7

# MARINE POLLUTION CONTROL, EMERGING ISSUES AND STRATEGIES FOR SUSTAINABLE DEVELOPMENT


Obviously, environmental pollution and degradation should be prevented or controlled by appropriate measures. However, problem arises in defining how much effort and financial resources are justified for this purpose. The matter becomes more difficult when there is insufficient basic scientific knowledge on the sources, amounts and fate of contaminants and their interactive relationship with the environment, or when there is inadequate technology available to achieve satisfactory prevention or control (GESAMP, 1990).

With this view, the previous chapters of this report reviewed the current state of the marine environment of RSA in order to understand the physical and ecological features of the Region, the major socio-economic activities as well as the health of the ecosystem. Once such basic facts are established, appropriate policies could then be formulated, suitable prevention and control measures against environmental deterioration are taken and strategies are drawn for the effective management of the marine environment, the coastal areas and their resources. The present chapter summarises and updates the information on the measures and policies for pollution prevention and controlled strategies that were fully addressed in SOMER 1999.

## 7.1 Prevention and Control of Marine Pollution

The mechanism for prevention and combating marine pollution starts from the adoption of certain policies and preventive measures, establishing of environmental legislation and developing of necessary institutional arrangements for active implementation.

### 7.1.1 Policies for Pollution Prevention and Control

The policies for pollution prevention and control address the national policies and initiatives, regional initiatives and policy instruments, protected areas and marine parks, contingency plans and emergency response, precautionary environmental protection policy, public awareness and implementation procedures. The latter encompasses an overview of Environmental Impact

Assessment (EIA) procedures and the necessity to adopt the ambient coastal and marine water quality criteria.

### 7.1.2 Environmental Legislation

Environmental legislation includes principal issues such as, national legislation/ regulation, the Kuwait Regional Convention and its Protocols, and the international conventions and programmes relevant to the protection of the marine environment.

More recent attempts at harmonisation of environmental legislation and institutions have taken place. Some Member States have imposed new types of liability or increased penalties for environmental offences in order to secure better environmental quality. In Bahrain, for example, any person found guilty of causing oil pollution in the marine environment or of dumping wastes in territorial waters from ships or land-based sources is liable to large fines. In Kuwait, the resolution to establish the so-called "Environmental Court" has been adopted by the government. Violators are also responsible for the cleanup of the contaminated area within a specific time (UNEP, 1995). Nevertheless, most national environmental legislation and regulations in some countries of the Region obviously need updating and revision, particularly with reference to acceptable and adequate norms and standards.

Naturally all ROPME members are adhered to the ROPME regional legal instruments (Kuwait Convention and various protocols dealing with different sources of pollution). However, these instruments contain only very general provisions on the question of civil liability and compensation.

The Kuwait Regional Convention for Co-operation on the Protection of the Marine Environment from Pollution (1978) has four related protocols that were developed in accordance with the recommendations of the Legal Component of the Kuwait Action Plan. These protocols included:

i) Protocol concerning Regional Co-operation in Combating Pollution by Oil and other Harmful Substances in Cases of Emergency, 1978;
ii) Protocol concerning Marine Pollution resulting from Exploration and Exploitation of the Continental Shelf, 1989;
iii) Protocol for the Protection of the Marine Environment against Pollution from Land-Based Sources, 1990; and
iv) Protocol on the Control of Marine Transboundary Movements and Disposal of Hazardous Wastes and Other Wastes, 1998.

The status of signature and ratification of the Convention and its protocols by the Member States is presented in Table (7.1).

