



Overview on Land-based Sources and Activities Affecting the Marine Environment in the ROPME Sea Area

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Preface

The Global Programme of Action for the Protection of the Marine Environment from Land-based Activities was adopted by an intergovernmental conference held in Washington, D.C., United States of America, from 23 October to 3 November 1995. The goal of the Global Programme of Action is to prevent degradation of the marine environment from land-based activities by facilitating the realization of the duty of States to preserve and protect the marine environment. It is designed to assist States in taking actions individually or jointly within their respective policies, priorities and resources, which will lead to the prevention, reduction, control and/or elimination of the degradation of the marine environment, as well as to its recovery from the impacts of land-based activities. Implementation of the Global Programme of Action will contribute to maintaining and, where appropriate, restoring the productive capacity and biodiversity of the marine environment, ensuring the protection of human health, as well as promoting the conservation and sustainable use of aquatic living resources.

The Washington Conference designated the United Nations Environment Programme (UNEP) as secretariat of the Global Programme of Action and requested that, as coordinator and catalyst of environmental activities within the United Nations system and beyond, it should, through its programmes and secretariat role:

- Promote and facilitate implementation of the Programme of Action at the national level;
- Promote and facilitate implementation at the regional, including subregional, level through, in particular, a revitalization of the regional seas programme; and
- Play a catalytic role in the implementation at the international level with other organizations and institutions.

Under the direct supervision of the Coordination Office for the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities and the Regional Office for West Asia (ROWA), and in close coordination with the Regional Organization for the Protection of the Marine Environment (ROPME), a consultant was asked to prepare a comprehensive overview of land-based sources and activities affecting the marine, coastal and associated freshwater environments, including the status of activities dealing with the protection of those environments from land-based activities in the Kuwait Action Plan region, based on a review of the relevant information and activities of the individual countries making up the region. This regional overview included the identification of priorities and the formulation of recommendations for addressing the problems arising from land-based activities. It will also be the basis for formulating a regional strategic programme to address land-based activities.

The overview was considered by government-designated experts during the regional workshop on implementation of the Global Programme of Action in the Red Sea and Gulf of Aden/Kuwait Action Plan regions, held in Bahrain from 2 to 5 December 1996.

Based on the topics outlined in paragraphs 16-35 of the Global Programme of Action, the overview included (when possible) for each country and the region as a whole, available information related to:

- Identification and assessment of problems;

- Establishment of priorities;
- Setting management objectives for priority problems;
- Identification, evaluation and selection of strategies and measures, including management approaches;
- Criteria for evaluating the effectiveness of strategies and programmes; and
- Programme support elements.

In preparing the overview, the consultant made full use of existing relevant information, and consulted with the relevant regional and national authorities and experts. To facilitate the work, the consultant has:

- Visited the ROPME to review relevant information and consult with substantive programme officers;
- Established communication with national experts from the region, soliciting their input to the overview;
- Visited UNEP (Water Branch) headquarters in Nairobi to obtain information on land-based activities affecting the marine environment of other regions and contact the relevant programme officers.

PREPARATION OF THE OVERVIEW

The overview was prepared on the basis of information obtained from various resources, including: documents provided by the UNEP Coordination Office for the Global Programme of Action; the UNEP Regional Office for West Asia (ROWA); ROWA Library, Bahrain; the ROPME staff and library, Kuwait; reports provided during the first and second workshops on the implementation of a Global Plan of Action in the ROPME region (Kuwait, December 1995 and Bahrain, December 1996); the UNEP library, Nairobi; computer search at Sultan Qaboos University Library, Oman; numerous papers and reports provided by individual scientists; Middle East Environment, Bahrain, and, finally, the personal library of the consultant.

Information was organized by individual member States and the ROPME region. No attempts were made to compare data from different areas of the ROPME region as data were collected at different times and were inconsistent. The data and information obtained were critically assessed and, whenever possible, cross-checked to help identify areas for which data are lacking.

The consultant reviewed the general objectives (paras. 18-35) and implications of the Global Programme of Action. Possible elements of regional framework strategies were identified based on the recommended approaches by source category (chapter V) of the Global Programme of Action. Requirements for the development and implementation of national action programmes were considered based on available information. Data and information on land-based activities in the ROPME region were then considered within the framework of programme objectives and recommended approaches by source category.

The overview was then organized under the following chapters: Introduction; Characteristics of the ROPME sea area; Country-by-country analysis of land-based pollution sources (Bahrain, Iraq, Islamic Republic of Iran,

Kuwait, Oman, Qatar, Saudi Arabia and United Arab Emirates); Overall assessment of all countries; and Regional analysis of land-based pollution sources.

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Executive summary

The ROPME sea area includes the coastal and marine waters of the eight countries (Bahrain, Iraq, Islamic Republic of Iran, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates) that make up ROPME. This region is arid, with large seasonal fluctuations of air and water temperatures and thus the greatest extremes among tropical marine climates. While its natural resources have supported the coastal populations for thousands of years, the marine environment has recently been degraded as a result of a wide range of land-based sources and activities.

Available information on land-based sources and activities affecting the marine environment of each member State is presented, and the main pollution sources identified and assessed. These include power and desalination plants, sewage treatment facilities, industrial facilities, solid waste, recreation and tourism facilities, oil refineries, agricultural activities, coastal construction, mining and quarrying activities, port facilities, and others. Priorities were established and it was found that action priorities differed among States because of their socio-economic and physiographic differences. Management objectives for priority problems, available, based on current legislation and regulations, as well as development plans are presented. Strategies and measures were evaluated and selected on the basis of a comparison between current activities and existing environmental conservation efforts. Criteria for evaluating the effectiveness of strategies and programmes were formulated where possible. Programme support elements are presented for each member State and the ROPME region.

Recent development activities in the ROPME region have heavily concentrated on fragile terrestrial and marine resources. Coastal habitats are being converted to urban and industrial development. The coastal zone is fast becoming the repository for liquid and solid wastes. Major ecological problems have arisen from the loss and degradation of coastal habitats, caused by landfill, dredging and sedimentation. Furthermore, the region is subjected to frequent oil spillages.

All ROPME member States have their own national policies and legislation which deal with many aspects of land-based sources and activities affecting the marine environment. They are also parties to many regional and international conventions under which they are committed to protecting their marine environment from land-based sources. In addition, some member States have their own monitoring programmes dealing with air and marine pollution. Furthermore, some member States have taken action to reduce marine pollution from land-based sources, and have involved the private sector in their development planning.

The available data, however, are inconsistent and must be verified and updated. While very important information is available from government institutions it is in the form of raw data or is formatted in a way that makes it difficult to detect pollution trends. In addition, coordination between government and research institutions is lacking in many cases.

Current programmes on land-based sources and activities affecting the marine environment of the ROPME region varies greatly from one country to another. In some countries, most actions and measures recommended under the Global Programme of Action have been implemented with varying degrees of success, while in other countries, very little has been done to protect the marine environment from land-based activities.

The ROPME member States recognized the urgent need to protect the marine environment from land-based activities and prepared the Protocol for the Protection of the Marine Environment against Pollution from Land-based Sources. The Protocol was signed by the contracting States in February 1990 and entered into force in

January 1993.

ROPME reviewed the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities with particular reference to:

- Characteristics of the region in relation to source category;
- Specific needs of the region; and
- Listing of priorities.

An analysis of priority issues from a regional perspective indicated the following order of priority for source categories:

- Oil (hydrocarbons) and combustion products (e.g., PAHs);
- Physical alteration, sediment mobilization and destruction of habitats;
- Sewage and nutrients;
- Litter;
- Atmospheric deposition;
- Persistent organic pollutants (POPs);
- Heavy metals;
- Radioactive substances.

Each of these source categories was assessed in terms of extent, impact (where possible) and means of controlling, reducing and preventing marine pollution from land-based sources.

The capacity-building resources of ROPME, in terms of both human resources and institutional capacity, are adequate to execute the Global Programme of Action in the ROPME sea area. One of the main problems facing the ROPME, however, is the acquisition of updated data from member States. Bureaucratic delays and the lack of information exchange with ROPME on a regular basis have been the major factors impeding the implementation of many environmental programmes targeted at the time of initiation (Al Awadi, 1995).

The acquisition of updated data from members States is subject to four major constraints:

- (a) Weak development rationale;
- (b) Lack of adequate financial resources;
- (c) Inadequate human resources; and

(d) Development boom and economic diversification in many member States.

It is suggested that all the ROPME member States adopt and implement the ROPME Protocol, and that it be considered part of their national legislation. Each State needs to build a framework of initiatives (plan of action) to control marine pollution from land-based sources. This cannot be achieved without prior training of the personnel involved. The plan of action should have targets and timetables for affected areas and for individual industrial, urban and other sectors. Specific areas known to be a source of pollution should be selected when a complete inventory of specific sources is updated and impact is assessed. Meanwhile, measures to reduce, control and prevent marine pollution should be enforced. Regular monitoring of selected areas should be carried out.

On the basis of available information, the following selected areas are suggested: Bahrain Island industrial estate, Shatt al' Arab (Iraq), Bandar-Imam industrial zone (Islamic Republic of Iran), Al Shuaiba industrial estate (Kuwait), Mina Al-Fahl and Al Ghubra (Oman), Umm Said and Dukhan (Qatar), Al Khobar, Tarut Bay including Ras Tanura and Jubail (Saudi Arabia), Ruwais industrial complex and Gabal Ali in Dubai (United Arab Emirates).

A concrete programme of action is urgently needed to control marine pollution from various land-based sources. Specific activities under the ROPME Regional Programme of Action that have been approved by the ROPME Council are:

- Regional and global cooperation;
- Updating the survey of land-based activity source categories, capabilities and constraints;
- Carrying out a pilot study on persistent organic pollutants (POPs);
- River basin management;
- Development of guidelines, standards and criteria for the management of land-based sources.

In addition, the following activities are suggested:

- Establishment of reception and recycling facilities for solid and liquid waste;
- Initiation of a study on radioactive substances;
- Preparation of an integrated coastal zone management plan;
- Coordination of the regional fisheries management programme;
- Strengthening of environmental education programmes.

These activities require a strong political will, public support and multilateral cooperation. ROPME is the only wide-forum region in the area through which cooperation can be achieved.

1. Introduction

The ROPME sea area is defined as extending between the following latitudes and longitudes, respectively: 16° 39' N, 53° 3' 30" E; 16° 00' N, 53° 52' E; 17° 00' N, 56° 30' E; 20° 30' N, 60° 00" E; and 25° 04' N, 61° 25" E (figure 1). It includes the coastal and marine waters of the eight ROPME countries, Bahrain (126 km), Iraq (90 km), Islamic Republic of Iran (1,259 km), Kuwait (350 km), Oman (1,700 km), Qatar (700 km), Saudi Arabia (790 km) and United Arab Emirates (650 km).

The ROPME regional marine biota have undergone selection for survival under high-stress conditions. Many endemic species are capable of tolerating high water temperatures and salinity, although these may be close to the physiological limits (Sheppard *et al.*, 1992; Price, 1993). Any additional stress imposed by human activities may have a significant impact on these biota (Fouda, 1995c).

For thousands of years, the natural resources of the ROPME region have nourished the development of a maritime and trading culture linking Arabia and Africa with Europe and Asia. The renewable and non-renewable resources of the region remain the cornerstone of life and development in the ROPME member States. These resources contribute to meeting the food, transport, industrial, recreational and other needs of local people.

The region plays a particularly vital role in providing most of the population with freshwater from desalination plants. Fisheries are of considerable social and economic importance. The discovery of oil during the 1930s and 1940s led to a massive increase in shipping and was principally responsible for the immense economic wealth and geopolitical importance of the region today. The ROPME sea area basin harbours three strategic fluids: oil, gas and desalinated water. The largest onshore oil field (Ghawar), the largest offshore oil field (Safaniya), the largest non-associated gas field (Northfield) and the largest desalination plant (Al Jubail) are all within the inner part of the area (Al Hajr and Ahmed, 1997).

The limited freshwater resources in the ROPME region are under intense pressure. Fisheries are also under significant pressure from the overexploitation of target species, and in some States, illegal fishing is having increasingly devastating results.

The effects of prolonged human use of the ROPME coastal and marine environment of the are multiple and complex. Particular environmental pressures may arise from a variety of human uses (Price, 1993). Therefore, the ROPME member States are becoming increasingly aware of the benefits of managing their marine environment on a sustainable basis, and this requires collective efforts at the national, regional and international levels. An integrated approach and stringent environmental protection standards are needed.

2. Characteristics of the ROPME sea area

2.1 PHYSICAL CHARACTERISTICS

2.1.1 Water temperature profile

There is normally little stratification of the water, as the entire water column is mixed, owing to the strong winds. In the summer months, however, a temperature stratification may develop in the central part, the deeper water being about 10° C cooler than the surface water. There is a well-defined seasonal pattern in the sea surface temperature: It shows a temperature increase from north to south in December, then the difference is reduced in March and they both become almost equivalent temperature in May and a reverse is observed in August. Temperature in the north-western part of the area, however, shows a much wider range with a maximum of 35° C in August and a minimum of about 15° C in February (Linden *et al.*, 1990).

The outer coastal areas are exposed to one of the most unusual temperature environments especially in the southern region (Dhofar), where summer upwelling generated by south-western monsoon winds (June-September) reduces surface water temperatures to between 16° C and 19° C. This annual upwelling effect is continuous and pronounced as far north as Ra's al Hadd. Upwelling effects are also observed in the Gulf of Oman, where summer temperatures can decrease radically (from 32° C to 24° C) over a short period, as gyres of cold, deep water sweep into shallow areas (Coles, 1995).

2.1.2 Climatology of the ROPME sea area

2.1.2.1 WIND

Climatic effects are strongly influenced by prevailing winds. In the winter, winds generally cross the area from the east or the north-east. During this period, strong storm (*shamal*) winds often carry large

amounts of dust and sand, which are deposited in the waters of the area. Winds from the north can also cause a dramatic temperature drop in shallow waters, often resulting in large-scale mortality among the nearshore tropical fauna. The *shamal* is a north-west wind that occurs year-round and is nearly continuous from June to July. In summer, strong winds are also caused by differences in the temperature of the land mass and the water. This results in large waves and vertical mixing of the water column (Carpenter *et al.*, 1997).

2.1.2.2 AIR TEMPERATURE

While the region is a subtropical zone, it is surrounded by arid land masses; hence, the summers, are hotter and the winters are colder than in most subtropical zones. Air temperatures frequently reach 0° C in winter and 50° C in summer. The monthly average values of air temperatures, however, range from 16° C in January to 35° C in July (ROPME, 1997).

2.1.2.3 RAINFALL

Annual precipitation in the area averages 152 mm and is limited almost entirely to the winter months.

2.1.3 Water circulation

Water circulation in the inner part of the area is driven by density gradients (Sheppard *et al.*, 1992). Water of normal oceanic salinity enters through the Strait of Hormuz at the surface and through a compensatory outflowing current of highsalinity water along the bottom. The general circulation pattern of the water is counter-clockwise; there is a water movement northwards along the Iranian coast and a corresponding one southwards along the Arabian coast, with a current speed of 1-1.5 knots.

2.1.4 Current and tide

Tides in the area are basically semi-diurnal. They are not influenced by the Indian Ocean, and vary from 3 to 4 m in the north to less than 1 m in the south. The

ebbing tide in Kuwait exposes tidal flats more than 1 km wide during the day in winter and at night in summer. Consequently, the intertidal zone is rarely exposed to excessive heat and desiccation. The strong tidal current of the area flushes out its waters; its total water volume is completely renewed every one to three years (Hinrichsen, 1996). The Gulf of Oman has a typical tidal regime of 1.5-2.5 m and is of the mixed semi-diurnal type.

The dominant density-driven, counter-clockwise current is more prevalent in the south. The extent of northerly flow due to inflow from the Strait is counteracted by prevailing winds from the north. The extent of this inflow is stronger during the summer and weaker during the winter because of stronger winds from the north in winter.

The northern currents are heavily influenced by wind-driven forces and modified by river outflow (Reynolds, 1993). A southerly flow along the Iranian coast is driven by density differences from fresh-water runoff in the northern part of the basin. This current is weakened in the winter by *shamal* winds, but strengthened in the summer, when it can reach almost to the head of the basin. The surface current of the rest of the northern area is predominantly wind driven in a southerly direction. In the north-central region, a secondary wind-driven northerly flow counteracts the southerly flow and creates an area of low net drift. Around this low-energy region, the flow is variable; depending on changing wind patterns, it can be north, south, clockwise, or counter-clockwise.

2.1.5 Topography and bathymetry

The marine basin is approximately 1,000 km long and 200 to 300 km wide. It is separated from the Gulf of Oman by the Strait of Hormuz which is restricted to 56 km at its narrowest point. Its depth averages 35 m and most of the basin is less than 60 m deep. It is generally deeper in the south-east where depths of over 100 m are found, and it is deepest near the opening of the Strait of Hormuz. The eastern part is very shallow, with extensive intertidal areas that are less than 5 m deep and up to 5 km wide.

The bottom topography is mostly flat and featureless, dominated by soft sediments. However, island ecosystems are also present along some coasts. A series of low sandy islands with fringing reefs and patch reefs of coralline origin extends from Kuwait Bay south along the Saudi Arabian coast. These shallow reefs make up the most diverse habitat of the area. The Gulf of Salwa between Bahrain, Saudi Arabia and Qatar is shallow and hypersaline, and also has many islands and reefs, with productive sea-grass beds. The waters between Qatar and the United Arab Emirates are also very shallow and form an area of restricted circulation and pronounced evaporation. A series of islands off the western United Arab Emirates restrict water flow further in the shallow coastal area.

2.2 CHEMICAL CHARACTERISTICS

2.2.1 Salinity

Due to the high rate of evaporation in the area, the 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. Salinities as high as 70‰ have been reported in the Gulf of Salwah at its southern extremity (Basson *et al.*, 1977). In winter, the salinity is somewhat higher than in summer, due apparently to the variation of fresh water influx through the Shatt al' Arab and to meteorological effects, particularly evaporation (ROPME, 1997).

2.2.2 Dissolved oxygen

Throughout most of the region, dissolved oxygen is near saturation in surface waters. Exact levels vary according to temperature and salinity, since saturation typically ranges from about 4.8 to 6.5 ml O₂ per litre, being lowest in warmer waters of high salinity (Sheppard *et al.*, 1992). The saturated layer in the inner part of the area extends to the bottom. On the other hand, critically low levels of O₂ (0.2-1 ml per litre) are usually recorded below a depth of 100 m in

the Gulf of Oman and the Arabian Sea.

2.2.3 Nutrients

In general, nutrients show a large variation in the area (Sheppard *et al.*, 1992). In the western areas of the area, nutrient concentrations fluctuate considerably, but are generally higher in interior bays than in nearshore and offshore waters (IUCN/UNEP, 1985). Nutrient concentrations around Oman vary seasonally according to the monsoon system. For example, in areas of intensive upwelling during the south-west monsoon, nitrate levels rise from 5 to 20 mg m³ at NO₃ m³ and phosphate values to 1.5-2.5 at PO₄ m³. These values are three to five times greater than the winter, non-upwelling values (Barnett *et al.*, 1986).

2.3 FRESHWATER ENVIRONMENT

The major river inflow system that drains into the basin of the inner part of the area is shown in figure 2. These rivers are all on the Iranian side, except the Shatt al'Arab, which is based along the boundary between the Islamic Republic of Iran and Iraq. The small streams of Mehran (5 m³/s) and Mirab (9m³/s) are also located close to the Strait.

The Shatt al' Arab is the major freshwater inflow that drains into the area basin head. It is a combination of three rivers: the Iraqi rivers Tigris and Euphrates together provide an annual average of 708 m³/s and the Iranian river Karun adds 748 m³/s (table 2). This gives the total average inflow of the Shatt al' Arab as 1,456 m³/s (Reynolds, 1993). The largest runoffs of the Shatt al' Arab and the Karun, are the only navigable and portable water bodies along the Iranian coast. Dams upstream have reduced their volume discharge into the area and the quality may deteriorate owing to increased pollutant sources (Al Hajr and Ahmed, 1997). All other small rivers have a high salt content owing to soil conditions. The most significant marshes are those of the Shatt al' Arab. This marsh system acts as a pollutant sink and filters the pollutants contained in the runoff.

The total runoff into the inner part of the area is 1.1

x 102 km³/yr (Reynolds, 1993). Industrial and agricultural development are having a pronounced effect on the outflow from the Shatt al' Arab. While river outflow is considerably less than evaporation (140-500 cm/yr), its concentration in the northern closed end supports a counter-clockwise circulation (Chao, *et al.*, 1992). Annual rainfall in the arid climate of the area is small, on the order of 7 cm/yr. The drainage of freshwater flowing into the area creates brackish conditions suitable for many fish and shrimp species. The water balance in the area was computed; renewal time, defined as the time it takes water from the Gulf of Oman to fill the area was estimated to be 2.1 years (ROPME, 1997).

2.4 BIOLOGICAL CHARACTERISTICS

2.4.1 Mangroves

The mangroves of the area are significant not just biologically but also historically (Sheppard *et al.*, 1992). They were the first mangroves to be reported in the world literature by Nearchus and Theophrastus over 2,000 years ago. In addition, the existence of a mangrove forest at Qurm (Muscat, Oman) and man's exploitation of and dependence on this ecosystem more than 7,000 years ago was confirmed by Biagi *et al.*, 1984 and Coppa *et al.*, (1985). The strong relationship between mangrove forests and ancient cities in the area indicates that people there have long known the value of mangroves. They used the wood for fuel and building materials and the green leaves as fodder for camels and goats. Such mangrove forests have all but disappeared and the remaining ones are scattered over an estimated area of 125-130 km² (Sheppard *et al.*, 1992). The Iranian coast contains most of this mangrove vegetation, approximately 90 km² while less than 10 km² remain along the coasts of Saudi Arabia, and Bahrain, and the United Arab Emirates coastline. These mangroves have low species diversity which is attributed to severe climatic and environmental conditions, as well as limited habitats and niches (Sheppard *et al.*, 1992). Nevertheless, they continue to play an important role in the ecology of the region, particularly in Oman

(Fouda and Al-Muharrami, 1995).

Mangrove (*Avicennia marina*) vegetation in the area is simple in structure, varying from 2 to 6 m in height in the Gulf of Oman and up to 10 m in the Arabian Sea (Fouda and Al Muharrami, 1996). The differences in the structural development of mangroves are site-specific. In the inner part of the area, stunted individuals (1-2m) of the same species (Basson *et al.*, 1977) occur where winter temperatures fall to nearly 0° C. While salinity has also been suggested as a limiting factor affecting mangrove height, Chapman (1984) maintained that low temperature, rather than salinity, is the main limiting factor, however, neither salinity nor temperature, but rather aridity is the main limiting factor. According to Fouda and Al Muharrami, (1996).

Phenological data for *A. marina* suggest trends related to latitude in the area. Fruiting occurs during autumn in the Arabian Sea area, spring in the Gulf of Oman area (Fouda, 1995) and summer in the inner part of the ROPME sea area (Abdel Razek, 1991). The differences in latitude in some ROPME countries may be small, but environmental differences are great (Fouda, 1995a).

In the Arabian Sea area (Mahout Island in the Gulf of Masirah), mangroves sustain large-scale shrimping centred mainly on *Penaeus indicus* and *P. semisulcatus* (Fouda and Al Muharrami, 1996), whereas in other parts of the area, small-scale fishing of mullet, milkfish and other species, usually with gill-nets, cast-nets and handlines.

Mangrove communities include faunal assemblages of many species, consisting mainly of fish (86 species), crustaceans (40 species), and molluscs (50 species) as well as smaller numbers of sponge, echinoderm, coelenterate, polychaete and ascidian species (Fouda, 1995). Large wildlife include over 200 bird species, turtles (3 species) and mammals (4 species) (Fouda and Al Muharrami, 1996).

2.4.2 Sea-grass

The ROPME region is known to have four sea-grass species of which *Halodule uninervis* and *Halophila ovalis* are the most prevalent (Sheppard *et al.*, 1992). Further offshore, however, these species appear to be less prevalent, at least along the coast of Saudi Arabia. In Bahrain, sea-grass is more extensive, although it generally does not extend below a depth of 8 m (Price *et al.*, 1993). In the ROPME sea area, (Basson *et al.*, 1977; McCain, 1984; Coles and McCain, 1990). The biota show the greatest affinities with those found in of subtidal sand and subtidal mud. They are characterized by a small proportion of sea-grass “specialists” and a larger proportion of “generalists”. The overall importance of sea-grasses and its role in the maintenance of populations, including through fisheries production, has been recognized.

2.4.3 Coral reefs

The coral reefs in the inner part of the area occur in an environment with great extremes of temperature and salinity, as well as high turbidity. Normal winter temperatures in the area are among the lowest at which coral reefs occur (Downing, 1985). There are wide seasonal variations in air temperature which result in sea temperatures ranging from 15° C in winter to 36° C in summer. Coral coverage, is abundant, although the number of species is limited. Both species diversity and percent coverage decrease with proximity to the shoreline, suggesting that coral survival is limited where physical conditions are more extreme. It has been pointed out (Coles and Fadlallah, 1991) that a combination of extreme conditions, and especially the length of time that a set of extreme conditions prevails, is more important than simple extremes of a single environmental variable. Therefore, many species of corals in the area live close to their tolerance thresholds. Only 57 hermatypic coral species occur on offshore island reefs; of these, only 24 are found on inshore reefs, and no corals are found where salinities exceed 46 ppt.

The most northerly reefs in the inner part of the area lie near the islands off Kuwait, where around 26 coral species are present; like all known reefs in the area, they support insignificant coral growth below a depth of 15m. Corals also occur in isolated colonies on rocky outcrops on the southern mainland of Kuwait, but towards the northern part of the country, the influence of the Shat Al-Arab estuaries precludes coral growth. The six Saudi Arabian Islands have the most developed reefs in the area, with approximately 50 coral species. Patch reefs close to the mainland are much less diverse (Coles, 1988, McCain et al., 1984).

Coral reefs in Bahrain and western of Qatar appear to be fairly representative of reefs located in the area near the mainland. Bahrain has numerous reefs along its northern and north-eastern shores and offshore, patch reefs extend down its coast to the level of its southern tip. The offshore waters, of the United Arab Emirates are very shallow; however, while they are generally muddy and suitable for most corals, there are numerous patch reefs dominated by *Acropora*. Fringing reefs occur around numerous low islands, as well as along the eastern and northern coasts of Qatar. These areas tend to have a high coral cover, but a low diversity of perhaps under 20 species (UNEP/IUCN, 1988). Very little is known about the coral reefs of the Islamic Republic of Iran.

In the Sultanate of Oman there are four regions which support coral growth (Salm, 1993): the Musandam Peninsula, at the entrance to the inner part of the area; the rocky shores, the bay and the islands adjacent to the capital area (Muscat, Gulf of Oman); the strait west and south of Masirah island; and a number of sheltered bays along the southern mainland of Dhofar and the offshore Hallaniya islands in the Arabian Sea. The other parts of the Omani coast either lack corals or support limited growth of small, scattered colonies. This is due to the absence of a suitable stable substrate, as on the Batinah coast, or a seasonal upwelling of cold water, vigorous algal growth and heavy wave action, as on most of the Arabian Sea coast. There are 91 species of corals belonging to 53 genera and 18 families (Sheppard and Salm, 1988; Salm, 1993). Coral diversity in-

creases southwards towards the equator, with Musandam (41 genera), Muscat (42 genera) and Dhofar (48 genera). On Masirah Island there are 27 genera, which reflects the isolation of this island (Salm, 1993). Coral communities tend to be confined to a maximum depth of 12-18 m, but the live coral cover drops abruptly below 10m, from 75 per cent or more to less than 40 per cent and seldom reaches 10 per cent at a depth of 15 m. *Porites* is the dominant builder of framework reefs throughout Oman (Salm, 1993). Coral had a wider distribution along the Omani coast during the Pleistocene era than at present.

2.4.4 Fishes and fisheries

There are marked differences throughout the ROPME region in the structure and composition of fish assemblages which reflect the heterogeneous nature of the environment (Sheppard *et al.*, 1992). Unlike more stable tropical marine environments, the area is characterized by a generally low diversity of fish species, although individual species may occur in very high numbers. The inner part of the area supports more than 500 species (Kuronuma and Abe, 1986; Krupp, personal communication), of which at least 125 are found on the reefs (Sheppard *et al.*, 1992), including 85 from reefs off Kuwait (Downing, 1985), 71 from Bahrain (Smith *et al.*, 1987), and 106 from reefs in Saudi Arabia (McCain *et al.*, 1984; Coles and Tarr, 1990; Krupp and Muller, 1994). On the other hand, approximately 1,000 fish species have been recorded in the Gulf of Oman and the Arabian Sea (Fouda and Hermosa, 1993; Randall, 1995); most of them are reef species. The high diversity of Omani fish fauna is attributed to the diverse coastal habitats, huge exclusive economic zone (300,000 km²), wide climatic spectrum and its unique geographic location of the country in the upwelling region of the north-western Indian Ocean. 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*) and 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). Pearl oysters (*Pinctada margaritifera* and *P. radiata*) had been harvested in the area in the past, but the fishery died towards the middle of this century (Sheppard *et al.*, 1992).

The total marine harvest for this region ranged from 327,000 to 580,000 metric tons (t) during 1985-1993, almost all of the harvest being produced from territorial waters. Artisanal fisheries contribute over 79 per cent of the total landings. A substantial portion of the harvest is exported in fresh and processed form to the countries within and outside the region. Fresh and processed fish and invertebrates are also imported from outside the region, especially from India, Pakistan, Thailand, and Taiwan, to supplement local supplies (Siddeek *et al.*, 1997).

In general, fish landings in the region appear to have stagnated during late 1980s and early 1990s. This is due primarily to fishing effort sharing which reached nearly the maximum sustainable yield (MSY) on some stocks and exceeded optimum levels on many other stocks. This led to restrictions on fishing in many countries. In Kuwait, for example, a number of shrimp trawlers were removed from the fishery in order to by implement a buy-back policy. Fishing is also restricted through closed seasons and areas: for example, shrimp trawl-fishing season is closed from January to March and from July to September in the shrimp-producing countries.

2.4.5 Turtles

Marine turtles are a prominent part of the fauna of the area, which contains some globally important nesting beaches. All five of the pantropical species are known in the region: hawksbills, greens, leatherbacks, loggerheads and Oliver Ridley. These turtles are classified as endangered in the World Conservation Union (IUCN) Red Data Book. The most im-

portant part of the region for turtles is the Arabian Sea (Oman), in terms of both the number of breeding species and the abundance of individuals (Ross, 1979; Salm and Salm, 1991). The loggerhead is the most numerous turtle, with almost 30,000 breeding females nesting on the north-western side of Masirah Island. Oman also supports the largest nesting population of green turtles, with 6,000-13,000 females nesting annually at Ra's al Hadd, which separates the Gulf of Oman from the Arabian Sea.

2.4.6 Birds

The area supports a diverse marine bird community of great international importance. Huge numbers of sea-birds breed on the offshore islands, especially the Socotra cormorant (most of the world population) and *Sterninae* terns (e.g., bridled tern, white-cheeked tern, lesser crested tern) (Gallagher *et al.*, 1984). The intertidal zone is estimated to support up to 4 million Charadrii waders in winter, making the area one of the five most important regions in 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 waterbird species, including grebes, cormorants, herons, flamingos, gulls and terns. The Gulf of Oman and the Arabian Sea are also of great importance for wintering shore birds and other waterfowl, as well as many resident birds. These include cormorants, herons, egrets, spoonbills and terns. The most important shore birds are crab plover, sand plover, dunlin and redshank.

2.4.7 Marine mammals

The dugong (sea cow) is found in the inner part of the area; it is not known to exist along the shores of the Arabian Sea. In the Gulf of Oman area there has been only a report of a carcass having washed up on the Batinah coast (Clark *et al.*, 1986). The largest herd ever recorded, over 600 individuals, was observed in the Gulf of Salwah between Bahrain and the Qatar peninsula (Preen, 1989). These animals also occur in significant numbers among the shoals

and islands west of Abu Dhabi. The estimated population is 7,310 ($\pm 1,300$) individuals, making the inner part of the area the most important area for this species in the western part of its range, second only to Australia in global importance.

Other marine mammals of interest include whales and dolphins of which some 20 species are found in the region, representing 25 per cent of all known species in the world (Baldwin and Salm, 1994). Baleen whales (toothless whales) include Bryde's, humpback, minke, fin and blue whales. Toothed whales include sperm, killer and false killer whales. With respect to dolphins and porpoises, sightings of the bottlenose dolphin and the Indian-Pacific humpback dolphin have been recorded.

3. Country-by-country analysis of land-based pollution sources

3.1 BAHRAIN

3.1.1 Introduction

The State of Bahrain is an archipelago comprising 33 low-lying islands, with a total area of 690.86 km². It is located in the inner part of the area, with Saudi Arabia to the west and Qatar to the east. The main island, Bahrain, represents 85 per cent of the total area, and is the centre of most activity; it has the capital city (Manama), the primary port (Mina Salman), oil fields and the oil refinery. Apart from a narrow, fertile strip of land extending some 6 km along the northern coast, the lands are rocky and bare, and consist of limestone rock covered with sand of varying depth. About 19 km from the northern end of the island, a small compact group of hills rises to about 125 m, the highest point being Jabal ad Dukhan. Muharraq, the second largest island in the northern group, is connected to Manama by a causeway 2.4 km long. In addition, the airport, an iron-pelletizing plant, and a dry dock are located on this island. To the east of Bahrain is Sitrah, the third largest island, which is connected to the mainland by another causeway. Sitrah, an industrial centre, has an oil reservoir, a port, a power plant, a desalination plant and sand and gravel companies. Moreover, a petrochemical manufacturer of ammonia and methanol is located at Sitrah. Umm Al Nassan is another large island located in the north-west.

The population of Bahrain is estimated at 600,000. The majority of the population is concentrated on the three main islands, namely, Bahrain, Muharraq and Sitrah.

The inshore waters are generally shallow and the intertidal zone is 3000 m or more in width in several places. The islands lie in a particularly enclosed part of the area where water exchange is restricted by the

Qatar Peninsula, the Saudi Arabian mainland and the barrier of reefs extending from Bahrain itself. The Gulf of Bahrain and the Gulf of Salwah are mostly less than 10 m deep, and temperature extremes and salinities, which are commonly over 50 ppt and up to 55 ppt at the southern end of the island, exert strong controls on the marine biota. In addition, much of the substrate is muddy or sea-grass-dominated, which impairs coral reef development.

The weather in Bahrain is typical of the area, being hot and humid. From May to October the maximum average temperature reaches 30° C or above, falling to 20° C or below during winter. Rainfall is light in Bahrain; no rain is recorded for the months of June to September. There is light rainfall during winter, and the average annual rainfall is less than 80 mm, occurring mostly from December to May. Thus, the area lacks washout, which is one of the important atmospheric scavenging mechanisms.

Winds come predominantly from the north and the north-west. The north-west winds persist for a long period and sometimes transport large quantities of dust from Saudi Arabia. These winds, however, are favourable, because all industries in Bahrain are located south and south-east of the heavily populated areas, so that industrial emissions are not directed towards the residential areas. About 20 per cent of the time, however, the wind blows south-south-east, carrying industrial pollutants towards the populated areas, while about 16 per cent of the time, calm winds cause localized air pollution problems. Average wind speeds were more than 10.3 m/sec during the period 1969-1984 (Cowiconsult, 1984).

3.1.2 Identification and assessment of main pollution sources

3.1.2.1 POWER AND DESALINATION PLANTS

There are five major power plants in Bahrain, namely, Manama, Slira, Rifa'a, IPA and Alba. They produce a total of 5,000 GW/h, with a total local consumption capacity of 1,200 MW (consumption per capita

is 8,300 kW) (ESCWA, 1997). The major MSF desalination plant is at Sitra Island, with a capacity of up to 115,000 m³/d of freshwater. Other desalination plants produce 45,000 m³/d on 58.4 m³/yr (Al Zubairi, 1977).

It is reported that desalination plants produce 12,000 m³/h hot effluents which are discharged directly into the sea (Madany and Danish, 1993). These effluents cause physical changes in sea water, mostly in terms of temperature and salinity.

3.1.2.2 SEWAGE TREATMENT FACILITIES

The major sources of coastal pollution in Bahrain are the domestic sewage effluents discharged from urban and rural areas of the country. These effluents are discharged into the marine environment through numerous outfalls located along the coast. The quality of the effluents and their pollution strength vary from one area to another, and from one outfall to another, depending on the degree and type of treatment to which the area sewage water is subjected. In general, the quality of the discharged effluent can be classified in the following three categories:

Treated effluents: These are generated from the various existing sewage treatment plants. The quality of the discharge varies significantly from one plant to another, depending on the stages of treatment and the method used at each plant.

Partially treated effluents: These are generally the overflows from the septic tank systems serving different parts of the country, including Samahij, Al Jasrah, Galali and Bapco beach.

Untreated effluents: Raw sewage from Awali and a few other areas are discharged through old sewer system, directly into the marine environment. All sewage is discharged at the sea surface into the shallow coastal waters.

Coliforms, fecal coliforms and coliphages were detected in the raw sewage in high numbers during the months having a maximum average temperature of 20° C. The secondary and tertiary effluents showed a 99 per cent-100 per cent removal of the three indicators of fecal pollution (Qureshi and Qureshi, 1990).

According to the Ministry of Works, Power and Water (Sewerage and Drainage Directorate) only 6 per cent of the population is served by a sewerage system discharging untreated sewage into the marine environment. A further 12 per cent of the population is served by septic tanks or cesspits which discharge their partially treated effluent into the sea. As more areas of the country are connected to treatment plants, the volume of untreated and partially treated sewage effluent will continue to fall. At present, about 70 per cent of the total population of Bahrain is connected to the sewerage network system, and 100 per cent expected by 2015. Nevertheless the quantities of untreated and partially treated sewage effluent discharged into the sea are still considered in absolute terms.

