State of Oil Pollution Along the Qatari Coastline

Prepared for
Scientific & Applied Research Centre (SARC)

by
Dr. Ossama Aboul Dahab
SARC
University of Qatar
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PROJECT STAFF

Dr. Ossama Aboul Dahab (Assistant Prof. of Marine Chemistry and Pollution, Principal Investigator).

Prof. Dr. Ahmed El-Toukhy (Chemistry).

Dr. Homaid Al-Madfa (Chemistry).

Mr. Abdul-Rahman Al-Na'maa (Chemical Engineering).

SUMMARY

The present study focuses on the spatial distributions of petroleum hydrocarbons in the Qatari coastal-belt waters and sediments. It also describes the state of tar pollution on the Qatari beaches. Petroleum hydrocarbons are omnipresent in the studied waters and sediments. Dissolved and dispersed petroleum hydrocarbons levels in Qatari waters were different from one area to another and showed a decreasing sequence in the following order: Umm Said (5.8 $\mu g l^{-1}$) > Doha (4.6 $\mu g l^{-1}$) > Ruwais (4.4 $\mu g l^{-1}$) > Al-Zubarah (4.0 $\mu g l^{-1}$) > Fuwairet (2.7 $\mu g l^{-1}$) > Dukhan (2.1 $\mu g l^{-1}$ Kuwaiti oil equivalents). The areal distribution of petroleum hydrocarbons in the studied sediments was very heterogeneous from one area to another and showed a decreasing trend in the following order: Al-Zubarah (215 $\mu g g^{-1}$ dw) > Dukhan (143 $\mu g g^{-1}$ dw) > Ruwais (108 $\mu g g^{-1}$ dw) > Umm Said (89 $\mu g g^{-1}$ dw) > Fuwairet (81 $\mu g g^{-1}$ dw) > Doha (54 $\mu g g^{-1}$ dw Kuwaiti oil equivalents).

Tar abundance on Qatari beaches was highly variable in space and time. This varies from heavily oiled northern and northwestern beaches to nearly pollution-free beaches in the southeast. Such variations call for different clean-up approaches.

The results obtained clearly indicate that the possible sources of oil in the Qatari coasts are mainly external on the western side and local on the eastern one.

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1. INTRODUCTION

1.1 General introduction

1.1.1 Fate of oil in the marine environment

The fate of oil in the marine environment is multiform and depends o the physical, chemical, and biological characteristics of the ambient environment and on the physical and chemical properties of the oil. Several processes, of importance for the dispersion and degradation of oil in the marine environment, will be briefly described.

1.1.1.1 Physical changes

The moment oil is spilt on the sea it begins to disperse. The rate of this dispersion depends on various environmental factors such as the speed of the wind, size of the waves, temperature, salinity, depth of the water column, and currents as well as on the nature of the oil, its specific gravity, degree of refinement, and the quantity involved (Bishop, 1983). The viscosity, density, chemical composition, and discharge point of the oil and the wind speed and currents will influence the rate of spreading. Emulsification reduces the tendency of the oil to spread (Johnston, 1984). As the oil spreads out, its polar components begin to dissolve and leach out of the oil slick (McAuliffe, 1977). At the same time the volatile components are evaporating. The sum of these processes is termed "weathering" and its product is "weathered oil".

Dissolution and evaporative losses are hindered by the emulsification of the oil. Emulsions of both oil-in-water and water-in-oil occur. The term "chocolate mousse" has been used to describe water-in-oil emulsions with a water content of from 50% to 80% (Geyer, 1980). Oil droplets in sea water are more susceptible to weathering, adsorption to suspended organic and inorganic matter, consumption by zooplankton with incorporation of the oil into faecal pellets, and to hydraulic transport (Bishop, 1983). By adhering to suspended sediments of greater density, oil droplets dispersed in water may also sink to bottom waters and sediments.

Spray from waves and bursting bubbles also help to remove petroleum hydrocarbons from the sea surface as well as evaporation and dissolution. A considerable quantity of spilt oil sinks naturally. In shallow waters where bottom material is churned up, the oil clings to particulates and settles on the bottom. Masses of sunken oil are rolled along the bottom by wave and current action, accumulate larger particles of sand, shells, and stones, and are eventually washed up on the beaches as tar mats and tar balls. These tarry deposits can be buried in the intertidal zone or carried back by tidal currents and deposited on the sea bed.