**Table (7.1): Status of signature and ratification of the Kuwait Regional Convention and its Protocols by ROPME Member States.**

| State | Kuwait Regional Convention for Cooperation on the Protection of the Marine Environment from Pollution and its Protocol (1978) | | Protocol concerning Marine Pollution resulting from Exploration and Exploitation of the Continental Shelf (March 1989) | | Protocol for the Protection of the Marine Environment against Pollution from Land-Based Sources (February 1990) | | Protocol on the Control of Marine Transboundary Movements and Disposal of Hazardous Wastes and Other Wastes (March 1998) | |
|---|---|---|---|---|---|---|---|---|
| | Date of Signature | Date of Ratification | Date of Signature | Date of Ratification | Date of Signature | Date of Ratification | Date of Signature | Date of Ratification |
| Bahrain | 24.04.1978 | 01.04.1979 | 29.03.1989 | 16.05.1990 | 21.02.1990 | 16.05.1990 | 17.03.1998 | |
| I.R. Iran | 24.04.1978 | 03.03.1980 | 29.03.1989 | 01.04.1992 | 21.02.1990 | 14.06.1993 | 17.03.1998 | |
| Iraq | 24.04.1978 | 04.02.1979 | 29.03.1989 | 11.11.1989 | ---- | ---- | --- | |
| Kuwait | 24.04.1978 | 07.11.1978 | 29.03.1989 | 31.10.1989 | 21.02.1990 | 23.05.1992 | 17.03.1998 | 22.02.2000 |
| Oman | 24.04.1978 | 20.03.1979 | --- | 19.11.1989 | --- | 09.12.1991 | 17.03.1998 | |
| Qatar | 24.04.1978 | 04.01.1979 | 29.03.1989 | 21.05.1989 | 21.02.1990 | 23.02.1992 | 17.03.1998 | 28.07.1998 |
| Saudi Arabia | 24.04.1978 | 26.12.1981 | 29.03.1989 | 4.11.1989 | 21.02.1990 | 04.10.1992 | --- | 30.01.2000 |
| U.A.E. | 24.04.1978 | 01.12.1979 | 29.03.1989 | 17.04.1990 | 21.02.1990 | --- | 17.03.1998 | |

The international agreements relevant to the protection of the marine environment are divided into international conventions and global programmes. The United Nations Convention on the Law of the Sea (UNCLOS, 1982) is the overarching international convention that deals with almost all matters related to the ocean and seas in the world. Other conventions deal with specific subjects relevant to the prevention of marine pollution from various sources.

The following are the main conventions and associated legislation relating to marine pollution by oil:

i) International Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972 with Amendments (London Convention) and the 1996 Protocol to Amend the Convention (LC Protocol);

ii) International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage, 1971 as amended by Protocols

1976 and 1984 (FUND Convention) – 1992 Protocol to amend the Convention (FUND Protocol);

iii) International Convention on Civil Liability for Oil Pollution Damage, 1969, as amended by Protocols 1976, 1984 and 1992 (CLC Convention);

iv) International Convention Relating to Intervention on the High Seas in Cases of Oil Pollution Casualities, 1969 (INTERVENTION Convention) – Protocol relating to Intervention on the High Seas in cases of Pollution by Substances other than Oil, 1973 (INTERVENTION Protocol);

v) International Convention for the Prevention of Pollution from Ships, 1973 and Protocol 1978 (MARPOL 73/78); and

vi) International Convention on Oil Pollution Preparedness, Response and Co-operation 1990 (OPRC).

The status of participation of ROPME Member States in the conventions dealing with the marine environment directly or indirectly is summarised in Table (7.2).