There are nearly 30 sewage plants in Bahrain; 12 of them are wastewater treatment plants operated by the Sewerage Directorate and were mostly commissioned after 1980. Of the existing plants, 24 are of small, packaged types, designed for population equivalents ranging from 300 to 2,500. The full treatment plants in operation are listed in tables 3 and 4.

The major treatment works in operation are presented below:

- (a) **Tubli Water Pollution Control Centre (Tubli WPCC).** The plant is intended to treat the wastewater flow of several metropolitan areas, including Manama, Muharraq and Isa Town, together with the developing areas of Sanábis, Jidhafs and Al Khamis. The project has been divided into three phases for implementation. Phase I commenced in 1980 and was completed in July 1982, and is intended to serve a population of 200,000. Phase II is

to serve about 300,000 inhabitants, and Phase III is to serve 600,000 by the year 2008.

This is the main sewage treatment plant in Bahrain, with an average daily flow of 54,000 m³. It is based on the extended aeration process, followed by tertiary treatment, using dual media filtration plus chlorination. Recently, an ozonation plant was added, with a view to using the effluent for agriculture. Tubli WPC is designed to produce a secondary effluent with a quality standard of better than 20:25 (Bbiochemical oxygen demand:55) and a tertiary standard of better than 5:7 (Bbiochemical oxygen demand:55). All waste sludge from Jubli WPC is recycled for agricultural use on government farms;

(b) **Bani Jamrah STP.** This plant was commissioned in late 1982 and is designed to treat flows from a population of 1,900, with an average daily flow of 462 m³. It is a Simon Hartley packaged plant and consists of four steel tanks, for aeration, settlement, sludge holding and chlorine reaction. A Fay International package plant consisting of the same processes has been constructed on land adjacent to the Bani Jamrah plant to serve Budaiya, with a population equivalent to 4,000 inhabitants. Both plants are designed to produce effluent quality of better than 20:30 (Bbiochemical oxygen demand:55);

(c) **Nuwaidrat STP.** The plant was commissioned in 1983 and is designed to treat flows from a population of 6,460 with an average flow of 1,760 m³ per day. It consists of two lines, one facultative and the other a maturation pond in series. The ponds are designed to produce effluent quality of 20:50 (Bbiochemical oxygen demand:55);

(d) **North Sitra Industrial Area STP.** The plant was opened in 1985 to treat a maximum daily flow of 5,800 m³ for a population equivalent of 21,300. It is an extended-aeration-process-type plant, similar to Tubli and Bani Jamrah, and comprises, in addition to the aeration tanks, oil grease, removal tanks, balancing tanks with surface aerators and chlorination tanks. The plant is designed to treat domestic and treated industrial wastewater and to produce effluent quality of 30:40 (Bbiochemical oxygen demand:55). Waste sludge is taken to landfill and sludge from the small plants is tankered to Tubli.

3.1.2.3 INDUSTRIAL FACILITIES

The following are the major industries:

- Gulf Petrochemical Industries Company (GPIC), with a daily production capacity of 1,700 tons of granulated urea;
- Aluminum Bahrain (ALBA), which produces 500,000 tons/yr of high-grade aluminium (one of the World's largest world aluminium companies);
- Arab Shipbuilding and Repair Yard (ASRY), which has several docks able to accommodate and repair vessels of up to 500,000 tons dryweight;
- The Refinery - Bahrain Petroleum Company (BAPCO);
- Midal Cables;
- Limestone production plant;
- Cement plant;
- Ammonia and methanol.

These and other major industries are located in the industrial estate areas, comprising about 35 km², mostly on the eastern coast of Bahrain Island. Extractive industries (oil and natural gas) contribute 17.4 per cent of GDP whereas manufacturing industries (e.g., aluminum, cement, plastics, fertilizers, etc.) share 15.1 per cent of GDP in Bahrain (Anon, 1996). Wastes of these industries are gases, liquids and solid wastes; their amount are considerably high.

3.1.2.4 SOLID WASTE

The total solid waste loads from industrial sources (1985-1987) was estimated at 50,085 tons/yr, of which 18,500 tons/yr were oil sludges (ROPME, 1997). In a recent study, solid waste from industrial sources has increased to 53,000 tons/yr, of which 20,000 tons are classified as semi-solid waste (Anon, 1996). The solid waste load from domestic sources amounts to 161,343 tons/yr (4.4 per cent of the ROPME member States (ROPME, 1997).

Only wastes are dumped in landfills, often close to the sea. The Arab Shipbuilding and Repair Yard (ASRY) in Bahrain is currently constructing a marine sludge treatment plant in operation since May 1997 (Boutari, 1997). The plant, the first of its kind in the region, is designed to minimize the volume of waste materials through an oil separation phase followed by a soil remediation process. The final products of the plant are clean oil, clean water suitable for ocean discharge and environmentally safe solids, either landfill-disposable or compost that can be used on non-food-bearing ornamental plants.

Legislation regarding solid wastes in Bahrain falls within the framework of the 1973 Law on General Health and the new Environmental Law (No. 21/96), containing guidelines for protecting the environment from all sources of pollution.

3.1.2.5 RECREATION AND TOURISM FACILITIES

These facilities are rapidly developing in Bahrain to accommodate tourists (mostly in transit on their way

to the Far East), expatriates and locals. Bahrain has superb facilities for sports, shopping, dining and entertainment. Most international airlines operate in Bahrain, providing direct links to over 100 cities worldwide. The country offers a wide selection of luxury modern hotels and furnished holiday apartments and an extensive range of restaurants. Since the construction of the bridge between Bahrain and Saudi Arabia, many tourists from Saudi Arabia visit Bahrain, usually during weekends.

3.1.2.6 OIL REFINERIES

There is one oil refinery at Sitra which produces 280,000 barrels/d (ESCWA, 1997). Solid waste from this refinery is estimated at about 4,000 tons/yr (Madany and Danish, 1993).

3.1.2.7 AGRICULTURAL ACTIVITIES

Agricultural output in Bahrain is estimated at \$49 million, representing 1 per cent of GDP. There are about 5,000 ha of cultivated land which require 1,000 tons of fertilizers (200 kg/ha) (ESCWA, 1997). This cultivated land is irrigated by groundwater, representing 70 per cent of all water resources available annually. Most agricultural products are imported with the exception of dates and fish.

Agricultural landuse declined steadily from 64.6 km² in 1956 to 37.48 km² in 1982 and to 30 km² in 1994 (ESCWA, 1997). This reduction in agricultural activity was due to several factors:

- Urban and industrial expansion on land used for agricultural purposes;
- Migration of labour from agriculture to other occupations, particularly in industry;
- Deterioration of the quality and the quantity of groundwater, which was the only source of irrigation water; (Madany and Akhter, 1990; Raveendran and Madany, 1991). The increased salinity of groundwater led to the accumulation of salts in the soil and the

subsequent decrease of plant growth; and lastly,

- Absence of a proper drainage network, combined with an impermeable layer of either limestone or sand cemented with gypsum at a depth of about 1.5 m, which caused a gradual rise in the water table, leading to waterlogging and soil salinization in about two-thirds of the cultivated area. Moreover, coastal reclamation activities have disrupted the naturally occurring drainage, resulting in a rise in the water table and loss of vegetation (Madany *et al.*, 1987).

The traditional flood irrigation method employed in Bahrain necessitated the construction of an adequate drainage system; this was accomplished by excavating 35 main drains for an area of 44 km². The effluent from the drainage channels is discharged directly onto the shallow sea coast.

3.1.2.8 COASTAL CONSTRUCTION, MINING AND QUARRYING ACTIVITIES

This category is ranked as the first-priority pollution source affecting the marine environment of Bahrain. Development projects involved extensive dredging and land reclamation operations, which have been carried out in the coastal zone of Bahrain, as in some other ROPME member States.

During the past 60 years, a number of sites along the coast of Bahrain as far south as Sitra Island have been either dredged or reclaimed. These activities increased significantly in the 1970s, serving both industrial and residential purposes. Recently, several new reclamation operations involving large areas, such as the site for the GPIC plant (0.6 km²), an iron ore pelletizing plant (1 km²) and about 12 km of embankments constructed for the Saudi Arabia-Bahrain (King Fahd) causeway, were carried out. More recent reclamation projects were completed, one at Sanábis on the north coast, the second at Budiaya on the north-west coast, and the third on three small is-

lands east of Sitra. The total area reclaimed from the three projects is approximately 3 km². Moreover, several reclamation projects were carried out randomly by the private sector. Changes in the area of Bahrain in the last few years are shown in tables 5 and 6, figure 3 (Al Madany *et al.*, 1991).

Reclamation of land from the sea is relatively inexpensive in Bahrain because the sea is very shallow for a considerable distance from the shoreline. Approximately 2 m of fill, readily available from offshore dredging, is sufficient to raise the level above the highwater mark and permit development. Moreover, the seabed has a sandy, rocky bottom which facilitates development. The government follows a policy of leasing some reclaimed land to industry, the leases range from \$2.1 to \$3.1 per m², or \$1,590 to \$4,750 per year, depending on the location of the site. While this operation seems very profitable when viewed from a standpoint of a simple cost-benefit analysis, in terms of the jobs gained through industrial development, it may not be so if the long-term adverse environmental and social impact is also investigated.

The major adverse environmental effects of the dredging and land reclamation activities carried out in Bahrain are summarized below:

- Damage to the spawning grounds of various marine species that lay their eggs on the bottom;
- Damage to the seagrass beds, mangroves and coral reefs;
- Removal or alteration of the benthos that are the main food source for many commercial fish species, which will result in a smaller fish catch;
- Increased turbidity, locally irritating or clogging fish gills, interfering with visual feeding and inhibiting photosynthesis;
- Changes in the general current pattern, water

movement and water quality in the area;

- Increase in siltation owing to the outslip of fine sediment, both at the cutter head of the dredger and at the outfall end of the discharge pipe. Moreover, thick silt layers make it difficult for fishermen to reach their fish traps, causing them to lose;
- The discharge of fine material during dredging operations, possibly resulting in the release of toxic compounds previously buried in the sediments;
- Damage to barrier traps, long lines, pots and other types of nets;
- Increase in the salinity of groundwater;
- Disconnection of the natural drainage of irrigation water, causing damage to vegetation.

3.1.2.9 PORT FACILITIES

Mina Sulman is the primary port in Bahrain. There is another port on Sitra Island. No information is available on these ports.

3.1.2.10 OTHERS

The atmospheric emission sources in Bahrain consist mainly of power plants, mobile combustion, industrial processes and drastic sources. Vehicle emissions have recently increased significantly owing to the daily influx of thousands of vehicles across King Fahd causeway between Saudi Arabia and Bahrain.

Examination of the data indicates that the highest emission load is that of cobalt (44 per cent), followed by sulphur oxides (SO_x) (23 per cent), nitrogen oxides (NO_x) (17 per cent), hydrocarbon (HC) (9 per cent) and particulates (7 per cent) (table 7) (ROPME, 1997). The highest percentage of contamination (47.1 per cent) results from mobile combustion (71,452 tons/yr). Industrial processes contribute 67,158 tons/

yr (44.3 per cent). Power plants contribute 12,861 tons/yr (8.5 per cent). The contribution of domestic emissions is negligible.

A national air quality monitoring programme began in Bahrain several years ago with the following objectives:

- Monitoring of atmospheric pollutants at a number of geographical locations in Bahrain;
- Provision of daily, weekly, monthly and annual reports on ambient air quality;
- Evaluation of seasonal and geographical trends in ambient air quality; and
- Maintenance of an effective tool for the evaluation of the environmental policies and measures implemented to manage sources of air pollutants.

The results of the data analysis for the period from January 1994 to December 1995 show that:

- Carbon monoxide, sulphur dioxide and nitrogen dioxide concentration levels meet the standards of the Saudi Arabian Meteorology and Environmental Protection Administration (MEPA);
- Higher carbon monoxide levels were recorded at Manama than at other sites, which can be attributed to traffic load affecting the site;
- There is a slight declining trend in the levels of sulphur dioxide (SO₂) levels and inhalable particulate matter from June to the end of the year;
- Inhalable particulate matter (PM₁₀) and ozone levels have exceeded MEPA standards many times during the monitoring period; PM₁₀ peak concentrations occurred at the same time at all sites, which could

indicate that there is no direct source, but rather that the concentrations of it is due to natural dust episodes.

Levels of aromatic petroleum hydrocarbons in the coastal sea water of Bahrain were monitored twice a month in two stations during the period from October 1993 to December 1996. The two stations were located in the north-eastern and northern part of Bahrain and were similar in terms of their possible sources of pollution. The overall mean concentration of petroleum hydrocarbons at station 1 was 4.33 and 3.06 mg/l, expressed as equivalent concentration, of chrysene and ROPME crude oil, respectively, whereas at station 2 the mean was 2.24 and 2.3 mg/l, respectively. The results showed no significant variation in the concentrations of petroleum hydrocarbons between the two stations. Moreover, there were no significant temporal differences between the two areas. Generally, the levels of petroleum hydrocarbons were relatively high between the two areas as compared with other areas in the region, suggesting a chronic oil pollution problem.

Thus, the sources of air pollution in Bahrain are known, and the levels of different air pollutants have been monitored for several years and compared with Saudi Arabia standards. No action has yet been taken, however, to reduce air pollutants especially CO, methane (CH₄) and non-methane hydrocarbons (NMHC) in the vicinity of the petrochemical plants. There is no information available on the formulation and implementation of awareness and education campaigns aimed at the public and at industry.

A summary of liquid industrial waste in Bahrain provided by ROPME (1997) shows that the leading contaminant generated is total suspended solids (TSS) (10,071 tons/yr), followed by Biochemical oxygen demand (8,263 tons/yr), oil (7,819 tons/yr), chemical oxygen demand (Biochemical oxygen demand), (3,670 tons/yr), nitrogen (728 tons/yr), and total dissolved solids (TDS) (163 tons/yr). Car service stations and ballast water contribute most of the oil discharged into the sea in Bahrain. Furthermore, most of the industrial process discharge is oily (ROPME,

1997).

Sources of heavy metals in Bahrain include tanker accidents, ballast discharges, industrial effluents, dumping activities and atmospheric deposition. Data obtained by the former office of Environmental Protection during 1995 on heavy metals and sediments in sea water did not differ significantly from values reported earlier by Linden *et al.*, 1990.

3.1.3 Establishment of priorities

During the workshop on implementation of the Global Programme of Action in the ROPME region held in Bahrain in December 1996, national priority issues were discussed. The Bahraini representatives suggested the following order of priority issues:

1. Physical alteration, sediment mobilization and destruction of habitats;
2. Oils (hydrocarbons) and combustion products (e.g., polycyclic aromatic hydrocarbons-PAHs);
3. Sewage and nutrients;
4. Litter;
5. Heavy metals;
6. Atmospheric deposition;
7. Persistent organic pollutants (POPs);
8. Radioactive substances.

3.1.4 Setting management objectives for priority problems

Management objectives for land-based sources and activities affecting the marine environment fall within the framework of articles 61-64 of the (1975) Law on General Health, the (1993) Law on Protection of Wildlife and the (1996) Law on the Environment. These laws, however, are of a general nature. There

is an urgent need for a specific programme to be established under the Environmental Affairs Ministry of Housing, Municipalities and Environment (EA) which would assess the severity of sources of pollution from land-based sources and activities, explore technologies and methodologies for reducing sources of pollution and address ways in which regional and international organizations could assist in developing and implementing waste management schemes, and the political commitment needed for effective implementation of environmental regulations. Special consideration should be given to coastal construction, oil pollution and solid and liquid wastes. Specific targets and timetables should be set for specific areas, such as the Bahrain Island industrial estate, and the existing regulations should be implemented and reviewed every two to three years.

3.1.5 Identification and selection of strategies and measures

The existing strategies and measures to protect the marine environment from land-based sources and activities must be coordinated. The following strategies have been adopted by EA:

- Establish a database for all sources of marine pollutants from land-based sources and activities;
- Assess the level of stress to which the marine environment is subjected;
- Establish national standards for effluent discharge into the marine environment;
- Implement periodic monitoring and evaluation programmes; and
- Prohibit land reclamation and development in Tublic Bay and the mangrove areas.

Industry is being asked to promote cleaner technology, minimize waste, install pollution control equipment, and increase efficiency and recycling. New development projects are carefully analysed by EA

and, where necessary, the developer is requested to submit an environmental impact statement.

3.1.6 Evaluation of the effectiveness of strategies and measures

The following actions are recommended in order to provide criteria for evaluating the effectiveness of strategies and measures:

- Set targets for reducing or eliminating sources of pollution from land-based activities with specific timeframes for their achievement;
- Emphasize the role of the competent agency (EA) to ensure appropriate implementation of specific activities, either alone or in conjunction with other agencies (such as the Sewerage and Drainage Directorate);
- Conduct training programmes, seminars and workshops on the assessment of land-based sources and activities;
- Undertake public awareness and education campaigns to promote environmentally sound management of land-based sources and activities.

3.1.7 Programme support elements

Many laws relating to environmental protection have been passed in order to meet with rapidly increasing development along the coasts of Bahrain. The first significant measure passed in 1975, was the Law on General Health, which at the time was considered to be one of the most comprehensive laws dealing with human health and the environment. The law consists of 83 articles. Articles 61-64 contain provisions establishing requirements at ports, where ships are not permitted to discharge oil and other pollutants into the water. The disposal of harmful substances in the marine environment is prohibited.

EA was established in 1980 to implement laws and

regulations dealing with all aspects of environmental issues in Bahrain. It was authorized to carry out environmental studies, coordinate with different ministries and propose and amend legislation dealing with the environment. In 1993, another law on the protection of wildlife was passed, giving priority to marine habitats and requesting the national committee for the protection of wildlife to designate protected areas with the cooperation of the different ministries concerned. Accordingly, the Minister of Housing, Municipalities and the Environment issued several decisions prohibiting land reclamation and development in Tubli Bay and establishing protected areas around the Hawar Islands. The most recent law (No. 21/1996) aims to protect the Bahraini environment from all sources of pollution and to halt or reduce environmental degradation. This law is of general scope, not concerned only with the marine environment but also with the terrestrial environment, agricultural crops, natural resources, climate, and so on. In addition, there are several laws which deal with fishery resources and management (i.e., reducing fishing efforts by lengthening the closed season on shrimp, banning some fishing gear, especially fish trawlers, and so on). The following are examples of some successful programmes and activities:

As a result of government efforts and the AE policy of mitigating and minimizing environmental stress and hazards, the discharge of untreated and insufficiently treated wastewater into the sea has been reduced through the expansion of the sewerage system, the installation of treatment plants in large industrial enterprises, the growth of environmentally oriented industries and the improvement of some treatment facilities in various plants;

EA recently requested all industries, through the Ministry of Development and Industry, to perform self monitoring of their effluent and to report the result frequently to EA. This strategy is aimed at ensuring the involvement of all sectors in minimizing emissions into the environment. The role of EA in this regard is to collect random samples so as to ensure quality control and compliance with discharge guidelines;

Effluent guidelines must be followed by all plants discharging their effluent into the marine environment. This will ensure that potentially highly hazardous chemicals are not being discharged into the marine environment (table 8). Moreover, EA and the Ministry of Development and Industry have realized the importance of incorporating the environmental impact assessment (EIA) process for new industries, whereby both parties have recently signed "A memorandum of understanding", which ensures flexibility in the fulfillment of their objectives, taking into account the need to promote industrial investment and sustainable development;

In order to monitor the effects of coastal development and to implement the recommendations on coastal resource management, an inventory of the distribution and conditions of all marine resources around Bahrain was undertaken by means of satellite remote sensing (Vousden, 1988). The inventory was published in two volumes by EA and was supported and financially assisted by the ROPME. Volume II, entitled "Habitat Maps", contains the distribution of more than 200 intertidal and subtidal habitat types around Bahrain, including areas of scientific and commercial importance and areas recommended for protection, conservation and management. This volume also contains a chart giving a more detailed and precise interpretation of the satellite habitat characterization image, in which the number of habitat types has been expanded and their boundaries defined more accurately through the use of additional data from field studies, together with information from bathymetric charts, helicopter overflights, local knowledge, and so on.

Priority zone maps were classified into three priority areas:

- (a) **Full protected status:** the Hawar Islands, Mashtan Island and surrounding reef areas; the western and southern coastline of Tubli Bay;
- (b) **Conservation status:** the east coast reef and seagrass zone for dugong, the northern

edge of Fasht Adhm, the inner northern and eastern parts of Tublic Bay, and the outer reefs of Jarad and Fasht Dibal;

- (c) **Seasonal management status:** the southwestern coastal strip of main islands, the eastern coastal strip (Sitra to Askar), and island nesting sites.

The Sewerage and Drainage Directorate is the authority competent to monitor and control industrial discharges to the sewer system. Preliminary laws have been enacted for this purpose, and the Directorate has a comprehensive sampling, monitoring and analysis programme covering all industrial discharges.

Research institutions in Bahrain have carried out substantial studies of marine resources and provided baseline information on habitats and the environmental impact of dredging and land reclamation. The University of Bahrain has published numerous scientific papers dealing with marine biota. Similarly, the University of the Arabian Gulf has studied several aspects of marine pollution. The Bahrain Centre for Studies and Research and the Environmental Studies Section of the Ministry of Works and Agriculture have been interested in many aspects of the marine environment, so that considerable knowledge is now available on the marine environment of Bahrain.

Thus, legislation and baseline data exist; however, the enforcement of environmental regulations is considered a major problem in Bahrain.

Up to now, the activities proposed by the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities concerning sources of pollution have not been formulated while the sources of pollution are known, an assessment of the sources and the establishment of action priorities have not yet been carried out, National programme deal mostly with pollution monitoring, however, the staff is fully occupied with other environmental issues. It is suggested that activities

proposed by should be discussed at the national level and the formulation of actions, policies and measures should be considered carefully.

3.2 IRAQ

There are numerous scientific publications dealing with different aspects of pollution in the marine environment, especially the Shatt al' Arab region. These deal with sewage and nutrients (Al-Saad, 1980, 1983, 1985, 1987; Al-Saadi *et al.*, 1989; Schiever *et al.*, 1982); pesticides (Dou Abdoul *et al.*, 1989; Al-Saad, 1987); heavy metals (Al-Hashmi and Salman, 1985; Abaychi *et al.*, 1988; Al-Mudafar *et al.*, 1982; Al-Saad and Al-Timuri, 1989); oil pollution (Fayad *et al.*, 1996; Douabul *et al.*, 1997) and fisheries (Siddeek *et al.*, 1997). These scientific publications deal with the level of different pollutants in water, sediments and biota, but provide very little information on the source and quantity of pollutants.

The Iraqi focal point did not attend the two workshops on land-based activities in the ROPME region. Therefore, it is very difficult to provide information on source categories, extent, distribution, impact, and so on. As a first step, the Iraqi focal point must identify different source categories and their order of priority. This should be followed by inventories and an assessment of each source category, as proposed by the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities.

3.3 ISLAMIC REPUBLIC OF IRAN

3.3.1. Introduction

The Islamic Republic of Iran has a total area of approximately 1,650,000 km² with a population of 67 million (1995 estimate). It has over 2,000 km of coastline which is predominantly limestone with some shales and salt domes. Annual rainfall in the coastal region ranges from 100 to 300 mm, mostly falling between November and April. Temperatures reach 45⁰ C in summer and fall to 5-10⁰ C in the winter.

Harrington (1976) divides the coast into ten segments and describes the features of each in some detail. The western half of the coastline contains estuarine conditions, sand dunes, extensive tidal flats and mangroves, with an area of cliffs near the Strait of Hormuz. The eastern most part of the RSA coast has eight offshore islands which extend from Asaluyeh (Bandar Asaluyeh) east to Bandar Abbas in the Strait: Qeshm, Hormuz, Larak, Hengam, Forur, Kish, Hendorabi and Lavan (Sheyk Sho'eyb). All are rocky and sparsely populated and the easternmost are surrounded by substantial coral reefs, although no patch or barrier-like systems have been reported (Marini, 1985). Nineteen coral species were recorded and the best reef development was found on the south-eastern margin of the Hormuz Island. In the Gulf of Oman, offshore depths increase to over 50 m and the coastline has extensive sand dunes, sand beaches and areas of cliffs. The sublittoral has hard substrate, corals and reefs. The large bays at Chah Bahar and Poz in south-eastern Baluchistan are two of the finest bays along Iran's south coast and lie in a region with an extremely rich and diverse marine fauna. Chah Bahar has important seagrass beds, beautiful coral, averages about 6 m in depth and normally has good visibility.

Green turtles *Chelonia mydas* nest in a small number at Bushehr (Bandar Bushehr) 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 Pakistan border (Groombridge, 1982; Ross and Barwani, 1981). There are an estimated 10,000 hectares of *Avicennia marina* along the Iranian coast. The westernmost mangrove stand at Asaluyeh has been badly cut and is rapidly disappearing. The largest stand (6800 ha) is in the Khoran (Khoran) Straits and is included within the 82,000 hectares of Hara National Park (Harrington, 1976). There is a large artisanal fishery in Iran but this is largely based on pelagic, rather than reef species (Morgan, 1985).

The coastal region is divided into four provinces (Khuzistan, Bushehr, Hormuzgan and Sistan-

Baluchistan), with a population of 10-11 million (16-18% of the total population). Many cities and villages are scattered all over the coast and islands, most of them are undeveloped. Population density is 5-25 person/km² except at Bushehr and Bandar-Abbas (200,000 each). Bandar-Imam is the main industrial zone (petrochemical industry). Agriculture is extensive in many coastal areas. Major sources of pollution are urban run-off, sewage, solid waste, industrial effluents and waste, and port activities.

3.3.2. Identification and Assessment of Marine Pollution Sources

3.3.2.1. POWER AND DESALINATION PLANTS

Information available on power stations in Iran indicates that the exploitable potential hydroelectric power is equal to 56,000 mw whereas installed capacity for 1993 is equal to 1,957 mw. The largest gas turbine station for electricity exists in Kuran. There is also information on nuclear power station, however, it is not yet in operation. There is one MSF desalination plant at Bushehr with freshwater capacity of 260, 609 m³ /d, representing 5% of all MSF plants in RSA. There are smaller desalination plants in Bandar Abbas and other coastal areas.

3.3.2.2. SEWAGE TREATMENT FACILITIES

Sewage treatment facilities along the Iranian coast of RSA exist in large coastal cities such as Bandar-Imam, Bandar-Abbas and Bushehr. In large industrial sites (e.g., Khuzistan), treatment facilities exist for sewage. However, capacity of sewage plants and level of treatment are not known. Small treatment plants also exist in less populated sites, however, no information is available on capacity and level of treatment. It is known that raw sewage is one of the main sources of pollution affecting the marine environment in the Iranian coast of RSA, mostly from Bandar Bushehr and Bandar Abbas, as well as Karun River.

3.3.2.3. INDUSTRIAL FACILITIES

Bandar-Imam is the major industrial city in the Iranian coast, where petrochemical plants exist. There is also a large petrochemical plant in Khore Musa, and mining activities at Sar Cheshmeh where copper plant exists (the largest in the Middle East). In these industrial cities, there are power plants and natural gas plants. Reception facilities exist for garbage, sewage and solid waste, however, the amount of waste and the level of treatment are not known. There are also industrial facilities at Kish, Qeshm, Kharg, Lavan and Sirri Islands, mostly oil terminals and oil industries. Offshore facilities are mainly oil platforms (13).

Major sources of pollution in industrial sites and large cities (e.g., Bushehr, Bandar-Abbas and Bandar-Imam) are urban run-off, sewage, solid waste, industrial effluents and waste and port activities. The largest contribution to the industrial liquid pollution is BOD, followed by SS and oil (ROPME, 1997).

3.3.2.4. SOLID WASTE

No information available.

3.3.2.5. RECREATION AND TOURISM FACILITIES

The main recreation and tourism facilities are in Kish and Qeshm Islands where Iranians from inland usually visit to enjoy nature and make use of tax-free shopping.

3.3.2.6. OIL REFINERIES

The oil refinery in Bandar-Abbas is known to be the largest refinery in the world. Many of oil refineries were damaged during the Iraq/Iran war, some have been renovated and others under construction. The Bandar Abbas oil refinery started working in early 1998.

3.3.2.7. AGRICULTURAL ACTIVITIES

Along the Iranian coast of RSA, the following are the major rivers: Karun ($700 \text{ m}^3/\text{sec}$, > 50% of the whole watershed). Jarrahi ($66 \text{ m}^3/\text{sec}$), Zohreh ($74 \text{ m}^3/\text{sec}$), Helleh ($31 \text{ m}^3/\text{sec}$), Mond ($42 \text{ m}^3/\text{sec}$), Kal ($15 \text{ m}^3/\text{sec}$), and Minah ($11 \text{ m}^3/\text{sec}$). Water consumption in coastal areas are as follows: rural = $268 \times 10^6 \text{ m}^3 = 33\%$ of the country, urban = $785 \times 10^6 \text{ m}^3 = 25\%$, industry and mines = $383 \times 10^6 \text{ m}^3 = 40\%$ and agriculture = $23,448 \times 10^6 \text{ m}^3 = 35\%$ of the country. Agricultural activities in the coastal provinces are considered the largest in the whole RSA. It is expected that such agricultural activities have considerable impact on the marine environment of RSA, mostly due to the use of fertilizers and pesticides. However, the extent of such impact is not known.

3.3.2.8. COASTAL CONSTRUCTION, MINING AND QUARRYING ACTIVITIES

There are numerous aquaculture facilities, mostly in Bushehr where there exist many shrimp and finfish farms. Metallic ferric and copper mining activities exist in Hormuz island and at Sar Cheshmeh. Sedimentation is a serious problem where it is transported by rivers in the north and dust fall-out in the south. In addition, urban run-off, raw sewage and solid waste are polluting the marine environment of RSA. However, the level of pollution is not known.

3.3.2.9. PORT FACILITIES

Port facilities exist in commercial/industrial cities at Chah-Bahar, Bandar-Abbas, Bandar Lengeh, Bushehr, Khoramshahr, Kish Island and Bandar-Imam. Oil terminals exist in Sirri Island, Kharg Island, Lavan Island and Mahshahr. Facilities to receive wastes exist in these sites. There is a GEF (Global Environment Facility) project to study the national requirements for reception facilities and to improve the existing ones. However, the major sources of pollution are the oily ballast water and oily wastes. It is known that the Iranian coast, like the rest of RSA coasts, is a major tanker and shipping area for goods entering and leaving the coun-

try. These commercial ports are used for loading petroleum and unloading industrial and commercial products throughout the Region. However, no information is available on the amount of ship ballast water.

3.3.2.10. OTHERS

The industrial wastes discharged into the RSA from Iranian side were estimated at 8,020 t/yr (103,600 x 10³ m³ /yr) (rapid assessment report in 1984). The main contaminants from industrial processes were oil, N and BOD. Atmospheric emissions were 29,048 t/yr, mostly CO² (45%) from both Bushehr and Bandar Abbas (ROPME, 1997). Sources of atmospheric emissions are stationary (46.4%) and mobile (53.6%) combustion. Domestic liquid wastes discharged into the RSA, were 12,916 t/yr (1984 estimate) mostly from Bandar Bushehr and Bandar Abbas, as well as Karun river.

3.3.3. Establishment of Priorities

Based on available data, the following order of priority source categories are suggested:

1. Physical Alteration, Sediment Mobilization and Destruction of Habitats
2. Oils (hydrocarbons) and Combustion Products (e.g., PAHs)
3. Sewage and Nutrients
4. Persistent Organic Pollutants (POPs)
5. Litter
6. Heavy Metals
7. Atmospheric Deposition
8. Radioactive Substances

3.3.4. Setting Management Objectives for Priority Problems

It is suggested that a programme to be established within the Department of the Environment (DOE), for the protection of the marine environment from land-based sources and activities. This programme needs to be developed with specific targets, areas and timetables. In addition, actions should be defined, based on the recommended approach of source category as suggested by GPA.

3.3.5. Identification and Selection of Strategies and Measures

- Establish database for all land-based sources of marine pollution. Selected areas suggested, based on available information, are Bandar Abbas and Bushehr, as well as Karun river.
- Assess stress on the marine environment in these areas.
- Establish national standards for effluent discharge into the marine environment.
- Implement periodical monitoring and evaluation programmes.
- Update the survey of land-based activities.

3.3.6. Evaluation of Effectiveness of Strategies and Measures

Effective strategies and measures require strong political will, public support and multinational cooperation. The role of DOE, particularly that of its provincial offices along the RSA, should be emphasized to ensure appropriate implementation of specific activities. This can be achieved by providing financial and training facilities specific for land-based sources affecting the marine environment. Furthermore, public awareness programmes should be provided.

3.3.7. Programme Support Elements

I.R.Iran is an active member of the Regional Organization for the Protection of the Marine Environment

(ROPME). The Department of the Environment has presented details of its policies regarding marine discharges and permissible levels of effluents (Keyvani, 1984). The organizational structure of the government with regard to marine and environmental monitoring is also given. The main law covering conservation within Iran is the Environmental Protection and Enhancement Act of 1974 (IUCN/UNEP, 1985). Early descriptions of environmental management and protection are given by Firouz (1976) and Firouz et.al., (1970).

I.R.Iran has taken great strides in the field of environmental conservation. This is most notable in the system of national parks, national nature monuments, wildlife refuges and protected areas, one of the most extensive systems of its kind in any developing country. UNESCO has since designated nine of these areas as Biosphere Reserves and four Iranian national parks as World Cultural and Natural Heritage.

Iran has also given considerable attention to the natural ecosystem of its coasts. Four areas in the Kuwait Action Plan Region, namely, the tidal mud - flats of southern Khuzestan, the Khouran Straits, the deltas of Rud-e-Shur, Rud-e Shirin and Rud-e Minab, and the deltas of the Rud-e Gaz and Rud-e Hara, have been designated as wetlands of international importance and have been included in the list appended to the Ramsar Convention on Wetlands of International Importance especially as Waterfowl Habitat.

Iran has further set aside five marine reserves in the Kuwait Action Plan Region. These are:

- i) Shadegan Protected Area which contains some 75 Km of tidal mud-flats of great importance for wintering of tidal shorebirds;
- ii) Khark and Kharku Islands notable for their large breeding colonies of seaturtles and terns;
- iii) Sheedvar Island, off the west end of Lavan Island, again the site of very large

sea-turtle and sea-bird colonies, and an area of excellent coral reefs;

iv) Hara National Park in the Khouran Straits, with its very extensive and complex mangrove forests and large waterfowl populations; and

v) Bahu Kalat Protected Area which includes 55 Km of the Baluchestan coast bordering Pakistan, remarkable for its fauna and flora and its outstanding scenery.

3.4 KUWAIT

3.4.1 Introduction

Kuwait lies in the northeastern part of the area. It has approximately 500 km of coastline. Two main seasons mark the year, with a long, hot, dry summer and a warm winter with little rainfall. More specifically, the climate is characterized by:

- (a) Warm, sunny days and cold nights with maximum temperatures of 21° C in December, January and February;
- (b) Warm days and cold nights with sudden drops in temperature and a maximum temperature of 24° C in March, April and May;
- (c) Very hot long sunny days with temperatures reaching 50° C during June, July, August and September. Dry northwesterly winds cause occasional sandstorms which reduce visibility to a few metres. Humidity is relatively high in the coastal area;
- (d) Warm days and cool nights with sudden showers and average temperatures of 26° C in October and November.

This climate is characterized by strong thermal in-

versions, which trap pollutants near the ground and promote their accumulation and long distance dispersion. Moreover, sandstorms are an important natural source of air pollution.

According to a 1995 estimate, Kuwait has a population of 1,547,000 (World Resources, 1996-1997). Kuwait has an area of 18,818 km². and comprises five governorates, namely Kuwait City, Hawalli, Al-Ahmadi, Al-Jahrah and Farwaniya. Within these governorates there are a number of populated areas with industrial and oil production activities, as follows: Failakah, Al Liyah, Al-Jahrah, Doha, Shuwaikh industrial area, Al Rai, Kuwait City, Solaibiya, Amghara, Sabhan industrial area.

3.4.2 Identification and assessment of main pollution sources

3.4.2.1 POWER AND DESALINATION PLANTS

There are five major power and desalination plants and 13 smaller power stations. The total output of electricity is about 18,000 GW/h, whereas the production capacity is 7,000 MW (ESCWA, 1997). Consumption per capita is 12,000 kW. The major desalination plants are located at Doha, Shuwaikh, Shuaiba and Al Zoor, with a total freshwater capacity of 1,050,126 m³ /day, representing 20 per cent of all MSF plants in the area.

3.4.2.2 SEWAGE TREATMENT FACILITIES

There are three major sewage treatment plants at Ardiya, Rekha and Jahrah. The total daily volume of sewage received by these plants is 275,000 m³ and the total treated sewage effluent is about 240,000 m³/d. These plants receive sewage from about 70 per cent of Kuwait's coastal population and 14.6 per cent of the waste water from industrial sources (EPA, 1997). The impact of sewage outfalls on marine sediments is most noticeable in the intertidal zones.

The current capacity of the existing plants will be doubled over the next few years, and a new facility

will be built to meet a sewage flow target for the year 2025 of about 1 million m³/d (Middle East Environment, 1995).

One year after the Gulf War crisis, approximately 52 intertidal (surface) sediments were analysed in order to assess sewage and oil pollution (Al-Omran, 1996). The data indicated high levels of organic sewage-derived material and biodegraded petroleum hydrocarbons, with relatively low levels of n-alkane and PAHs. In general, the high levels are characteristic of Kuwait Bay. The overall distribution patterns of sewage-derived material suggests that the prevailing tidal currents contribute to faecal contamination of bathing beaches.