1.1.1.2 Chemical degradation

Oil is also subject to oxidation or photo-oxidation. Sunlight starts off free-radical reactions that convert hydrocarbons into hydroperoxides. The hydroperoxides are then further transformed into alcohol, acids, and other oxygenated compounds. The free radical reactions also bring about the polimerisation of the partially oxidized hydrocarbons. The resulting "tar" is denser, more polar, and more viscous than the parent hydrocarbons (McAuliffe, 1977). The rate of oxidation depends on temperature, intensity of sunlight, and the physical state of the oil.

1.1.1.3 Microbial degradation

After evaporation and solution, most of the oil remaining at sea is believed to be destroyed by microbial oxidation. Several species of bacteria, yeasts and moulds that metabolize oil compounds have bee isolated from the sea (Johnston, 1984).

1.1.1.4 Formation of oil residues

After low and medium molecular weight compounds have dispersed or degraded, a significant fraction of oil remains in the sea in a physically changed but chemically unaltered form. A semi-solid residue is left, dispersal is halted, and oxidative processes are restricted primarily to the surface boundary of the oil mass (Bishop, 1983).

Tar balls are the most common form of residual oil. Because of the high molecular weight and resultant inertness of these oil residues, the time needed for their decay may be a matter of years. Since degradation is limited to their surface boundary, these oil residues usually have a weathered crust. Some volatile or degradable compounds can be effectively sealed inside. The relatively small surface area of a tar ball that is exposed to the air, water, oxygen, and to microbes protects it from evaporation or oxidation or bio-degradation. Oil residues on sea surface either slowly degrade in a year or more, or they are stranded on beaches or they sink through increase in density.

1.1.1.5 Fate of oil in sediments

The degradation of petroleum hydrocarbons in marine sediments is caused by the interaction of microfauna, meiofauna and macrofauna.

1.1.1.6 Uptake of oil by biota

Petroleum hydrocarbons enter the marine food web in several ways:

i. Adsorption on the particles, both living and dead, followed by ingestion of these particles;

ii. Active uptake of dissolved or dispersed oil;

iii. Passage into gut of fish which gulp or drink water.

After petroleum hydrocarbons are taken up by an organism, they may be excreted unchanged, they may be metabolized, or they may be stored with possible elimination at a later date.

1.1.2 Effects of oil pollution

The presence of oil in marine waters can have adverse effects on both natural and human-manufactured resources. Among the effects on natural systems are the following:

i. Hazard to humans from ingesting contaminated food.

ii. Damage to fisheries, seaweeds, birds, marine mammals, and other wildlife.

iii. Damage to beaches and other recreational areas.

iv. Damage to marine ecosystem by eliminating or decreasing populations of certain species.

v. Modification of habitats, delaying or preventing re-colonization.

1.1.3. Sources of oil pollution in Qatar waters.

1.1.3.1 Anthropogenic sources

Oil reaches Qatari waters from a number of anthropogenic sources, e.g. routine operations of oil and gas exploration and exploitation, accidental shipping loss, ship traffic to and from Doha, Naval and Umm Said harbours, recreational boats, industrial discharges and atmospheric fallout. Oil also may reach Qatari waters from accidental oil spills and chronic discharges from tankers bound from oil terminals in the northern part of the Arabian Gulf.

1.1.3.2 Natural sources

In addition to anthropogenic sources of oil pollution, it may also enter Qatari waters from natural seeps.

1.1.4 Study area

The investigated area extends more than 500 km along the Qatari coast from Abu Samra on the western side to south of Umm Said on the eastern side (Figure 1). It includes Abu Samra, Umm Bab, Dukhan, Bir Zikrit, Al-Zubarah, Abu Dhuluf, Al-Ariech, Ruwais, Fuwairet, Al-Ghariyah, Doha and the shore to the south of Umm Said.

1.1.5 Scope and aim of the study

The object of the present study was to assess the state of oil pollution along the Qatari coastline. It surveys oil existence in the following forms:

i. Tarry deposits on beaches.

ii. Dissolved and dispersed petroleum hydrocarbons in Qatari territorial waters.