**Table (7.2): Status of participants of ROPME Member States in international environmental agreements.**

| No. | International Conventions/Protocols | Bahrain | I.R.Iran | Kuwait | Oman | Qatar | Saudi Arabia | United Arab Emirates |
|---|---|---|---|---|---|---|---|---|
| 1 | United Nations Convention on the Law of the Sea, 1982 (UNCLOS) | X | • | X | X | • | X | • |
| 2 | International Convention for the Prevention of Pollution from Ships, 1973 and Protocol 1978 (MARPOL 73/78); Annex II (1973/85); Amendment to Annex I (1997) | | | | X | | | |
| 3 | International Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972 with the Amendments 1978/80 (LONDON Convention) | | X | • | X | | | X |
| | • 1996 Protocol to Amend the Convention (LC Protocol) | | | | | | | |
| 4 | International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage, 1971 as amended by Protocols 1976 and 1984 (FUND Convention) | X | | X | X | X | | X |
| | • 1992 Protocol to Amend the Convention (FUND Protocol) | X | | | X | | | X |
| 5 | International Convention on Civil Liability for Oil Pollution Damage, 1969, as amended by Protocols 1976, 1984 and 1992 (CLC Convention) | X | | X | X | X | X | X |
| 6 | International Convention Relating to Intervention on the High Seas in Cases of Oil Pollution Casualities, 1969 (INTERVENTION Convention) | | X | X | X | X | | X |
| | • Protocol Relating to Intervention on the High Seas in Cases of Pollution by Substances other than Oil, 1973 (INTERVENTION Protocol) | | X | | X | | | |
| 7 | International Convention on Oil Pollution Preparedness, Response and Co-operation, 1990 (OPRC Convention) | • | X | | | | | |
| 8 | Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal, 1989 (BASEL Convention) | X | X | X | X | X | X | X |
| | • 1995 and 1998 Amendments | | | | | | | |
| 9 | Convention on Wetlands of International Importance, Especially as Waterfowl Habitat, 1971 (RAMSAR Convention) | X | X | | | | | |
| | • Protocol to amend the Convention, 1982 (RAMSAR Protocol) | X | X | | | | | |
| 10 | Convention on the Conservation of Migratory Species of Wild Animals, 1979 (BONN Convention - Migratory Species) | | X | | | | X | |
| 11 | Convention Concerning the Protection of the World Cultural and Natural Heritage, 1972 (WORLD HERITAGE Convention) | X | X | | X | X | X | |
| 12 | Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), 1973, as amended | | X | • | | | X | X |
| 13 | Convention on Biological Diversity, 1992 (BIODIVERSITY Convention) | X | X | • | X | X | | • |
| 14 | Framework Convention on Climate Change, 1992 (Convention on CLIMATE CHANGE) | X | X | X | X | X | X | X |
| 15 | Convention for the Protection of the Ozone Layer, 1985 (OZONE LAYER Convention) | X | X | X | | X | X | X |
| | • Montreal Protocol on Substances that Deplete the Ozone Layer, 1987, with Amendments and Adjustments (MONTREAL Protocol) | X | X | X | | X | X | X |

X Ratified / Acceded to • Signed but not Ratified

7.1.3 Institutional Arrangements

Institutional arrangements are måde at the regional level, as well as the national, in the form of government and non-governmental bodies dealing with environmental issues or through the follow-up with the overall co-ordination bodies.

All ROPME Member States now have environmental ministries or institutions in place, with some countries having restructured these institutions in the recent years, giving them higher political standing. At present, two Member States have ministers of environment in the cabinets, namely, Bahrain (Ministry of Housing, Municipalities and Environment) and Oman (Ministry of Regional Municipalities and Environment). I.R. Iran has established the post of a Vice-President for the environment. Kuwait, Saudi Arabia and the UAE have public authorities dedicated for the environment (Table 7.3). Qatar has a supreme council for the Environment and Natural Reserves. Recently, the Government of Kuwait has passed the resolution towards the establishment of environmental court in the country.

**Table (7.3): Governmental environment institutions and agencies in ROPME Member States.**

| Country | Policy Institutions | Executive Agency |
|---|---|---|
| Baharin | Environmental Affairs | Ministry of Housing, Municipalities, and Environment |
| I.R. Iran | Environmental High Council | Department of the Environment |
| Iraq | National Council for the Protection and Improvement of Environment | Ministry of Health |
| Kuwait | Environment Public Authority (EPA) | Environment Public Authority |
| Oman | Council of Ministers | Ministry of Regional Municipalities and Environment |
| Qatar | Council of Ministers (Permanent Commission for Environmental Protection) | Supreme Council of The Environment and Natural Resources |
| Saudi Arabia | Ministerial Committee on Environment | Meteorology and Environmental Protection Administration (MEPA) |
| United Arab Emirates | Council of Federation | Federal Environmental Agency (FEA) |

The role of Non-Governmental Organisations (NGOs) is becoming increasingly important particularly in areas that require active public participation, and in raising public awareness of environmental issues. In almost all ROPME Member States, environmental NGOs are operational and have a wide range of activities, many of which are related to the marine environment. A good example to note is the Environmental Protection Society of Kuwait which has recently formulated a diver team that helped in some diving activities for the cleanup of contaminated sites.