3.4.2.3 INDUSTRIAL FACILITIES

Industry began in Kuwait in the early 1960s and is currently concentrated in the Al Shuaiba area about 40 km south of Kuwait City. Industrial activities include food industries, petrochemicals, fertilizers, plastics, other chemicals, cement, minerals, and others (Anon, 1996). Extractive industries in Kuwait centred on oil (2 million barrels/day) and natural gas (5,993 billion m³), represent 39.2 per cent of GDP, while manufacturing industries contribute only 10.6 per cent of GDP (ESCWA, 1997).

These industries generate various types of pollutants (oil, cooling waters, Bbiochemical oxygen demand and suspended particles (Table 9) which are discharged into the marine environment. The coastal area between Al-Jahrah and Shuaiba receives most of the urban waste and industrial effluents (EPA, 1997). Nevertheless, legislation has been passed to prevent and reduce air and marine pollution, including through monitoring programmes.

3.4.2.4 SOLID WASTE

Solid waste loads from industrial sources in Kuwait total 293,035 tons/yr, or 23 per cent of all industrial solid waste in the area, (ROPME, 1997). Oil sludges contribute 49,514 tons/yr. Solid waste loads from domestic sources are estimated at one million tons/

yr (ROPME, 1997). These data were collected during 1984-1987. Other recent estimates of the industrial solid waste generated in the Shuaiba area alone puts it at 694,000 tons/yr. Some factories recycle or make use of these wastes in manufacturing certain products (Anon, 1996).

Landfilling is the most common method of solid waste disposal. Landfills are needed for household, industrial and commercial wastes. If the government of Kuwait continues to rely on landfill as the ultimate disposal site, contamination of ground and subsurface water is the most likely consequence, since the leachate emitted by a landfill contains various types of pollutants. Adequate control measures are required to minimize the hazards of landfill leachate.

The existing landfills in Kuwait accept wastes from domestic and industrial sources at the rate of 500,000 gal/d of industrial liquid, 3,600 gal/d of sludge, 4,000 tons/d of domestic wastes and 2000 tons/d of construction wastes (Al-Muzaini and Muslimani, 1994). The Shuaiba landfill is currently operated by the Kuwait Municipality and is used for dumping of household refuse and industrial wastes. The Shuaiba landfill receives about 500 tons/d, occupies approximately 1,500 m², and is located on sandy limestone soil. The landfill has operated since 1980. Based on forecasts of the quantity of waste generated and of future population growth, an increasing amount of domestic and industrial wastes, will be generated. The quantity of domestic waste projected for the years 1994 and 1998 was 1,500,000 tons/yr and 1,700,000 tons/yr, respectively (Al-Muzaini and Muslimani, 1994).

Four monitoring wells at a distance of 500 m were constructed the Sulaibiya landfill area. Leachate samples were collected twice a month from March to May 1994 (Al-Muzaini, 1995). Samples were analysed and the concentration of pollutants in leachate, including heavy metals (cadmium, nickel, palladium and V), conventional pollutants (Bbiochemical oxygen demand, chemical oxygen demand and total organic carbon), and nutrients (ammonia and NO₃), was determined. Water tempera-

tures ranged from 23° C to 25° C, while the pH values of the leachate varied from 6 to 9. Chemical data on Bbiochemical oxygen demand, chemical oxygen demand, total organic carbon and heavy metals showed that concentrations of contaminants were higher in downstream wells than in upstream wells. The leachates are not expected to affect the groundwater quality since the landfill area is distant from the water supply wells.

Based on the national report on the state of the environment, the following quantities of industrial wastes were generated: 1. Refining industry: 1,140 tons Bbiochemical oxygen demand/y; 2. food industry: 235 tons Bbiochemical oxygen demand/y; and 3. agro-industry: 3,030 tons Bbiochemical oxygen demand/y.

The handling of household refuse by the Kuwait Municipality has passed through several phases. Up to the 1950s, disposal took place on uncontrolled land and through coastal dumping. During the following years, household refuse was disposed of first via open-burning dumps and then transferred to disposal sites by mechanized collections: later in the 1980s it was disposed of in safe landfills. There are still problems, however, in the execution and control of disposal to a sanitary landfill (Middle East Environment, 1995). The estimate of household refuse currently generated in Kuwait is about 2,000 tons/day. This amount was projected to increase to 3,000 tons/day by the year 2010. Currently, the refuse is landfilled mainly at two sites, Sulaibiya and Abbassia.

The feasibility of establishing composting and shredding plants to recycle household refuse and metal scrap waste was assessed in 1988. Cost and economic evaluation models were developed and applied to the identified technologies to determine their feasibility. Based on the study results, it was recommended that consideration should be given to establishing a composting industry as well as metal scrap recycling. The characteristics of domestic waste were analysed; it contains a considerable amount of minerals, but the heavy metal content is low.

3.4.2.5 RECREATION AND TOURISM FACILITIES

No information is available on recreation and tourism facilities in Kuwait; however, tourism is based both on local residents and on expatriates. Facilities include diving centres, water sports, fishing centres, parks and gardens, golf courses, yacht clubs, racing clubs and many others. The area between Ras Al Zor and Al Khiran has a large recreational complex.

3.4.2.6 OIL REFINERIES

The total output of the oil refineries in Kuwait is 790,000 barrels/day, representing 39.5 per cent of 1995 oil production (ESCWA, 1997). With the expansion of oil-refining capacities, it is expected that this figure will increase in the next few years to 44.5 per cent.

3.4.2.7 AGRICULTURAL ACTIVITIES

The total cultivated area is estimated at 5,000 ha, with an output of \$72 million, or 0.3 per cent of GDP (ESCWA, 1997). Most of this area is irrigated by water from groundwater wells. Imported agricultural products are estimated at \$1.14 billion.

3.4.2.8 COASTAL GEOMORPHOLOGY AND COASTAL CONSTRUCTION, MINING AND QUARRYING ACTIVITIES

The extreme aridity of the land and the lack of agricultural resources traditionally forced the people of Kuwait to concentrate on the coastal zone. Among other factors, the coastal geomorphology was instrumental in forcing them to settle in particular locations. The extensive *sabkhats* (or salt-flats) and tidal mud-flats to the west and north of Kuwait Bay, for example, continued to impede urban occupation of these areas (EPA, 1997).

Today, the urban population of Kuwait is concentrated along the southern coastline of Kuwait Bay between Al-Jahrah and Ras Al Ardh, and extends southwards along the coastline to Fahaleel. The area

immediately south of Fahaleel is occupied by the enlarged Shuaiba industrial area and other industries, whereas the coastal strip of the area further south is inhabited.

The coastal area between Al-Jahrah and Shuaiba receives the majority of urban waste and industrial effluents from four oil-loading terminals at Shuaiba, petrochemical and other industries at Shuwaikh, and Shuaiba, power plants at Doha, Shuwaikh and Shuaiba, and numerous storm water and sewage outfalls throughout the area. The area between Ras Al Zor and Al Khiran is also becoming increasingly populated and now has an oil-loading terminal, two power plants and a large recreational complex (EPA 1997).

The coastal area is affected to varying degrees. Considerable sections of the intertidal areas around Kuwait City and some portions of the southern coast have been reclaimed. Most land reclamation, particularly in the earlier stages, started with the dumping of heterogeneous fill, mostly construction waste material, on the upper tidal flat and along the beach front. Natural deposits were generally used to cover this fill. Land reclamation disturbed the natural hydrodynamic conditions of the coastal water, and the fill material is not stable under native beach processes, so significant erosional problems have developed along most of the fill edge of the reclaimed areas. Fine material from the fill edge has been washed out by wave action and redistributed along the tidal flat, leaving coarse debris that includes blocks and boulders on the beach. Dredging is usually associated with filling activities. 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 (Al-Bakri, *et al.*, 1985). Such a modification would naturally be accompanied by the loss of the ecosystem and the death or migration of the fauna of the affected areas. Other, less serious effects include increased erosion along the affected areas and the destruction of the area's natural beauty.

Seven months of occupation by the Iraqi invaders has had a major impact on beach stability and littoral drift. Al-Sarawi and Bu-Olayan (1996) studied the disturbance of the shoreline configuration in relation to trenching, damage to the coastal dunes, sand and beach rock removal, dredging, blocking, the destruction of coral reefs, fencing, the explosion of oyster banks and the placement of barbed wire around all intertidal flats. Beach profiling, grainsize analysis, photo interpretations, sediment transport and longshore current have, together with coastal processes and hydrodynamics, revealed serious damage to the shoreline configuration. The most apparent impact was the disturbance of the sediment balance, which aggravated the erosion and deposition problems, changes in the beach configuration, major cliff retreat, formation of coastal ridges and siltation increase in most of the tidal flats. Rehabilitation processes and the clean-up of the shoreline have resulted in further damage to beach stability and to the coastal environment.

3.4.2.9 PORT FACILITIES

While detailed information on port facilities in Kuwait is not available, there are four oil-loading terminals at Shuaiba, as well as petrochemical and other industries. There is also an oil-loading terminal in the area between Ras Al Zor and Al Khiran (EPA, 1997). Thus, the majority of oil spills occur at Shuaiba and, to a lesser extent, at Ras Al Zor. The highest tar ball densities were observed at Ras Al Zor (EPA, 1997).

3.4.2.10 OTHERS

The potential for atmospheric transport of pollutants is enormous because of the high air temperatures, extreme aridity, and frequent dust storms. Processes affecting the aeolian transport of particulate matter may affect the transport of pre-contaminated soils from the urban and industrial centres of Kuwait to the marine environment. Contaminants in these soils may be derived from a variety of sources, for example, lead from car exhaust emissions. The lead levels in local soils have been found to be higher near

a busy street than in soils only a few metres away (Zarba *et al.*, 1985). Other pollutants, however, may also enter the marine environment from more distant sources, for example, pesticides from agricultural lands in the Mesopotamian region.

Data on atmospheric emissions from all industrial sources in Kuwait show that 49 per cent of the contaminant load (610,601 tons/yr) results from sulphur oxides. CO contributes an additional 28 per cent (about 350,000 tons/yr). Nitrogen oxides particulate and hydrocarbon contribute 9.8 per cent and 5 per cent respectively (ROPME, 1997).

An analysis of atmospheric pollution from different industrial sources in Kuwait shows that mobile combustion (34 per cent), oilfields and export terminals (30 per cent) and power desalination plants (20 per cent) contributed the largest quantity of industrial atmospheric emissions. The leading contaminant from mobile combustion is CO (337,622 tons/yr). Sulphur oxides is the leading contaminant from oilfields and export terminals (372,800 tons/yr) and power and desalination plants (207,940 tons/yr). The power and desalination industry also produces 62,060 tons/yr of nitrogen oxides atmospheric emissions.

The average monthly dust salting in various parts of Kuwait is frequently in the range of 10 to 100 g/m² (ROPME, 1987). Such figures are probably the highest in the world (Linden *et al.*, 1990).

During the period from January to November 1991, everyone in Kuwait came into contact with oil-related contaminants borne by the air, water, food, dust and aerosols. Although pollution sources were controlled, the human health risks associated with massive environmental contamination must not be ignored. Because carcinogenic PAHs are among the most harmful and persistent components of Kuwaiti crude oil, potential contact between the human body and these chemicals, or their absorption through an environmental medium, is a real threat. Al-Yakoob (1996) estimated the risks associated with exposure to PAHs through breathing in oil dust and consum-

ing fish contaminated through oil spills.

Industrial effluents may contain inorganic pollutants: for several years, for example, a salt and chlorine plant at Shuwaikh was believed to contribute significant quantities of mercury to the nearby marine environment. The results of water, sediment and biota analysis indicated a localized source of mercury pollution in that area. Discharges from this plant have recently been halted (EPA, 1997).

The total quantity of industrial liquid wastes discharged into the sea is 82,072 tons/yr, representing 46.9 per cent of the industrial liquid wastes of all the ROPME countries. They include suspended solids (43,324 tons/yr), oil (26,905 tons/yr), Bbiochemical oxygen demand (15,045 tons/yr) and nitrogen(2,798 tons/yr). The liquid domestic waste data from the rapid assessment report of Kuwait (1994-1996) indicate that the highest contaminant load results from chemical oxygen demand (2,152 tons/yr), followed by suspended solids, total Kjeldahl nitrogen (TKN), P and Bbiochemical oxygen demand. The waste load resulting from waste-water treatment plant effluents in Kuwait is shown in table 10. The Ardiya treatment plant produces 70 per cent of the total waste load, the Rikka plant 29.6 per cent and the Al-Jahrah plant a further 0.4 per cent.

3.4.3 Establishment of priorities

During the workshop on implementation of the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities for the Protection of the Marine Environment from Land-based Activities in the ROPME region, the Kuwaiti representative suggested the following order of priority for source categories:

1. Sewage and nutrients;
2. Oil (Hydrocarbons) and combustion products;
3. Physical alteration, sediment mobilization and destruction of habitats;

4. Persistent organic pollutants (POPs);

5. Litter;

6. Heavy metals;

7. Atmospheric deposition;

8. Radioactive substances.

3.4.4 Setting management objectives for priority problems

It is suggested that a programme on land-based sources and activities affecting the marine environment of Kuwait be established within the Environment Public Authority (EPA). The objectives of this programme should be directed towards assessment of the scarcity of pollution from land-based sources and activities, exploration of technologies and methodologies for reducing pollution sources, implementation of a waste management scheme and enforcement of environmental regulations to limit or prevent pollution from land-based sources. An inventory of all pollution sources should be updated and given first priority for action.

Attention should be given to the first three categories in the order of priority, namely, sewage and nutrients, oil and combustion products and physical alteration, sediment mobilization and destruction of habitats. Specific affected areas should be selected for a complete inventory of all pollution sources. It is suggested that the Shuaiba industrial estates where industrial effluents and sewage are posing real threat to the marine environment be selected as a target. A master plan is being developed for waste water management at the Shuaiba industrial area, where treated water will be used for irrigation and nothing will be discharged into the marine environment. Emphasis should be given to the issue of land reclamation activities which pose a serious threat to the intertidal zones.

3.4.5 Identification and selection of strategies and measures

According to recommendations in the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities, EPA is required to identify specific measures:

- (a) To promote sustainable use of coastal and marine resources and to prevent/reduce degradation of the marine environment;
- (b) To modify contaminants or other forms of degradation after generation; and
- (c) To prevent, reduce or ameliorate degradation of affected areas. EPA is also required to formulate requirements and incentives for action to comply with the measures suggested, establish institutional arrangements with the Authority in order to carry out management tasks, identify short and long-term data collection and research needs, develop a monitoring system and, lastly, identify financing sources to cover the administrative and management costs of the strategies and programmes.

Industry should be asked to promote cleaner technology, minimize waste, install pollution control equipment, increase efficiency and recycle. New development projects should be carefully analysed, and the developer should be requested to submit an environmental impact assessment.

3.4.6 Evaluation of the effectiveness of strategies and measures

Effective strategies and measures require a strong political will, public support and multinational co-operation. EPA has been active in providing appropriate strategies and measures to implement specific activities, either alone or with other agencies. However, those strategies and measures must be evaluated every few years.

3.4.7 Programme support elements

Kuwait is one of the ROPME countries which has developed and promulgated many laws and regulations for the protection of its marine environment and resources, such as the 1984 Prohibition of Marine Pollution by Oil Act, the 1972 Establishment of the Kuwait Municipality Act, the 1973 Protection of Oil Resources Act, the 1980 Protection of Fisheries Resources Act, the 1980 Protection of the Environmental Act, the 1980 Establishment of Environmental Protection Council Act, and the 1995 Environmental Public Authority Act. Kuwait has also either signed or ratified many regional and international conventions, such as the ROPME Convention, the United Nations Convention on the Law of the Sea and the Convention on Biological Diversity.

While the existing legislation is adequate to protect the marine environment from land-based sources and activities, there is a need to revise it in order to cope with the challenges posed by increasing development projects (Al-Awadi, 1996). Information on government institutions dealing with the marine environment is set forth below.

- (a) **Environmental Public Authority (EPA)**, which was established in 1996 and is under the authority of the Kuwaiti Cabinet. Its responsibilities include:
 - (i) Preparing, participating in and supporting environmental research and studies;
 - (ii) Following up all issues related to international environmental Law;
 - (iii) Monitoring of environmental and public awareness programmes;
 - (iv) Coordinating with all government agencies dealing with environmental services;
 - (v) Approving environmental impact

studies for all development projects;

(vi) Preparing a national environmental emergency plan;

(vii) Preparing and implementing environmental training programmes;

(viii) Preparing an annual environmental report.

EPA produced the 1997 *State of the Marine Environment Report for the State of Kuwait* in which the main pollutants discharged into the marine environment from land-based sources were assessed and prevention and control measures were provided.

(b) **Kuwait Institute for Scientific Research**, whose Environmental Science division has carried out several applied research projects and is active in the following areas:

(i) Fate and toxicity studies (Bioassay laboratory of the Mariculture and Fishery Department);

(ii) Establishment of comprehensive databases containing oceanographic data and data on oil and non-oil pollutants;

(iii) Preparation of environmental impact assessment studies in such areas as: desalination and power plants; intertidal zone; development projects (navigation channel, site selection, pisciculture); Gulf war consequences; bacterial pollution; and coastal modelling;

(iv) Participation in the Kuwait Action Plan at the regional and national levels;

(v) Provision of training in the above-mentioned fields;

(a) **The Environment Protection Centre (EPC)**, stationed at the Shuaiba Area Authority, which is responsible for conducting monitoring programmes covering the state of the marine environment and air quality for the vicinity of the expanded industrial area;

(b) **The Public Authority for Agriculture and Fisheries**, which conducted monitoring programmes for physical and biological oceanography in the late 1970s. At present, it concentrates only on fish stock dynamics. There is a high level of cooperation between the Authority and the Kuwait Institute for Scientific Research.

3.5 OMAN

3.5.1 Introduction

Oman occupies the south-eastern corner of the Arabian Peninsula between 16° 40' and 26° 20' north latitude and 51° 50' and 59° 40' east longitude. It has a coastline extending more than 1,700 km from the Strait of Hormuz in the north to the border of Yemen in the south. Most of this coastline is sandy beach or mixed sand and shallow rocky areas. Coastal features include mangroves, coral reefs, wadis, offshore islands, sea-grass beds, cliffs, beaches and dunes. Oman has a huge exclusive economic zone of about 300,000 km² and is bordered by three seas: the Gulf, the Gulf of Oman and the Arabian Sea. The total area of Oman is approximately 300,000 km², and it is the second largest country in the Arabian Peninsula. The population is estimated, at 2,000,000. Most of the population is engaged in agriculture, trade, fishing, traditional industries and handicrafts. The estimated average annual growth rate is about 3.5 per cent.

The climate of the Omani coastal waters is dominated by the seasonal monsoon which affects winds, cloud cover and precipitation throughout the country. Southerly and south-westerly winds dominate during the summer monsoon period from May to

September, with the monsoon reaching its peak during July and August. North-easterly winds dominate during the winter monsoon which extends from November to March. While the climate varies from one area to another, it is generally hot and arid. The characteristic features of Oman's coastal waters are low rainfall (under 100 mm/yr), high air temperature (average 27° C/yr), relative humidity (over 70 per cent) and evaporation rate (over 3,000 mm/yr). Rainfall occurs mostly between February and May, thereafter, there is little rain, except in the southern part of the country, where heavy, regular rainfall occurs between June and October (Fouda, 1995a).

Information on the industry in Oman is provided every year by the Ministry of Commerce and Industry. Industrial estates are located at sites far distant from the coast, at Rusayl (Muscat) and Sohar. There are plans for industrial estates at Sur and Khasab (Musandam). The Industrial Statistics and Information Centre provides valuable information for the assessment of land-based sources affecting the marine environment.

Oman has taken a number of sound initiatives to link its rapid socio-economic development to the planned protection of natural resources. Many environmental issues have been addressed through royal decrees, and controlling authorities and infrastructure mechanisms have been put in place. Examples of such these conservation efforts include the Conservation of the Environment and Prevention of Pollution Act (Royal Decree 10/81, amended by Royal Decree 7/89), the requirement that all private and governmental projects must have an Environmental Permit, the preparation of the national conservation strategy, the coastal zone management plan, the establishment of the marine protected areas, the coral reef management plan and programmes on monitoring of marine pollution, environmental awareness, habitat restoration and many others.

3.5.2 Identification and assessment of main pollution sources

3.5.2.1 POWER AND DESALINATION PLANTS

The first large project to provide electricity in any quantity was the construction of the Al Ghubr power station near Muscat in 1976, with an initial capacity of 2.5 MW. The first major extension was completed in 1983, raising the capacity to 287 MW. The latest expansion, with the addition of two gas units, with a 190 MW capacity, has raised productivity to 500 MW (Ministry of Information, 1996). There are 31 power stations with a total installed capacity of 1,662 MW, using the following sources of energy;

Steam: 100 MW	=	6.1 per cent
Gas: 1151 MW	=	69.5 per cent
Diesel: 405 MW	=	24.4 per cent.

The current capacity of the largest desalination plant at Al Ghubr is 29 million gallons per day, which will soon increase to 35 million gallons per day. Currently, about 75 per cent of water consumption in the Muscat area is provided by the Al Ghubr desalination plant complex, while the other 25 per cent comes from groundwater.

Outside the greater Masqat area, there are a total of 14 government-owned desalination plants, located in Musandam, Ash Sharqi-jah (Sur and Gulf of Masirah) and Al Wasit (table 5). Their production capacities vary from 500 m³/day (Mahawt) to 250,000 m³/day (Sur). In addition, there is a considerable number of privately owned desalination plants; however, their distribution and production capacity are not known. Current, and future estimated domestic and industrial water needs in Oman are shown in table 12.

It is reported that industrial liquid wastes are not discharged into the marine environment. Cooling water from power stations and hypersaline water from desalination plants are normally discharged, but no figures are provided. Liquid effluent standards for

disposal into the marine environment (table 13) do not include water temperature and salinity.

3.5.2.2 SEWAGE TREATMENT FACILITIES

Sewage is treated by the activated sludge extended aeration process. The water is usually then filtered and sterilized. Much research has been conducted over recent years into different methods of treatment. Several government-designed waste sterilization ponds with seed-bed tertiary treatment are now being installed in order to speed up the provision of treatment facilities in some rural areas (Al-Sabahi, 1997).

The total capacity of all existing sewage treatment facilities in most coastal cities is currently sufficient to treat the domestic waste-water with an almost negligible impact on the marine environment. There are plans to improve the existing sewage facilities and cope with the expected demands by the year 2010. The importance of waste-water reuse in water management is emphasized; the Government has supported many national, regional and international conferences on the subject. Sewage treatment plants are operated by a variety of agencies and private developers. These include the municipalities, the Royal Oman Police, the Ministry of Defense, the Ministry of Health, private developers and individuals (Al-Sabahi, 1997).

There are currently some 250 waste-water treatment plants operating in Oman. Apart from a few centralized facilities (in Muscat, Sur, and Sohar), the majority of treatment plants are of a localized nature and are site-specific, belonging to individuals, the more modern housing developments, or urban areas associated with the major hospitals, colleges, government premises, hotels, industrial estates and security for homes and private housing compounds (Al-Sabahi, 1997). The treatment plants currently in use range in capacity from 8 m³/day (package-type plants) to civil engineering units of 15,000 m³/day (Darsait, Muscat). In total, these generate some 28.9 million m³ per year of reclaimed waste-water. Of this total, 21.5 million m³/yr is reused for irrigation (74.4

per cent), 7.2 million m³/yr is reused for aquifer recharge via soakaways (24.9 per cent), 0.1 million m³/yr goes to industrial reuse, and the remainder is discharged into the sea.

There are 12 waste-water treatment sites which discharge their effluents into the marine environment. They are scattered all over the coasts of Oman (Musandam, Goat island, Masirah island, Muscat and Sur). The daily discharge into the sea is very low, ranging from 8 m³/day to 271 m³/day, except at one site in Darsait, Muscat, where from this plant's daily production of 10,800 m³/day of treated effluent about 2,000 – 3,000 m³/d are surplus to irrigation requirements in the winter months December to February. Thus an annual total of up to 270,000 m³ is discharged to the sea. Liquid effluent standards for disposal into the marine environment in Oman (Ministerial Decision No. 7184) are shown in table 13.

The current production of treated sewage effluent in Oman is estimated at around 70,000 m³/d (table 14). The future production of treated sewage effluent by the year 2010 is estimated at about 445,000 m³/day (Al-Sabahi, 1997) (table 15).

Waste-water standards for treated sewage effluent were defined by the MRME in Ministerial Decision No. 145/93 of 13 June 1993, containing regulations for waste-water reuse and discharge. The maximum quality limits are presented in table 16. In terms of microbiological quality, the waste-water standards in the table follow closely the recommendations made by the World Health Organization (WHO, 1989). In terms of the non-biological indicators, the water quality for application type A is close to WHO supply water quality with adjustments to suit its agricultural use.

3.5.2.3 INDUSTRIAL FACILITIES

Extractive industries (850,000 barrels/d of oil, 7.24 billion m³ of natural gas) contribute 40.4 per cent of GDP, whereas manufacturing industries (food and beverages, chemicals, metals, wood, textiles, paper, non-metallic mineral products, and so on) contrib-

ute 4.8 per cent of GDP. Industrial estates are located at sites quite distant from the coast, at Rusayl (Muscat) and Sohar. There are large projects under way or planned around the coastal cities of Sur, Salalah and Khasab, including liquid natural gas, fertilizer and petrochemical plants. These projects are required to submit an environmental impact assessment.

3.5.2.4 SOLID WASTE

Solid waste from industrial sources totalled 49,172 tons/yr, representing only 4 per cent of all solid wastes of the ROPME countries (1,276,231 tons/yr, according to 1984-1987 data). Domestic solid waste accounted for 1,800,000 tons/yr, a significant amount in comparison with other ROPME member States (49.5 per cent of all the ROPME solid waste). These solid wastes are either dumped in landfill sites or burned in open pits. The burning method is tending to be abandoned due to air pollution. Composting is receiving increasing attention, since it yields a compost material of suitable quality for the sandy soils of the area (Linden *et al.*, 1990).

Current levels of solid waste are not considered to be a major problem in Oman. With the issuance of Ministerial Decision No. 17/93 containing regulations for the management of non-hazardous solid waste, most is dealt with in a scientific way and is not a danger to the environment or to human health. The Government established a system for the collection, storage and transport of all non-hazardous solid waste. The waste is without creating any health or environmental hazard. Sanitary landfills are licensed by MRME and non-hazardous solid waste is disposed of in accordance with the aforesaid regulations. Records of daily operations are kept for each site and an environmental impact assessment is prepared for each sanitary landfill or dumping site. In addition, MRME is in the process of preparing a master plan for the collection, storage, transport, treatment and disposal of non-hazardous solid waste over a 15-year period. The import of non-hazardous solid waste into Oman is prohibited.

3.5.2.5 RECREATION AND TOURISM FACILITIES

Beaches are used for a variety of recreational purposes in Oman. An inventory of these uses and their locations are supplied in a set of databases and reports (Salm 1989, 1991 and 1993). They include water sports, football, fishing, picnicking, and camping. In a number of places throughout the country, picnic areas and other amenities are provided on the beach. More elaborate facilities are usually associated with private clubs, which restrict access to the beaches. Privatization of the beaches also encourages the construction of boat launch ramps and other structures.

Tourism has been designated as an important growth industry for the diversification of the Oman economy. Therefore, the protection of the coastline from human-induced erosion and other destructive activities helps to preserve an economic resource. The Directorate-General of Tourism announced plans to set up more picnic centres across the country, with one or two on the coast. Plans have also been drawn up to establish camping sites throughout the country, including one near the sea turtle beaches of Ra's Al Junayz. The development of water sports facilities on beaches in and close to the Muscat region is also under the control of the Directorate-General. There are plans to erect more sunshades on several local beaches to promote their use by the general public and by tourists. The Al Rawda marina, near Muscat, was opened last year and can handle some 550 pleasure craft of varying sizes, both in the water and in dry dock.

3.5.2.6 OIL REFINERIES

There is only one oil refinery in Oman: it was constructed at the oil terminal at Mina Al Fahal near Muscat, and began operating in 1982. Its current production is 80,000 barrels/d. At Mina Al Fahal, there are four operating companies engaged in the production, storage, marketing and transport of exports of blend, crude and refined products from Oman, and with imports of refined petroleum prod-

ucts. Petroleum Development of Oman is the main producer of crude oil throughout the country. Crude oil is transported to Mina Al Fahal by pipeline after separation of water and gas. The oil is then depressurized, dehydrated and stored in tanks. Approximately 10 per cent of the dehydrated crude is delivered as feed stock to the Oman Refinery Company and the remainder is exported as crude via offshore moorings (Dames and Moore, 1992). The area is subjected to oil pollution from occasional leaks in valves and pipe work. In addition, there is a discharge of ballast water during oil-loading operations. The existing refinery effluent is discharged at the shore where the load factor is around 90 per cent of full capacity. At full load, the maximum discharge is 4,100 m³/h, and, with an anticipated content of 2 ppm, the waste is 74 tons of oil per year.

Thus, the refinery produces a range of hazardous and non-hazardous wastes. The hazardous wastes are currently produced from product tank chemicals, sludges, drums and containers, while the non-hazardous waste include containers, general non-hazardous industrial waste and office waste (Dames and Moore, 1992).

Monitoring programmes have shown that pollution by oil, both crude oil and fuel oil waste illegally discharged by tankers, is a major concern (Linden, *et al.*, 1990). The new Oman National Marine Pollution Monitoring Programme is intended to be both a background and a trend-setting programme which will run for several years (Mathews, pers. comm). The design of this programme takes into account Oman's responsibilities to the ROPME and also extends the geographical spread, tackles the existing problems; and investigates the potential problem of organophosphate reaching the marine environment. Stations sampled for the ROPME programmes are: Muscat, Khasab, Lima, Masirah island and Raysut. Analyses have detected petroleum hydrocarbons, chlorinated hydrocarbons, Lindore, DDT, PCBs and heavy metals (Hg, cadmium, Pb) in sediment and biota.

Al-Kharusi (1996) studied the different sources oil

pollution and measured their distribution in water, sediment, fish, molluscs and algae. She found that the Mina Al Fahal area was relatively more contaminated by crude oil products than were urban areas without industrial activities; however, the current regime flushes the contaminants out of the affected area. Similarly, data from the MRME laboratory indicate that the level of oil pollution at Mina Al Fahal does not exceed 5 ppm, which means it is not severe (Mathews, pers. comm.)

Beach tar concentrations in the capital area near Muscat were measured 20 times at nine sites from February 1993 to February 1995 (Coles and Al-Riyami, 1996). The tar concentrations were highly variable, with averages for the three transects at each station ranging from 0 to over 5 kg/m of beach front. The tar values for the November 1993 sampling period averaged 10-100 times the concentrations of other periods. These high tar concentrations were measured about two weeks following an offshore storm, which may have caused tankers to jettison petroleum. The MRME Department of Marine Pollution carried out a quantitative study of oil residues (tar balls) on 17 beaches in Oman during February and March 1996. The results have shown that tar balls in Muscat area was much higher (367-533 g/m) than those reported by Coles and Al-Riyami (1996). In addition, data from Khabourah (average 10,500 g/m) and Ra's al Hadd (average 1,163 g/m) were highest compared with other sites (varying from 51 g/m in Sawadi). Thus, the level of tar balls in the Gulf of Oman has worsened in recent year, mainly because of deballasting of oil tankers before entering the Strait of Hormuz.

3.5.2.7 AGRICULTURAL ACTIVITIES

The total cultivated area in Oman is 63,000 ha. There are few locations in Oman where agriculture is practised near the beach. Typically, farming occurs behind the dune line or over 100 m from the intertidal zone. Where agriculture does occur, it usually takes in the form of date plantations, partly because of the high salt tolerance of the date palm. Farming on the shore was found only north of Shinas and in small

areas at the mouths of wadis along the Batinah. In a few areas south of Khaburah and south of Seeb, palm plantations are interspersed with residential housing. Except in areas where natural erosion is an ongoing process or a structure such as a harbour block the longshore transport of sand, agriculture is not especially threatened by beach erosion, although some damage can be expected due to severe storms. The date plantations situated at the mouths of wadi are liable to erosion from flooding.

Grazing by camels, goats, cattle and, to a lesser extent, sheep and donkeys is sporadic along areas of the open coast, depending on the time of year and the abundance of vegetation. Overgrazing is found on the Batinah, Masirah (Weidleplan, 1991) and in the Dhofar region (Atkins, 1989). The effect of such grazing on the important fore-dune vegetation is unknown; however, the large quantity of camel droppings on the beaches in some areas attests to the presence of livestock. The effects of grazing on the khawrs and mangroves are in many cases readily apparent (Atkins, 1989; Fouda, 1995b). Overgrazing by cattle in the Dhofar region has forced farmers to obtain fodder from other sources (Atkins, 1989). Agricultural products have increased in recent years and currently contribute more than 3 per cent of GDP. Oman is self-sufficient in fish and dates and these products are exported.

3.5.2.8 COASTAL CONSTRUCTION, MINING AND QUARRYING ACTIVITIES

The role of the Ministry of Regional Municipalities and the Environment in the coastal zone includes the establishment and enforcement of discharge standards through the environment permit, the coordination of all environmental protection efforts with other ministries and government agencies and the preparation and implementation of a national plan for the conservation of the environment and prevention of pollution.

The principal form of coastal development in Oman is residential construction. Most of this development consists of high-density, single-family dwellings. The

past 20 years have seen explosive residential and other development along the coastline, with trends indicating continuing coastal development pressure.

In many parts of Oman, houses are built near the beach. This is especially the case on the Batinah coast, where an almost continuous strip of housing, governmental and commercial development now links the towns between Majis and Masna'ah. Almost continuous development also occurs in the Barka area, the Seeb area, the capital area from Azaiba to Bandar Jissah, Sur, and the Salalah area from Raysut to Dahariz.

Although houses have been built near the shore for centuries, historically they were made only from semi-permanent materials, such as palm fronds. Forts, mosques, and shops were built with mud bricks and were constructed well inland from the beach. Today structures are typically built with concrete blocks. Even palm-frond fishing huts on the beach are being replaced with more permanent concrete structures.

Coastal erosion occurs in several regions (Musandam, Batinah, Sharquiah, Dhofar). While some erosion is natural and is part of the continuing evolution of the shoreline, massive and irreversible erosion occurs primarily because activities such as the construction of dams, roads and harbours are carried out without regard to their impact on the shoreline.

Although prohibited by law, the mining of beach sand continues in Oman. This is readily apparent at the beach behind Sib Airport and at Makalla Wabar and Bimmah beaches on the Sharquiah coast. In these locations, sections of the dunes or the back-beach have been removed.

Wadi mining is extensive throughout the country (MRME, 1992b). Mining is made easy in Oman by the fact that the river beds are an dry for much of the year. The wadis are important source of sand and gravel for construction purposes. Bed fill for roads is another purpose for which wadi sediments are

used. Mining tends to create vast pits in the wadis which have been measured at 5 m in some places. Offshore mining and dredging, however, are not common practices in Oman. Future dredging for harbours could have an effect on beach erosion.

3.5.2.9 PORT FACILITIES

Mina Qaboos at Muttrah was built in 1974 and equipped to handle 2 million tons of cargo annually. The ever-increasing volume of imports and exports in the succeeding years has entailed continual expansion, with the construction of a container terminal, modern warehouses, engineering workshops, and deep water wharfage. Currently, Mina Qaboos has 13 berths, comprising a deep-water and 4 shallow-water berths. It has a transit shed area of 27,000 m² and an open storage area of 150 m². The container terminal has an area of 4.7 ha with a storage capacity of 2,700 loaded and empty containers. A fleet of 6 tugs, fitted with the most modern equipment, serves the port. The port is equipped with 2 25-ton gantry cranes and 13 other cranes of varying capacities for handling containers and other cargo.

Mina Raysut, in the south of Oman, serves Salalah as the Governorate of Dhofar. The Ministry of Communications is currently conducting a comprehensive study of a port development plan, including a master plan for Mina Raysut. The study will produce recommendations concerning development options for phased implementation up to the year 2015. Ministry plans for making the port attractive for shipping lines may include tariffs re-structuring, the installation of modern equipment, round-the-clock operation and the reduction of waiting time to a minimum.

The principal town in Musandam, Khasab, has a small port with two berths and a water depth of only 3.5 m. There will be a need in the future to increase the number of berths and the water depth. The Ministry is working on a development plan for the period up to the year 2010.

There are few fishery harbours or improved fish-land-

ing facilities in the country, other than a commercial pier at the port of Muscat, where large trawlers land their catches. Currently, the following eight fishing harbours and jetties are in operation: jetty at Masirah island; fishery harbour at Mirbat; jetty at Al Hallaniyah island; fishery harbour at Khasab; fishery harbour at Dabba; fishery harbour at Bucha; fishery harbour at Quriyat; and fishery harbour at Sur.

The Directorate General of Fisheries built 11 small marketing-support facilities along the coast from Muscat to the Dhofar district. These facilities generally consist of ice plants of 5-10 ton capacity, small cold storage rooms and machinery for power generation. These facilities were rented to private fish-processing companies and were used mainly as fish-buying stations under a programme begun in 1987.

The fish and shellfish export-processing companies have all installed their own processing, freezing and cold storage facilities. These are located mainly in the Muscat area. Additional government-owned cold storage space is available mainly in Muscat and Salalah.

3.5.2.10 OTHERS

MRME carries out ongoing monitoring, inspection, sampling, analysis and evaluation of all sources of air pollution. Data are usually collected on the levels of nitric oxide (NO), nitrates (NO₃), nitrogen oxides (NO_x), sulphur dioxide, carbon monoxide (CO), ozone (O₃) and dust. In addition, meteorological parameters (e.g., relative humidity, temperature, wind direction and wind velocity) are also measured. At certain industrial sites, such as PDO, where air pollution is likely to occur, data are usually obtained on total suspended particulates, total hydrocarbons and lead. Scientists have prepared a computer model and an advanced mathematical model, as well as a database, for air pollution. Currently, there are permanent monitoring units, three in Muscat, one in Sohar and one in Sur, in addition to a mobile laboratory for air pollution monitoring. These units are currently in the test-operation stage.