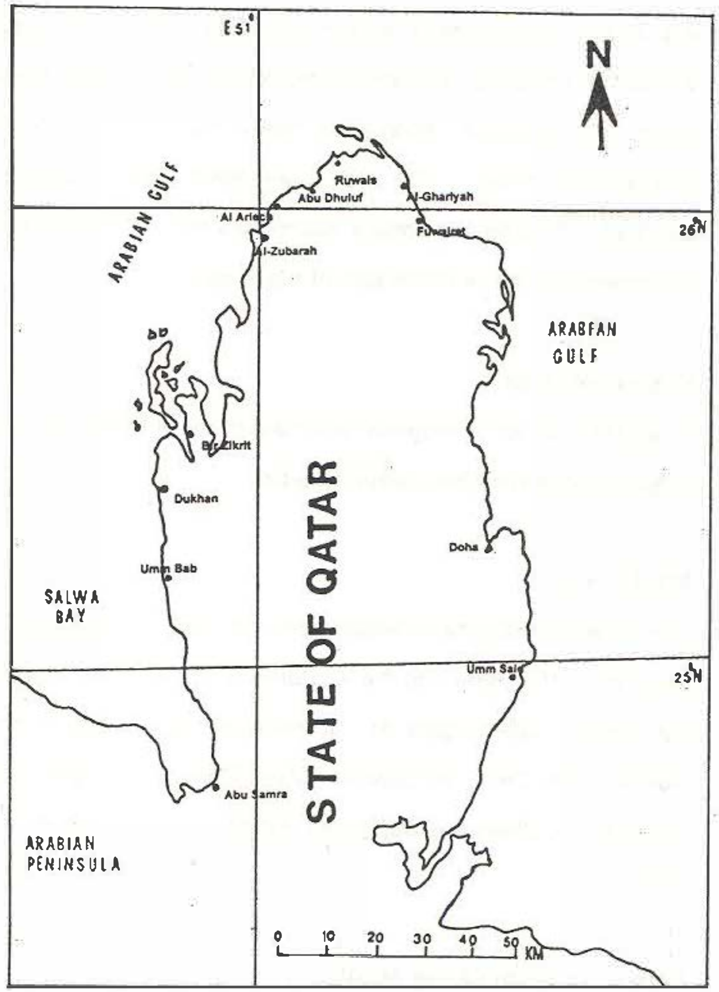

Figure 1. Study area

iii. Total petroleum hydrocarbons in Qatari coastal sediments.

The results of the present study will certainly help decision makers to better:

i. Assess the impact of the 1991 Gulf oil spill on the Qatari coast.

ii. Identify oil pollution "hot spots" along the Qatari coastline and consequently determine priority areas for clean-up operations.

iii. Select the appropriate oil pollution combating techniques for the Qatari coastal areas.

Previous studies on oil pollution in Qatari coastal waters were limited to the determination of dissolved and dispersed petroleum hydrocarbons in sea water (Hassan and El-Samra, 1988).

2. METHODOLOGY

2.1 Tar on beaches

Several visits were made during the period from February 1991 to August 1993 to the following beaches:

i. Abu Samra

ii. Umm Bab - Dukhan - Bir Zikrit

iii. Ruwais - Abu Dhuluf - Al-Ariech - Al-Zubarah

iv. Fuwairet - Al-Ghariyah

v. Doha

vi. South of Umm Said.

These visits aimed at describing the state of tar pollution on the investigated beaches.

In addition to the previously mentioned visits, ten sampling stations (Photo 1) were established along the Qatari coastline at the following locations: Abu Samra, Umm Bab, Dukhan, Bir Zikrit, Al-Zubarah, Al-Ariech, Al-Ghariyah, Fuwairet, Doha and South of Umm Said (Figure 2). All the stations were located on sandy beaches with uniform shorelines and gentle slopes. Beach tar deposition was surveyed following the guidelines of the Manual of Oceanographic Observations and Pollutant Analysis Methods (MOOPAM, 1989). The intertidal zone at each station was sampled at approximately monthly intervals from September 1991 to June 1992.