The overall co-ordination bodies in the area can be summarised into three categories: national level, regional level and international level. The creation of these bodies and the nature of the cross- cutting among them are fully addressed in SOMER (1999).

## 7.2 Current and Emerging Issues

Previous chapters of this report reviewed the present state of the marine environment in the RSA, and the impacts of human activities on the marine and coastal environments. This section describes the main current and emerging environmental issues that warrant further attention.

### 7.2.1 Current Issues

Several steps at the national and regional levels are needed to be taken to support the National Focal Points (NFPs) in implementing the provisions of regional and global conventions.

At the national level, the following can be stated:

i) Strengthening NFPs through the provisions of technical, administrative and legal support;
ii) Supporting monitoring programmes and quality assurance;
iii) Monitoring close relationship with the political and social structure;
iv) Adoption of the regional approach;
v) Carrying-out environmental impact assessment as a tool for good preventive approach; and
vi) Following of the integrated approaches to coastal area management.

At the regional level, the following are of significance:

i) Marine pollution resulting from oil production and transportation;
ii) Increase of land-based activities affecting the marine environment;
iii) Increase of pollution from municipal releases and low percentage of treated effluent re-use (< 40%);

iv) Loss of fisheries, biodiversity and ecosystems as a result of over-fishing and the use of illegal ways or means); and
v) Huge amount of marine contaminants from industrial sources.

A full explanation of the above are referred to in SOMER (1999).

7.2.2 Emerging Issues and Challenges

Several emerging issues were addressed in SOMER 1999 which are indicated hereunder:

i) Designation of marine and coastal protected areas;
ii) River basin management;
iii) Harmonisation of environment regulations;
iv) Continuity of regional monitoring programmes and data consistency; and
v) Participation in and follow-up of the international conventions.

Based on the current and emerging issues, the environmental challenges that face the region can be stated as follows:

7.2.2.1 *Marshlands of Mesopotamia*

The draining of marshlands of Mesopotamia in Iraq by drying up and diverting the feeder streams and rivers, has posed serious threats to the ecological balance of vast areas, affecting water quality of Shatt Al-Arab and the spawning grounds of shrimp and migratory species of fish at the river delta.

Considering the significant environmental impact of the river discharge on the north-western part of the ROPME Sea Area, a river basin management programme has been developed for Shatt Al-Arab and its entire basin, in co-operation with UNEP and other concerned UN and non-UN international organisations. There is a need for international support and Member States to pursue a successful programme in addressing this environmental catastrophe.

7.2.2.2 *Land-Based Activities*

The ROPME Region has witnessed one of the highest rates of economic growth in the world, over the past three decades. The rise in industrialisation, together with a high population growth and rapid urbanisation have resulted in ever-increasing environmental problems of the Region. Almost all development projects have been established on the coasts, taking advantage of the access to sea for transportation, obtaining water for cooling and other uses or to releasing their effluents hence, affecting the most productive areas of the marine environment.

The impacts of municipal sewage and industrial effluents particularly those of petroleum refineries and petrochemical industry are significant. Power plants cause thermal pollution and desalination plants contribute chlorine, brine and thermal loads to the seawater. Dredging and land reclamation are also a permanent feature in many coastal areas of the Region with significant damaging effects on the environment.

ROPME has developed guidelines on "Integrated Coastal Area Management" to harmonise development activities in the coastal zone. Member States are also taking appropriate measures to develop ICAM plans, and to prevent, abate and combat pollution from land-based activities.

7.2.2.3 *Pollution from ships*

The ROPME Sea Area is considered to be an area with one of the highest oil pollution risks in the world. This is mainly due to the concentration of offshore installations, tanker loading terminals and the huge volume and density of marine transportation of oil. According to the Oil Spill Intelligence Report, out of 20 cases of oil spill greater than ten million gallons world-wide, six cases have been related to the ROPME Region. Smaller scale oil pollution incidents such as submarine pipeline rupture and well blowout are more frequent in the ROPME Sea Area.