Other achievements in combating air pollution include:

- Monitoring of air pollution and measurement of pollutant concentration and emissions from the various industries (mining, cement, vehicles and oil, particularly hydrocarbons emitted during the loading of crude oil into tankers;
- Coordination with the two cement factories in Muscat and Salalah in order to select non-polluting technologies;
- Continued cooperation with the copper factory to identify the most effective methods of minimizing the huge quantities of sulphur dioxide;
- Establishment of the requirement that new industries must install pollution-control equipment; and
- Noise Pollution Section is already established and operating as part of the Air and Noise Pollution Section. Noise Pollution Control Regulations, MD 79/94 and 80/94 have been established. Monitoring and control of Noise Pollution has been exercised since 1994.

Previous surveys carried out by MRME did not reveal significant concentrations of heavy metals in biota and sediment. Most activities likely to cause heavy metal pollution are controlled by the Protection of the Environment and Prevention of Pollution Act (Royal Decree No. 10/82) and by two ministerial decisions. The first decision deals with regulations concerning the disposal of liquid effluents in to the marine environment. Liquid effluents must not contain more than 0.05 mg/l, cadmium not more than 0.5 mg/l; (No. 5/1984), iron not more than 2.0 mg/l and palladium not more than 0.1 mg/l (see table 13). The second ministerial decision (No. 18/1993) deals with regulations for the management of hazardous waste. According to this ministerial decision, any

company or business owner handling any type of waste which is hazardous or potentially hazardous to human health, plants or animals, or the air, soil or water must have a licence from the Ministry of Regional Municipalities and the Environment. They must observe the regulations concerning transport, recycling, storage, pre-treatment and disposal.

3.5.3 Establishment of priorities

An analysis of priority issues from an Omani perspective indicates the following order of priority:

1. Physical alteration, sediment mobilization and destruction of habitats;
2. Oil and combustion products;
3. Sewage and nutrients;
4. Litter;
5. Atmospheric deposition;
6. Persistent organic pollutants;
7. Heavy metals;
8. Radioactive substances.

3.5.4 Setting management objectives for priority problems

Management objectives for land-based sources and activities affecting the marine environment of Oman fall within the framework of the Protection of the Environment and Prevention of Pollution Act. The implementing regulations to this Act set specific objectives for controlling, reducing and eliminating sources of pollution from sewage, hazardous materials, and so on. For some source categories, there are definite targets and timetables; in the case of sewage, for example, the future production of treated sewage effluent by the year 2010 is estimated at about 443,000 m³ /day. In order to reduce the adverse impact on coastal communities, all development

projects are now required to obtain an Environmental Permit.

It is suggested that a specific programme on land-based sources and activities affecting the marine environment of Oman be established within MRME and that all government agencies coordinate their activities in this framework. The first step in this programme is to set management objectives for priority problems. Secondly, a programme should be carried out to train personnel to update the inventory of all sources of marine pollution from land-based activities and to study their likely impact. Thirdly, the current legislation and regulations should be evaluated and, amended where necessary in accordance with the probable impact of land-based activities affecting the marine environment. Fourthly, the programme should be evaluated every two to three years.

3.5.5 Identification, evaluation and selection of strategies and measures

This issue is relevant where most of the recommendations contained in the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities have been implemented for some time. For example, there is an ongoing air pollution monitoring programme, together with co-ordination with industry aimed at selecting non-polluting equipment technologies. In many instances, industries were required to install air pollution control. This is not the case for other source categories because the MRME staff are occupied with both technical and management issues. Efforts are being made, however, to reduce all sources of pollution in the marine environment.

3.5.6 Criteria for evaluating the effectiveness of strategies and measures

This issue is difficult to identify at the current stage for the following reasons: considerable financial resources were allocated to environmental issues and very few economic gains have been made so far, the cutbacks in government funding have created new

and severe limitations; the development boom has led to diversification of the economy and has strengthened the role of the private sector; and several programmes on land-based sources are still in the preliminary stage. Local technical staff are gaining experience and errors are to be expected. It will take time to provide valid criteria for evaluating the effectiveness of strategies and measures.

3.5.7 Programme support elements

In Oman, the following bodies have been identified as potential sources of programme support:

(a) **Ministry of Regional Municipalities and the Environment (MRME), Muscat:**

Within MRME, the directorates of Environmental Affairs and Natural Protectorates are the main institutions involved in protecting the marine environment. They have developed a system of conservation areas for coastal zone management, which is in the process of being implemented, the national conservation strategy, entitled "Environmental Protection and Natural Resources: as well as Conservation for Sustainable Development", which incorporates the provisions of regional and international conventions. They have also prepared the National State of the Environment Report, participated in many regional and international conferences, hosted many national and international symposia, prepared environmental legislation, trained personnel and improved infrastructure, supervised many environmental education and public awareness programmes, carried out numerous scientific projects, including on coastal erosion and water circulation, and developed for tracking the aftermath of oil spills, currently, these agencies are in the process of implementing a coral reef management plan.

A review of the organizational structure of the MRME, the focal point for all environmental policies and programmes in Oman, shows that the following directorates and departments are relevant to the Global Programme of Action:

(i) **Directorate-General of Environmental Affairs**, comprising the following units:

- Environmental Monitoring Directorate;
- Environmental Planning and Permits Directorate, incorporating the Environment and Development Department and the Environmental Permits Department
- National Conservation Strategy Directorate, incorporating the Coastal Zone Management Department;
- Environmental Affairs Directorate, Muscat;
- Inspection and Control Directorate, incorporating the Air Pollution and Noise Department, the Water Pollution Department, the Marine Pollution Department and the Solid Waste Pollution Department;
- Environmental Laboratories Directorate;
- Environmental Research and Studies Directorate;
- Regional Environmental Affairs Directorate;

(ii) **Directorate-General of Nature Reserves**;

(iii) **Directorate-General of Public Relations and Guidance**, comprising the Environmental Awareness and Guidance Department and the Information Service Department.

Each of these directorates and departments has its own national programme dealing with a specific topic, such as the marine

pollution monitoring programme. They have good facilities and infrastructure, which has enabled them to carry out high-quality programmes, as indicated earlier. Thus, a capacity-building effort in terms of both personnel and institutional capacity has existed for the past 25 years. It should be remembered, however, that MRME has relied on large numbers of expatriates, while at the same time training nationals at home and abroad. Nevertheless, cutbacks in government funding have created new and severe limitations in recent years, and this is expected to continue. Thus, the lack of adequate financial and human resources will create severe difficulties in implementing the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities in Oman, at a time when the development boom and diversification of the economy are expected to have a rapid environmental impact.

(b) **Marine Science and Fisheries Centre, Ministry of Agriculture and Fisheries, Muscat**: This centre was established in 1986 with the objective of carrying out research on various aspects of marine science and fisheries in order to promote national fisheries development efforts and provide advice on the formulation of policies and on the legal aspects of fishing activities. The centre has seven departments: Oceanography, Marine Ecology, Large Pelagic Fish, Small Pelagic Fish, Demersal Fish, Food Technology and Mariculture. It has a well-established aquarium and library. The facilities include eight laboratories, a research vessel, an aquarium, a museum, a computer centre and limited facilities for teaching marine science. Cooperative programmes exist with the United Nations Educational, Scientific and Cultural

Organization (UNESCO), the Japan International Cooperation Agency (JICA), and some Arab, United States and European institutions. The centre offers limited opportunities for training and encourages exchanges of marine scientists. It hosted several regional conferences on the marine and fisheries resources of the ROPME sea area, the Gulf of Oman and the Arabian Sea;

- (c) **Sultan Qaboos University, Department of Fisheries Science and Technology and Department of Biology, Muscat, Oman:** Sultan Qaboos University was established in 1986. Two of its departments are involved in teaching and research in the field of marine science and fisheries: the Department of Fisheries Science and Technology in the College of Agriculture and the Department of Biology in the College of Science. The Fisheries Science and Technology Department has a staff of 24 and offers 31 fisheries and marine science-related courses. Members of the fisheries faculty and staff conduct basic and applied research on fisheries biology, coral reef management, mangroves, oceanography, marine ecology and aquaculture.

At present, three projects funded by the Fisheries Research Fund are being carried out by the department, they are entitled: “Basic Studies for Evaluating Long-Term Changes on Coral Reefs and Reef Fish Communities at Muscat”, “Shrimp Stock Assessment Project in the Gulf of Masirah” and “Kingfish Fisheries”. Because of the diversity and magnitude of the marine resources of Oman and the need to develop these resources on a sustainable basis, the Department of Fisheries Science and Technology is being given the status of a college of marine science and fisheries.

The department of Biology has only two staff members, who are involved in teaching and research in the area of marine ecology. The facilities at Sultan Qaboos University include well-equipped laboratories, and excellent library, a computer centre, workshops, and so on.

3.6 QATAR

3.6.1 Introduction

Qatar is situated mid-way down the western coast of the ROPME sea area. It is a peninsula jutting northwards into the sea with an area of 11,437 km² and a number of islands, such as Halul, which is an oil storage terminal, Hawar, Shar’ouh, Al Ashalt, Al Safiyah, Al Aliya, Jana, Rakan, Al-Bashiriya, Al Dawakhil and the small headland of Ras Abrouk.

The 1985 rapid assessment report provided the following information on the main centres in Qatar:

- (a) **Doha (Ad Dawhah):** Doha is on the edge of the area and is the capital and the administrative centre. It is situated halfway down the eastern coast of the Qatar peninsula. The majority of the population lives in Doha. It is an important cultural and commercial centre with a main port and an international airport linking the country with other parts of the world;
- (b) **Umm Said:** This is an industrial centre whose growth is a direct result of the oil production in Dukhan. Situated on the east coast, 45 km. south of Doha. Umm Said has an oil refinery and an export terminal, a commercial deep water port, a steel plant, a chemical fertilizer plant, a petrochemical plant and flour mills;
- (c) **Al Khawr:** Qatar’s second largest town, Al Khawr, is on the north-east coast. It faces a small bay which curves inland for

about three km and contains an old harbour for fishing dhows;

- (d) **Al Wakrah:** Situated halfway between Doha and Umm Said on the east coast of Qatar, Al Wakrah is a fishing and poultry farming centre;
- (e) **Al Ruwais:** In the north of Qatar, Al Ruwais is an old village at the centre of the northern educational zone and one of the country's main fishing centres;
- (f) **Dukhan:** This town is the main oil-producing centre of Qatar, situated on the west coast. It was built as a direct result of the discovery of oil in the area.

The estimated population of Qatar is 530,000.

3.6.2 Identification and assessment of main pollution sources

3.6.2.1 POWER AND DESALINATION PLANTS

The total electrical capacity of Qatar is 14,000 MW, with an output of 5,500 GW/h (consumption per capita is 12,000 kW) (ESCWA, 1997). There are Ministry of Electricity and Water (MEW) desalination plants at Ras Abu Aboud and Ras Abu Fantas, with a total capacity of 309,128 m³/d of freshwater. Qatar is constructing a new power and desalination plant at Al Wasil. It is also expanding the capacity of the old power stations at Al Wagbah, Ras Abu Fantas and Duhkan. There is a plan for a regional electricity network connecting Qatar, Bahrain, Saudi Arabia and Kuwait.

3.6.2.2 SEWAGE TREATMENT FACILITIES

In the past, raw sewage was be discharged directly into the sea at Halul island. A sewerage system was completed in the mid-1980s, and it seems that domestic effluents are no longer discharged into the sea. There are two large and nine small

sewage-treatment plants in Qatar. The large plants have a total capacity of 80,000 m³/day and the sewage is treated by secondary and tertiary processes. About 70,000 m³/day is reused as fertilizer for fodder crops, gardens and landscaping. The small plants have a capacity ranging from 120 to 3,000 m³/day (Al-Zubari, 1997).

3.6.2.3 INDUSTRIAL FACILITIES

Oil and natural gas are the main extractive industries. Qatar produces 422,000 barrels of oil per day while natural gas is estimated at 13,497 billion m³. These industries represent 31 per cent of GDP. The manufacturing industries consist mainly of petrochemicals, food industries, chemicals, fertilizers (ammonia, urea), iron and others. They represent 12.5 per cent of GDP (Anon, 1996). Most of these industries are located in the Umm Said industrial area.

3.6.2.4 SOLID WASTE

Solid waste loads from industrial sources in Qatar during 1984-1987 totalled 19/6,014 tons/yr, of which 21,742 tons/yr were oil sludges. Solid waste loads from domestic sources totalled 66,742 tons/yr, of which 20,300 tons/yr were sludge (ROPME, 1997). Recent estimates of domestic solid waste in Qatar have increased to 95,999 tons/yr (Anon, 1996). Most of the solid wastes in Qatar contain oily sludge, iron dust and other solids generated from the iron industry.

3.6.2.5 RECREATION AND TOURISM FACILITIES

No information is available, but recreation and tourism facilities exist and are used by locals and expatriates.

3.6.2.6 OIL REFINERIES

There is one oil refinery in Qatar with a total production of 63,000 barrels/day (ESCWA, 1997). Pollution from crude oil affects many beaches and coastal areas. Shipping causes oil pollution, particu-

larly near Doha Port (Environmental Resources Ltd., 1986). No information is available on other significant sources of oil pollution.

3.6.2.7 AGRICULTURAL ACTIVITIES

There are about 8,000 ha of cultivated areas in Qatar, most of which are irrigated by groundwater, representing 68 per cent of all water resources available. The value of agricultural products is estimated at \$79 million, representing 1.1 per cent of GDP (ESCWA, 1997). These values are much lower than in 1993 when agricultural products contributed 5.7 per cent. Most agricultural products are imported, with the exception of dates and fish.

3.6.2.8 COASTAL CONSTRUCTION, MINING AND QUARRYING ACTIVITIES

Qatar has completed a detailed coastal inventory using fine-scale, airborne image analysis; however, the inventory has not yet been provided. In addition, land colour composite, band-7 and colour slice have been applied successfully to the mapping and detection of shallow sea-bottom conditions around Qatar (Yehia, 1986). Image anomalies were compared with bathymetric charts and a coloured bathymetric map was prepared. The rate of deposition, and the rate of erosion in the submerged shoreline, were detected by a sequential study of Landsat imagery, and thus the distribution of coastal changes is readily displayed.

The formation of the depositional coastal line in the Umm Said industrial area through the deposit of sediments from the island sand dunes and the northern sand spit is of great importance in the development of plans for the protection of the Umm Said harbour and for further extensions or alternatives.

The coastal geomorphology of Qatar may be considered under the categories of erosion landforms and depositional landforms, as follows:

Erosion Landforms: under erosion landforms, the following features may be identified in Qatar:

- (a) **Erosion marine plains**, which are low relief regional features, bounded on the sea-facing side by the shore and on the land-facing side by highlands. In Qatar, they rise gently, frequently in a series of terraces or flats covered by gravel. The coastal plains in Qatar are the product of continuing erosion and accretion processes since the Miocene and Pliocene eras. They are more prevalent in the western coastal zone than on the east coast, especially in Ras Dukhan, Ras Abruk and Ras Ushayriq;
- (b) **Spikes**, which are erosion land forms, occurring where there are differences in rock hardness. In Qatar, limestones is dissolved through chemical weathering, and siliceous rocks are resistant and contain spikes (Ras is an Arabic term for spike). They are numerous in the north of Qatar, in Ras Umm Hasah and Ras Abu Amran. They are also formed on the eastern and western coasts, near to Ras Laffan, Ras Umm Sa', Ras Abu Abbud, Ras Abu Finta's, Ras Ushayriq, Ras Abruk and Ras Umm Hish;
- (c) **Douhat** (Doha, an Arabic word, for "curved bench"), a land form characteristic of some parts of the Qatari coastline which occurs in Doha (the capital), Umm Said, on the eastern shore, and Douhat El-Hussein, Douhat Salwa, on the western shore;
- (d) **Khor** (Arabic for "small bay"), which is the predominant coastal land form, not only in Qatar, but also in most of the area. Most *khors* in Qatar are structurally controlled, e.g., Khor al-Udeid, which occurs in a synclinal fold: al Khor and Khor Dhakhira, which occur in anticlinal folds; and Douhat al Hussein and Zekrit, which occur in synclinal folds;

- (e) **Cliffy coasts**, which occur in different parts of Qatar's coastline, due to the action of waves, as in Fuwairat to the east and Ghar al-Buraid south-west of the peninsula, where marine erosion of the oolitic limestone has taken place: these cliffs are not more than 4 m above sea level. Old cliffs are more prevalent in Al Khawr, Dokhan, Abruk and Zekrit;
- (f) **Offshore islands**, of which Qatar has a number. North of Dukhan lie the small islands Hawar, Abrouq and Shara'ou. North of the peninsula, opposite Ruwais, is Rakan island. A'liyeh and Safliyah are two small islands, north-east of Doha, while Bashiriyah is opposite Umm Said and al-As Hat lies to the south, opposite Al Audied. Halul island is located east of Ehha.

Depositional landforms: under depositional landforms, the following features may be identified:

- (a) **Depositional marine plains**, or:
Aggradation beaches—a depositional landform—occur north of Qatar from Ras Umm Hash in the east to Ras Al Asish in the west. The marine beach has its maximum width at Nijian (about 20 km);
- (b) **Spits** (cusped foreland), which refer to the development of “compound spits” or bars in a series of cusps. The growth of these cusped features from intertidal bars into dry land takes place by means of successive oscillations of the sea level. They may take a variety of forms, but the most typical one is more or less triangular, with the apex of the triangle pointing out into the water. In Qatar, examples can be seen along the eastern coast at Ras Abu Amran, Ras Al Arish, Umm Hasah and Abu Abbud, and on the western coast at Ras Umm Hish and Ras Owinat, while at Ras Al Allak, the spit is curved and

perpendicular to the coastline. In Dhakhira it is also parallel to the coastline;

- (c) **Coral reef bars**, which are mainly of biological origin, being built by coral polyps. The distribution of reefs is largely controlled by geomorphological, structural and ecological factors. Gradually, however, the winds and currents gain in importance and play a dominant role, particularly in the ultimate stages of reef development, as seen at Ras Abrouk and Ras Al Allak;
- (d) **Coastal lagoons**, which are elongated bodies of water, lying parallel to the coastline and separated from the open sea by a barrier. Lagoons have been considered to be evidence of the emergence of low-lying coastal areas. Owing to the presence of the offshore bars, lagoons have developed in various parts of the Qatar coastline such as, as in Ras Abruk and al-Khor east of Qatar;
- (e) **Sabkhat**, an Arabic term for a flat depression which is generally close to the water table and covered with a salt crust: *Sabkhats* are widespread along the coastal margins of Qatar, especially along the eastern coast south of Umm Said. They are characterized by a deep to shallow profile (30-130 cm). Their texture ranges from calcareous, sandy clay loam to clay loam with greyish subsoil;
- (f) **Beach dunes**, which consist mainly of pseudo-oolitic limestone with cross bedding deposited parallel to the old shore line. Geographically, these land forms are predominant on the eastern, rather than the western shore of Qatar, specifically, at Fuwairat, al-Ghariyeh and Hazm Talb, north of Doha;
- (g) **Mangroves:** North of the Al-Khawr area,

vegetation plays an important part in the shaping of the depositional beach.

Mangroves border the Khor Dhakhira stretch, where estuarine conditions are found.

3.6.2.9 PORT FACILITIES

There is one harbour at Umm Said, east of Doha (the capital). It has been developed and expanded in recent years, although the extent of development is unknown.

3.6.2.10 OTHERS

The primary sources of air pollution in Qatar are the oil refineries and the petrochemical, ammonia, urea and iron industries. Most of these industries are located in the Umm Said industrial area. The level of air pollutants (tons/yr) in Qatar indicates high levels of air pollution and ammonia (UNEP, 1987). Data reported to the ROPME (1985-1987) indicate that SO and cobalt are the highest contributors to atmospheric emissions (27 per cent and 25 per cent, respectively). Additionally, particulates, nitrogen oxides and other contaminants contribute 15 per cent, 14 per cent and 13 per cent respectively. An analysis of the atmospheric emission contaminant load by industrial sources shows that the highest contaminant loads result from external combustion (38 per cent), industrial processes (32 per cent), and internal combustion (28 per cent) (ROPME, 1997).

Industrial effluents discharged into the sea total approximately 3.5 million m³/yr (Anon, 1996). These effluents contain large quantities of organic matter and heavy metals. An analysis of certain species of fish and crustaceans (shrimp and crabs) indicated as high level of chromium (441mg/kg wet weight). Mercury levels in fish amounted to 872 mg/kg in Grouper, 655 mg/kg in barracuda and 957 mg/kg in lizardfish. While these concentrations are considered to be low as compared with the international standards, it was found that 30 per cent of the groupers and 50 per cent of the lizardfish contained considerably higher concentrations of mercury than the in-

ternationally recommended limits (Anon, 1996).

A summary of liquid waste generated from industrial sources in Qatar indicates that oil (120,438 tons/yr) constitutes 56 per cent of the total waste generated, whereas suspended solids constitute 68,913 / yr (32 per cent). The discharged industrial liquid waste profile is provided in table 17. Information from the rapid assessment report of Qatar gave no information on the discharges from various sources except for ship ballast (11,802 tons/yr of oil) and sea-port activity (11,550 tons/yr of oil). Examination of the 1984 data shows that ship ballast makes up 64.7 per cent of the total industrial discharge, as compared with 35 per cent from industrial processes. Oil constitutes 80 per cent of the total contaminant load; Nitrogen contributes the rest (18.1 per cent).

3.6.3 Establishment of priorities

Based on available data, the following order of priority is suggested for source categories:

1. Physical alteration, sediment mobilization and destruction of habitats;
2. Oil (hydrocarbons) and combustion products (e.g., PAHs);
3. Atmospheric deposition;
4. Litter;
5. Sewage and nutrients;
6. Heavy metals;
7. Persistent organic pollutants (POPs);
8. Radioactive substances.

3.6.4 Setting management objectives for priority problems

In a Plan of Action, the Environment Department (ED) of the State of Qatar has identified key land-based sources of marine pollution and corresponding priority actions required to control these. The ED is presently working on a more acceptable timetable and methodology of compliance.

3.6.5 Identification and selection of strategies and measures

The Qatar Environmental Committee is responsible for identifying specific measures to promote the sustainable use of coastal and marine resources and to prevent or reduce degradation of the marine environment from land-based sources and activities. The ED/Ministry of Municipal Affairs and Agriculture has finalised specific environmental standards for industries. These regulate air pollution, water pollution, and disposal of wastes arising from various process activities including offshore installations. Industry should be asked to promote cleaner technology, minimize waste, install pollution-control equipment, increase efficiency and recycle.

3.6.6 Evaluation of the effectiveness of strategies and measures

Effective strategies and measures require a strong political will, public support and multinational co-operation. In order to define criteria for evaluating the effectiveness of the measures, the following are actions are suggested:

- Define specific areas and targets to reduce or eliminate sources of pollution from land-based activities. It is suggested that areas in Umm Said and Dukhan which are known pollution sources be selected;
- The role of the European Community should be emphasized to ensure the appropriate implementation of specific activities; and

- Conduct training programmes on the assessment of land-based sources and activities affecting the marine environment.

3.6.7 Programme support elements

The Environmental Committee was established in 1981 and is currently under the supervision of the Ministry of Municipalities and Agriculture. It is chaired by the Minister and by representatives of the following ministries: Health, Defence, Energy and Industry, Education, Electricity, and Water,) in addition to representatives of the University of Qatar and the General Organization for Youth and Sports. The Committee is in charge of all environmental affairs in Qatar including:

- Preparation of environmental legislation and regulations;
- Coordination with government agencies;
- Monitoring of environmental programmes; as a follow-up to Environmental Standards, the heavy industries in Mesai'eed and Ras Laffan have already begun their programme and action plan for environmental monitoring. In RLC two continuous ambient air quality monitoring stations are already operational;
- Approval of the environmental impact assessment for all development projects.

While the Committee has carried out many environmental projects and programmes (e.g., establishment of protected areas, public awareness activities), it lacks adequate financial and human resources to implement them. Qatar has, however, signed many regional and international conventions and joined many organizations, including ROPME. Qatar is a signatory to the ROPME Protocols for the Protection of the Marine Environment from Land-based Sources; on Oil Spills; and on Transboundary Movement of Hazardous and other wastes. In addition, Qatar is also signatory to, a protocol on phasing out

of ODS, and the Convention concerning the Protection of the World Cultural and Natural Heritage.

3.7 SAUDI ARABIA

3.7.1 Introduction

The area of the Eastern Province is 1 million km². It consists of 27 cities and 232 villages with a population of 2,345,387. The 1993 (1413 H) census reports as follows:

- (a) **Dammam Area:** This area consists of Dammam, Al Khobar, Dhahran and the interurban area. The population of this area is 500,000;
- (b) **Al Hassa:** This area consists of al-Hofuf (49 villages), al-Mubarraz and Abqaiq (21 villages). The population of Al-Hassa is 458,241;
- (c) **Al Khafji:** This area consists of Al Khafji, Hafr al-Baten, al-Nairiyah, Jarardh, and 17 villages. The total population of this area is 192,487.

The climate of the Eastern Province is characterized by two main seasons. One begins in January and lasts until March, and is usually cold, with precipitation averaging 14 mm per month. Usually this period has a mean relative humidity of approximately 52 per cent and an average temperature of 13°C. A sharp drop in temperature to 3°C usually occurs in January, which is considered to be the coldest month of the year. From April to the end of the year, the climate is hot and dry, with sandstorms especially in June and July. A peak is reached in June when it is common for there to be blowing dust and strong winds particularly in the afternoons on 13 out of 30 days. These sandstorms are caused by eastward-moving low-pressure systems.

The Saudi Arabian coast of the area has witnessed a major increase in development activities in recent years. While most of this development was related

to the petroleum industry, a large percentage of growth has occurred in basic industry and in the commercial, residential and transport facilities created by industrial development. These activities have a considerable impact on the marine environment.

3.7.2 Identification and assessment of main pollution sources

3.7.2.1 POWER AND DESALINATION PLANTS

Saudi Arabia has an electrical capacity of 21,500 MW, with an output of 78,000 GW/h (consumption per capita is 4,480 kW) (ESCWA, 1997). There exist 10 power stations in the Eastern Province, namely Ghazlan, Quaryyah, Faras, Shedgum, Berri, Qaisumah, Dammam, Safaniyah, Uthamaniyah and a few other small plants. In addition, few desalination plants and industrial complexes namely Al-Khafji, Al-Jubail and Al-Khobar also generate electricity in association with desalinated water.

MSF desalination plants in the Eastern Province are located at Al Khafji, while smaller MSF plants are at Gazlan, Al-Grays, Safaniyah, Tanajib and Ras Tanura. These major plants have varying freshwater production capacity. There are additional desalination plants which use other methods of desalination (e.g., RO) producing 79,000 m³/d of freshwater. Desalination plants are located close to coastal areas and use a vast amount of sea water and energy to produce desalinated water. Heated brine (salt water) is discharged back to the sea as a byproduct. Although heated brine is likely to disturb the balance of the marine ecosystem, its impacts on the marine environment are not yet well established.

3.7.2.2 SEWAGE TREATMENT FACILITIES

Saudi Arabia has thirty (30) major sewage treatment plants (STPs) with a design capacity of 1,426,000 m³/d. These STPs are both secondary and tertiary level aerobic biological irrigating landscape areas and parks, recreation facilities and highways (Al-Zubairi, 1997). There are seven STPs operating in the east-

ern province namely Dammam, Al-Khobar, Al-Hassa, Qatif, Khafji, Jubail and Saudi Aramco facilities. Design capacity of these STPs is 577,000 m³. Treated waste water is partially used for landscape irrigation and the rest is discharged to the sea.

3.7.2.3 Industrial facilities

The eastern coast of Saudi Arabia is far more developed. Large oil fields along the coast have attracted much of the development over the past 30 years. Today, approximately 40 per cent of the coast is developed, with numerous primary and secondary industries.

Industrial development is concentrated at several locations along the coast, namely, Jubail, Ju'aymah and all around Tarut Bay, including Ras Tanura, Qatif, Dammam, Saffaniyah, Tanaqib and Khobar. Industrial developments in these areas include petroleum facilities, power plants, desalination plants, domestic and industrial waste water treatment plants, and other primary and secondary industries such as fertilizers and plastics. Marine transport plays an important role in coastal development. The entire area is a major shipping area, particularly for oil tankers. The large industrial ports along the Saudi coast are located at Tanaqib, Saffaniyah, Jubail, Ju'aymah, Ras Tanura and Dammam.

In addition to heavy industry, light industry and other commercial activities are sited along the coast. An important example is the fishing industry, with numerous small fishing villages scattered along the coast. The industrial fishing ports and processing facilities are primarily clustered near the urban areas. As this industry is further developed, additional processing facilities and ports may be needed along the coast.

Extractive industries (more than 8 million barrels of oil per day and 37,807 billion m³ of natural gas) contribute 32.5 per cent of GDP whereas manufacturing industries (e.g., petrochemicals, iron and steel, fertilizers and plastics) contribute 8.6 per cent of GDP (ESCWA, 1997).

3.7.2.4 SOLID WASTE

Solid waste is generated as a result of municipal, commercial and industrial activities. Total municipal and commercial solid waste in the Kingdom was estimated to be approximately twelve (12) million tons/year. Approximately two (2) million tons is generated in the eastern province. The municipalities of Dammam, Al-Khobar, Al-Khafji, Qatif, Al-Hassa and Al-Jubail have constructed municipal landfills to receive and discharge this waste. Recreational beaches in few coastal areas sometimes receive litter thrown by the residents visiting the beaches. However, the local municipalities on the initiative of the regional governments undertake beach cleaning campaigns.

A MEPA study has estimated the quantity of hazardous waste generated by the industry in the eastern province of the Kingdom of Saudi Arabia to be approximately 106,700 ton/y. The Kingdom has developed an effective hazardous waste management system with the stringent rules and regulations in place and through the participation of licensed private sector companies for the transport, treatment and disposal of hazardous waste. The Kingdom has various licensed companies having landfill, landfarm, chemical treatment, encapsulation, and incineration facilities for the environmentally sound management of hazardous waste.

To reduce air and marine pollution in the eastern province, there exist measures to limit pollutants into air, monitoring programmes, emergency response and environmental surveys on critical habitats.

3.7.2.5 RECREATION AND TOURISM FACILITIES

Recreation and tourism facilities are developing very fast, although these facilities are, by and large, only used by locals and expatriates. Available leisure activities include water sports, shopping, parks, zoos, diving, archaeological sites and others. There are attractive sites for recreation and tourism at Jurayd and Jana islands, Jubail, Muntazah, Dawhat As Sayh and Zalum and Al Khobar.

3.7.2.6 OIL REFINERIES

The total production of oil refineries for the entire Kingdom is estimated at 1,676,000 barrels/day. The total production of oil refineries in the eastern province of Saudi Arabia is estimated at 551,351 barrels/day refined products, representing the total production from three refineries, namely Jubail, Ras Tanura and Ras-Al-Khafji. Oil refineries cover a fairly large area and are located close to the coast to facilitate marine transportation. Associated facilities include pipelines, roads, ports, jetties, tank farms, waste treatment facilities and power plants. Support facilities such as light industry and housing developments are also sited adjacent to oil refineries.

Saffaniyah is the largest offshore oil field. Principal oil fields are adjacent to the coast include Manifah, Berri and Qatif north of Ras Tanura. Gas plants are located at Jubail, Ras al Ju'aymah and north of Ras Tanura. Petrochemical plants are at Jubail. In summary, the country's petroleum facilities are scattered along the eastern coast.

3.7.2.7 AGRICULTURAL ACTIVITIES

No information is available on agricultural activities in the eastern province. The total area under cultivation in Saudi Arabia is about 1.4 million ha. Agricultural products are worth US\$8,441 million, representing 7 per cent of GDP. The Government supports all kinds of agricultural activities, including the distribution of land free to farmers, work to improve infrastructure, the development of water resources, and it encourages investment in agriculture. As a result, wheat production has increased from 142,000 tons in 1980 to 4 million tons in 1992. This has led to self-sufficiency and even export of wheat. In addition, vegetable and fruit production has increased significantly in recent years. Saudi Arabia is still, however, the largest importer (about US\$3.1 billion) of agricultural products in the area.

3.7.2.8 COASTAL CONSTRUCTION, MINING AND QUARRYING ACTIVITIES

Much of the commercial and the residential development along the coast has taken place around Jubail, and further south around Tarut Bay, Dammam and Khobar Corniches (coastal highways) have been built in these areas. The corniche along the sea front of Khobar extends south beyond Dawhat As Sayh (Sunset Beach) to Dawhat Zalum (Half Moon Bay). Industrial development has taken place at many sites along the coast.

One of the most destructive activities associated with coastal development is landfilling. Major landfilling activities have been conducted on the Saudi Arabian coast particularly around Tarut Bay. Unfortunately, the construction of causeways, ports, residential and commercial areas, industrial facilities and roads on landfilled areas is viewed as an inexpensive way to increase coastal development. Not only does landfilling cause permanent destruction of coastal habitats, it can also have indirect environmental impacts such as sedimentation, which are often just as severe. Frequently, coastal landfilling projects are designed with little thought as to how they may affect natural water circulation in a bay or other coastal areas. Changes in water circulation can alter the structure of the resident plant and animal communities. In some cases, construction of causeways or other structures that block the flow of water and slow natural flushing action can make the area more susceptible to water pollution. An example of this problem is the pollution in parts of Tarut Bay resulting from construction of the Qatif island causeway.

In addition to the significant adverse environmental effects of landfilling, there are also economic repercussions associated with landfilling, particularly with residential landfilling. Major landfills can reduce the property values of those houses or other facilities that were previously on the waterfront. The construction of new houses or industrial facilities can also overburden the infrastructure of the adjacent urban area. These developments will need water, electricity, sewage treatment and solid waste disposal services. The

full costs of such landfill projects should be carefully analysed before they are started.

Examples of major landfill projects include the King Abdul Aziz port development at Dammam, the landfilling for both industrial and residential projects at Madinat Al Jubail Al Sinaiyah and residential landfill developments along the Khubar-Dammam coastline.

Like landfilling, dredging causes destruction of the immediate environment and often has indirect impacts from sediment loading in adjacent waters. Significant dredging has been conducted to obtain material for the landfill at Madinat Al Jubail Al Sinaiyah. Dredging has also been necessary to deepen shipping channels and harbours, such as those at Jubail and Dammam. Approximately 46.5 km² (4,650 hectares) of coastal habitats have been dredged along the Saudi coast to alter the coastline and deepen the Gulf waters. While sedimentation stimulated by dredging is often harmful, it can be beneficial to some species, such as waders, by creating new sedimentary feeding areas. This phenomenon is apparent in certain parts of the Tarut Bay area.

3.7.2.9 PORT FACILITIES

Major commercial and industrial ports are located at Jubail, Ju'aymah, Ras Tanura and Dammam. Ports are usually located in protected harbours and, if they are not deep enough, require dredging. Piers, marine causeways, jetties, floating marine service barges, small ship repair and maintenance facilities, berths, naval bases and storage areas are to be found in many of the ports along the Saudi Arabian eastern coast. Smaller port facilities are located at Tanaqib, Saffaniyah and Qatif. The King Fahd industrial port in Jubail has oil and petrochemical tank farms, seven tanker berths, an iron-ore ship-unloading facility and a urea-storage ship-loading facility. It serves 250 tankers and cargo carriers. The Jubail commercial port has two container berths, 14 general cargo berths and bulk cement facilities and it serves over 1,000 vessels. There is a fishing port nearby. A Saudi Arabian government naval base is also located south of

Jubail. At Ju'aymah there is an LPG* marine loading platform with two berths at the end of a 10 km concrete trestle. The trestle supports a road, LPG* pipelines and other fuel lines and is operated by Aramco. The Ju'aymah offshore single point mooring system operated by Aramco has six berths, an oil platform and a control platform. The King Abdul Aziz Port in Dammam has facilities for general cargo, Ro-Ro containers, bulk grain, bulk cement, bunkering and ship repairs. At Ras Tanura, 1 km from shore, there are piers with six tanker berths connected by six product pipelines to shore. There are other piers to the east, west and south-all operated by Aramco. There are minor ports at Tanaqib Al Mish'ab and a jetty at Saffaniyah, Qatif. In addition, there are causeways at Berri, Abu'Ali, Qatif to Tarut island and Azisiyah to Bahrain. A wharf and sea island are located at Ras al Mishab.

3.7.2.10 OTHERS

Industrial liquid wastes discharged into the sea were reported to be 10,972 m³/year through cooling canal at Jubail Industrial City (ROPME 1997; Table 18) with BOD 8,211 t/y, TSS 2,377 t/y and oil 384 t/y. Royal Commission For Jubail and Yanbu, Jubail Project (RC) operates a tertiary level Central Industrial Waste Water Treatment Plant (JIWWTP) which receives approximately 28,000 m³ industrial waste water every day. The IWWTP effluent is reused by the RC for the irrigation of landscape in the area.

Dammam Industrial City I, which houses approximately 120 diversified medium and small scale industries, discharge their waste water to Dammam Sewage Treatment Plant (DSTP). The volume of waste water discharged to DSTP from the industrial city is not known. Part of the effluent of DSTP is reused for landscape and the remaining is discharged to the sea (data for DSTP was provided to ROPME). Dammam Industrial City II, which houses approximately seventy (70) industries, industrial waste water is treated in a secondary level Central Industrial Waste Water Treatment Plant (DIWWTP). 6,000 m³/d Treated waste water from DIWWTP is discharged on land rather than discharging to the sea.

Saudi Aramco has four industrial facilities discharging treated waste water to the sea after partial use for landscape activities. The data on the volumes discharged from these facilities to the sea and volume used for irrigation has not been provided.