Photo 1. Tar sampling station at Abu Samra beach

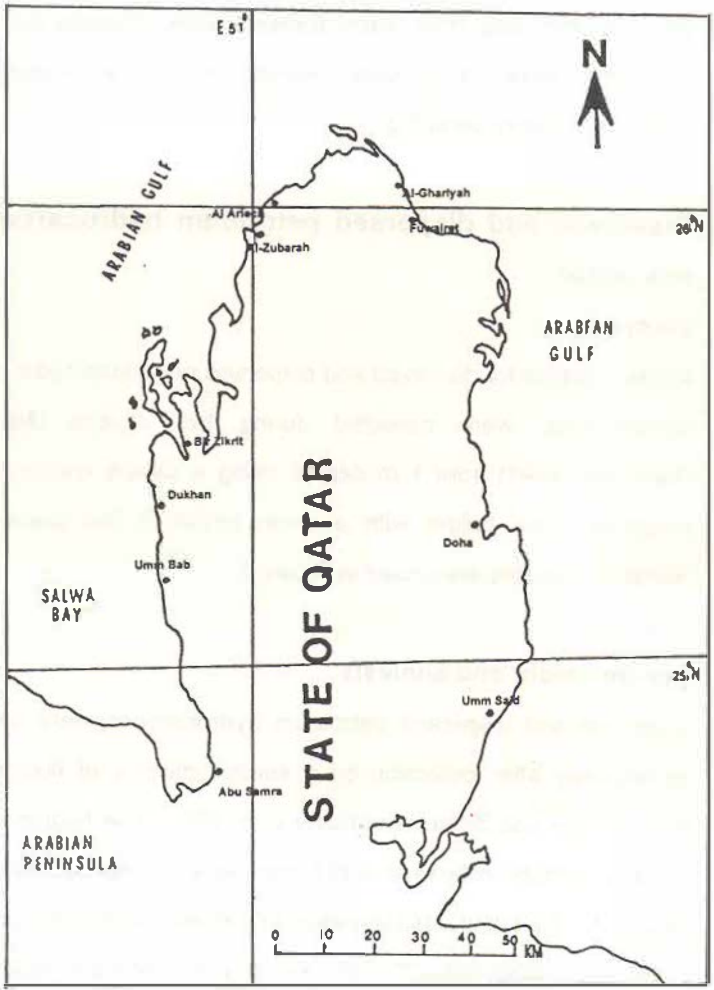

Figure 2. Tar sampling locations along the Qatari coastline

All solid and semi-solid tarry deposits on beach surfaces were collected from triplicate 1 m wide randomly selected transects running from the water's edge to the recent high tide line. Tarry deposits collected from each transect were transported to the laboratory where they were cleaned of non-tar material and weighted to the nearest 1 g.

2.2 Dissolved and dispersed petroleum hydrocarbons in sea water

2.2.1 Sampling

Water samples for dissolved and dispersed petroleum hydrocarbons determination were collected during two cruises (May and December 1991) from 1 m depths using a device consisting of a weighted bottle holder with a clean amber 3 litre glass bottle. Sampling stations are shown in Figure 3.

2.2.2 Pre-treatment and analysis

Dissolved and dispersed petroleum hydrocarbons were extracted immediately after collection by a solvent mixture of fluorescence free hexane and dichloro-methane (7/3, V/V). The fluorescence of sample extracts in hexane and blanks was measured in the same way as for the standards (chrysene and Kuwaiti crude oil), i.e., at an excitation wavelength of 310 nm and an emission wavelength of 360 nm with the instrument set at the same sensitivity at which the standard were run (MOOPAM, 1989). The detection limit of this procedure was 0.5 µg. Kuwaiti crude oil per litre (corresponding to the equivalent of 0.042 µg chrysene per litre).