ROPME is supporting every effort towards the ratification of MARPOL Convention and meeting the requirements of adequate reception facilities in the Region in order to declare the ROPME Sea Area as a "Special Area". There is an urgent need to establish reception facilities and protect our marine environment from operational discharges of oil tankers, commercial ships and port facilities. We are also concerned about the introduction of alien species introduced by ballast water and have initiated a project to this effect.

ROPME has exerted best efforts in carrying out a Feasibility Study on regional requirements for establishing reception facilities. The project was supported by the European Union, GCC Secretariat, IMO, oil companies, ROPME Member States and UNDP. The Final Report of the Feasibility Study has been approved by ROPME Executive Committee and is attentively pursued to be implemented by June 2002.

7.2.2.4 *Offshore Operations*

The offshore installations of oil and gas are located in the inner RSA, which is badly suffering from extremes of salinity, temperature and oil pollution. The evaporation is high, the precipitation is poor and the river discharges is decreasing. The water lost by evaporation of the sea is mainly compensated by water exchange through the Strait of Hormuz. However, the rate of water exchange is low and the retention of pollutants is prolonged. Such being the case, the impacts of offshore operations on the marine environment especially in shallow waters or near to ecologically sensitive areas are more noticeable.

The high salinity, temperature and oil content of produced water from offshore oil wells are among the main causes of stress for the marine life. To this end, ROPME is to exert best efforts to address all components of produced water in a comprehensive way to minimise its detrimental impacts on the marine environment.

#### 7.2.2.5 *Conservation of Biodiversity*

The marine life in the ROPME Sea Area is particularly suffering from extremes of temperature, salinity, sedimentation and pollution. The stress factors, both anthropogenic and climatic, are the main threat to marine ecosystems and to the great biodiversity of species that depend on them. The fish and corals are more susceptible to such stress factors and respond to changes quickly.

The Marine mortality episodes are familiar phenomena in the Region and the toll of fish, dolphins, dugongs, whales, waterfowl, algae and corals has set a record in the past two decades. The mortality phenomena have been attributed to high levels of anthropogenic contaminants, unseasonably warm temperatures, disease agents, biotoxins and changes in food supply.

ROPME has initiated a Plan of Action on Marine Mortality (PAMM) and has established a permanent Regional Group of Experts to address the mortality events. There is a need to protect, preserve and restore the valuable marine ecosystems in this Region. Also there is a need to develop a number of marine protected areas and register the representative marine and coastal ecosystems in the lists of "Biosphere Reserves" and "World Heritage Sites".