Estimated atmospheric emissions in the eastern province were 211,211 tons/y (ROPME 1997) with oxides of nitrogen 152,370 tons/y while quantities of suspended particulate matter and carbon monoxide were estimated to be low. The primary sources of atmospheric emissions were found to industrial facilities at Dammam, Khobar and Jubail.

3.7.3 Establishment of priorities

The Saudi Arabian representative at the workshop in Bahrain, December 1996, provided the following list of source categories, arranged in order of priority:

1. Oils (hydrocarbons) and combustion products (e.g., PAHs);
2. Physical alteration, sediment mobilization and destruction of habitats;
3. Sewage and nutrients;
4. Litter;
5. Atmospheric deposition;
6. Persistent organic pollutants (POPs);
7. Heavy metals;
8. Radioactive substances.

3.7.4 Setting management objectives for priority problems

Management objectives for land-based sources and activities affecting the marine environment fall within the framework of the law on "pollution control and

environmental protection". Like other member states, it is suggested that a programme should be established within the Meteorology and Environment Protection Administration (MEPA) for the protection of the marine environment from land-based sources and activities. This programme needs to be developed and should include specific targets, areas, and timetables to achieve specific targets. In addition, actions are needed on certain issues at the national, regional and global levels. The recommended approach by source category, as suggested in the Global Programme of Action, should be consulted.

3.7.5 Identification and selection of strategies and measures

There is an urgent need to update information on land-based sources and activities affecting the marine environment. It is suggested that certain areas should be selected (e.g., Al Khobar, Tarut Bay including Ras Tanura, Al Jubail) known to be the source of pollution. At these sites, activities should be monitored and regulations and measures should be enforced. This will be followed, after two or three years, by an evaluation and, where necessary, legislation will be made.

3.7.6 Evaluation of effectiveness of strategies and measures

Based on available information, marine pollution from land-based sources varied greatly according to source and area. MEPA executes many programmes to protect the marine environment (e.g., coastal zone management, establishment of wildlife sanctuary at Al Jubail), in addition to monitoring programmes. However, the existing strategies and measures need to be updated and require strong political will, public support and multinational cooperation. MEPA should be committed to the suggested programmes for the protection of marine environment from land-based sources and activities, and should provide financial and technical assistance to implement these programmes.

3.7.7 Programme support elements

In the early 1980s and after joining the ROPME and other regional and international conventions, Saudi Arabia issued many environmental laws to implement its commitment to the conventions and to protect the environment. In 1980, a Decree was issued on pollution control and environment protection. This law addressed many issues, such as setting standards for pollution control, the conduct of research surveys and monitoring programmes to study the state of environment and the identification of alternatives to control and solve pollution problems. In 1986, the Royal National Commission for Wildlife Conservation and Development was established. It carried out numerous important projects (e.g., preparation of the publication *Fauna of Saudi Arabia*; establishment of a wildlife sanctuary at Jubail; monitoring of the turtle population; bird-watching programmes and many others).

Meteorology and Environmental Protection Administration (MEPA) is the central agency for environment in the Kingdom of Saudi Arabia which is part of the Ministry of Defense and Aviation. MEPA was established in 1980 from the Directorate of Meteorology by adding environmental responsibilities to its functions. The functions and responsibilities of MEPA are (a) conducting environmental surveys (b) recommending environmental protection regulations (c) preparing environmental standards (d) assessing existing pollution levels (e) recommending practical measures for dealing with emergency environmental plans and (f) keeping abreast of developments in the field of environment on the international level. MEPA, in its short span of existence, has achieved many goals including promulgation of environmental standards, survey and inventory of gaseous and liquid emissions and discharges and solid waste, monitoring of the source emissions and discharges, environmental impact assessment of developmental projects, compliance with the regulations and standards, monitoring of ambient air quality and marine environment, National Oil Spill Contingency Plan, National Coastal Zone Management Plan, Environmental Law, Standards and Guidelines for Hazard-

ous Waste Management, Medical Waste Management, Asbestos etc.

In addition to routine monitoring programmes, MEPA has also carried out various comprehensive marine environment studies for the eastern coast of Saudi Arabia. Prominent among them are: Eighteen (18) months studies for ROPME (1985-1986), MEPA-IUCN study (1987). A national public awareness programme "SEAP" has been established with the objective of increasing environmental awareness among teachers, students and common man through education and publicity materials.

The Research Institute of the King Fahd University of Petroleum and Minerals is one of the most active research institutions in Saudi Arabia. The extensive capabilities of the Water Resources and Environment Division are concentrated on research related to water resources management and use, water quality air quality, environmental pollution, oceanography, marine biology, and mathematical modelling of hydrodynamic events in the marine environment. Problems are addressed by task groups capable of providing the necessary foundations in basic science to meet the research needs of clients. The number and composition of these groups is not fixed; they evolve to meet specific needs. Projects may involve contributions from more than one group, thus expanding the capability of the Division to meet a wide range of requirements in water resource and environmental research.

The Ministerial Committee on Environment (MCE), chaired by HRH Prince Sultan Bin Abdulaziz, the Second Deputy Premier and Minister of Defense and Aviation and Inspector General, is the highest institutional and decision making authority on environmental issues in the Kingdom. The MCE is composed of the concerned sector ministries namely Ministries of Agriculture and Water, Industry and Electricity, Finance and National Economy, Foreign Affairs, Health, Interior, Municipal and Rural Affairs, and Petroleum and Mineral Resources as well as the Presidents of King Abdulaziz City for Science and Technology (KACST) and Meteorology and Envi-

ronmental Protection Administration (MEPA), the latter having been designated as Secretary General for the MCE. The functions and responsibilities of MCE are as follows:

- (i) To establish the Kingdom's position on environmental issues at national, regional and international levels;
- (ii) To formulate a National Environmental Strategy; and
- (iii) To coordinate and follow-up on environmental activities within the Kingdom.

The MCE is assisted by Preparatory Committee Chaired by HH Assistant to HRH the Minister of Defense and Aviation and Inspector General and consists of Deputy Ministers of the sector Ministries and the Presidents of MEPA and KACST as members. The functions of the Preparatory Committee are to act as a clearing house for MCE and prepare necessary studies and actions for the MCE's review and approval. MEPA acts as the Secretariat of the Preparatory Committee also.

3.8 UNITED ARAB EMIRATES

3.8.1 Introduction

The United Arab Emirates is a federation of seven internally self-governed emirates: Abu Dhabi, Dubai, Sharjah, Ras Al Khaimah, Ajman, Umm al-Quwain and Fujaira. All seven emirates are coastal settlements. Some of them, however, have inland enclaves surrounded by the territories of one or more of the other emirates. Except for Fujaira, all the emirates lie on the southern shores of the area and they present a continuous, crescent-shaped coastline stretching about 640 km from the Qatar peninsula in the west to the Musandam peninsula in the east.

The United Arab Emirates is largely a desert area located between 51°-56.5°E longitude and 22°-26.5°N latitude. It consists of the Batinah coastal plain in the Gulf of Oman, the central and southern sand dune area and the western coastal plain along

the ROPME sea area. Only the region to the north of Oman is mountainous with elevations exceeding 1,000 meters above sea level. All capitals lie on the Gulf, except for Fujaira which has its capital on the Batinah plain on the Gulf of Oman. The total area of the United Arab Emirates is 1,165 km².

Abu Dhabi is by far the largest of the emirates, and it has two main population centres, the town in Abu Dhabi and the oasis settlement of Al Ain, which is part of the Buraimi group. This is an island located in the area near the coast of Abu Dhabi, with an area of 60 km². There are many islands which belong to the emirates, the most important of which are Das (3 km²) located 170 km to the north-west of the capital, famous for the oil fields surrounding it. Sier Bani Yas, located 180 km to the west of the capital, has an oil terminal for exporting the crude oil produced in Merban and Bou-Hasa fields. There is also Umm el-Nar where an oil refinery is in operation. Besides these oil activity-related islands, there is Al-Sa'adiyat, located to the east of the capital, which has on its territory an agricultural research station producing one tonne of vegetables daily under controlled environmental conditions. Al Ain city is the capital of the eastern area of the Emirates and is recognized for its fertile soil.

Dubai is located at longitude 55°E and latitude 25°N. Its total area is approximately 3,885 square km with a 72 km seafront. The main population is centred in the city of Dubai. The city has the largest deep-water harbour in the Middle East and has a major dry dock.

The estimated total population of the United Arab Emirates in 1995 was 1,904,000, consisting of 33 per cent females and 67 per cent males and 80 per cent of whom are expatriates. About 80 per cent of the population live in urban areas.

The inland areas have a typical desert climate while the coastal areas are hot and humid. The maximum and minimum recorded temperatures are 47.3° C and 9.2° C respectively, with high relative humidity along the coast. The average relative humidity throughout the year is 61 per cent. The average, maximum and

minimum rainfall measurements recorded in 1983 were 24.8 mm, 85.7 mm and 0.2 mm respectively.

Temperature inversion is common throughout the year with a frequency of low level inversions of the order of 45 per cent. These tend to trap emissions, thus causing high pollutant concentrations in the vicinity of the sources. Moreover, certain conditions may arise which promote the long distance transport of pollutants. Wind directions are variable but those from the west and south are the most common. Calm conditions prevail for over 6 per cent of the time.

3.8.2 Identification and assessment of main pollution sources

3.8.2.1 POWER AND DESALINATION PLANTS

No information is available on the number of power stations. According to World Resources (1996-1997) and the Economic and Social Commission for Western Asia (ESCWA, 1997), however, the United Arab Emirates has a total energy production of 5,282 MW, of which 4,387 MW come from liquid and 895 MW from gas sources. Electricity production is estimated at 18,000 GW and consumption per capita is 1,060 kW.

The United Arab Emirates is the largest producer of desalinated water from the inner area as a source of freshwater supply, providing 34 per cent of its freshwater needs in this way (Al Hajr and Ahmed, 1997). The seven MSF plants produce 1,766,580 m³/day. The distribution of desalination plants along the coast of United Arab Emirates is presented in figure 4 and table 19, varying from 1,125 to 532,915 m³/day.

3.8.2.2 SEWAGE TREATMENT FACILITIES

There are four large sewage treatment plants in the United Arab Emirates (Al-Zubari, 1997) with treatment facilities of 295,000 m³/day. Treatment is at the tertiary level. The current volumes of treated wastewater is 280,000 m³/day. Reused water output is 170,000 m³/day, and this is utilized in irrigation

parks, golf courses, highways and urban water features.

However, Banat *et.al.* (1996) found that the Abu Dhabi and Dubai creeks had occasional high nutrient levels with some fluctuations and wide spatial and temporal variations, suggesting the presence of anthropogenic sources of pollution, creating these conditions, near the sampling sites. Sharjah and Ajman creeks had much lower nutrient levels. The bacterial counts of the total saprophytic bacteria, salt-tolerant bacteria and Gram-negative bacteria had distinct patterns peaking in spring and summer and diminishing during winter. Total and faecal coliform counts fluctuated depending on the presence of nearby recreation and commercial areas; these were at no time consistently high, however, *Bacillus*, *Pseudomonas*, *Staphylococcus*, *Micrococcus* and *Alteromonas* were the predominant bacterial genera in these waters.

3.8.2.3 INDUSTRIAL FACILITIES

Oil and natural gas constitute the main extractive industries. The United Arab Emirates produces 2.2 million barrels of oil per day, whereas natural gas is estimated at 42,335 billion cubic meters. These extractive industries represent 34.2 per cent of GDP. The primary manufacturing industries are petrochemicals, textiles, food industries, chemicals, tools, paper mills and fertilizers, together representing 8.4 per cent of GDP. Abu Dhabi is the centre of the oil and natural gas industry whereas Dubai and Sharjah are the centre of the manufacturing industries.

The Ruwais Industrial Complex is situated on the southern coast, some 235 km west of Abu Dhabi and just a few kilometres east of Abu Dhabi Company for Onshore Oil Operation (ADCO), crude oil loading and export terminal at Jabal Dhamma. The capacity of this terminal is 1,280,000 barrels/day. Approximately 40 oil tankers call at this terminal each month to deliver Abu Dhabi crude oil to various parts of the world. The facilities at Ruwais comprise a 120,000 barrels/day refinery, a BGL separation plant for the production of butane, propane, in-

frastructure support to the industrial plants (e.g. housing units), a fertilizer plant for the production of ammonia and urea, a 90 MW power and utilities plant and cargo terminals. A hazardous waste facility has been developed recently for the appropriate handling and disposal of a variety of waste materials, to reduce air and marine pollution.

The Dubai municipality has an extensive waste disposal programme, and a programme for the monitoring of air, land and marine pollution and is already engaged in educational activities designed to stimulate greater public consciousness. An Environmental Protection and Safety Management Plan (EPSS) has been signed by the Director of the Health Department for Dubai municipality and the chairman of the Al Jadaf Shipyard, Dubai. The plan sets out the basis for future environmental and safety improvements.

Since 1978, Sharjah Municipality has been composting much of its domestic and commercial waste at a site adjacent to the city's sewage treatment plant. The plant had an initial capacity of 100 tons per day. In opting for the composting strategy, Sharjah took the same line as had already been taken by the municipalities of Abu Dhabi, Al Ain in the United Arab Emirates and Doha in Qatar. Since it was first commissioned, the plant has undergone various modifications and expansions: in 1983 a refining unit was added in order to produce compost with a finer texture, and in 1986 the capacity of the plant was doubled. The most recent expansion, which was completed during summer 1993, was the installation of a destoner which removes residual stones and pieces of glass before bagging.

Today, the 200 tons/day capacity of the plant falls far short of the total domestic and commercial garbage produced within a city which has grown well beyond its 1978 limits. In addition to the 200 tons which go to the composting plant every day, 300 tons of garbage go to landfills. The composting plant is adjacent to Sharjah's sewage treatment works and takes advantage of this proximity, adding about 60 gallons of sewage sludge to every tonne of

compostibles as the garbage passes through the digester drum. (The compost plant also has access to the laboratory facilities at the sewage treatment plant for monitoring and analysing the quality of the compost it produces.) The material passes through the drum in about 12 hours and then requires another six to eight weeks fermentation before being ready for bagging. Sharjah municipality takes about 50 per cent of the final product while the balance is sold on the open market throughout the United Arab Emirates for use by farmers and nurserymen.

It was estimated that Union Paper Mills in the United Arab Emirates produced 27,000 tons of recycled paper products for use in packaging. Union Paper Mills has its own fleet of pick-ups which collect scrap paper from around the United Arab Emirates. Combined with the waste paper sold to the plant by independent scrap collectors, this averages out at between 90 and 100 tons/day of waste paper for processing. A variety of contaminants, i.e., plastic straps and string, metal staples and sand, are removed from the paper during processing, with the result that about 1.2 tons of raw scrap is needed for every ton of finished product (Middle East Environment, 1993).

3.8.2.4 SOLID WASTE

Based on rapid assessment studies conducted over 1985-1987, solid waste loads from industrial sources in the United Arab Emirates amounted to 687,953 tons/yr, of which 94,397 tons/yr are oil sludges and 593,555 tons/yr come from other industries. Oil sludges are generated from refineries and oil export terminals, whereas other wastes are the products of industrial processes, including blood, paunch, Hoover, cartar, plastic, spare parts, minerals, mud, paints and solvents (ROPME, 1997).

Solid waste loads from domestic sources amount to 209,737 tons/yr, of which 94,397 tons/yr are sludge and 115,340 tons/yr are refuse (ROPME, 1997).

3.8.2.5 RECREATION AND TOURISM FACILITIES

Recreation and tourism facilities are rapidly developing in the United Arab Emirates. Although no information is available on the number of tourist arrivals per year, available data suggest that Dubai has superb facilities for sports, shopping, dining and entertainment. This developing tourism sector is well equipped to cater to the diverse needs of individual travellers, families or incentive groups. For example, Dubai alone is served by 80 airlines, which provide direct links to over 120 cities worldwide. The United Arab Emirates has a wide selection of luxury modern hotels and furnished holiday apartments and an extensive range of restaurants. Water sports on offer include sailing, fishing, wind-surfing, water-skiing, scuba diving and snorkelling. There also exist tax-free open markets for many international products (mostly electrical goods and textile products). Attractions and sights in Dubai include the city, creek, souks (markets), museums, the Dubai Wonderland, the World Trade Centre, the zoo, parks and gardens, diving centres, archaeological sites, the golf course, the yacht club, the racing club, and many others.

3.8.2.6 OIL REFINERIES

Most of the oil refineries in the United Arab Emirates are situated in Abu Dhabi (at Umm el-Nar island). The total production of the oil refineries in the United Arab Emirates is 205,000 barrels/day, representing 9.3 per cent of its oil production. With the expansion of oil refinery capacities, this figure is expected to increase to 25 per cent of oil production within the next few years (ESCWA, 1997).

3.8.2.7 AGRICULTURAL ACTIVITIES

Agricultural land is very limited and diminishing in area. It is mainly found on El-Batinah plain, in the northern region and in Al Ain region. There is a total area of 45,500 ha, most of it irrigated by water from *aflaj* (inclined tunnels made to reach the ground water) or groundwater wells. The current level of

water resources used in agriculture is estimated at 950 million m³ (data for 1990) and is expected to increase to 1,400 million m³ by the year 2000 (ESCWA, 1997). The amount of fertilizers used in agriculture is 27,700 tons/yr-equivalent to 608.8 kg/ha. Agricultural products represent 6.6 per cent of GDP. The United Arab Emirates is self-sufficient in dates, fish and tomatoes. Other products and grains are imported.

3.8.2.8 COASTAL CONSTRUCTION, MINING AND QUARRYING ACTIVITIES

Major economic and social developments have taken place in various coastal parts of the United Arab Emirates, such as the expansion of modern urban centres, the construction of modern deep-water ports, new industrial complexes and desalination plants and the development of modern sewage networks with marine outlets. Examples of these artificial modifications are the following:

Dredging works around and at the entrances of Abu Dhabi lagoon, Khor Um Al Quwain, and Khor Kalba to provide deep water channels for access to modern ports;

Dumping of sewage from growing cities into the lagoons;

Dumping of earth material into shallow and marginal parts of the lagoons for construction purposes.

The first two modifications were responsible for the improvement of environmental conditions by preventing water salinity values from rising as high as those previously recorded in the 1960s, and by increasing the supply of nutrients, leading to the spread of mangrove in several localities. The third man-made modification was responsible for the elimination of mangrove from some tracts where construction works were necessary (Embabi, 1993).

3.8.2.9 PORT FACILITIES

The Dubai Port Authority has overall responsibility

for operations at Port Rashid and Jebel Ali Port for the Jebel Ali Free Zone, where there are already some 530 lessee organizations in the Free Zone and a steady stream of new arrivals. Waste disposal is an essential part of the Authority's role; since, wherever people congregate, there are waste disposal problems, arising out of the presence of those people and from their commercial activities.

At both ports marine pollution control has followed international rules, and precautions have been taken to prevent and deal with spillages from ships and to prevent the dumping into the harbour of wastes which do not meet appropriate specifications.

Dubai Port Authority is encouraging private investors to set up a complete MARPOL 73/78 oily waste reception facility at its Jebel Ali Terminal. In return for support from the Dubai Port Authority, the facility is required to utilize the best practicable environmental option for dealing with sludge and slop waste.

A sludge/slops reception facility is being developed at the strategic location of Jebel Ali Port, Dubai, the largest man-made port in the world. The port has 15 km of quay, 667 berths and a water depth of up to 14 m. The facility will initially cover 24,000 m² of land and will have its own loading and unloading jetty, oil storage tank farm and an in-house laboratory. The main process features of the project are:

- A reaction plant for chemical treatment of sludges comprising: de-emulsification, coagulation, flocculation, wax inhibition;
- A thermo-physical separation plant to separate solids, oil and water, including decanter and disk stack centrifuges in series;
- A wastewater treatment plant comprising: equalization, de-emulsification, coagulation, flocculation, dissolved air flotation, pressurized sand filtration, activated carbon filtration, sludge dewatering;

- An oil recovery plan;
- A solids stabilization plant; and
- A lined landfill comprising: impermeable barriers, leachate detection and collection system, groundwater monitoring system.

3.8.2.10 OTHERS

A summary of industrial liquid waste generated from industrial areas in the United Arab Emirates is presented in tables 20 and 21. It is noted that the highest contaminant load is oil (19,407 tons/yr) resulting mainly from ship ballast water and chemical manufacturing. Biochemical oxygen demand is also high (7,659 tons/yr) and results mainly from the agricultural industries. The total amount of dissolved solids is 5,337 tons/yr, which is mainly generated. Domestic liquid waste discharges to the sea in the United Arab Emirates, based on the rapid assessment report of the United Arab Emirates, indicate that the two plants in Dubai and Sharjah discharge treated and untreated effluents, while Abu Dhabi's discharges are treated. This may no longer be the case, however. The total level of discharges from all these plants treated and untreated clearly shows that the highest load is sulphates ($-\text{SO}_4$) (4,552 tons/yr), followed by suspended solids (607 tons/yr), biochemical oxygen demand (470 tons/yr), phosphorous (308 tons/yr) and ammonia-nitrogen (251 tons/yr). Nitrates ($-\text{NO}_3$) and nitrogen dioxide (NO_2) contribute an additional 155 and 20 tons/yr, respectively (ROPME, 1997).

Atmospheric emissions from the United Arab Emirates during the period 1995-1997 amounted to 725,159 tons/yr (18.85 per cent) of all the ROPME member States. The major pollutants were cobalt (251,033 tons/yr), sulphur oxides (164,823 tons/yr), nitrogen oxides (148,445 tons/yr), particulates (129,263 tons/yr) and hydrocarbon (31,595 tons/yr) (ROPME, 1997).

Dubai Municipality has invested in one million UAE dirhams' worth of air pollution monitoring equipment (Middle East Environment, 1993). It managed

to get new regulations introduced, enforced them and collected fines for offenders. The same is happening in other Emirates.

To reduce air pollution, Emirates Petroleum took an initiative in 1992 to introduce unleaded petrol. Marketed under the name "Ultima", Emirates Petroleum's high-octane unleaded fuel has a lead content of just 0.013 g/l compared to 0.4 g/l in conventional petrol (Middle East Environment, 1993).

3.8.3 Establishment of priorities

The United Arab Emirates representative did not attend the two meetings in Kuwait and Bahrain, and no information was provided on order of priority. Based on the available information, the following are source categories arranged in suggested order of priority:

1. Physical alteration, sediment mobilization and destruction of habitats;
2. Oil (hydrocarbons) and combustion products (e.g., PAHs);
3. Litter;
4. Atmospheric deposition;
5. Sewage and nutrients;
6. Heavy metals;
7. POPs;
8. Radioactive substances.

3.8.4 Setting management objectives for priority problems

It is suggested that a programme should be established within the Federal Environment Authority for the protection of the marine environment from land-based sources and activities. This programme needs to be developed and includes specific targets,

areas, and timetables to achieve specific targets. In addition, actions need to be defined, based on recommended approach by source category as suggested by the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities.

3.8.5 Identification and selection of strategies and measures

The first step should be the conduct of an updating survey on land-based sources and activities affecting the marine environment. This can be achieved by training local staff in how to collect the appropriate data, to verify data and to use data in drawing up policies and legislation. The second step is to select areas known to be main sources of pollution. It is suggested that two sites at Dubai and Abu Dhabi be selected, where major industries are located and where there are already extensive waste disposal programmes and programmes to monitor air, land and marine pollution. These two sites should be at Jebel Ali (Dubai) and Ruwais Industrial Complex (Abu Dhabi) where the hazardous waste disposal facilities and the oil spill response centre are located. At these two sites, activities will be monitored, and regulations and measures will be enforced. Where necessary, sanctions may be taken against enterprises committing breaches of the regulations by:

- Ordering instant closure if danger is imminent;
- Ordering correction within a certain time;
- Imposing fines for persistent small offenses.
- The third step will be evaluation of the programme after two to three years, followed by modification and amendment of legislation where necessary.

3.8.6 Evaluation of effectiveness of strategies and measures

To provide a proper evaluation of the effectiveness

of strategies and measures, the following are suggested:

- The Federal Environment Authority (FEA) should be considered responsible for the programme for the protection of the marine environment from land-based sources and activities;
- FEA should provide training programmes for its local staff;
- Technical and financial facilities should be provided to implement the programme;
- Staff should have the power to enforce regulations and measures;
- FEA should consider the amendment of the existing regulations if proved ineffective;
- FEA should request industry to apply cleaner technology;
- FEA should provide awareness and environmental education programmes.

3.8.7 Programme support elements

3.8.7.1 FEDERAL ENVIRONMENT AUTHORITY, ABU DHABI

FEA was established in 1993, as a public authority to look after environmental affairs at state level. Though autonomous, it is affiliated with the Cabinet and has a board of Directors headed by the Minister of Health. The board includes as members nine senior officials concerned with environmental affairs. Its jurisdiction includes the protection and development of the environment through the development of laws and the promulgation of policies and plans to protect the environment from harmful effects of the various activities on human health, wildlife, marine life, natural resources and climate. It undertakes the implementation of such policies and the adoption of measures to check the deterioration of the

environment and to combat pollution in various forms, in order to protect present and future generations. FEA has drafted a number of laws concerning the environment and developed a strategy for environmental awareness and information which is to be implemented in the near future.

3.8.7.2 NATIONAL AVIATION RESEARCH CENTRE, ABU DHABI

The National Bird Research Centre was established in 1989 as a research organization devoted to the wise use of natural resources. Its aim is to carry out ecological research to further knowledge, understanding and public interest in the conservation of birds and other United Arab Emirate wildlife in general. At present, the centre has an international and professional team of more than 30 scientists, agriculturists and veterinarians. Most of the Centre's staff work from and live in the desert research station near the town of Sweihan (55 km from Al Ain) as well as the island of Abu Al-Abyadh and the capital, Abu Dhabi.

3.8.7.3 MARINE ENVIRONMENT SCIENCE SECTION, DESERT AND MARINE ENVIRONMENT RESEARCH CENTRE, UNITED ARAB EMIRATES UNIVERSITY, AL AIN

The Marine Environmental Science Section of the Desert and Marine Environment Research Centre was established in 1987 with the objectives of carrying out research and studies in the field of the development of fish resources, economic invertebrates and marine plants, as well as research and studies in the field of marine environment and pollution, with the aim of protecting the environment from the dangers that may threaten it. Considerable work has been done on baseline studies, including mangrove ecology, mangrove restoration and coral reef ecology. The Section coordinates most of its activities with the Biology Department in the Faculty of Science of the University of Al Ain.

3.8.7.4 MARINE RESOURCES RESEARCH AND CULTIVATION CENTRE, UMM AL QUWAIN

The Marine Resources Research and Cultivation Centre, Umm Al Quwain was established in 1987 under the technical cooperation programme between the United Arab Emirates, represented by the Ministry of Agriculture and Fisheries, and the Japanese Government, represented by JICA. The centre is engaged in surveys, research and cultivation of different species of fish and shrimps. It has a seed production unit, a fish feed production unit, laboratories, an aquarium (29 tanks), a library, a workshop and maintenance section, a water supply and distribution system and extension activities outside the centre.

Each of the emirates has its own municipal authority responsible for the collection of waste. Marine oil pollution is controlled by oil companies. Municipalities have extensive programmes in the area of waste disposal, monitoring of air, land and marine pollution, and are already engaged in educational activities designed to promote greater public awareness.

4. Overall assessment

All the ROPME member States have their own national policies and legislation that deal with land-based activities affecting the marine environment. They are also members of many regional and international conventions (such as the United Nations Convention on the Law of the Sea and the Convention on Biological Diversity) under which they are committed to protecting their marine environment from land-based sources. In addition, some member States (such as Bahrain, Kuwait, Oman, Qatar and Saudi Arabia) have their own monitoring programmes dealing with air and marine pollution and they take into consideration their responsibilities to ROPME, by reporting their results. Furthermore, some member States have taken actions and measures to reduce marine pollution from land-based sources, and have also involved private sector (for example, in Saudi Arabia and the United Arab Emirates) in their development planning.

The available data, are not consistent, however, and need to be verified and updated. Although laboratories of some member States have implemented new quality control and quality assurance procedures and good laboratory practice, they are still gaining experience in appropriate analytical skills. This phase should be considered as a learning period where errors are made and experience is gained. Other laboratories have local staff capable of producing data of a consistently high standard from marine biota and sediments. That is why it is difficult at this stage to assess all the available data and to obtain trends of marine pollution in the ROPME region.

Very valuable data are available in certain governmental institutions. They are in the form of raw data, however, or in a format that renders it difficult to detect pollution trends because of their inconsistency (gathered over too few months or too long ago). In addition, coordination between these governmental agencies and research institution is lacking in many cases. In other cases, however, (e.g., Ministry of Regional Municipalities and Environment of Oman),

there is good coordination, with data collected regularly and measures taken whenever a problem arises.

The overall picture of land-based sources and activities affecting the marine environment of the ROPME region varies greatly from one country to another. For instance, land-based activities in Oman do not represent a serious problem as all actions and measures suggested in the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities have been implemented for most source categories. Because of the expected development projects along the coast of several cities, however, careful consideration should be taken in the future to counter the expected impacts of these development projects on the marine environment. On the other hand, in other countries, very little has been done to protect the marine environment from land-based sources and activities.

Control efforts in some States have in many cases been below the desirable standards and have always been outstripped by further developments. The main reasons for the shortfall are:

- Scarcity of specialized staff;
- Inadequacy of laboratory facilities and quality control systems;
- Inadequate application and enforcement measures;
- Inadequacy of coordination among government institutions;
- Insufficient emphasis on preventative means during project and programme identification and preparation;
- Inadequate operational and management planning;
- Inadequate environmental awareness.

5. Regional analysis of land-based pollution sources

5.1 INTRODUCTION

Land-based sources of pollution constitute one of the major issues of common interest to all the ROPME member States. This issue has been raised at several places and it is one of the main items of the 1978 Kuwait Regional Convention for Cooperation on the Protection of the Marine Environment from Pollution.

Several inventory missions were carried out in the ROPME member States during 1980. ROPME analysed and compiled all the available information, including that held by other United Nations agencies, into a consolidated report. This study provided an evaluation of the situation of land-based sources of pollution, based on the information which was officially available in January 1984.

An in-depth study on the control of land-based sources of pollution in the region was conducted by ROPME. The basic objectives of the programme were to develop, in the space of a few years, an effective and realistic strategy for the abatement of pollution from land-based sources and to promote the implementation of the related control measures in close cooperation with national authorities. The study included an inventory for land-based sources of pollution, which was compiled by member States (1985-1987), to form the basis of the strategy. Unfortunately, the inventory has not been updated since that time. Recent assessments of land-based activities were prepared by the ROPME secretariat in 1995 and 1996, and focused on various types of pollution and their sources. They included air pollution, solid waste (domestic and industrial), liquid waste (ballast water discharges and industrial waste) and domestic waste water discharges (Said, 1996). With regard to the industrial source of pollution, it seems that the existing data do not cover all sources of ef-

fluents discharged into the marine environment. Domestic and industrial source inventories need to be updated (Atallah, 1995).

The ROPME member States have recognized the urgent need to protect the marine environment from land-based activities and, to that end, have prepared the protocol of the Marine Environment from Land-based Sources. The Protocol was signed in February 1990 by the contracting States and entered into force in January 1993 (Mohammadi, 1995). The Protocol was prepared in fulfilment of Article III, paragraph (b), and Article VI of the Kuwait Convention and draws mainly from the Montreal Guidelines for the Protection of the Marine Environment Against Pollution from Land-based Sources (1985) and Articles 194, 207, 212 and 213 of the Law of the Sea, 1982.

In order to comply with the Global Programme of Action and benefit from the global opportunity of exchange of experience and sharing of resources, and in accordance with Article III of the ROPME Protocol, a ROPME/UNEP Experts Consultation Meeting on the Control of Marine Pollution from Land-based Sources was convened at the ROPME secretariat on 16-18 December 1995 in cooperation with UNEP. The main objective of the meeting was to develop a programme of action to reduce, control and/or prevent marine degradation from land-based activities in the ROPME sea area that is consistent with the Washington Declaration and the Global Programme of Action.

The Expert Meeting reviewed in detail the elements of the Global Programme of Action, adopting largely verbatim its "Basis of Action" and "Objectives". Particular emphasis was given to:

- Characteristics of the region with regard to source category;
- Specific needs of the region; and
- Listing of priorities.

Source categories have been renumbered according

to the priority identified by the meeting. The final text of each subsection then specifies the nature of the ROPME regional priority and the potential activities relating to that category of contaminant. In setting priorities, the meeting emphasized that the issues and priorities for action defined within individual ROPME member States may differ among States because of socio-economic and physiographic differences. An examination of priority regional issues was made, however, to ensure that national action plans dealt, at a minimum, with issues of priority from a ROPME perspective.

An analysis of priority issues from the ROPME (regional) perspective indicated the following order of priority issues:

1. Oils (hydrocarbons) and combustion products (e.g., PAHs);
2. Physical alteration, sediment mobilization and destruction of habitats;
3. Sewage and nutrients;
4. Litter;
5. Atmospheric deposition;
6. POPs;
7. Heavy metals;
8. Radioactive substances.

5.2 ASSESSMENT OF LAND-BASED SOURCES AND ACTIVITIES IN THE ROPME SEA AREA

5.2.1 Oils (hydrocarbons) and combustion products (e.g., PAHs)

Oil is the real polluter in the area. Somewhere in the region of 25,000 tankers navigate in and out of the strait of Hormuz every year (figures 5 and 6). They carry about 60 per cent of the total of one billion

metric tons per year of oil carried by all ships throughout the world. The oil is exported from 34 major oil terminals scattered around the region. Most oil is carried by supertankers at least as large as 3/4 million tons. It is known that the ROPME member States sit atop the largest hydrocarbon reserves on the planet. Over 76 billion metric tons of recoverable oil lies under and around the area; while its national gas reserves amount to 32.4 trillion cubic meters (Hinrichsen, 1996).

With all this oil being pumped and transported, the area's waters are heavily contaminated with oil residues and tar balls. Roughly two million barrels of oils are spilled into the area's waters every year from the routine discharge of dirty ballast waters and tanker slops, and from the region's 800 offshore oil spills and gas platforms (Hinrichsen, 1996). The adverse environmental impact of oil pollution on mangroves, coral reefs and fisheries is well documented (Price *et al.*, 1993; Vogt, 1994).

Illegal discharges by tankers of crude and fuel oil wastes remain the most serious marine pollution problem. Actual amounts appear to have decreased in the last few years with the introduction of new tankers fitted with segregated ballast tanks and slop tanks. This, according to the International Maritime Organization (IMO), has also resulted in a shift, whereby discharges are now mainly composed of oily bilge water and fuel oil residues rather than crude-oil-contaminated tank washing of ballast water. Oil and tar pollution appears to have worsened in some ROPME member States, especially Oman (Coles and Riyami, 1996). There have been no recent measurements nor systematic monitoring of beach tar in all the ROPME member States, however.

Beach tar oil is still widespread, often in high concentrations throughout much of the area. This contrasts with the low levels generally found in the water column and biota (Price, *et al.*, 1993). Compared with beaches, the generally low levels of petroleum hydrocarbons in the offshore environment might be explained by their rapid breakdown, as a result of intense solar radiation and high summer tempera-

ture. This is undoubtedly enhanced by biological processes, since large numbers of bacteria which degrade oil hydrocarbons have been found in sea water samples from the region (Linden *et al.*, 1990).

In accordance with the recommendations of the Global Programme of Action, five actions are suggested at the regional level (e.g., regional agreements and programmes are encouraged to develop and implement programmes and measures to reduce and/or eliminate emissions and discharge of oil from industrial sectors). To develop such programmes there is an urgent need for inventories of significant sources of oils (e.g., oil tankers, oil refineries, oil terminals, oil fields, etc.) for subsequent assessment and establishment of areas for action. Such inventories do not exist so far and few quality criteria for marine waters are available for some countries.

ROPME established the Marine Emergency Mutual Aid Centre (MEMAC) in Bahrain (March 1983) to implement the objectives of the Protocol concerning Regional Cooperation in Combating Pollution by oil and other Harmful Substances in Cases of Emergency. To date, MEMAC has dealt only with oil. In addition, there are environmental monitoring programmes for oil and combustion products, including the development of assessment criteria and the adoption of internationally accepted quality control and quality assurance procedures. The outcome of such programmes at the regional level is not yet known, however, but available data suggest that some States have active programmes (e.g., Oman and Kuwait). There is a need to strengthen these environmental monitoring programmes for oil and combustion products. There is also a need to strengthen MEMAC to deal not only with oil but also with other harmful substances.

To promote cooperation on the development of cleaner production programmes based on the best available techniques and best environmental practice, the large oil companies (e.g., ADCO, ARAMCO, in Saudi Arabia) have means at the national level to develop such programmes. At the same time, international organizations, such as UNEP, the

Intergovernmental Oceanographic Commission, the International Atomic Energy Agency (IAEA) and IMO, and regional organizations such as the GAOCMAO, Regional Organization for the Conservation of the Environment of the Red Sea and the Gulf of Aden (PERSGA) and the Gulf Cooperation Council (GCC), need to continue their cooperation with ROPME. Although such cooperation has existed since 1979 and has helped in implementing programmes and activities related to marine monitoring and researches (e.g., the conduct of surveys and studies, including feasibility studies, the raising of environmental awareness; the conduct of workshops and training courses on various marine environmental disciplines, oil pollution, response operations; etc.), support and continued cooperation should be directed toward implementing the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities in the ROPME region.

With regard to the provision of regional reception and recycling facilities for oily waste, a feasibility study was recommended by the participants at the conference on tanker discharges and protection of the marine environment, held in Muscat in April 1995, to be undertaken, without delay, on installing an oily waste reception facility close to the strait of Hormuz. So far, little has been done.