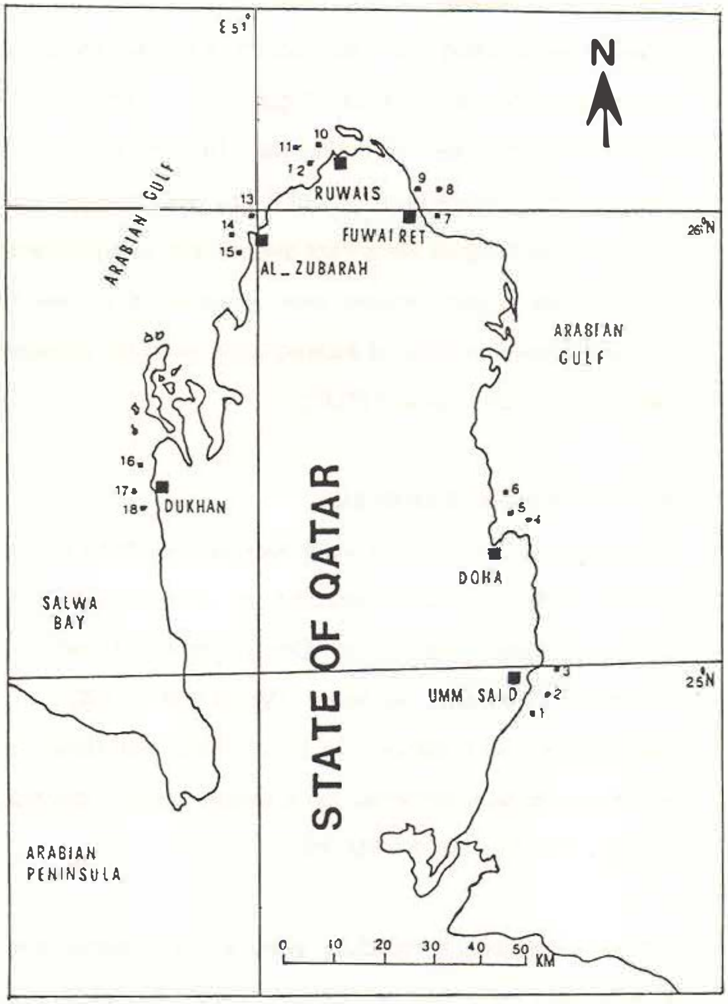

Figure 3. Sea water and bottom sediments sampling stations

2.3 Bottom sediments

2.3.1 Sampling

The sampling strategy was to take three samples from each of six different areas along the Qatari coastline to give some idea of the variability within each area (Figure 3). Samples of surface sediments were collected during May 1991 by using a Van Veen grab, and the surface layer (about 2 cm) was collected with a glass spatula. The samples were kept deep-frozen in pre-cleaned Pyrex glass bottles. Sub-samples were wrapped in organic-free, pre-cleaned aluminium foil and subsequently used for determination of the organic carbon content (TOC).

2.3.2 Pre-treatment and analysis

After air-drying and sieving, each sample (less than 63-μm fraction of the sediment) was extracted in a soxhlet extractor with dichloromethane (Manual of Oceanographic Observations and Pollutant Analyses Methods, MOOPAM, 1989). Extract saponification was carried out by alcoholic potassium hydroxide, and clean-up was achieved by a simple column chromatography (aluminium oxide) (MOOPAM, 1989).

Ultra-violet fluorescence (UVF) analyses were carried out by using a Shimadzu recording spectrofluorometer Model RF-540. The petroleum hydrocarbon content of the extracts was measured by comparing the intensity of fluorescence emission at 360 nm when excited at 310 nm. Chrysene and Kuwaiti crude oil were used as standards. Blanks were equivalent to 0.1 μg, but they were not subtracted from the results quoted.

3. RESULTS AND DISCUSSION

3.1 Tarry deposits on Qatari beaches

3.1.1 State of tar pollution on beaches

3.1.1.1 Abu Samra

Abu Samra beach consists mainly of medium to coarse sand with some scattered rocks particularly at its southern part (Photo 2). Few traces of tarry deposits could be seen on the sandy areas. Moderate quantities of weathered tarry deposits were found under the shallow water and between the rocks. (Photo 3). Some rocks were heavily contaminated with degraded oily wastes (Photo 4).

3.1.1.2 Umm Bab - Dukhan - Bir Zikrit

Bir Zikrit shores are very flat with shoals extending far offshore (Photo 5). In Dukhan area there are the largest onshore oil fields in Qatar. The shore in this area is made of long, flat sandy beaches extending for tens of kilometres to the south. Very scarce desert vegetation borders these beaches. The surrounding waters are shallow (average depths vary between 1 and 6 m) and these shoals stretch for 1 - 3 km offshore. Some sand banks are exposed during low tide. The access to all the beaches in the area is good.