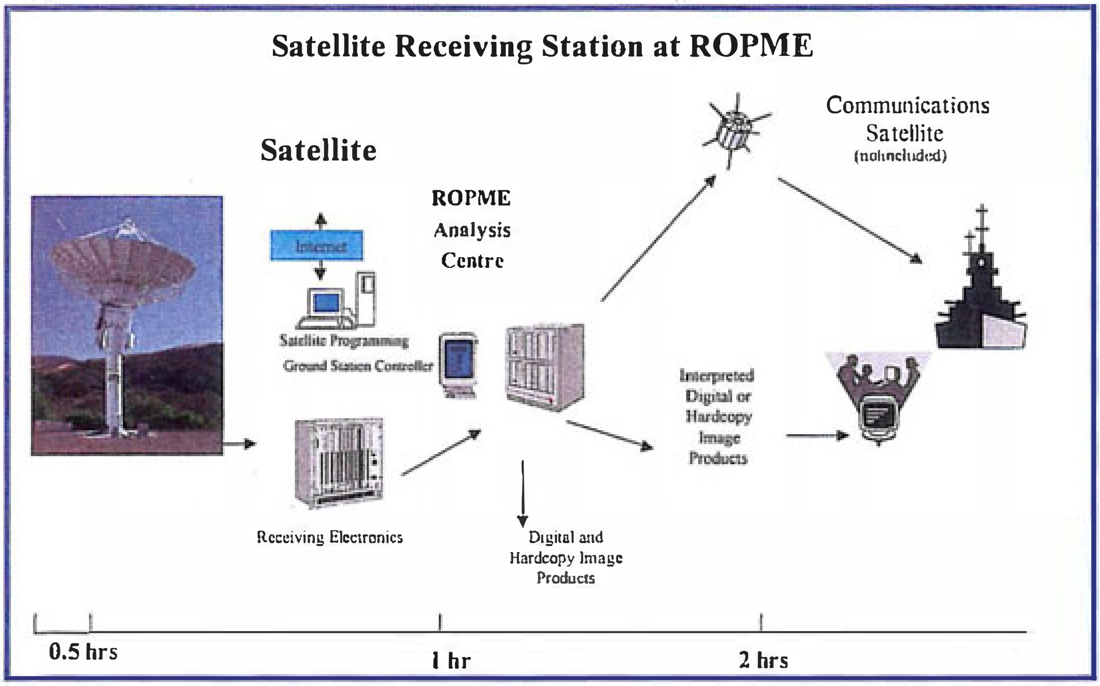
ROPME Member States recognising the need to provide necessary protection for the natural biodiversity and habitats of the Region, within a framework of sustainable development, have agreed to develop a Protocol on Biodiversity and the Establishment of Protected Areas. In this respect, ROPME Secretariat is seeking assistance from the competent regional and international organisations and conventions in an effort to prepare a comprehensive and all-encompassing Protocol.

#### 7.2.2.6 *Satellite Receiving and Processing System*

The satellite-based technologies are widely used in environmental monitoring and research activities. To this effect, ROPME has established a Remote

Sensing Laboratory to acquire the existing aerospace remote sensing materials and to prepare the satellite thematic mapping and habitat characterisation and distribution in the Region.

ROPME is to upgrade the capabilities and acquire a Satellite Receiving and Processing System for monitoring of marine and coastal areas. Member States and the concerned regional and international organisations are to support ROPME's proposal for satellite receiving station.



Satellite Receiving Station at ROPME

## 7.3 Strategies and priority action for Sustainable Development

Long-term high-level commitment by the Governments of the Region is crucial for the effective protection, management and sustainable development of the RSA and its resources. Government support is required to ensure that the regional and global priorities are adequately addressed and are supported through policy measures, effective implementation of the relevant regulations, enforcement of laws and legally binding agreements and protocols, and through capacity building of regional and national institutions and experts. Integration of regional and global conventions and policies into national legislation provides the region with the opportunity to interact, benefit from and influence the development of global programmes and policies.

Regional organisation can act as an interface between the global and national concerns. Integrating environmental concerns of the region into the political and socio-economic agenda of member states is at the essence of the Rio Declaration (1992). This section identifies some of the priority issues to be included in strategies for environmental protection in the Region.

### 7.3.1 Integrated Coastal Area Management (ICAM)

National ICAM plans may be developed with a regional perspective to provide an overall framework for coastal area management, complemented by more specific plans for urban and industrial areas, areas around industrial ports and free zones, and special plans for management of tourist areas and ecologically sensitive areas including coastal and marine reserves and protected areas.

Another planning tool that is complementary to ICAM, but also applies to major development projects and human activities is the environmental impact assessment (EIA) procedures that would help to significantly reduce the degradation of the environment, particularly from land-based activities.

### 7.3.2 Conservation Strategies

Because of the increased threats to the marine and coastal environments and their integrity, there is an urgent need for more effective mechanisms for conservation in a manner that could counteract fragmented decision making. The protection and, where necessary, restoration of coastal and marine habitats is of highest priority for biodiversity conservation. Spawning grounds and critical nursery areas of key species are of particular importance. The integrity of the Region must be taken into consideration and areas that are of regional significance should receive special attention. Both national and regional regulatory systems need to be improved to enhance habitat conservation. National and regional conservation strategies are complementary and should be developed for key habitats such as, coastal wetlands, mangroves, seagrass beds, coral reefs and oyster bank in the RSA.