5.2.2 Physical alteration, sediment mobilization and destruction of habitats

Coastal and marine environments all over the ROPME sea area are becoming subjected to increasing human pressures, most of which have resulted in harmful environmental effects. More acute ecological problems have arisen from the loss and degradation of productive habitats, caused by landfilling, dredging and sedimentation and related practices. In some countries, almost 40 per cent of the coastline has now been developed, and a significant proportion of the shoreline of Kuwait and Bahrain is artificial (Price and Robinson, 1993).

Coastal investment in the region is estimated to be worth between \$20 million and \$40 million per km. Over 20 major industrial complexes have either been completed or are under construction (figure 7). Other land-based activities include sediment run-off, agriculture and reduction in freshwater seepage due to groundwater extraction. These activities are also contributing to the degradation of coastal environment.

Dredging and coastal reclamation probably represent one of the most serious impacts on the ROPME environment. Reclamation has been undertaken for residential developments, ports, bridges, causeways, corniche roads and other purposes. Favoured areas include intertidal flats, often with mangroves, shallow embayments and other biologically productive areas, whose true bioeconomic value is seldom recognized by developers.

Coastal erosion is attested in several parts of the area. Some erosion is a natural process and part of the continuing change of the shoreline. In many areas, however, massive and irreversible erosion occurs, primarily because construction activities have not considered impacts on the shoreline. Dams, ponds and harbours are necessary for economic development but they should be designed to minimize coastal erosion.

These activities led to physical alteration of the areas coasts, sediment mobilization and destruction of habitats. Loss of habitat extends to other parts of the region, where a considerable proportion of the mangrove forests may have been lost over the past 20 years. Overfishing of targetfish and shellfish is a major concern in some areas of the region. Degradation of coral reefs from fishing practices, recreation and tourism uses is becoming widespread.

Over the last 15 years, ROPME has implemented many projects to achieve, among other things, the following:

- Assessment of the state of the marine environment, including socio-economic development activities;

- Development of guidelines for management of those activities which have an impact on environmental quality or on the protection and use of renewable marine resources on a sustainable basis;
- Development of legal instruments providing a legal basis for cooperative efforts to protect and develop the region on a sustainable basis;
- Supporting measures, including national and regional institutional mechanisms and structures needed for the successful implementation of the Kuwait Action Plan;
- Measures for marine and coastal environmental protection and development, designed to lead to the promotion of human health and well-being.

In June 1996, the ROPME Council approved four projects for the protection of the marine environment from land-based activities, namely:

- Updating the survey of LBA source categories and impacts, capabilities and constraints in the region;
- Development of criteria, guidelines and standards for the management of land-based activities;
- Preparation of a river basin management programme;
- Conducting of a pilot study on POPs.

In addition to approving those projects, the ROPME Council allocated an amount of \$350,000 for their implementation.

According to the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities, the objectives of this land-based activities source category are:

- To safeguard the ecosystem function and to maintain the integrity and biological diversity of habitats, that are of major socio-economic and ecological interest, through the integrated management of coastal areas;
- Where practicable, to restore marine and coastal habitats that have been adversely affected by anthropogenic activities;
- To reduce control and to prevent the degradation of the marine environment due to changes in coastal erosion and siltation caused by human activities.

To achieve the objectives for this source category at the regional level, the four projects and related activities approved by the ROPME Council need to be extended and the following actions implemented:

- Regional systems of marine and coastal protected areas: Few ROPME States (Bahrain, Oman, and Saudi Arabia) have developed coastal zone management plans, some are in the process of being implemented. Marine protected areas have been established in Oman and Saudi Arabia. There is therefore an urgent need for an integrated coastal zone management plan for the ROPME region, where a system of marine protected areas can be established. GCC is proposing a plan for an integrated marine protected areas for GCC countries; nothing, however, has yet been achieved. Similarly, the ROPME Council approved in principle a system of integrated marine protected areas for the ROPME sea area, but thus far nothing has yet been worked out in detail;
- Regional programme of action and protocols on important species and habitats: The most successful and recent marine reserve in the ROPME Sea Area is the Wildlife Sanctuary at Jubail, Saudi Arabia. The Gulf of Sulwa region, including Bahraini and Qatari

waters, contains the world's second largest population of dugong and therefore constitutes an area of vital conservation significance for this species. If the Gulf of Sulwa is declared a regional protected area, it would be a very good example for regional cooperation within the area;

- Management of important migratory marine resources (e.g., kingfish): These resources are shared among several countries of the ROPME. Fisheries management is seriously hampered, however, by lack of data. Multinational coordination of data collection and management is essential to safeguard future yields. In addition, the increasing pollution, degradation or loss of nursery areas could cause declines in yield. To manage these marine resources effectively, there is a need to strengthen cooperation between ROPME and the Food and Agriculture Organization FAO. The Gulf Committee for Fisheries Management has organized many workshops in the region, dealing with pelagic and demersal resources. Regrettably, however, very few activities of this committee related directly to the marine environment. Therefore, cooperation between ROPME and FAO needs to be enhanced. The GCC countries have recently started a regional project on management of kingfish fisheries in the region;
- Promotion of regional cooperation, where appropriate, for the establishment of programmes and priority measures to control anthropogenic modifications to sedimentation/siltation: To date, very little has been achieved in this regard;
- Exchange of information on the technology and techniques and experience regarding sedimentation and siltation.

5.2.3 Sewage and nutrients

5.2.3.1 SEWAGE

Two investigations were conducted to estimate the volume and quality of the sewage discharged into the ROPME sea area. The first was in 1980 and the second in 1986 (Taylor, 1986). The second study covered the urban centres in the coastal area, development of the sewage system, the existing sewerage, the annual pollution load from domestic wastewater and future discharges into the ROPME sea area from each State.

The total amount of treated and untreated sewage discharged in the area was 940,033 tons/yr. The highest discharged contaminant was total dissolved solids (840,543 tons/yr), representing 89.42 per cent of all domestic waste (Table 22). Waste sludge from municipal wastewater treatment plants was reported only from Qatar (20,300 tons/yr) and United Arab Emirates (94,397 tons/yr) (ROPME, 1997).

Currently, almost all the ROPME States have working sewage treatment plants, covering most of their coastal population. Before the Gulf War, nearly 95 per cent of Kuwait's population was served by three-stage sewage treatment plants. Today, over 75 per cent of Bahrain's population is covered by a sewage treatment network, as is close to 100 per cent of the United Arab Emirates and Oman, and 79 per cent of the Islamic Republic of Iran (Hinrichsen, 1996). Accordingly, there has been considerable improvement in recent years, with regard to controlling the discharge into the sea of municipal pollution water.

The present gap between water demands and available water resources has led many member States to consider domestic wastewater as an integral part of their water resources. At present, Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates recycle no more than 35 per cent of their total treated wastewater (Al-Zubari, 1997), contributing 2.2 per cent of their total water supply (Tables 23 and 24). Treated sewage waters are used mainly in landscaping and fodder crop irrigation and for

some industrial uses. The main handicaps to reuse expansion are both social (psychological aversion and religion as opposition) and technical (microbiological pollutants, potential accumulation of heavy metals in irrigated soil, and industrial mixing).

If only 50 per cent of domestic water supplies are treated and recycled in agriculture, recycled water has the potential to meet more than 11 per cent of total water demands of GCC countries, could satisfy more than 14 per cent of their agricultural sector demands, and could reduce fossil groundwater withdrawal by more than 13 per cent by the year 2020 (Al-Zubari, 1997).

5.2.3.2 NUTRIENTS

Little scientific information is available on the biological effects of contamination by nutrients in the area. Signs of eutrophication close to some industrialized areas (e.g., methanol/ammonia plants) are common, however (Linden, *et al.*, 1990), where dense mats of filamentous green algae in the intertidal zone are obvious signs of organic pollution and increased levels of nutrients in the water.

The severe subjection of the ROPME sea area to high levels of nutrients is being suggested by some of the more recent oceanographic data. Moreover, the increase in numbers and production capacity of plants for the manufacture of fertilizers and detergents also warrants a careful consideration of the input of nutrients into the ROPME sea area (ROPME Secretariat, 1995).

To date, no inventory has been compiled of significant marine areas in the region where nutrient inputs are causing or likely to cause pollution directly or indirectly. There is a need to identify the source of pollution, calculate nutrient inputs to the aquatic environment from agriculture and other sources, implement measures to reduce nutrient inputs, assess the effectiveness of these measures and develop strategies for reducing eutrophication in areas already affected and those susceptible to being affected.

5.2.4 Litter

Litter from both mainland, shores and ships pose an increasing problem in the area. 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 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 entire scrapped automobiles at some localities. Oil sludge constitutes the most important type, in terms of quantity, of solid waste (Linden *et al.*, 1990). Much of the lighter debris has now been spread along extensive tracts of shoreline through wind and water movements.

Solid waste loads in the ROPME member States are close to 5 million tons/yr (tables 25 and 26). Domestic solid waste loads are much higher (3,636,672 tons/yr) than industrial waste (1,289,142 tons/yr). Oily sludges represent 15 per cent (187,953 tons/yr) of the total industrial solid waste loads. In Bahrain, Qatar, Saudi Arabia and the United Arab Emirates, these sludges are disposed on the ground, often in locations close to the sea. In Kuwait and Oman, they are burned, while about 10 per cent of the sludges generated in the United Arab Emirates are directly discharged into the sea (Linden, *et al.*, 1990). Both of these disposal methods are unsafe. Ground disposal may result in sea and underground water contamination, while open-pit burning generates oil pollution. Direct discharge into the sea may create a number of negative effects on marine life.

The problems with the solid wastes and sludges are becoming more acute and it is clear that there is an urgent need for adequate methods of disposal. Alternative means of solid waste disposal, especially oily sludges, should be considered. Regional actions should include the promotion of regional cooperation for the exchange of information on practices and experiences regarding both waste management recycling and reuse and cleaner production, as well as

regional arrangements for solid waste management.

Solid wastes made up of building and road construction materials are used as land-fill in coastal areas of many countries of the region. These materials include concrete, steel and asphalt. The most significant hazard posed by this approach, aside from destroying the coastal habitat, comes from the oil and tar content of the material. During the summer, the tar frequently melts in the high temperature and this may damage littoral biotic communities. In addition, the natural erosion processes due to tidal action and waves may cause this material to be washed into the lower intertidal zone. To date, there is no information available on the quantity of solid waste made up of building and road construction material.

Littering of the shoreline is an obvious sign of environmental deterioration in many parts of the region. Particularly near more densely populated areas, this has rendered many beaches unsuitable for recreation. In most cases, the litter has probably been left there by visitors, but in some remote areas, the beaches are also severely contaminated by litter, probably washed on to the beaches by the sea.

5.2.5 Atmospheric deposition

The primary sources of atmospheric emission are:

- Flaring, venting and purging gases;
- Combustion processes, such as diesel engines, plant exhaust and gas turbines;
- Fugitive gases from pits, loading and tankage operations and released from process equipment;
- Airborne particulates from soil disturbance during construction and from vehicle traffic;
- Particulates from other burning sources such.

The principal emission gases include carbon diox-

ide, carbon monoxide, methane, volatile organic carbons and nitrogen oxide. Emissions of sulphur dioxides and hydrogen sulphide can occur and depend upon the sulphur content of the hydrocarbon and diesel fuel, particularly when used as a power source. In some cases, sulphur content can lead to odour production.

Major sources of air pollution in the ROPME region, particularly the more industrialized centres, include oil refineries, oil wells and oil platforms; petrochemical and fertilizer plants; and motor traffic. It may be added that smoke from the incomplete combustion of fuels is currently a serious environmental problem in the region. All the ROPME member States have national air pollution programmes. The results of these programmes are not available, however, except for Bahrain and Oman.

Data available on the transport of dust in the north-western part of the region indicate that the average monthly levels of dust settling in various sites in Iraq and Kuwait tend to be in the range of 10 to 100 g/m², although maximum levels of some 600 tons/km² have been recorded (ROPME, 1987). Such figures are probably among the highest in the world (Linden, *et al.*, 1990).

Atmospheric emissions from the ROPME member States amounted to 3,847,755 tons/yr, most of these consisting of carbon monoxide (28 per cent), sulphur oxides (27 per cent) and particulates (23 per cent) (table 27). Such data do not include carbon dioxide and do not specify the source of contamination. Nevertheless, four ROPME member States are included among the fifty countries with the highest industrial emission of carbon dioxide, in 1992 (World Resources, 1996-97). These include the Islamic Republic of Iran, ranking nineteenth with 235,478 million metric tons, followed by Saudi Arabia-twenty-first-with 220,620 million metric tons, the United Arab Emirates-thirty-ninth-with 70,616 million metric tons, and Iraq-forty-first-with 64,527 million metric tons.

At the regional level atmospheric emission should

be viewed in the context of total emissions from all sources. The recorded levels should then be integrated into a model in which the effects of coastal breezes are considered, for a better understanding of the effects of atmospheric deposition into the marine environment. The oil and gas industry should be committed to improve the performance and significant reduction of atmospheric emissions. There are a number of emerging technologies and good practices that can help to improve performance, in particular by reducing flaring and venting, improving energy efficiency, developing of low nitrogen oxides, controlling fugitive emissions and examining replacements for fire-fighting systems. The relative costs and environmental benefits depend heavily on specific situations as was the case after the Gulf War.

5.2.6 Heavy metals

Several States in the region monitor levels of heavy metals in the marine environment (in fish, bivalves, water and sediments) as part of their national monitoring programmes. Through the ROPME-coordinated 18-month marine monitoring programme, heavy metal mercury, cadmium, copper, lead, and vanadium contaminants are being measured by sampling stations distributed on the coastal areas of the eight ROPME member States. The complete results of this project are not yet available, however (Linden, *et al.*, 1990).

The comparison of levels in bivalves taken from different areas may be difficult, since sometimes the species sampled are different. In addition, data on sex, stage of development, etc. are often lacking. In general, increased levels of lead, mercury and copper have been found in areas influenced by port activities and heavy industrialization (Fowler, 1985). In rock and pearl oysters in Bahrain, increased lead concentrations were noted in an area influenced by effluents from a refinery (Linden, 1982). In Saudi Arabia, pearl oysters selectively accumulated cadmium, phosphorus and zinc in their tissues (Sadiq and Alam, 1989). The available data on mercury in fish from the region are comparable to those for other

regional seas. The level of mercury in groupers from the region reaches up to 0.75 ppm (ROPME/IAEA, 1988). The concentrations of cadmium, nickel and chrome in the sediments from the region were higher than the values reported from other parts of the world (Sadiq and Zaidi, 1985).

Liquid industrial wastes in the area which are discharged into the marine environment contain contaminants (e.g., biochemical oxygen demand, chemical oxygen demand, suspended solids, total dissolved solids, oil and nitrogen). The highest discharged contaminant is oil (102,440 tons/yr), accounting for 55 per cent of the total contaminants discharged (187,963 tons/yr) (Table 28). The sources of these contaminants are:

- Industrial processes, including agriculture and livestock, food manufacturing, chemical manufacturing, petrochemical industries and metal and non-metal industries;
- Power and desalination plants;
- Ship ballast water;
- Car service stations;
- Seaport activity.

In 1992, the GCC countries' production capacity of petrochemical industries was over 11 million tons of petrochemical products (excluding fertilizers) and their annual plastics production capacity is about one million tons (GOIC, 1994).

The ROPME region hosts the largest desalination plants in the world (table 29). Of the 15,582,000 m³/day capacity of desalination plants worldwide at the end of 1991, 7,744,055 m³/day (or 50 per cent) is accounted for by the six GCC countries (Rogers and Lydon, 1994). The major environmental problems associated with all desalination plants are: the disposal of the waste brine into the sea; thermal pollution resulting from brine disposal; pre and post-treatment chemicals (e.g., anti-scaling agents,

anti-fouling agents, polyphosphates); and corrosion products (heavy metals), (Khordagui, 1997).

Millions of tons of industrial effluents are dumped into the ROPME shallow waters every year with little or no treatment (Hinrichsen, 1996). At the same time, however, controlling industrial pollution is receiving increasing attention, because most of the region's drinking water comes from the sea.

Regional actions should include: development and implementation of monitoring programmes and measures to reduce and/or eliminate emissions and discharges of heavy metals and materials containing these substances from the appropriate industrial sectors, products and groups; promotion of cooperation in the development of cleaner production programmes. So far, some States (for example, Oman) have introduced measures to reduce emission and discharges of heavy metals into their marine environments.

5.2.7 Persistent organic pollutants (POPs)

POPs are organic compounds of natural or anthropogenic origin that resist photolytic, chemical and biological degradation. They are characterized by low water solubility and high lipid solubility, resulting in bioaccumulation in fatty tissues of living organisms. POPs are semi-volatile and, therefore, able to move long distances in the atmosphere, and are also transported in the environment in low concentrations by the movement of fresh and marine waters, resulting in widespread distribution across the earth, including in regions where they have never been used. Thus, both humans and environmental organisms are exposed to POPs around the world, in many cases for extended periods of time.

Over the past several years, the risks posed by POPs have become of increasing concern to many countries, resulting in actions to protect human health and the environment being taken or proposed at the national or regional level and, more recently, in international initiatives, such as the Global Programme

of Action for the Protection of the Marine Environment from Land-based Activities.

Examples of POPs include: many persistent pesticides (e.g., dieldrin, DDT, toxaphene, chlordane); several industrial compounds (e.g., polychlorinated biphenyls (PCBs), chloroparaffins); and some degradation, industrial and combustion by-products (e.g., polycyclic aromatic hydrocarbons (PAHs), polychlorinated dibenzofurans (PCDFs), and hexachlorobenzene).

POP emissions originate almost exclusively from anthropogenic activities associated with the manufacture and use of certain organic chemicals, with some melting and refining processes, with some chlorine-based pulp and paper manufacturing, with leaks, spills and dumping of these materials, with the combustion of both fuels and wastes and with the application of pesticides.

Polycyclic aromatic hydrocarbons (PAHs) are a major group of POPs, and the PAH benzo(a)pyrene (BaP) is commonly used as an indicator of the presence and carcinogenicity of PAH in air. PAHs are generated from incomplete combustion of organic matter, particularly fossil fuels. Anthropogenic high temperature processes are the major sources and involve a wide range of applications.

An assessment of chlorinated hydrocarbons in sediment and biota from the area has been reported by Linden *et al.*, 1990. The limited data available on the subject, indicate relatively low levels of contamination by these compounds compared to other regional seas. Levels of aldrin, lindane, dieldrin and DDT in sediment from the north-western part of the region were all below 1 mg/g (Litherathy *et al.*, 1986). The levels of PCBs in the northwestern part of the region were generally below 5 mg/g (Litherathy *et al.*, 1986). Levels comparable to these ranges have been reported for Bahrain, Oman, Qatar, and United Arab Emirates (Fowler, 1985). The levels of DDT ranged from 1 to 11 mg/g in fish from the northwestern part of the region. Endrin levels ranged from 1 to 7 mg/kg in most fish samples but reached as high as

45 mg/kg in a few cases (Douabul *et al.*, 1987). DDT levels in clams from Kuwait ranged from 8.8 to 88 mg/kg, whereas dieldrin values ranged from 2.2 to 36 mg/kg and other compounds were below 1 mg/kg (Litherathy, *et al.*, 1986).

Because of the current expansion of oil refinery capacities (construction of more petrochemical plants) and increased agricultural activities in recent years, however, POPs concentrations are expected to increase in the future and will probably spread across greater areas of the area as a result of water circulation patterns. Cleaner technology is therefore imperative.

In view of the limited data on the production, use and environmental distribution of POPs in the marine environment of the area, the ROPME Council approved and allocated funds for a pilot study to determine types and amount of POPs manufactured or used in the region and to assess the significance of their presence in the marine environment. Results are to be made available to member States in order to be incorporated into the Regional Programme of Action.

In addition, regional actions should include encouraging existing agreements and programmes to setup and implement measures to prevent, reduce or eliminate emissions and discharges of POPs from all sources. Over the last decade, many ROPME member States have approved a number of new environmental laws and standards of hazardous materials.

5.2.8 Radioactive substances

Radioactive substances (i.e., materials containing radio nuclides) have entered or are entering the marine and coastal environment, directly or indirectly, as a result of a variety of human activities and practices. These activities include the production of energy, the reprocessing of spent fuel, military operations, nuclear testing, medical applications, etc. Other activities, such as the transport of radioactive material, pose risks of such releases. Radioactive materials can present hazards to human health and to the

environment. Suspected radioactive contamination of foodstuffs can also have negative effects on the marketing of such foodstuffs.

In the early 1980s the local press reported stories of unknown ships dumping unknown wastes in the marine environment. The area's waters have been over the last 17 years and are still exposed to active military activities and the environmental consequences of these activities are still not known (Al-Hagri and Ahmed, 1997).

Because of the limited activities involving the use and release of radio nuclides in the ROPME region, low priority has been assigned to radioactive substances. Some member States, however, (e.g., Oman), have regulations concerning the management of hazardous materials (including radioactive substances). These regulations cover the transport, storage, use and disposal of hazardous wastes. Nevertheless, the presence and/or development of nuclear power plants in the region and the use of radioisotopes in medicine and industry warrant some attention to releases of radionuclides from such anthropogenic sources. Member States should be asked to provide information on releases from any radiologically regulated practice within their jurisdiction, such as from nuclear power stations, and on the medical and industrial use of radioisotopes, including an evaluation of the health effects. They should also establish criteria for assessing and/or reporting on the use in their region of best available techniques to prevent and eliminate pollution by radioactive substances.

5.3 SETTING MANAGEMENT OBJECTIVES FOR PRIORITY PROBLEMS

The principal objective of the regional programme is to implement the Protocol for the Protection of the Marine Environment from Land-based Sources in the area. This Protocol provides a framework for an environmentally sound, technologically feasible and comprehensive approach, particularly appropriate to the needs of the region, to control land-based pollution sources. The main objectives of the Protocol are

to: Reduce, control and prevent marine degradation from land-based activities in the ROPME sea area. The Regional Programme seeks the following:

- To build or augment national or regional capabilities to plan and implement strategies for the control of land-based sources of pollution;
- To provide for the implementation of regional assessment and monitoring of water quality and coastal habitats of the area;
- To facilitate the development of technical and financial arrangements for the implementation of the Regional Programme of Action;
- To provide for cooperation among the countries in the area and others in controlling land-based sources of pollution.

Specific activities of the ROPME Regional Programme of Action that have been approved by the ROPME Council include:

- Regional and global cooperation;
- Updating the survey of land-based activities source categories, impacts, capabilities and constraints;
- Carrying out a pilot study on POPs;
- River basin management;
- Development of guidelines, standards and criteria for the management of land-based sources.

To implement the ROPME Regional Programme of Action activities proposed by the Protocol should have targets and timetables for areas affected and for individual industrial, urban and other sectors. For that reason, specific areas known to be pollution sources should be selected and complete inventory

of specific sources updated and impacts assessed. At the same time, measures to reduce, control and prevent marine pollution should be enforced. Regular monitoring of specific source categories should be carried out. It is suggested that each member State select these areas for assessment.

5.4 IDENTIFICATION AND SELECTION OF STRATEGIES AND MEASURES

Since the ROPME Protocol for the Protection of the Marine Environment from Land-based Sources has been approved by the Council, ROPME is required to seek regional and global cooperation to implement its Regional Programme of Action. This can be achieved by approaching organizations such as UNEP, PERSGA, IMO, WHO, IAEA, UNIDO, UNESCO, GCC, GAOCMAO, IUCN, FAO and others. The following strategies are suggested:

5.4.1 Preparation of the river basin management programme

The principal objective of this programme is to develop a river basin management programme for the major rivers of the region which are significant contributors of land-based contaminants and sediments, as well as nutrients, into the ROPME sea area. The cooperation of non-contracting States (i.e., Syria and Turkey), is essential and should be sought in developing a management programme for the Shatt al' Arab.

The following tasks are recommended for the implementation of the river basin management component of the Regional Programme of Action:

- Developing an inventory of the flow of rivers and the river-borne input of contaminants into the ROPME sea area;
- Determining the requirements for regional arrangements to develop a river basin management programme for the major rivers of the Region. Essential to this task is the

cooperation of non-contracting States, such as Syria and Turkey, in developing such a programme for the greater Shatt al' Arab river system;

- Developing an implementation scheme in cooperation with UNEP, the United Nations Industrial Development Organization (UNIDO), the United Nations Development Programme (UNDP) and other relevant agencies, including regional organizations such as ESCWA and ROWA.

5.4.2 Establishment of reception facilities

A feasibility study is being conducted for regional reception and recycling facilities for oil waste. IMO and PERSGA are to be approached for technical assistance.

5.4.3 Updating the surveys of land-based activities source categories, impacts and capabilities and constraints

For the purpose of updating the surveys, the following measures are indicated:

- The national focal points would be required to nominate national experts for the task of updating the survey of pollutants and filling the current gaps in baseline information;
- A consultant shall be required, working in conjunction with UNEP, to assist the national experts in carrying out the updates to the surveys;
- Two workshops are to be held, the first to review progress of implementation and the second to finalize the draft regional assessments based on the updated national surveys.

For the updating of the surveys of land-based activities source categories, capacity training is imperative to augment national and regional capabilities in pollution control technologies. Training manuals and programmes are to be drawn up with assistance from experts both within and outside the region. Training workshops should be held to discuss and exchange information on enforcement of pollution control legislation. These workshops should develop appropriate strategies for the improved enforcement of existing legislation and the formulation of additional enforceable legislation.

5.4.4 Development of guidelines, standards and criteria for the management of land-based sources

In fulfilment of Articles IV, V, VI and VIII as well as Annexes I, II and III of the Protocol, the following activities are envisaged for 1997 and 1998, to be carried out in close cooperation with UNEP and, possibly, UNIDO, as appropriate:

- Preparation of a management scheme with high priority pollution abatement programmes and measures for land-based sources and activities in the ROPME region;
- Development of regional guidelines and criteria along with programmes and measures for their industrial sources through joint or combined effluent treatment;
- Development of regional regulations for waste discharges and for the degree of treatment of significant categories of land-based sources and activities;
- Development of regional guidelines, standards or criteria for the quality of sea-water used for specific purposes;
- Provision of technical assistance for the development of technical guidelines for the assessment of potential environmental impacts and for the cost benefit analysis of

major development projects.

5.4.5 Pilot study on POPs

The following POPs-related measures are recommended:

- A pilot study is needed with a view to the compilation of information on the sources and loads of POPs carried into the region, in conjunction with the national and regional monitoring programmes carried out by ROPME;
- Analytical verification of the levels and spatial and temporal distribution of POPs in the marine environment. Modifications of the regional and national monitoring programmes may be required to include POPs in the surveys;
- A regional workshop or seminar should be organized in 1998 to assess the magnitude of contaminant POPs in the area and to develop criteria for the source reduction of POPs in the region. Cooperation would be required with ROPME and IAEA in the area of methodology and quality assurance.

5.4.6 Study on radioactive substances

There are indications that radioactive substances are entering the marine environment either because they are naturally occurring or as a result of a variety of human activities. Data are lacking, however, on this source category (both quantity and impacts). A study is therefore needed to determine radioactive substances and to study their spatial and temporal distribution. Later, a regional workshop or seminar should be organized to assess the magnitude of radioactive substances in the area and to develop criteria for the source reduction of radioactive substances. Cooperation would be required with IAEA in the area of methodology and quality assurance.

5.4.7 Integrated coastal zone management

Integrated coastal resource management plans have proved to be useful tools for ensuring that coastal development provides a sustainable economic return. Many countries have passed legislation, and some have prepared and approved coastal zone management plans (e.g., Oman, Saudi Arabia). The mechanisms for implementing most of these plans are still beyond their own technical and economic capabilities, however. A large majority of the marine protected areas exist only on paper (IUCN/CNPPA-World Bank, 1993), except for those that received technical and financial assistance from the European Community and other sources. For that reason, international and regional agencies should initiate and implement, with national agencies, an integrated coastal zone management plan for the ROPME sea area.

Key to the successful implementation of the ROPME Regional Programme of Action is the agreement of member States to use the ROPME Protocol as part of their national legislation and the execution of the programme by national institutions in close cooperation with ROPME, UNEP and other organizations. Accordingly, all the ROPME countries are required:

- To take appropriate measures to provide for the effective assessment and monitoring of water quality and coastal habitats of the area;
- To undertake practical steps in implementing control measures and developing a pollution control infrastructure;
- To implement capacity training programmes in the management and control of pollution;
- To encourage public participation and to boost public awareness and community education in the development and implementation of integrated waste management programmes; and

- To prepare, develop and implement coastal zone management plans, to be incorporated into an integrated regional coastal zone management plan.

5.4.8 Coordinated fisheries management

Fisheries management in the area in general is seriously hampered by the lack of accurate data on most stocks. It is known that some are being overexploited, others are not yet fully utilized and still others have not been exploited at all (mesopelagics). The problem is that many fish stocks are shared among several countries. Consequently, multinational cooperation in fish data collection is essential to the development of a realistic management plan for the sustainable use and conservation of fisheries resources. There is a need for standardization of statistical systems, which should not only be limited to the amount of fish landed and species competition but should also be extended to include accurate data on associated fishing effort and should consider both economic and social factors. Trawl and acoustic surveys should be carried out regularly to improve our understanding of the existing fish stocks. The impact of pollution, habitat degradation and loss of nursery and spawning areas on fisheries should be studied. Exchange of data in a readily accessible format should be encouraged among the countries. Finally, the role of FAO in the development of fisheries management in the Arabian region should be strengthened.

5.4.9 Environmental education

Education provides important support for the monitoring and management of the marine environment. Measures that could be considered include the use of national and international resources and cooperation to improve the environmental aspects of education in the following areas: public education, education of tourists, preparation of films and books, and advanced education. The basis for such education programmes are being established. These include public aquariums, coral reef observatories, research and visitors' centres, exhibitions, lecture series, labo-

ratories, workshops, photo archives, posters, brochures, videos, documentation and press distribution. There are many existing films on the marine environment of a number of the countries in the region. Perhaps there is a need for a documentary film on the marine environment of the whole area, covering environmental setting, resources, human uses and conservation. The involvement of international agencies and cooperation, including UNESCO, the British Broadcasting Corporation (BBC) and others can be enlisted to enhance the environmental education programme for the area.

5.5 EVALUATING THE EFFECTIVENESS OF STRATEGIES AND MEASURES

The above-mentioned strategies and measures require strong political will, public support and multilateral cooperation. ROPME is capable of providing the organizational context for cooperation on marine and environmental issues in the region.

5.6 PROGRAMME SUPPORT ELEMENTS

ROPME was established in 1978 to implement the Kuwait Action Plan. It is also in charge of the Kuwait Regional Convention for the Cooperation on the Protection of the Marine Environment from Pollution and the Protocol concerning Regional Cooperation in Combating Pollution by Oil and other Harmful Substances in cases of Emergency. A number of projects, have been carried out, largely directed towards controlling pollution (e.g., MEMAC, GAOCMAO). ROPME has also supported a series of ecological studies with IUCN and UNEP and, in 1992, it sponsored jointly with IOC and UNEP the Mt. Mitchell 100-day expedition, to assess the impacts of oil spills, after the Gulf War in 1991, on the marine environment of the area. Extensive results of the expedition have been published (Price and Robinson, 1993). The ROPME member States have recognized the need to protect the marine environment from land-based activities, and have approved the Protocol for the Protection of the Marine Envi-

ronment from Land-based Activity. In addition, the ROPME Council has approved the Regional Programme of Action and the budgetary requirements.

Between 1982 and 1990, more than 500 technicians received special training, organized by ROPME, in oil and non-oil pollutant sampling, data handling, oceanographic modelling, marine research and monitoring and marine pollution prevention.

ROPME headquarters is in Kuwait, housed in substantial premises with many facilities including meeting rooms, a fine library, computers with Internet and graphics capabilities, geographic information systems (GIS), photocopying and printing facilities, etc. Human resources include more than 20 staff members headed by an Executive Secretary and including the following posts: Coordinator, Programme Officer, Protocol Implementation Officer, Database Expert, Legal Officer and Administrator. The library contains a comprehensive range of publications dealing with environmental law, conservation, resources, impact assessment, etc. There are also recent periodicals and Arabic journals and magazines (including many for children) dealing with environmental issues. Recent environmental information from member States, except Kuwait, is lacking, however. ROPME is very active in environmental awareness, as is evident from numerous posters, booklets (many for children), newspapers, etc. A Programme Officer is in charge of several projects: land-based activities, marine biodiversity, monitoring of marine pollutants and open-sea cruises.

Unfortunately, the ROPME region has been racked by wars for a decade. Consequently, ROPME programmes have been put on hold. In addition, the countries in the area have hampered ROPME by providing an annual budget of only some \$2 million, barely enough to pay for basic coordination work. Nevertheless, ROPME remains the only regional forum in the area through which cooperation on marine and environmental issues can be achieved. The capacity-building of ROPME, both in terms of human resources and institutional capacity, are re-

quired for the implementation of the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities in the area.

References

- Abaychi, J.K., Darmonoian, S.A. and Douabul, A.A.Z. (1988). The Shatt al'Arab River: A nutrient salt and organic matter source to the Arabian Gulf. *Hydrobiologia* 166, p. 217-224.
- Abdali, F.K., Al-Hemond, A., Abul, A.T., Al-Hayyan, S., Al-Sharrah, M. and Al-Awadi, M. (1996). The Infernal Smoke: The impact of air pollution upon mortality pattern in Kuwait. International Conference on the Long-term Environmental Effects of the Gulf War. Kuwait, November 1996 (abstract).
- Abdel-Moati, M.A.R. (1996). Trace metals and total petroleum hydrocarbons in sediments from the Western Coast of Qatar five years after the Gulf War oil spill. International Conference on the Long-term Environmental Effects of the Gulf War, Kuwait, November 1996 (abstract).
- Abdel-Moati, M.A.R. and Al-Said, T. (1997). Bioaccumulation of some pollutants in marine organisms from Qatari waters. International Conference on the Biology of the Coastal Environment of Bahrain, April 1997 (abstract).
- Abdel-Razik, M.S. (1991). Population structure and ecological performance of the mangrove *Avicennia marina* (Forssk.) Vierh on the Arabian Gulf coast of Qatar. *Journal of Arid Environment* 20, p.331-338.
- Abdulqader, E.A.A. (1994). Bahrain benthic resources. Paper presented at the Eight Session of the IOFC Committee for the Development and Management of the Fishery Resources of the Gulf. 17-21 December 1994, Muscat, Oman IOFC: DMG/94/Inf.11.
- Abou-Leila, H., Al-Houty, L. and Al-Samman, H. (1996). Effect on Qatar atmosphere from the burning of Kuwait oil fields during the Gulf War. International Conference on the Long-term Environmental Effects of the Gulf War, Kuwait, November 1996 (abstract).
- Abuzinada, A.H. and Krupp, F. (1994). The status of coastal and marine habitats two years after the Gulf War oil spill. *Cour. Forsch. - Inst. Senckenberg*, 166. Frankfurt am Main, 103, 1994, 80 p.
- Ahmed, J.H. (1980). Soil surveys for agricultural development in arid lands with special reference to Bahrain. M.Sc. thesis. University of Nottingham, England, 207 p.
- Al-Alawi, Z.S. (1991). Water quality at different locations in Bahrain coast. *Proceeds of the Symposium on Marine Chemistry in the Arab Region*. Suez, Egypt. p.207-228.
- Al-Awadi, A.R. (1995). Regional legislation and programmes for the protection of the marine environment of the ROPME sea area. *Conference on Tanker Discharges and Protection of the Marine Environment*, Muscat, April 1995, p.39-80.
- Al-Awadi, F. (1996). Environmental Laws in the GCC Countries. *Kuwait Foundation for the Advancement of Science*. Kuwait, 324 p. (in Arabic).
- Al-Bakri, D., Fouda, M., Behbehani, M, Khalaf, F., Shublaq, W., Al-Sayed, M.I., Al-Sheikh, Z., Kihaneh, W., Khuraibit, A. and Al-Kadi, A. (1985). The environmental assessment of the intertidal zone of Kuwait. *Kuwait Institute for Scientific Research, Report No. KISR 1687*, Kuwait.
- Al-Busaidi, S.S.M. (1995). "Out of sight, out of mind" - chronic marine pollution. *Conference on Tanker Discharges and Protection of the Marine Environment*, April 1995, Muscat, Oman, p.90-94.
- Al Hajr, K., and Ahmed, H.D. (1997). The Gulf Sea basin: A clean water supply intake or dumping sink? *Third Gulf Water Conference*, Muscat, March 1997, Vol. 3, p.977-997.
- Al-Hashimi, A.H. and H.H. Salman (1985). Trace metals in the sediments of the north-western coast of Arabian Gulf. *Marine Pollution Bulletin* p.16, p.118-120.