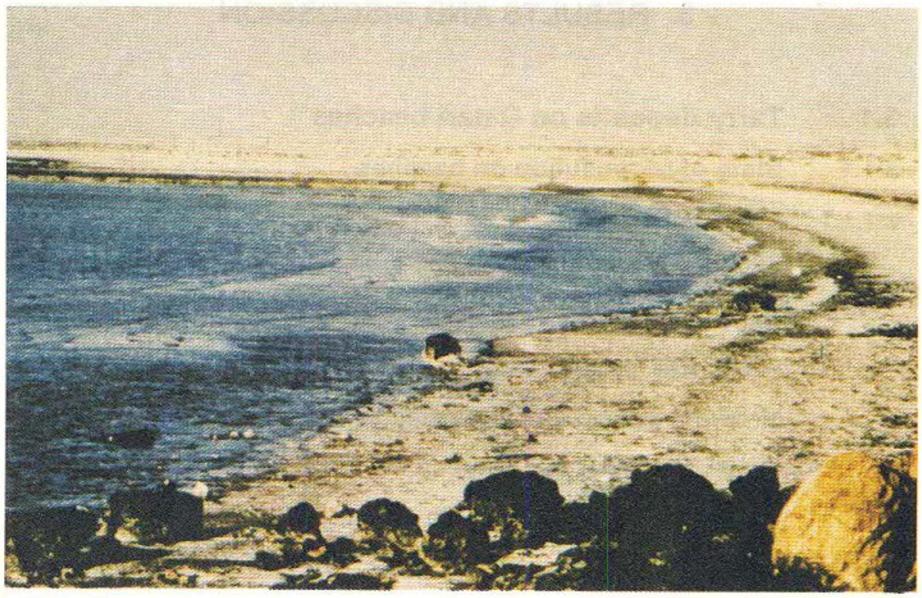

Photo 2. Abu Samra beach

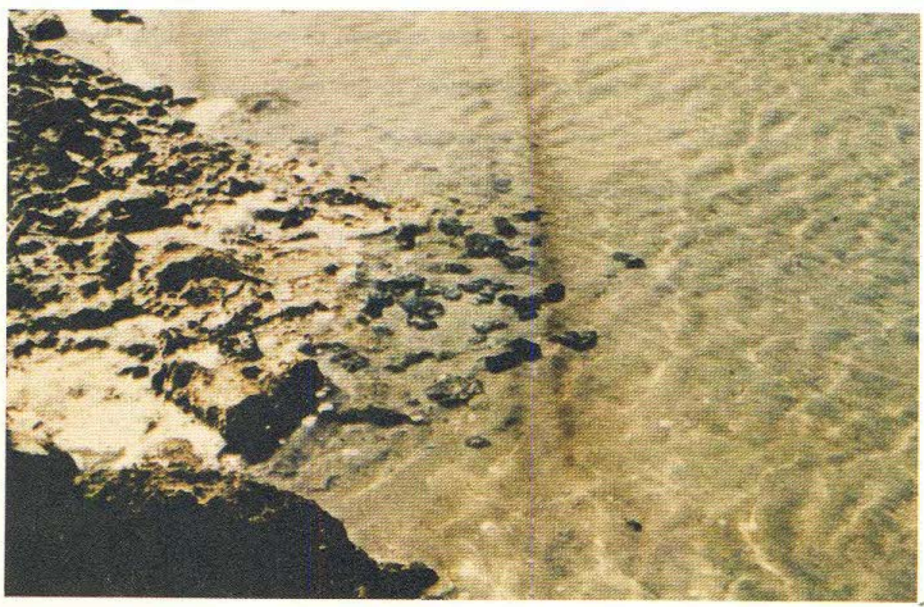

Photo 3. Under water tarry deposits in Abu Samra beach

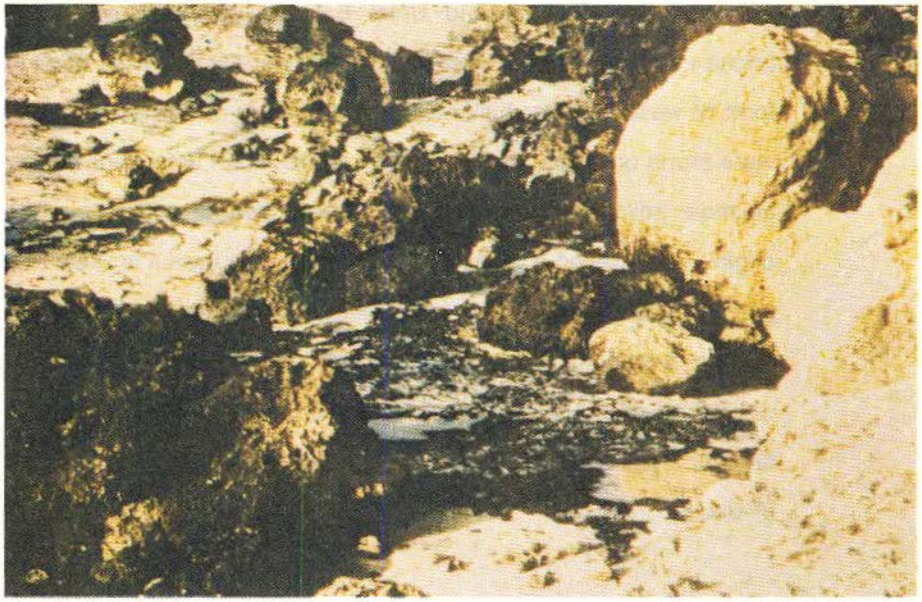

Photo 4. Rocks contaminated with weathered oil in Abu Samra beach

Photo 5. Bir Zikrit shore

Beaches near Dukhan and Umm Bab are used for recreation (picnics, fishing, etc.) by local people. Only sporadic traces of oil in form of weathered tar balls mixed with smaller quantities of debris were found on these beaches (Photo 6). Dukhan area appeared to be more polluted but mostly with debris of natural and man-made origin. Considering a great deal of activity in the area it is likely that part of the debris came from local sources. The coast near Bir Zikrit and to the north of it showed