### 7.3.3 Strengthening the Implementation of ROPME's Protocols

As mentioned, the Kuwait Regional Convention has four related protocols concerning various aspects of marine environmental protection and management. These protocols have been adopted to further specify the mandate of the Convention with the objective to ensure that development and other human activities are controlled and do not cause damage to the marine environment, jeopardise its living resources or cause hazards to human health. Another objective has been the development of an integrated management approach to the use of the marine environment and the coastal areas in a sustainable way, which will allow the achievement of environmental and developmental goals in a harmonious manner.

It becomes necessary, therefore, that the implementation of ROPME's protocols be further enhanced and followed up vigorously by the concerned authorities in each Member State, in order to achieve the objectives set for these important legal instruments. Such strengthening of protocol implementation should be part and parcel of the national strategies of Member States for the protection and sustainable development of the marine and coastal areas under their jurisdiction.

### 7.3.4 Capacity Building

An important factor in achieving the environmental objectives and in effectively addressing the prescribed concerns is building the national and regional capacities that would enable Member States of ROPME to meet the challenges and honour their obligations. Intensive capacity building programmes should therefore be rigorously pursued both at the national and regional levels and in all areas outlined in this Report. ROPME programmes of in-house training, short courses or visits at qualified laboratories/institutions are to be further encouraged and augmented by establishing a programme of exchange of scientists both within the region and in co-operation with other regions. This requires greater interest in environmental issues by teaching institutes and universities. These issues should be a major part of all the curricula taught in different specialities in order to train specialists in various fields of the environment to face the future challenges of the Region.

### 7.3.5 Enhancement of Public Awareness, Information Sharing and Networking

Environmental public awareness is an essential component of any national policy for the protection and conservation of the environment. At the regional level, strategies for the enhancement of environmental awareness among the public should be developed and followed-up, making use of the national experiences already available in several Member States of ROPME. In this connection, it has to be noted that the large number of stakeholders involved in the coastal area require multi-level awareness programmes targeting different groups.

### 7.3.6 Co-operation with Non-Governmental Organisations (NGOs)

A growing number of non-governmental organisations (NGOs) have been established in most countries of the ROPME region. However, their role in planning and implementation needs to be strengthened. In addition, there is a need for capacity building to increase the involvement of NGOs as well as other institutions and the private sector in the environmental policy-making and in taking action in the respective priority areas of ROPME's programme. The

NGOs themselves also need to ascertain their objectives and role in the development of national policies and to provide advice, constructive criticism and assistance to national environmental authorities.

### 7.3.7 Co-ordination between Regional and International Organisations

An equally important strategic element is the increased co-ordination between regional environmental organisations and bodies dealing with the marine environment. An excellent example of such co-ordination is that existing between ROPME and PERSGA which culminated in the organisation of the Sea to Sea Conference in 1995 and has got momentum ever since. Co-operation with the GCC on issues such as conducting the study on reception facilities, development of port state control and the preparation of a regional protocol on biodiversity and the establislunent of protected areas is another example of regional co-operation. The Regional MOU between CAMRE, PERSGA, ROPME and UNEP, which was signed in 1999, provides for regional co-operation with full transparency, avoidance of duplication and sharing of experience and information. Similar activities between ROPME and other regional environmental bodies are required and should be encouraged and formalised.

### 7.3.8 Harmonisation of Legislation

ROPME Member States as members of the international community have collectively a significant role to play at the global arena. However, the process can only be a two way stream, i.e. contributing to global policies, conventions and programmes, and adapting the national policies and legislation to meet the global objectives. Global conventions can only be unfair to our region, if we fail to be present at their development stages. UN conventions are developed by hard negotiations but on the bases of consensus, however, once they enter into force, change becomes even harder.

### 7.3.9 Acquisition of New and Cost Effective Monitoring Technologies

Needless to say, monitoring is the basic element in the process of environmental assessment. However, environmental monitoring of coastal and marine ecosystems requires the commitment of laboratories and well-trained personnel for long periods of time. Equally, coastal surveillance to detect oil and other waste releases in offshore areas and along coastlines, as is the case in Oman, Iran and Saudi Arabia, is complicated and expensive.