- Al-Jabri, M.M., Al-Jufaili, S.A., Al-Arami, M. and Matthews, A.D. (1992). Coastal Zone Vulnerability Maps, Vol. 1; Coastal Zone Resources Maps, Vols. 1 and 2, Ministry of Regional Municipalities and Environment, Sultanate of Oman.
- Al-Jabri, M.M. and Mathews, A.D. (1994). Coastal Erosion - Batinah Coast, 1992-1994. Report submitted to Ministry of Regional Municipalities and Environment, Muscat, Oman, 16 p.
- Al-Kharusi, L.H.S. (1996). Distribution and accumulation of oil pollutants on the region of Mina Al-Fahal in the Sultanate of Oman and their effects on the marine environment. M.Sc. thesis, Suez Canal University, Egypt. 136 p.
- Al-Khayat J. and Jones, D.A. (1997). A comparison of the macrofauna of natural and replanted mangroves in Qatar. International Conference on the Biology of the Coastal Environment of Bahrain, April 1997 (abstract).
- Al-Madany, I.M. and Danish S. (1988). Measurement of air pollution in Bahrain. *Environment International* 14, p.49-58.
- Al-Madany, I.M. Abdalla, M.A. and Abdu, A.S.E. (1991). Coastal zone management in Bahrain: An analysis of social, economic and environmental impacts of dredging and reclamation. *Journal of Environment Management* 32, p.335-348.
- Al-Mudaffar, N., Fawzi, F.N., Al-Edanee, T.E. and Abed Al-Kareem, A.H. (1992). The distribution of trace metals in sediment and biota from Shatt al' Arab River, Iraq. *Fresenius-Environmental Bulletin* 1, 579-585.
- Al-Muharrami, M.A. (1994). Resource Management of Mangroves in the Arid Environment in the Sultanate of Oman. M. Phil. thesis, Newcastle University, United Kingdom 119 p.
- Al-Muzaini, S. (1995). Environmental Pollution from Landfill Leachate in Kuwait. *Journal of the Faculty of Science, United Arab Emirates University*, 8 (2), p.46-55.
- Al-Muzaini, S. and Muslimani, M. (1994). Study of the environmental pollution from landfill sites receiving wastes generated during the Iraqi occupation. Kuwait Institute for Scientific Research, Report No. KISR 4451, Kuwait.
- Al-Omran, L.A. (1996). Sewage and oil pollution in the intertidal areas of Kuwait. International Conference on the Long-term Environmental Effects of the Gulf War, Kuwait, November 1996 (abstract).
- Al-Saad, H.T. (1987). Distribution of polycyclic aromatic hydrocarbons (PAH's) in surficial sediments from Shatt al' Arab river and the north-west region of the Arabian Gulf. *Marine Pollution Bulletin* 18, p.248-251.
- Al-Saad, H.T. and Al-Timari, A.A. (1989). Distribution of polycyclic aromatic hydrocarbons (PAH's) in marsh sediments, Iraq. *Bulletin of Environmental Contaminants Toxicology* 43, p. 864-869.
- Al-Saadi, H.A., Hadi, R.A.A., Schiewer, U., and Al-Mousawi, A.H. (1989). On the influence of the sewage drainage from Basrah City on the phytoplankton and related nutrients in the Shatt al' Arab Estuary, Iraq. *Archiva Hydrobiological* 114, p. 443-452.
- Al-Sabahi, A.M. (1997). Wastewater treatment and reuse in the Sultanate of Oman. Third Gulf Water Conference, Muscat, March 1997. Vol. 3. p. 859-888.
- Al-Sajwani, T.M.A. and Lawrence, R.J. (1995). Small desalination plants in rural communities in Oman. *Water Resources Management in Arid Countries*, Muscat, Sultanate of Oman, p. 617-626.
- Al-Sarawi, M.A. and Bu-Olayan, A.H. (1996). Effects of the Gulf War on beach stability and geographic features along the Kuwaiti Coast. International Conference on the Long-term Environmental Effects of the Gulf War. Kuwait, November 1996 (abstract).

- Al-Sofi, M. (1994). Water Scarcity. The Challenge of the Future. *Desalination* 98, p. 425-435.
- Al-Yakoob, S.N. (1996). Assessment of human health risks associated with petroleum-related polycyclic aromatic hydrocarbons (PAH's) after the Gulf War. International Conference on the Long-term Environmental Effects of the Gulf War, Kuwait, November 1996 (abstract).
- Al-Zubari, W.K. (1997). Towards the establishment of a total water cycle management and re-use program in the GCC countries. The Third Gulf Water Conference, Muscat, 8-13 March, 1997, Vol. 1, p. 1-15.
- Anbar, H. (1996). Litter in the Arabian Gulf. *Marine Pollution Control*, 32 (6), p. 455-456.
- Anderlini, V.C. (1985). Protected Areas System Plan for the Sultanate of Oman. WWF/IUCN Report 9069, IUCN, Gland, 29 p.
- Anderlini, V.C., L. Al-Harmi, B.W. Delappe, R.W. Risebrough, W. Walker, B.R.T. Simoneit and A.S. Newton (1981). Distribution of hydrocarbons in the oyster *Pinctada margaritifera*, along the coast of Kuwait. *Marine Pollution Bulletin*, 12, p. 57-62.
- Anderlini, V.C., Mohammed, O.S., Zarba, M.H., Awayes, R.A. and Al-Jallili, R. (1986). An assessment of trace metal pollution in the Kuwait marine environment. In: *Marine Environment and Pollution*. Edited by Halwagy, R., Clayton, D. and Behbehani, M. Kuwait University, p. 131-156.
- Anon. (1994). Glance on Industries in Oman until June 1994: Facts and Figures. Ministry of Commerce and Industry, Industrial Statistics and Information Centre. 36 p.
- Anon. (1995). Ballast water still a problem in Gulf. *Marine Pollution Bulletin* 30, p. 434.
- Anon. (1996). The State of Industrial Pollution in the Arab Region. UNEP and League of Arab States. 59 p.
- Aspinall, S. (1996). Management of mangroves in the United Arab Emirates (Flora and Fauna of the Mangal Ecosystem). Symposium on the Conservation of Mangal Ecosystems, Al-Ain, United Arab Emirates (abstract).
- Atallah, S. (1995). Human health impacts resulting from degradation of the coastal environment. Sea to Sea: Regional Conference on Sustainable Use of the Marine Environment. Jeddah, October 1995, p. 139-160.
- Atkins, WS International (1989). Regional development plan of the southern region. Planning Committee for Development and Environment in the Southern Region, Sultanate of Oman. Two volumes.
- Auscon Consultants International Ltd. (1996). Presentation Consultancies for Monitoring Pollutants in the Marine Environment. Prepared for Ministry of Regional Municipalities and Environment, Oman.
- Badawy, M.I. and Al-Harthy, F.T. (1991). Tar loads on Omani beaches. *Bulletin of Environmental Toxicology*, 47, p. 732-737.
- Badawy, M.I., Al-Mujainy, I.S. and Hernandez, M.C. (1993). Petroleum-derived hydrocarbons in water, sediment and biota from the Mina al-Fahal coastal waters. *Marine Pollution Bulletin* 26, p. 457-460.
- Baldwin, R. and Salm, R. (1994). Whales and Dolphins Along the Coast of Oman. Seeb, Sultanate of Oman. 65 p.
- Banat, I.M., Hassan, E.S., El-Shahawi, S. and Abu-Hilala, A.H. (1996). Post-Gulf War nutrients, heavy metal ions and selected hydrocarbon pollution assessment in the coastal waters of the United Arab Emirates, International Conference on the Long-term Environmental Effects of the Gulf War. Kuwait, November 1996, (abstract).

- Barratt, L., Ormond, R.F.C. and Wruthall, T. (1986). Ecology and productivity of the sublittoral Algae *Ecklonia radiata* and *Sargassopsis zanardini*. Part 1. Ecological Studies of Southern Oman Kelp communities. Council for the Conservation of the Environment and Water resources, Muscat, Oman and Regional Organization for the Protection of the Marine Environment, Kuwait, 2.1-2.2.
- Basson, P.W. (1979). Marine algae of the Arabian Gulf Coast of Saudi Arabia. *Botanica Marina* 22, p. 47-64.
- Basson, P.W., Burchard, J.E. Hardy, J.T. and Price, A.R.G. (1977). Biotopes of the Western Arabian Gulf. Aramco, Dhahran, 284 p.
- Basson, P.W., Mohammed, S.A. and Arora, D.K. (1989). A survey of the benthic marine algae of Bahrain. *Botanica Marina* 32, 27-40.
- Biagi, P., Torke, W., Tosi, W. and Uerpmann, H.P. (1984). Qurum: A case study of coastal archaeology in northern Oman. *World Archaeology* 16 (1), p. 43-61.
- Boutari, A.E. (1997). Asry's Marine Sludge Treatment Plant. International Conference on the Biology of the Coastal Environment. Bahrain, April 1997, (abstract).
- Brown, D. (1995). The regional oil refining industry: Environmental responsibilities. Sea to Sea: Regional Conference on Sustainable Use of the Marine Environment. Jeddah, Saudi Arabia, October 1995, p. 23-30.
- Bu-Olayan, A.H., Al-Sarawi, M.A. and Subramaniam, M.N.V. (1996). Effects of the Gulf War oil spill on the water quality in relation to nickel, V and PAHs. International Conference on the Long-term Environmental Effects of the Gulf War, Kuwait, November 1996 (abstract).
- Carp, E. (1976). United Arab Emirates report of a survey of marine habitats carried out during 3-15 February 1995. *In: Promotion of the Establishment of Marine Parks and Reserves in the Northern Indian Ocean, including the Red Sea and Persian Gulf. Papers and Proceedings of the Regional Meeting held at Tehran, Islamic Republic of Iran, 6-10 March 1975, IUCN Pubs. N.S. 35, p. 107-114.*
- Carpenter, K.E., Krupp, F., Jones, D.A. and Zajonz, U. (1997). Living Resources of Kuwait, Eastern Saudi Arabia, Bahrain, Qatar and United Arab Emirates, FAO, Rome, 293 p.
- Chao, S.K., Kao, T.W. and Al Hajr, K.R. (1992). A numerical investigation of circulation in the Arabian Gulf. *Journal of Geophysical Research* 92, p. 424-428.
- Chapman, V.J. (1984). Mangrove biogeography. *In: Por, F.D. and Dor, I. (eds). Hydrobiology of the Mangal. Dr. W. Junk Publishers, The Hague, p. 15-24.*
- Clark, J.E., Al-Lumki, F., Anerdelini, V.C. and Sheppard, C.R.C. (1986). Sultanate of Oman. Proposals for a System of Nature Conservation Areas. IUCN, Gland, 477 p.
- Coles, S.L. (1988). Limitations on reef coral development in the Arabian Gulf: temperature or algal competition. Proceedings of the Sixth International Coral Reef Symposium, Townsville 3, p. 211-216.
- Coles, S.L. (1995). Corals of Oman. Richard Keech, Ahmed Yusuf and Steve Coles. Yorkshire, United Kingdom, 106 p.
- Coles, S.L. and Al-Riyami, K.A. (1996). Beach tar concentrations on the Muscat coastline, Gulf of Oman, Indian Ocean, 1993-1995. *Marine Pollution Bulletin* 32, p. 609-614.
- Coles, S.L. and Fadlallah, Y.H. (1991). Reef coral survival and mortality at low temperatures in the Arabian Gulf: New species-specific lower temperature limits. *Coral Reefs* 9, p. 231-237.

- Coles, S.L. and McCain, J.C. (1990). Environmental factors affecting benthic communities of the western Arabian Gulf. *Marine Environmental Research* 29, p. 289-315.
- Coles, S.L. and Tarr, A.B. (1990). Reef fish assemblages in the western Arabian Gulf: A geographically isolated populations in an extreme environment. *Bulletin of Marine Science* 47, p. 696-720.
- Coppa, A., Macchiarelli, R., Salvatori, S. and Santini, G. (1985). The prehistoric graveyard of Ras Al-Hamra. A short preliminary report on the 1981-1983 Excavation. *Journal of Oman Studies* 8, p. 97-102.
- Cowiconsult (1984). Wind statistics, Sitra Wharf. Report submitted for Bahrain Petroleum Company.
- Dames and Moore (1992). Environmental Audit Report of Mina Al-Fahal Industrial Area, for Ministry of Environment, Sultanate of Oman, Vol. II: Main report.
- Douabul, A.A.Z., Al-Saad, H.T. and Darmonoico, S.A. (1984). Distribution of petroleum residues in surficial sediments from Shatt al'Arab river and the north-west region of the Arabian Gulf. *Marine Pollution Bulletin*, 15, p. 198-200.
- Douabul, A.A.Z., Al-Saad, H.T., A-Obaidy, S.Z. and Al-Rekabi, H.N. (1987). Residues of organochlorine pesticides in fish. *Water, Air and Soil Pollution*, 35, p. 187-194.
- Downing, N. (1985). Coral Reef Communities in an extreme environment: The northwest Arabian Gulf. Proceedings of the Fifth International Coral Reef Congress, Tahiti, Vol. 6, 343-348.
- EPD (1985). Environmental Protection Department. Annual Report, 1985.
- EPD (1986). Environmental Protection Department. Annual Report, 1986.
- ESCWA (1997). Survey on socio-economic development in the ESCWA region, 1995. ESCWA, Amman (in Arabic).
- Economopoulos, A.P. (1993). Assessment of sources of air, water and land pollution. A guide to rapid source inventory techniques and their use in formulating environmental control strategies. WHO, Geneva. Two volumes.
- Emara, H.I., El-Samra, M.I., El-Deeb, K.Z. and Ahmed, I.F. (1985). A preliminary study of the chemical characteristics of coral reef areas in the Qatari waters (Gulf area). Proceedings of the Fifth International Coral Reef Congress, Tahiti Vol. 6, p. 13-16.
- Embabi, N.S. (1993). Environmental aspects of geographical distribution of mangrove in the United Arab Emirates. *In: Lieth, H. and Al-Masom, A. (eds). Towards the rational use of high salinity tolerants. Vol. 1, p. 45-58.*
- Environmental Public Authority (EPA) (1997). State of Marine Environment Report for the State of Kuwait. Edited by Al-Ghadban, A.N. and Al-Majed, N., EPA, Kuwait.
- Environmental Affairs, Bahrain (1996). Report on Wastewater Reuse. Ministry of Housing, Municipalities and Environment, Bahrain.
- Environmental Resources Ltd. (1986). Water and Solid Waste Assessment Report. Environmental Management Strategy. Report prepared for the Environment Protection Committee, Qatar. Environmental Resources Ltd.; London.
- Faraj, M., Al-Kadi, S., Al-Kandari, A., and Mohammed, E. (1996). Rehabilitation of Kuwait Beaches. International Conference on the Long-term Environmental Effects of the Gulf War, Kuwait, November 1996 (abstract).
- Fayad, N.M., El-Mubarak, A.H. and Edora, R.L. (1996). The fate of oil hydrocarbons in fish and shrimp after major oil spills in the Arabian Gulf. *Bulletin of Environmental Contaminant Toxicology*

56, p. 475-482.

Feltkamp, E. and Krupp, F. (1994). Establishment of a marine habitat and wildlife sanctuary for the Gulf region. Final report for Phase II. Submitted to the Commission of the European Communities, Brussels, and the National Commission for Wildlife Conservation and Development, Riyadh, 675 p.

Firouz, E. (1976). Environmental and Nature Conservation in Iran. *Environmental Conservation*, 3 (1),: p. 33-42.

Fita, N.I. (1993). Fisheries research activities in the Saudian Arab Gulf waters. Background paper presented at the Technical Consultation on Identification and Evaluation of Fish Stock Assessment Activities in the North-Western Indian Ocean (Gulf and Red Sea), 5-7 December 1993, Manama, Bahrain.

Fouda, M.M. (1995a). Status of mangrove resources in the Sultanate of Oman. *Journal of the Faculty of Science*, United Arab Emirates University, 8 (2), p. 169-183.

Fouda, M.M. (1995b). Fish resources of Dhofar Khawrs in the Sultanate of Oman. *Fisheries Management and Ecology* 2, 209-225.

Fouda, M.M. (1995c). Middle East seas: Issues and activities associated with coral reefs and related ecosystems. 1995 International Coral Reef Initiative Workshop, Dumaguete City, Philippines, May 1995, 52 p.

Fouda, M.M. (1996). Marine Protected Areas in the Arabian Seas. Symposium on the Importance of Protected Areas for the Conservation of Wildlife, Kuwait (in Arabic), 34 p.

Fouda, M.M. and Al-Muharrami, M. (1996). Significance of mangroves in the arid environment of the Sultanate of Oman. *Journal of Scientific Research (Agricultural Sciences)*, Sultan Qaboos University, 1, p. 41-49.

Fouda, M.M. and Al-Muharrami, M. (1995). An initial assessment of mangrove resources and human activities at Mahout island, Arabian Sea, Oman. *Hydrobiologia*, 270, p. 353-362.

Fouda, M.M. and Hermosa, G.V. Jr. (1993). A Checklist of Oman Fishes. Sultan Qaboos University, College of Agriculture. 42 p.

Fowler, S. (1985). Coastal baseline studies of pollutants in Bahrain, United Arab Emirates and Oman. Regional Symposium for the Evaluation of Marine Monitoring and Research Programmes. Al-Ain, United Arab Emirates, 1985.

Fowler, S.W. (1996). Contaminant survey of the coastal zone following the 1991 Gulf War. International Conference on the Long-term Environmental Effects of the Gulf War, Kuwait, November 1996 (abstract).

GESAMP (1990). The State of the Marine Environment. London, United Kingdom.

GOIC (1994). Petrochemical Industries in the GCC States, Doha, Qatar.

Gallagher, M.D., Scott D.A., Ormond, R.F.G., Connor, R.J. and Jennings, M.C. (1984). The distribution and conservation of seabirds breeding on the coast and islands of Iran and Arabia. In: Status and Conservation of the World's Seabirds. ICBP Technical Publication 2, p. 421-456.

Groombridge, B. (1982). The IUCN Amphibia-Reptilia Red Data Book, Part 1: Testudines, Crocodylia, Rhynchocephalia. IUCN, Gland, Switzerland, 426 p.

Harger, J.R.E. (1984). Rapid survey techniques to determine distribution and structure of coral communities. In: Comparing Coral Reef Survey Methods. UNESCO Reports in Marine Science 21, p. 83-91.

- Harrington, F.A. (1976). Iran: Surveys of the Southern Iranian Coastline with Recommendations for Additional Marine Reserves. *In: Promotion of the Establishment of Marine Parks and Reserves in the Northern Indian Ocean including the Red Sea and Persian Gulf. Papers and Proceedings of the Regional Meeting held in Tehran, Iran, 6-10 March 1975.* IUCN Publications New Series No. 35, p. 50-75.
- Hayat, L. and Al-Yakoob, S. (1996). Atmospheric polycyclic aromatic hydrocarbon, nickel and vanadium from Kuwait oil fires: Exposures and Biomarkers. International Conference on the Long-term Environmental Effects of the Gulf War. Kuwait, November 1996 (abstract).
- Hinrichsen, D. (1996). *Living on the Edges: Coasts in Crisis.* Island Press.
- IAEA/ROPME (1987). Identification of unknown halogenated hydrocarbons in sediment and oysters. International Atomic Energy Agency, report on project No. KA/5102-82 (unpublished).
- IMO/ROPME/UNEP (1984). Combating oil pollution in the Kuwait Action Plan Region. UNEP Regional Seas Reports and Studies No. 44, 397 p.
- IUCN (1980). *World Conservation Strategy: Living Resource Conservation for Sustainable Development.* IUCN, Gland, Switzerland.
- IUCN (1987). Arabian Gulf. Saudi Arabia: An assessment of biotopes and coastal zone management requirements for the Arabian Gulf. MEPA Coastal and Marine Management Series, report No. 5, IUCN, Gland, Switzerland.
- IUCN (1991). *Coastal Zone Management Programme for Oman. A Framework for Action.* 21 p.
- IUCN (1996). Sultanate of Oman: Key Issues in Environmental Management and Options for IUCN Support. IUCN discussion paper presented to MRME, February 1996, 16 p.
- IUCN/UNEP (1985). Management and conservation of renewable marine resources in the Kuwait Action Plan region. UNEP Regional Seas Reports and Studies 63, p. 1-63.
- IUCN/CNPPA - World Bank (1993). A global representative system of marine protected areas. A report to the World Bank Environment Department. Great Barrier Reef Marine Park Authority, Canberra, 171 p.
- Jackson, J.B.C. (1989). Ecological effects of a major oil spill on Panamanian coastal marine communities. *Science* 207, p. 1060-1071.
- Jessen, K. and Sparck, R. (eds) (1939-1949). Danish Scientific Investigations in Iran. Danish Scientific Investigations in Iran, part 1 (1939), part 2 (1940), part 3 (1944) and part 4 (1944-1949).
- Johnson, P. (1992). Water resources in Oman: The present and future. Nat. Seminar on Wastewater Re-use, Muscat, Oman, 12 p.
- Johnson, D.W., Al-Harassy, A. and Al-Harthy, M. (1992). The Sultanate of Oman Abalone Fishery, *In: S.A. Shepherd, M.J. Tegner and S.A. Gtuzman del Proo (Editors), Abalone of the World: Biology, Fisheries and Culture Fishing News Books, United Kingdom, chapter 32, p. 448-453.*
- Jones, D.A. (1985). The biological characteristics of the marine habitats found within the ROPME sea area. *In: Proceedings of the ROPME Symposium on Regional Marine Pollution Monitoring and Research Programmes (ROPME/GC-4/2), p. 71-89.*
- Kensler, C.B. (1994). Information about the coastal activities and harbours/shipping in the Sultanate of Oman. Report submitted to the College of Agriculture, Sultan Qaboos University, 16 p.
- Keyvani, N. (1984). Protection and management of the marine environment in the Islamic Republic of Iran. Country paper from the Technical Workshop on Marine Environment and Related Ecosystems,

organized by ESCAP, Bangkok, 20-28 February 1984.

Khan, N.A. (1995). Sustainable use of the Arabian Gulf in the vicinity of Madinat Al Jubail Al-Sinaiyah. Sea to Sea: Regional Conference on Sustainable Use of the Marine Environment of the Red Sea and Gulf of Aden (PERSGA) and the ROPME sea area, Jeddah, Saudi Arabia, p. 77-106.

Khan, N.Y. and Al-Ajmi, D. (1996). The Arabian Gulf Ecosystems: Health, Integrity and Post-war Management Imperatives. International Conference on the Long-term Environmental Effects of the Gulf War. Kuwait, November 1996 (abstract).

Khordagui, H. (1997). Environmental consideration of brine water disposal from desalination plants. Third Gulf Water Conference, Muscat, Sultanate of Oman, March 1997, Vol. 3, p. 957-976.

Krupp, F. and Khushaim, O. (1996a). Status of reef fish assemblages in the Jubail marine wildlife sanctuary five years after the Gulf War oil spill. International Conference on the Long-term Environmental Effects of the Gulf War, Kuwait, November 1996, (abstract).

Krupp, F. and Khushaim, O. (1996b). Status of Coastal and marine habitats and biota in the Jubail Marine Wildlife Sanctuary five years after the Gulf War oil spill. International Conference on the Long-term Effects of the Gulf War, Kuwait, November 1996, (abstract).

Krupp, F. and Muller, T. (1994). The status of fish populations in the northern Arabian Gulf two years after the 1991 Gulf War oil spill. Courier Forschungs-Institut Senckenberg, 166, p. 67-75.

Kureishy, T.W. and Al-Muftah, A.R. (1997). Total Hg levels in seawater, sediments and biota in the eastern coastal environment of Qatar. International Conference on the Biology of the Coastal Environment of Bahrain, April 1997 (abstract).

Kureishy, T.W., Al-Muftah, A.R. and Al-Khaireem, S.H. (1996). Levels of some toxic heavy metals in benthic algae and organisms around the Qatari coast. International Conference on the Long-term Environmental Effects of the Gulf War, Kuwait, Nov. 1996 (abstract).

Kuronuma, K. and Abe, Y. (1986). Fishes of the Arabian Gulf. Kuwait Institute of Scientific Research, Kuwait, 356 p.

Linden, O. (1982). Report on Marine Pollution and Fisheries in Bahrain. FI:TCP/BAH/001 Field Document 1, September 1982, FAO, Rome.

Linden, O., and Al-Alawi, Z.S. (1988). Effects of chronic oil pollution in a shallow subtropical marine environment. *Oil and Chemical Pollution*, 5, 65-79.

Linden, O., Abdurraheem, M.Y., Gerges, M.A., Alam, I., Behbehani, M., Borhan, M. A., and Al-Kassab, F. (1990). State of the Marine Environment in the ROPME Sea Area. UNEP Regional Seas Reports and Studies No. 112, Rev. 1, UNEP.

Literathy, P. (1996). Environmental weathering of petroleum residues of the Gulf War in Kuwait. Their pollution potential and future research needs. International Conference on the Long-term Environmental Effects of the Gulf War, Kuwait, November 1996 (abstract).

Literathy, P., Ali, M.A., Al-Harmi, L., Lee, J.W. and Farmer, A.S.D. (1985). Monitoring of oceanographic characteristics and baseline studies of oil and non-soil pollutants in the territorial waters of Kuwait. Kuwait Institute for Scientific Research, KISR Report No. 1662.

Literathy, P., Ali, M.A., Al-Harmi, L., Joseph, P.S. and Lee, J.W. (1986). Monitoring of oceanographic characteristics and baseline studies of oil and non-oil pollutants in the territorial waters of Kuwait. Phase II. Kuwait Institute for Scientific Research.

- McCain, J.C. (1984). Marine Ecology of Saudi Arabia: The nearshore, soft bottom benthic communities of the northern area, Arabian Gulf, Saudi Arabia. *In: Fauna of Saudi Arabia* 6, p. 79-97.
- McCain, J.C., Tarr, A.B., Carpenter, K.E. and Coles, S.L. (1984). Marine Ecology of Saudi Arabia. A survey of Coral Reefs and Reef Fishes in the Northern Area, Arabian Gulf, Saudi Arabia. *In: Fauna of Saudi Arabia* 6, p. 102-120.
- Madany, I.M. and Zainal, J.M. (1987). Marine Pollution in Bahrain and its Environmental Aspects. *Journal of Gulf Arabian Peninsula Studies* 13, p. 173-206.
- Madany, I.M., Ali, S.M. and Akhtar, M.S. (1987). The impact of dredging and reclamation in Bahrain. *Journal of Shoreline Management* 3, 255-268.
- Madany, I.M. and Akhter, M.S. (1990). Assessment of chemical and physical properties of Adari spring in Bahrain. *Environment International* 16, p. 297-300.
- Madany, I.M. and Danish, S.A. (1993). Quantity and quality of industrial solid waste in Bahrain. *Industrial Cooperation* 53, p. 6-26 p. Published in Qatar.
- Madany, I.M., Jaffar, A. and Al-Shirbini, E.S. (1996). Variations in the concentrations of aromatic petroleum hydrocarbons in Bahraini coastal waters during the period October 1993 to December 1995. International Conference on the Long-term Environmental Effects of the Gulf War, Kuwait, November 1996 (abstract).
- Marini, L. (1985). Study of a locality in Iran suitable for a marine biological station. *In: I Parchi Costieri Mediterranei. Atti del Convegno Internazionale, Salerno Castellabate, June 1973. Regione Campania Assessorato per il Turismo*, p. 685-706.
- Middle East Environment (1993). United Araba Emirates Annual Review. *Journal of the Environmental Protection Professional*, issue 2.
- Middle East Environment (1995). Kuwait Annual Review. *Journal of the Environmental Protection Professional*, issue 6.
- Ministry of Housing, Municipalities and Environment (1995). Marine Monitoring Program. Study of Physical and Chemical Oceanography in Bahrain Territorial Waters. Prepared by Environmental Protection Affairs, Bahrain, 17 p.
- Ministry of Housing, Municipalities and Environment (1996). Monitoring of the air quality in Bahrain. Prepared by Environmental Affairs, 20 p.
- Ministry of Information (1996). Sultanate of Oman, 1996.
- Ministry of Regional Municipalities and Environment (1992a). National Conservation Strategy: Environmental Protection and Natural Resources Conservation for Sustainable Development, Muscat, 3 volumes.
- Ministry of Regional Municipalities and Environment (1992b). Coastal Erosion in Oman: Draft Regulations for the Prevention of Erosion in the Sultanate of Oman. Prepared by James Dobbini Associates Incorporated, United States of America.
- Ministry of Regional Municipalities and Environment (1995). Monitoring Pollutants in the Marine Environment. Report by Auscon Consultants International, Ltd., United Kingdom.
- Ministry of Regional Municipalities and Environment (1996a). Current Study. Final report (4 volumes), prepared by Applied Science Associates, Inc., United States of America (ROPME 33/94).
- Ministry of Regional Municipalities and Environment (1996b). Coral Reef Management Plan (5 volumes). Prepared by L.G. Mouchel Ltd., in association with National Engineering Office, United Kingdom.
- Mohamed, S.A. (1991). Impact of oil spill on inter-

tidal organisms in Bahrain. SPE Middle East Oil Technical Conference and Exhibition, Bahrain, March 1991 (abstract).

Mohammed, K.H., Al-Musa, M. and Abdul-Ghaffar, A.R. (1981). Observation of the biology of an exploited species of shrimp, *Penaeus semisulcatus* de Haan, in Kuwait. *Kuwait Bulletin of Marine Science*, 2, p. 33-46.

Mohammadi, H. (1995). Summary of the principles of the ROPME Protocol for the Protection of the Marine Environment against Pollution from Land-based Sources. Presented at the ROPME/UNEP Expert Consultation. Meeting on the Control of Marine Pollution from Land-based Sources, Kuwait, December 1996 (ROPME/WG - 761 Inf. 4).

Morgan, G.R. (1985). Status of the shrimp and fish resources of the Gulf. FAO Fisheries Circular 792:49 p.

Nouh, M. (1992). The place of wastewater reuse in water management. National Seminar on Wastewater Reuse, Muscat, Oman, 12 p.

Nurun Nabi, M.D. (1976). Bahrain country Report I. Promotion of the establishment of marine parks and resources in the northern Indian Ocean including the Red Sea and Persian Gulf. Papers and Proceedings of the Regional Meeting, March 1975, IUCN.

Palson, L. (1992). Appropriate waste water treatment technologies and reuse in Oman. National Seminar on Wastewater Reuse, Muscat, Oman, 17 p.

Parvaneh, V. (1977). A survey on the mercury content of Persian Gulf shrimp. *Bulletin of Environmental Contamination Toxicology* 18, p. 778-782.

Parvaneh, V. (1979). An investigation on the mercury contamination of Persian Gulf fish. *Bulletin of Environmental Contamination Toxicology* 23, p. 357-359.

Phillips, R.C. and McRoy, C.P. (1980). *Handbook of Sea-grass Biology: An Ecosystem Perspective*. Gerland STPM Press, New York 353 p.

Preen, A. (1989). Dugongs vol. 1. The status and conservation of Dugongs in the Arabian Region. MEPA No. 10, MEPA, Jeddah, 200 p.

Price, A.R.G. (1990). Rapid assessment of coastal zone management requirements: A case study from the Arabian Gulf. *Ocean and Shoreline Management* 13, p. 1-19.

Price, A.R.G. (1993). The Gulf: Human Impacts and Management Initiatives. *Marine Pollution Bulletin* 27, 17-27.

Price, A.R.G. and Coles, S.L. (1992). Aspects of sea-grass ecology along the Western Arabian Gulf. *Hydrobiologia* 234, p. 129-141.

Price, A.R.G. and Robinson, J.H. (1993). The 1991 Gulf War: Coastal and Marine Environmental Consequences. *Marine Pollution Bulletin* 27, 380 p.

Price, A.R.G., Sheppard, C.R.C. and Roberts, C.M. (1993). The Gulf: Its Biological Setting. *Marine Pollution Bulletin* 27, 9-15.

Qureshi, M.A. and Qureshi, A.A. (1990). Efficiency of removal of coliforms, faecal coliforms and coliphages in the Tubli sewage treatment plant. *Water Resources* 24, p. 1459-1461.

ROPME (1984). Evaluation of the present situation on land-based sources of pollution within KAP member States. Report, ROPME, 1984.

ROPME (1987). Report on dust-fallout. ROPME/GC-S/005/1987.

ROPME (1988). Marine monitoring and research programme in the ROPME region: Assessment of the oceanography of the ROPME sea area. Summary report, prepared by A. Cruzado.

- ROPME Secretariat (1995). Report of ROPME/UNEP Experts Consultation Meeting on the Control of Pollution from Land-based Sources. ROPME/WG/76/2.
- ROPME (1996). A regional approach towards the implementation of the Global Programme of Action to Protect the Marine Environment from Land-based Activities (LBA). Workshop on Implementation of the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities in the ROPME and PERSGA Regions. Manama, Bahrain, December 1996, 16 p.
- ROPME (1997). Available data on the land-based sources of pollution in the ROPME sea area. ROPME, Kuwait.
- ROPME/IAEA (1988). Survey of mercury in fish and sediment from the ROPME sea area (unpublished report).
- Randall, J.E. (1995). Coastal Fishes of Oman. University of Hawaii Press, 439 p.
- Raveendran, E. and Madany, I.M. (1991). Characteristics of agricultural drainage water in Bahrain. *The Science of the Total Environment*, 104, p. 239-247.
- Reynolds, M. (1993). Physical Oceanography of the Gulf, Strait of Hormuz, and the Gulf of Oman: Results from the Mt. Mitchell Expedition. *Marine Pollution Bulletin* 27, p. 35-60.
- Reynolds, M. (1996). The Gulf Breeze and its Effect on Coastal Waters. International Conference on the Long-term Effects of the Gulf War, Kuwait, November 1996 (abstract).
- Reza, A.M. (1985). The endangered benthic organisms in effect of oil spilled in Nowruz platform in the Persian Gulf. Paper 49, Symposium on Endangered Marine Animals and Marine Parks. Marine Biology Association of India. Cochin, India, January 1985.
- Roberts C.M., Downing, N. and Price, A.R.G. (1993). Oil on Troubled Waters: Impacts of the Gulf War on Coral Reefs. In: R.N. Ginsburg (eds) *Global Aspects of Coral Reefs: Health Hazards and History, Collected Case Histories, 7-11 June 1993*, University of Miami, Miami, p. V35-V41.
- Rogers, P. and Lydon, P. (1993). Water in the Arab World. In: *Perspectives and Prognoses*. Harvard University Press, p. 216-222.
- Ross, J.P. (1979). Sea Turtles in the Sultanate of Oman. Report of the World Wildlife Fund Project 1320.
- Ross, J.P. and H.A. Barwani (1981). Review of sea turtles in the Arabian area. In: Bjorndal, K.A. (ed.), *Biology and Conservation of Sea Turtles*. Smithsonian Institution Press, Washington D.C., p. 373-383.
- Saad, M.A.H. (1983). Effects of pollution on the bottom sediments of the water channels of Shatt al' Arab, flowing through the City of Basrah. *Journal of the Faculty of Marine Sciences, Jeddah*, 3, p. 39-47.
- Saad, M.A.H. (1985). Distribution of Nutrients in Shatt al' Arab Estuary. *Bulletin of the Institute of Oceanography*. Cairo 11, p. 27-42.
- Sadiq, M. and Zaidi, T.H. (1985). Metal concentrations in the sediment from the Arabian Gulf Coast of Saudi Arabia. *Bulletin of Environmental Contaminant Toxicology*. 34, p. 565-571.
- Sadiq, M. and Alam, I. (1989). Metal concentrations in pearl oysters, *Pinctada radiata*, collected from the Saudi Arabian coast in the Arabian Gulf. *Bulletin of Environmental Contaminant Toxicology* 42, p. 111-118.
- Saeed, R., Al-Hashash, H., and Al-Matrouk, K. (1996). Assessment of the changes in the chemical composition of the oil in the lakes after weathering for five years. *International Conference on the Long-*

- term *Environmental Effects of the Gulf War*, Kuwait, November 1996 (abstract).
- Said, A.I. (1996). Environmental impact assessment and perspectives of the Gulf War. International Conference on the Long-term Environmental Effects of the Gulf War, Kuwait, Nov. 1996 (abstract).
- Said, M. (1996). Assessment of land-based sources of pollution in the ROPME sea area. Workshop on Implementation of the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities in the ROPME and PERSGA Regions, Manama, Bahrain, December 1996, 18 p.
- Salm, R.V. (1989). A general overview of the coast between Ra's al Hadd and Dhofar. IUCN Coastal Zone Management Project 9429. Sultanate of Oman, CZMP3:F6: 3 p.
- Salm, R.V. (1991). Oman coastal zone management program: A framework for Action. IUCN, Gland, Switzerland.
- Salm, R.V. (1993). Coral reefs of the Sultanate of Oman. *Atoll Research Bulletin*, 380, p. 1-85.
- Salm, R. and Baldwin, R. (1991). Snorkeling and Diving in Oman. Arabian Heritage Guidebooks, United Arab Emirates, 88 p.
- Salm, R.V., Jensen, R.A.C. and Papastavron, V.A. (1993). Marine Fauna of Oman: Crustaceans, Turtles, Seabirds and Shallow Water Corals. A Marine Conservation and Development Report. IUCN, Gland, Switzerland, 66 p.
- Salm, R.V. and Salm, S. (1991). Marine Turtles in Oman. The Historical Association of Oman, Muscat, 57 p.
- Schiewer, U., Al-Saadi, H.A. and Hameed, H.A. (1982). On the diel rhythm of phytoplankton productivity in Shatt al'Arab at Basrah, Iraq. *Archiva Hydrobio.* 93, p. 158-172.
- Shams Edin, A.M., Aziz, S. and Makhawi, B. (1994). Electricity and water production in the Emirates of Abu Dhabi and its impact in the environment. *Desalination* 97, p. 373-388.
- Sheppard, C.R.C. (1985). Report on reefs and other hard structures of Bahrain. ROPME critical habitat survey of Bahrain 1985. Environmental Protection Technical Secretariat, Bahrain.
- Sheppard, C.V., Price, A.R.G. and Roberts, C. (1992). Marine Ecology of the Arabian Region. *In: Patterns and Processes in Extreme Tropical Environments*, United Kingdom, 359 p.
- Sheppard, C.R.C. and Salm, R.V. (1988). Reef and coral communities of Oman, with a description of a new coral species (order *Scleractina*, genus *Acanthastrea*). *Journal of Natural History*, 22, p. 263-279.
- Siddeek, M.S.M., Fouda, M.M. and Hermosa, G.V. Jr. (1997). A review on the demersal fisheries of the Arabian Sea, the Gulf of Oman and the Arabian Gulf. Paper presented at the International Conference on the Biology of Coastal Environments, Bahrain, 6-9 April 1997 (abstract).
- Siddiqui, M.S. and Al-Mubarak, K.A. (1996). The post-Gulf War shrimp fishery management in the territorial waters of Kuwait. International Conference on the Long-term Environmental Effects of the Gulf War, Kuwait, November 1996, (abstract).
- Smith, G.B. and Saleh, M. (1987). Abundance and bathymetric distribution of Bahrain (Arabian Gulf) reef ichthyofaunas. *Estuarine Coastal and Shelf Science*, 24. 425-431.
- Smith, G., Saleh, M. and Sangoor, K. (1987). The reef ichthyofauna of Bahrain (Arabian Gulf) with comments on its zoogeographic affinities. *Arab Gulf Journal of Scientific Research Agricultural and Biological Sciences* B5, 1, p. 127-146.