ROPME has already exerted efforts to adapt advanced space age-based technologies for the monitoring efforts and to obtain accurate and predictive information and data on the location, type and quantities of oil spills almost immediately. Other data such as water quality, coastal morphology changes, and information that would otherwise require monitoring and surveillance programmes will also be obtained. Member States are to support this major regional effort towards a more achievable goal.

7.3.10 Control and Management of Oil Spills

As elaborated, pollution by oil is the most significant form of pollution in the RSA, and oil spills have long constituted serious threats to the region with visible and invisible impacts.

In spite of extremely heavy traffic of oil tankers through the RSA, only limited number of reception facilities exist in the region, most of which are inadequate to receive and process oily wastes, ballast water or other wastes from transiting ships. This general lack of adequate facilities in the region often leads to illegal dumping of huge quantities of ballast waters and other oily wastes into the marine environment and hence further contributing to the observed high level of pollution by oil in the region.

Implementing the recommendations of the Feasibility Study on Reception Facilities, which was finalised by national and international experts working under the auspices of ROPME, the RSA could be declared as a "Special Area" under MAROL 73/78. This would allow Member States as Parties to the MARPOL Convention, to inspect, survey and enforce its provisions on all ships operating in their navigable waters.

Acceding to MARPOL 73/78 and the establishing of reception facilities would also require the adoption of "Port State Control" according to which vessels transiting through waters within the Exclusive Economic Zone (EEZ) of a sovereign State could be inspected to ensure their compliance with international agreements that are in force in the region. The Port State Control provides for standardised procedures and fees in order not to allow vessels to call at ports where regulations are less stringent and reception facilities are inadequate.

7.3.11 Control of Land-Based Sources of Pollution

ROPME Member States should expedite the implementation of ROPME's Protocol for the Protection of the Marine Environment against Pollution from Land-Based Sources and the associated Regional Programme of Action (RPA). RPA components include survey of land based activities, carrying out a pilot study on persistent organic pollutants (POPs) and development of a river basin management plan for Shatt Al-Arab and other rivers in the RSA. Such efforts will require the potential co-operation and relationships with countries outside the RSA, the diplomatic skills and the ability to draw support and co-operation of the international and regional organisations concerned.

7.3.12 Control of Dredging, Reclamation Activities and Modification of Coastal Morphology

Dredging and reclamation activities are an almost permanent feature in many coastal areas in the RSA. As a remedial measure, strict government restrictions on dredging and reclamation activities should be imposed, and where legislation prohibiting these activities exist, they should be enforced and strictly adhered to. It is preferable that such destructive activities be totally avoided, if possible. If not, environmental impact assessments for such operations should be carried out and formal permit obtained prior to the initiation of any small- or large-scale project requiring dredging or filling, particularly those adjacent to environmentally sensitive areas. Furthermore, authorised dredging operations should follow clear operational standards. Impacts of such projects on the adjacent marine and coastal ecosystems should be carefully assessed and monitored. Projects involving land-filling and alteration of coastal morphology of a given State need to be evaluated from a regional perspective through ROPME in order to avoid major ecological changes in the Sea Area.

7.3.13 Restoration of Mangroves and Coral Reefs, Protection of Wetlands

Mangroves, coastal lagoons, seagrass beds and coral reefs represent important components of the ecological systems of RSA which have been subject to rapid deterioration. The restoration of damaged ecosystems and re-introduction of lost species or populations by a co-operative effect between research institutions, fisheries and environmental protection authorities are essential steps towards pushing back the tide of destruction and moving towards recovery of our habitats. Meantime, since the restoration projects are extremely costly, governments, development and finance funds/banks and the private sector are to support such an important regional effort.

7.3.14 Building of Environment Information System

The amount of data that are available from monitoring programmes as well as the results from cruises and other literature can be augmented and utilised in an environmental information system with capacity on geographic information system. Such an information system can be extensively used and benefited by all the concerned scientists and authorities towards the cause of our marine environment.

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