- Snowden, R. (1996). Evidence of an unusual ecological cycle on Kuwait's intertidal zone, and its implications for monitoring the effects of the Gulf War oil spillages. International Conference on the Long-term Environmental Effects of the Gulf War. Kuwait, November 1996 (abstract).
- Stirn, J. (1994). Oceanographic conditions and pelagic biological processes in Omani waters: A brief overview focused on aspects related to living resources. Report submitted to the Working Group on Mesopelagic Resources. Gulf Committee for Fisheries Management and Development, Muscat, Oman.
- Suda, S. (1990). A research report on mangrove afforestation in Qatar (December 1988 - March 1990). Department of Gardens and Parks, Ministry of Municipal Affairs and Agriculture, Qatar, 76 p.
- Suda, (1993). A research report on mangrove afforestation of Qatar (May 1991 - 1993). Department of Gardens and Parks, Ministry of Municipal Affairs and Agriculture, Qatar, 68 p.
- Symens, P. and Suhaibani, A. (1994). The impact of the 1991 Gulf war oil spill on bird populations in the northern Arabian Gulf - A review. Courier Forsch - Inst. Senckenberg, 166, p. 47-54.
- Taylor (1986). Wastewater discharges from domestic sources to the ROPME sea area. Report to ROPME prepared by John Taylor and Sons. 1986.
- The Khawrs of Dhofar (1993). Technical Secretariat of the Planning Committee for Development and Environment in the Governorate of Dhofar, 16 p.
- UNEP (1984). The State of the Environment in Qatar. UNEP Regional Office for Western Asia, Beirut, Lebanon.
- UNEP (1990). Directory of Marine Scientists and Marine Environmental Centres in the Arabia States. UNEP Regional Seas Directories and Bibliographies, No. 34, 213 p.
- UNEP (1994). Directory of Environmental Resource Persons and Research in West Asia, Bahrain (ROWA).
- UNEP (1995). Global Programme of Action for the Protection of the Marine Environment from Land-based Activities. UNEP (OCA) LBA/IG, 217.
- UNEP/IUCN (1988). Coral reefs of the World. Vol. 2. Indian Ocean, Red Sea and Gulf. UNEP Regional Seas Directories and Bibliographies. IUCN, Gland, Switzerland and Cambridge United Kingdom/UNEP, Nairobi, Kenya, 389 p.
- Uwate, K.R. and Shams, A. (1996). Video Technology Applied to the Management of Bahrain's Marine Resources. Naga ICLARM Quarter, April 1996, p. 9-11.
- Vogt, H. (1994). Status of the coral reefs after the Gulf war. Courier Forsch-Inst. Seckenberg, 166, p. 61-66.
- Vousden, D.H. (1988). The Bahrain Habitat Survey: A study of the marine environment of Bahrain using remote sensing as a rapid assessment methodology. Proceedings of the ROPME Workshop on Coastal Area Development. Kuwait, August 1997, p. 3-33.
- Wagnick, K. (1995). The historical development of the desalination market. Proceedings of the IDA World Congress, Abu Dhabi, Vol. II, p. 17-27.
- Weidleplan (1991). Study for Wildlife and Conservation Areas - Master Plan for the Coastal Areas of the Barr al Hikman and Masirah island. Final Report. Ministry of Regional Municipalities and Environment, Sultanate of Oman.
- WHO (1989). Health Guidelines for the use of wastewater in agriculture and aquaculture. Technical Report Series, No. 778.
- World Resources (1996-1997). The World Resources Institute, the United Nations Environment Programme and the United Nations Development

Programme, Oxford, 365 p.

World Resources 1996-1997. A Guide to the Global Environment. World Resources Institute, UNEP, UNDP and the World Bank, Oxford, 1996.

Yehia, M.A. (1986). Mapping of coastal and submarine features around the State of Qatar, using Landsat data. *In: Marine Environment and Pollution*, Halwahi, R., Clayton, D. and Behbehani, M., editors. Kuwait University, Faculty of Science, p. 43-51.

Zarba, M.A., Shunbo, F. and Nasser, L. (1985). Contribution of vehicular emission to lead level in surface soil. Annual Research Report of the Kuwait Institute for Scientific Research 1984, p. 134-135.

Zwarts, L., Felembon, H. and Price, A.R.G. (1991). Wader counts along the Saudi Arabian Gulf Coast suggest that the Gulf Harbours millions of waders. *Wader Study Group Bulletin* 63, p. 25-32.

Table 1

River inflow into the northern ROPME sea area coastline

Name of river	Discharge (m²/s) (flow station)	
Shatt al'Arab	708	(Basra)
Karun	748	(Ahwaz)
Jarahi	43	(Shadgan)
Hendijan	203	(Deh moila)
Hilleh	444	
Mand	1387	

Source: Reynolds, 1993

Table 2

Annual total catch (t) demersal and pelagic in the countries bordering the Arabian Sea, the Gulf of Oman, and the ROPME Sea Area for 1985-1994; and annual total demersal catch (t) (demersal fish and invertebrates) in the three water bodies for 1988-1993. Percentage values of demersal catch are given in parentheses

Country	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Oman	94893	96337	135089	166079	117537	118640	117765	112313	116470	118568	139861
United Arab Emirates	72260	79321	85247	89500	91160	95129	92300	95046	92000	108000	
Qatar	2484	1980	2678	3086	4374	5702	8136	7845	6994	5087	
Saudi Arabia (Gulf and Red Sea)	43696	45517	47767	46803	52190	40337	39911	45834	47235	58027	
Bahrain	7763	8057	7842	6736	9208	8105	7553	7983	8958	7629	
Kuwait	10118	7633	7704	10796	7653	4454	2034	7871	8561	7752	
Islamic Republic of Iran	96364	121771	169664	188515	210180	199620	277000	271000	247000		
Iraq	5500	5000	5000	5000	5000	3500	3000	4000	4500		
TOTAL (Demersal and Pelagic)	333078	365616	460991	516515	497302	475487	547699	551892	531718		
TOTAL (Demersal*)	-	-	-	213655 (41)	200976 (40)	197920 (42)	202555 (37)	205876 (37)	213919 (40)		

Source: Siddeek, et. al., 1997

* The 1991-1992 average Iranian demersal fish catch is substituted for each missing data for each year from 1988 to 1993 to account for Iranian demersal landings for those years.

Table 3**Estimate of emissions from wastewater treatment discharge flows in 1992 in Bahrain**

Plant	Average daily flow (m³/day)	Sea discharge
Tubli WPC	133422	112842
Nuwaydirat	4570	4570
Budaiya	2222	2222
North Sitra	1993	1993
Askar	300	300
East Riffa	270	-
Dumistan	305	-
Zallaq	200	-
Arabian Gulf University	435	-
Jau Training Camp	84	-
Private Treatment Plt. 1	15	-
Private Treatment Plt. 2	14	-
Sitra 77	100	100
Approximate total	143930	122027

Source: Environmental Affairs, Bahrain 1996

Table 4**Estimate of emissions from industrial wastewater treatment and discharge in Bahrain**

Plant	Average daily flow (m³/day)	Sea discharge
Sitra Sewage Treatment Plant	100	100
Bahrain Aluminum Extrusion Co.	200	
Tubli Water Pollution Control Centre	133,422	112,842
Gulf Petrochemical Industries Co.	552,000	
Aluminum Powder Coating (Al-Zamil)	108.7	
BAPCO 6 Separator	70,855	-
BAPCO	665,000	-
Ras Abu Jarjur R.O. Plant	3,785	-
Sitra Power Plant	1,470,000	-
Approximate total	2,895,470	

Source: Environmental Affairs, Bahrain, 1996

Table 5

Changes in the area of Bahrain due to reclamation activities

Year	Area (km²)
1975	661.87
1981	669.29
1983	684.98
1984	687.75
1985	690.86
1986	691.24
1987	692.39
1988	692.52
1990	693.15
1994*	700.00*

Source: Al Madany et. al., 1991

* obtained from Environmental Affairs, Bahrain 1996

Table 6

Area and purpose of land reclamation in Bahrain

Area reclaimed	Area (km²)	Purpose of reclamation
North Sitra	2.5	Industrial area (power and desalination plant, sulphuric acid, aluminium extrusion and rolling mill, sand and gravel companies, sewage treatment, plastic and food factories), roads.
Mina Salman		Port, industrial area (paint factories, metal and plastic fabrication, soap and detergent plant)
Tubli Bay	17	Sewage treatment, domestic waste pulverizing plant, housing, roads
Manama south		Islamic centre (0-3 km ²) and civic centre (0-2 km ²)
Sanábis		Housing government building, recreation (4-5 km ²)
GPIC	0.6	Methanol and ammonia plant, jetty
Budaiya	0.6	Housing, recreation
Al-Dar islands	0.033	Recreation
Al-Muharraq	4	Airport, housing, recreation
Arad and Al-Hidd	6	Industrial area (garages, fabrication), housing
ASRY and GIIC	2.2	Ship repairing yard, iron-ore pelletizing plant, workers housing, roads
King Fahad Causeway	2.0	Roads
Jaww	0.18	Police training centre
Askar	0.0075	Avoid nuisance smell from the coast

Source: Al Madany et. al., 1991

Table 7**Summary of atmospheric emissions from industrial sources in Bahrain (1985)**

Source	Contaminant load (tons/yr)							
	Particulates	SOx	NOx	HC	CO	Others	Total	% Total
Power Plants	300	1,742	8,758	529	1,531	N/A	12,861	8.5
Mobile Combustion	644	2,126	3,498	3,341	61,844	N/A	71,452	47.1
Industrial Processes	9,755	30,944	13,226	10,043	3,188	N/A	67,158	44.3
Domestic	32	35	51	7	7	N/A	132	0.1
TOTAL	10,731	34,847	25,534	13,920	66,570	N/A	151,603	100
PER CENT TOTAL	7	23	17	9	44	0	100	100

Source: ROPME, 1997

Table 8

Bahrain's proposed effluent guidelines

Parameters	Units	Maximum	Average	Methbiochemical oxygen demand used by EPC*
Physical properties				
Floating particles	mg/m ²	0	NIL	
pH	pH	9	6 to 9	4500 -H ⁺ B.
Temperature	C	CASE BY CASE		Thermometer
Total suspended solids	mg/L	35.000	20.000	2540 -D
Turbidity (NTU)	N.T.U.	75.000	25.000	2130 -B
Inorganic chemical properties				
Ammonical nitrogen as N	mg/L	3.000	1.000	4500 -NH ₃ E.
Dissolved oxygen	mg/L	>2		4555 -0 -C
Sulfide as H ₂ S	mg/L	1.000	.500	4500 -S ²⁻ -D
Chlorine residual	mg/L	2.000	.500	4500 -Cl -B
Cyanide as CN	mg/L	0.100	.050	4500 -CN -E
Chloride (CL ⁻)	mg/L	TO BE REPORTED		4500 -Cl ⁻ -B
Nitrate (NO ₃ ⁻) -N-	mg/L	10.000		4500 -NO ₃ -E
Nitrate (NO ₃ ⁻) -N-	mg/L	1.000		4500 - NO ₂ -E
Phosphorous - total	mg/L	2.000	1.000	4500 -P -E
M.B.A.S.	mg/L	1.000	0.500	5540 -C
Flouride (F ⁻)	mg/L	25.000	15.000	4500 -F -C
Organic pollutants				
Biological oxygen demand	mg/L	50.000	25.000	5210 -B
Chemical oxygen demand	mg/L	350.000	150.000	5220 -B
Total Kjeldahl nitrogen	mg/L	10.000	5.000	4500 -N-B
Hydrocarbons (FLOUR or IR)	mg/L	0.100	0.100	MOOPAM
Oil and grease (hexane ex.)	mg/L	15.000	8.000	5520 -D
Phenols	mg/L	1.000	0.500	5530 -D
Trace metals				
Aluminium	mg/L	25.000	15.000	3110- ***
Arsenic	mg/L	0.500	0.100	3110- ***
Camium	mg/L	0.050	0.010	3110- ***
Chromium total	mg/L	1.000	0.100	3110- ***
Copper	mg/L	0.500	0.200	3110- ***
Iron	mg/L	10.000	5.000	3110- ***

Lead	mg/L	1.000	0.200	3110- ***
Mercury	mg/L	0.005	0.001	3110- ***
Nickel	mg/L	0.500	0.200	3110- ***
Selenium	mg/L	1.000	0.200	3110- ***
Silver	mg/L	0.005		3110- ***
Zinc	mg/L	5.000	2.000	3110- ***
Total coliforms	No/100 ml	10000.000	1000.000	9222.B.

* Methods numbers mentioned here are from *Standard Methods for the Examination of Water and Wastewater* (17th edition).

** Methylene blue active substances

*** Relevant section using atomic absorption spectrophotometer

MOOPAN : *Manual of Oceanographic Observations and Pollution Analysis Methods*

Source: Environmental Affairs, Bahrain, 1996

Table 9

Principal pollutants discharged into the marine environment (tons/yr)

	1990	1991	1992	1993	1994	1995
1. Water (vol. m ³):						
- Industry	31189	33372	35708	38027	40882	43744
- Power plants	35270	38797	42677	46945	51639	56803
- Sewers	60508	69584	80022	92025	105829	121703
- Oil extraction and export	16200	16200	16200	16200	16200	16200
- Total	143167	143167	157953	193197	214550	238450
2. Bbiochemical oxygen demand:						
- Industry	35665	38162	40833	43692	46750	50023
- Power plants	45	50	55	61	67	73
- Sewers	2693	3097	3562	4090	4711	5417
- Oil extraction and export	0	0	0	0	0	0
- Total	38403	41309	44450	47843	51528	55513
3. T.S. solids:						
- Industry	109227	116872	125053	133807	143174	153196
- Power plants	5798	6378	7015	7717	8489	9337
- Sewers	1995	2295	2639	3035	3490	4014
- Oil Extraction and export	0	0	0	0	0	0
- Total	117020	125545	134707	144559	155153	166547
4. Oil:						
- Industry	3790	4055	4339	4643	4968	5315
- Power plants	3	4	4	4	5	5
- Sewers	22	25	29	34	39	44
- Oil extraction and export	24300	24300	24300	24300	24300	24300
- Total	28115	28384	28672	28981	29312	29664
5. Sulphates:						
- Industry	73	73	73	73	73	73
- Power plants	0	0	0	0	0	0
- Sewers	175	201	231	266	306	352
- Oil extraction and export	0	0	0	0	0	0
- Total	248	274	304	339	379	425
6. NO ₃ :						
- Industry	7026	7729	8500	9352	10287	11315
- Power plants	0	0	0	0	0	0
- Sewers	4515	5193	5972	6868	7898	9082
- Oil extraction and export	0	0	0	0	0	0
- Total	11541	12922	14472	16220	18185	20397
7. Phosphates:						
- Industry	0	0	0	0		
- Power plants	876	876	876	876		
- Sewers	1947	2239	2575	2957		
- Oil extraction and export	0	0	0	0		
- Total	2823	3115	3451	3833		

Source: EPA, Kuwait, 1997

Table 10

Summary of domestic liquid wastes discharged into the sea in Kuwait (1996)

Treatment plant	Discharged contaminant load (tons/yr)									Waste volume	
	Bbiochemical oxygen demand	Cbiochemical oxygen demand	SS	NO	NO ₃	TKN	P	Total	% Total	(10 ³ m ³ /y)	%
Ardiya (treated)	381	1,526	381	23	76	667	763	3,818	70.0	190	56.0
Rikka (treated)	71	617	807	N/A	N/A	121	N/A	1,616	29.6	100	29.5
Al-Jahrah (treated)	2	9	2	0	1	2	4	20	0.4	50	14.6
TOTAL	454	2,152	1,190	23	77	791	767	5,454	100	340	100
PER CENT TOTAL	8.3	39.4	21.8	0.4	1.4	14.5	14.1	100.0		100	

Source: ROPME (1997)

Table 11

Production capacities of the desalination plants in the Sultanate of Oman

No. of map	Location	Type	Capacity MGD	Capacity m ³ /d
Muscat				
1	Al-Ghubrah 1	MSF	5	22,700
1	Al-Ghubrah 2	MSF	6	27,300
1	Al-Ghubrah 3	MSF	6	27,300
1	Al-Ghubrah 4	MSF	6	27,300
1	Al-Ghubrah 5	MSF	6	27,300
Ash Sharqiyah				
	Sur	RO	1.000	4,550
2	Ra's al Hadd	RO	0.022	100
3	Ar Ruwais	RO	0.038	172
4	Asyilah	RO	0.021	95
5	Masirah 1	MSF	0.12	545
6	Masirah 2	TC	0.13	600
6				
Al Wusta				
7	Mahawt	MSF	0.01	50
8	As Saadanat	RO	0.01	50
9	Ash Shuayr	RO	0.01	50
10	Madrakah	RO	0.01	50
11	Haytam	RO	0.01	50
12	Abu Mudhabi	RO	0.01	50
Musandam				
13	Kumzar	Vapour compression	0.06	272
14	Shisar	Vapour compression	0.09	408
15	Lima	ED	0.05	230

Source: Al Sajwani and Lawrence, 1995

Table 12

Water demands in the Sultanate of Oman (total net usage in cubic metres per day)

Area	1990	2000	2010
Capital area	127397	198082	328493
Batinah	25425	75890	148658
Dhahirah	7753	17699	32767
Dhakliya	5288	21068	40384
Sharqiya	11726	40904	80301
Dhofar	28493	54795	98630
Musandam	1096	6301	11781
Total	207178	414739	741014

Source: Al-Sabahi, 1997

Table 13**Liquid effluent standards for disposal to the marine environment
in the Sultanate of Oman**

PARAMETER	UNIT	STANDARD NOT GREATER THAN
Ammoniacal Nitrogen (as N)	mg/1	40.0
Arsenic (As)	mg/1	0.05
Biochemical oxygen demand-5 day	mg/1	30
Cadmium (Cd)	mg/1	0.05
Chlorine total (not less than)	mg/1	2.50
Chromium (Cr)	mg/1	0.50
Copper (cu)	mg/1	0.50
Cyanide (CN)	mg/1	0.10
Fecal Coliforms	MPN/100 ml	100 (80% of samples)
Faecal Streptococci	MPN/100 ml	100
Salmonella	MPN/1 litre	Non detectable
Grease and oil	mg/1	5.0
Iron (Fe)	mg/1	2.0
Lead (Pb)	mg/1	0.10
Mercury (Hg)	mg/1	0.001
Nickel (NI)	mg/1	0.10
Ph	between	6-9
Phenols	mg/1	0.10
Phosphates	mg/1	0.10
Selenium (se)	mg/1	0.02
Silver (As)	mg/1	0.005
Sulfide	mg/1	0.10
Suspended solids	mg/1	30
Turbidity	JTU	75
Zinc	mg/1	0.10

Source: Al-Sabahi, 1997

Table 14

Existing production of treated sewage effluent in the Sultanate of Oman (cubic metres per day)

Area	TSE production (re-used)	TSE production (soak-away)
Capital area	45,568	3,324
Sharqiya	2,561	90
Musandam	425	42
Wusta	595	80
Dhahirah	2,035	448
Dhakliya	2,187	20
Batinah	4,013	3,799
Dhofar	1,605	3,581
Total	58,988	11,383

Source: Al Sabahi, 1997

Table 15

Estimated potential future treated sewage effluents in the Sultanate of Oman (cubic metres per day)

Area	TSE production (re-used)	TSE production (soak-away)
Capital area	118,849	197,096
Batinah	45,534	89,195
Dhahirah	10,619	19,660
Dhakliya	12,641	24,230
Sharqiya	24,542	48,181
Southern region	32,877	59,178
Musandam	3,781	7,069
Total	248,843	444,609

Source: Al Sabahi, 1997

Table 16

Wastewater maximum quality standards for reuse and discharge in the Sultanate of Oman (mg/l except where otherwise stated)

Parameter	A	B
Biochemical oxygen demand	15	20
Cbiochemical oxygen demand	150	200
Suspended solids (SS)	15	30
Total dissolved solids	1500	2000
EC ($\mu\text{S}/\text{cm}$)	2000	2700
SAR**	10	10
pH	6-9	6-9
Aluminum (Al)	5	5
Arsenic (As)	0.1	0.1
Barium (as Ba)	1	2
Beryllium (as Be)	0.1	0.3
Boron (as B)	0.5	1
Cadmium (as Cd)	0.01	0.01
Chloride (as Cl)	650	650
Chromium (total as Cr)	0.05	0.05
Cobalt (as Co)	0.05	0.05
Copper (as Cu)	0.5	1
Cyanide (total as Cn)	0.05	0.1
Fluoride (as F)	1	2
Iron (total as Fe)	1	5
Lead (as Pb)	0.1	0.2
Lithium (as Li)	0.07	0.07
Magnesium (as Mg)	150	150
Manganese (as Mn)	0.1	0.5
Mercury (as Hg)	0.001	0.001
Molybdenum (as Mo)	0.01	0.05
Nickel (as Ni)	0.1	0.1
Nitrogen: Ammonia (as NH^3)	5	10
Nitrate (as No_3)	50	50

Organic (as N)	5	10
Oil and grease - Total	0.5	0.5
Phenols (total)	0.001	0.002
Phosphorus (total as P)	30	30
Selenium (as Se)	0.02	0.02
Silver (as Ag)	0.01	0.01
Sodium (as Na)	200	300
Sulphate (as SO ₄)	400	400
Sulphide (total as S)	0.1	0.1
Vanadium (as V)	0.1	0.1
Zinc (as Zn)	5	5
Fecal coliform/100 ml	200	1000
Viable nematode ova/1	<1	<1

SAR:** Sodium absorption ratio = a measure of the effect on soil

Source: Ministerial Decision 145/93 dated 13 June 1993

Notes: A and B refer to application type. A is for vegetables, fruit, etc., and for public parks, lawns and areas with public access. B is for vegetables, fodder, cereal, etc., and for areas with no public access.

Source: Al-Sabahi, 1997

Table 17

Summary of industrial liquid wastes discharged into the Sea of Qatar

Source	Discharged contaminant load (tons/yr)								Waste volume	
	Bbiochemical oxygen demand	Cbiochemical oxygen demand	SS	TDS	Oil	N	Total	% Total	(10 ³ m ³ /y)	%
1. Industrial processes										
Agricultural/livestock	0	0	0	0	0	0	0	0.0	0	0.0
Food manufacturing ¹	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Beverage industry	0	0	0	0	0	0	0.0	0.0	0	0.0
Chemical manufacturing ²	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Petrochemical industry	0	0	0	0	0	0	0.0	0.0	0	0.0
Metal and non-metal industries ³	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A		N/A
2. Power plants	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A		N/A
3) Ship ballast water	0	0	0	0	11,802	0	11,802	50.5	7,868	100.0

¹ A portion of the effluents is believed to be discharged into the sea; no information is available on loads or treatment.

² The effluents are treated and then discharged into the sea; no information is available on loads or treatment.

³ Metal industries effluents are discharged into the sea after oil separation; no information is available. Non-metal industries effluents discharge and treatment are unknown.

4. Car service stations ⁴	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5. Seaport activity	0	0	0	0	11,550	0	11,550	49.5	N/A	N/A
6. Brine water/oil production ⁵	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TOTAL*	N/A	N/A	N/A	N/A	23,352	N/A	23,352	100	7868	100
Per cent of total generated *	N/A	N/A	N/A	N/A	19	N/A	19		100	
According to the ROPME 1984 report										
Industrial processes	488	N/A	87	N/A	5,026	5,860	11,451	35.3	3,347	19.3
Ship ballast water	0	0	0	0	21,000	0	21,000	64.7	14,000	80.7
TOTAL	488	N/A	87	N/A	26,016	5,860	32,451	100	17,347	100
PER CENT TOTAL	1.5	N/A	0.3	N/A	80.2	18.1	100	165	17,347	181

Source: ROPME, 1997

⁴ A portion of the effluents is believed to be discharged into the sea without treatment.

⁵ A portion of on-shore brine water is injected into wells; no information is available. Offshore brine water is believed to be discharged into the sea with no treatment.

* Loads are underestimated and do not represent the actual quantities discharged because of lack of information.

Table 18

Summary of industrial liquid wastes discharged into the sea in Saudi Arabia (by source) (1997)

Source	Discharged contaminant load (tons/yr)								Waste volume	
	Biochemical oxygen demand	Biochemical oxygen demand	SS	TDS	Oil	N	Total	% Total	(10 ³ m ³ /y)	%
Dammam industrial city I	0	0	0	0	0	0	0	0.0	0	0
Dammam industrial city II	0	0	0	0	0	0	0	0.0	0	N/A
Jubail industrial city	0	0	0	0	0	0	0	0.0	0	0
Cooling canal, Jubail	8,211	N/A	2,377	N/A	384	N/A	10,972	100.0	3,520	100.0
Saudi Aramco industrial facilities	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TOTAL	8,211	N/A	2,377	N/A	384	0	10,972	100	3,520	100
PER CENT TOTAL	74.8	N/A	21.7	N/A	3.5	0.0	100		100	

Source: ROPME 1997

Note: N/A indicates data not available.

Table 19

Production capacity of desalination plants in the United Arab Emirates

Location	Type	Capacity (MGD)	Capacity (CuM/D)
Villages and islands			
Jebal Dhana	RO	2.0	9,000
	Vapour compression	2.0	9,000
	MSF	1.75	7,950
Mirfa	RO	1.0	4,540
	Vapor compression	1.0	4,540
	MSF	1.0	4,540
Sila	RO	0.25	1,125
	Vapor compression	1.0	4,540
	MSF	1.0	4,540
Rafeek island	RO	0.25	1,125
Bukshisha island	RO	0.25	1,125
Sirbani Yas island	RO	0.5	2,250
Delma island	Vapour compression	2.0	9,000
	MSF	0.6	2,750
Abu Al Abyad	RO	0.5	2,250
Ajman	RO	4.0	18,150
Fujairah	RO	3.0	11,350
Umm al-Quwain	RO	2.5	11,350
Ras Al-Khaimah	RO	1.5	6,800
Sharjah			
Kalba	RO	3.5	15,890
Umm al-Nar East	MSF	20.0	90,800
Dubai			
Dubai East and West	MSF	115.4	532,915
Abu Dhabi City			
Abu Dhabi power station	MSF	12.7	57,650
Umm al-Nar East	MSF	36.6	166,160
Umm al-Nar West	MSF	48.0	217,920
Taweela "A"		29.2	132,560
Taweela "B"		76.2	345,950

Table 20

Summary of industrial liquid wastes discharged into the sea in the United Arab Emirates.

Source	Discharged contaminant load (tons/yr)							Waste volume		
	Biochemical oxygen demand	Biochemical oxygen demand	SS	TDS	Oil	N	Total	% Total	(10 ³ m ³ /y)	%
Industrial processes	643	0	856	0	335	0	1,834	10	786	7
Power plants	0	0	288	0	0	N/A	288	2	2	0
Ballast water	0	0	0	0	15,464	N/A	15,464	88	10,357	93
TOTAL	643	0	1,144	0	15,799	0	17,586	100	11,145	100
PER CENT TOTAL	3.7	0.0	6.5	0.0	89.8	0.0	100		78	
Per cent of total generated	8.4	0.0	46.0	0.0	81.4	0.0	46.1		77.7	

Source: ROPME, 1997

Table 21

Summary of industrial liquid wastes generated from industrial sources in the United Arab Emirates.

Area	Generated contaminant load (tons/yr)								Waste volume	
	Biochemical oxygen demand	Biochemical oxygen demand	SS	TDS	Oil	N	Total	% Total	(10 ³ m ³ /y)	%
Abu Dhabi	3,488	1,988	704	55	18,752	249	25,236	66.2	12,433	86.7
Dubai	868	686	1,455	4,861	322	10	8,202	21.5	1,125	7.8
Sharjah	1,508	71	123	28	16	4	1,749	4.6	264	1.8
Ras Al-Khaimah	779	102	130	320	290	9	1,630	4.3	303	2.1
Ajman	30	0	16	2	2	1	50	0.1	47	0.3
Umm al-Quwain	640	72	46	53	18	0	830	2.2	125	0.9
Fujeira	346	27	17	18	8	1	417	1.1	47	0.3
TOTAL	7,659	2,947	2,849	5,337	19,407	274	38,111	100	14,344	100
PER CENT TOTAL	20	8	7	14	51	1	100			

Source: ROPME, 1997

Table 22

Summary of domestic liquid wastes discharged into the sea from the ROPME member States (by country)

Country	Discharged contaminant load (tons/yr)											
	Biochemical oxygen demand	biochemical oxygen demand	SS	TDS	TKN	N	SO ₄	P	NO ₂	NO ₃	Total	% Total
Bahrain	4,977	10,853	8,308	47,796	N/A	669	7,885	996	N/A	N/A	81,484	8.7
Islamic Republic of Iran	5,823	N/A	6,000	N/A	975	N/A	N/A	118	N/A	N/A	12,916	1.4
Kuwait	454	2,152	1,190	N/A	791	N/A	N/A	2,481	23	77.00	7,168	0.8
Oman	0	0	0	0	0	0	0	0	N/A	N/A	0	0.0
Qatar	2,183	3,993	3,024	4,278	N/A	251	N/A	30	N/A	N/A	13,759	1.5
Saudi Arabia	3,858	12,801	7,062	788,469	N/A	1,792	N/A	4,361	N/A	N/A	818,343	87.1
United Arab Emirates	470	N/A	607	N/A	N/A	251	4,552	308	155.00	155.00	6,363	0.7
TOTAL	17,765	29,799	26,191	840,543	1,766	2,963	12,437	8,294	232	232	940,033	100
PER CENT OF TOTAL	1.89	3.17	2.79	89.42	0.19	0.32	1.32	0.88	0.02	0.02	100	

Data from Kuwait (1996) and Saudi Arabia (1997) are current.

Source: ROPME, 1997

Table 23

Treated water, reused water, treatment facilities, and type of utilization in the GCC countries

Country	Treated wastewater m ³ /d	Reused water		Treatment facilities			Type of utilization
		m ³ /d	%	Number of plants	Total capacity m ³ /d	Treatment level	
Bahrain	154,000	25,000 - 30,000	16-20	1 (large)	158,000	Tertiary	Irrigating fodder crops, gardens and highways landscaping
Kuwait	208,000	129,400	62	4 (large)	208,000 (354,000)	Tertiary	Irrigating crops, highways, coastal zones and Kuwait zoo
Oman	20,300	10,850 - 17,350	54-86	2 (large) 53 (small)	24,000 50-5,000	Tertiary	Irrigating landscape areas and parks, recreational activities and fountains
Qatar	75,000 - 80,000	69,000	92-86	2 (large) 9 (small)	80,000 120-3,000	Tertiary and Secondary	Fodder crops, gardens and landscaping
Saudi Arabia	1,230,000	275,000	22	30	> 1,230,000	Tertiary and Secondary	Crop irrigation, highways irrigation, landscaping and artificial recharge
United Arab Emirates	280,000	170,000	61	4 (large)	295,000	Tertiary	Irrigating parks, golf courses, highways and urban ornamentals
Total	1,972,300 (720 Mm³/y)	690,750 (252 Mm³/y)	35		1,995,000 (728.2 Mm³/y)		

Source: Al-Zubairi,

Table 24

Recommended microbial quality guidelines for wastewater use in agriculture (WHO, 1989)

Category	Reuse conditions	Exposed group	Intestinal nematodes ² (arithmetic mean no. of eggs/liter ³)	Faecal coliforms (geometric mean no/100 ml ³)	Wastewater treatment expected to achieve the required microbiological quality
A Unrestricted	Irrigation of crops likely to be eaten uncooked, sport fields, public parks ⁴	Workers, consumers, public	< 1	< 1000 ⁴	A series of stabilization ponds designed to achieve the microbiological quality indicated, or equivalent treatment.
B Restricted	Irrigation of cereal crops, industrial crops, fodder crops, pasture and trees ⁵	Workers	< 1	No standard recommended	Retention in stabilization ponds for 8- 10 days or equivalent helminth and faecal coliform removal.
C Localized	Localized irrigation of crops in category B if exposure of workers and the public does not occur.	None	Not applicable	Not applicable	Pretreatment as required by the irrigation technology, but less than primary sedimentation.

¹ In specific cases, local epidemiological, socio-cultural, and environmental factors should be taken into account, and the guidelines modified accordingly.

² *Ascaris* and *Trichuris* species and hookworms.

³ During the irrigation period.

⁴ A more stringent guideline (<200 faecal coliforms per 100 ml) is appropriate for public lawns, such as hotel lawns, with which the public may come into direct contact.

⁵ In the case of fruit trees, irrigation should cease two weeks before fruit is picked, and no fruit should be picked off the ground. Sprinkler irrigation should not be used.

Table 25**Summary of solid waste loads from industrial sources in the ROPME member countries (1985-1987)**

Country	Solid waste load (tons/yr)			
	Oil sludges	Other	Total	% Total
Bahrain	18,500	31,558	50,085	4
Islamic Republic of Iran	N/A	N/A	N/A	N/A
Kuwait	49,514	243,521	293,035	23
Oman	3,800	45,372	49,172	4
Qatar	21,742	174,272	196,014	15
Saudi Arabia	N/A	N/A	12,833	N/A
United Arab Emirates	94,397	593,555	687,953	54
TOTAL	187,953	1,088,277	1,276,231	100
PER CENT OF TOTAL	15	85	100	

Source: ROPME, 1997

Table 26**Summary of solid waste loads from domestic sources in the ROPME member countries (1984-1987)**

Country	Domestic Waste Load (tons/yr)			
	Sludge	Refuse	Total	% Total
Bahrain	N/A	161,343	161,343	4.4
Islamic Republic of Iran	N/A	397,850	397,850	10.9
Kuwait		1,000,000	1,000,000	27.5
Oman	N/A	1,800,000	1,800,000	49.5
Qatar	20,300	46,442	66,742	1.8
Saudi Arabia	N/A	N/A	N/A	N/A
United Arab Emirates	94,397	115,340	209,737	5.8
TOTAL			3,635,672	100.0

Source: ROPME, 1997

Table 27

Summary of atmospheric emission from the ROPME member States (by country) (1985-1987)

Country	Contaminants load (tons/yr)							
	Particulates	SOx	NOx	HC	CO	Others	Total	% Total
Bahrain	10,732	34,847	25,534	13,920	66,570	N/A	151,603	3.94
Islamic Republic of Iran	595	8,976	5,474	1,025	12,980	N/A	29,050	0.75
Kuwait	97,034	610,601	107,852	67,982	349,481	8,824	1,241,774	32.27
Oman	575,727	52,132	21,266	58,306	260,880	0	968,311	25.17
Qatar	79,088	139,034	70,843	31,173	132,343	68,166	520,647	13.53
Saudi Arabia*	1,670	31,003	152,370	26,100	58	N/A	211,211	5.49
United Arab Emirates	129,263	164,823	148,445	31,595	251,033	N/A	725,159	18.85
TOTAL	894,109	1,041,416	531,784	230,111	1,073,345	76,990	3,847,755	100
PER CENT OF TOTAL	23	27	14	6	28	2	100	

* 1997 Data

Source: ROPME, 1997

Table 28

Summary of industrial liquid wastes discharged into the sea from the ROPME member States (1985-1987)

Country	Discharged contaminants (tons/yr)							% Total
	Biochemical oxygen demand	Biochemical oxygen demand	SS	TDS	Oil	N	Total	
Bahrain	161	N/A	129	N/A	17,723	349	18,362	9.77
Islamic Republic of Iran	2,474	N/A	N/A	N/A	3,113	2,433	8,020	4.27
Kuwait	15,045	N/A	43,324	N/A	26,905	2,798	88,072	46.86
Oman	N/A	N/A	N/A	N/A	12,500	N/A	12,500	6.65
Qatar	488	N/A	87	N/A	26,016	5,860	32,451	17.26
Saudi Arabia *	8,211	N/A	2,377	N/A	384	N/A	10,972	5.84
United Arab Emirates	643	0	1,144	0	15,799	0	17,586	9.36
TOTAL	27,022	N/A	47,061	N/A	102,440	11,440	187,963	100
PER CENT OF TOTAL	14	N/A	25	N/A	55	6	100	

* 1997 data
Source: ROPME, 1997

Table 29

MSF plants in the ROPME sea area member States

Location	Freshwater capacity (m³/day)	%	Equivalent river outflow (m³/s)
Kuwait	(1,050,126)	20%	12.15
Al Doha plant	627,348		
Al Shoeikh plant	68,190		
Al Shaiba plant	136,380		
Al Zoor plant	218,208		
Saudi Arabia	(1,698,874)	33%	19.66
Al Jubayl plant	1,094,696		
Al Khobar plant	422,347		
Al Khafji plant	68,181		
Gazlan plant	22,730		
El Grays plant	45,460		
Safni, Tanajib, and Ras Tanura (plants operated by ARAMCO)	45,460		
Bahrain	(113,650)	2%	1.32
Sitra plant	113,650		
United Arab Emirates	(1,766,580)	34%	20.45
Almirfa plant	76,800		
Abu Dhabi plant	57,660		
Umm Alnar plant	397,500		
Al Taweelah plant	476,160		
Dubai Aluminum plant	113,900		
Jebel Ali plant	561,260		
Shajah plant	83,300		
Qatar	(309,128)	6%	3.58
Ras Abu Aboud plant	36,368		
Ras Abu Fantas plant	272,760		
Islamic Republic of Iran	(260,609)	5%	3.01
Bousher	260,609		
TOTAL	5,198,967	100%	60.17

Source: Al Hajr and Ahmed, 1997