slight to moderate coating of weathered oil probably deposited long time ago (Photo 7). Some large or small size, weathered oil lumps were also found in this area (Photo 8).

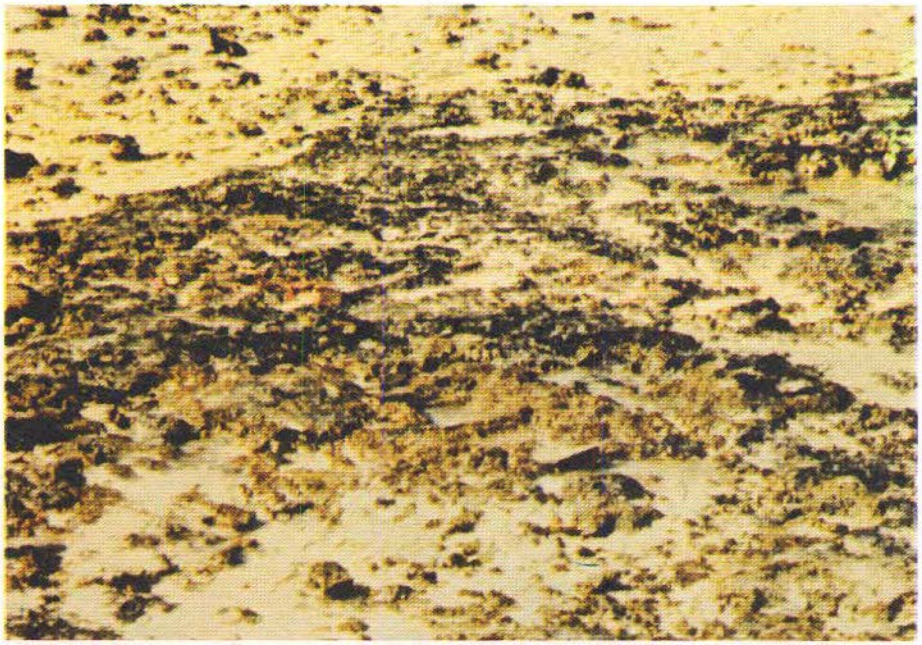

Photo 6. Weathered tar lumps covering a rocky area at Bir Zikrit shore

Photo 7. Tarry deposits and seaweeds on Bir Zikrit shore

Photo 8. Weathered tar lumps on Bir Zikrit shore

3.1.1.3 Ruwais - Abu Dhuluf - Al-Ariech - Al-Zubarah

North-western beaches extending between Al-Ariech to the south of Al-Zubarah are very difficult to describe. Massive deposits of tarry materials and many kinds of debris on these shores made it difficult to conceive their original state (Photos 9 - 12).

The coast appears to be very flat with shoals extending for kilometres offshore. These shoals are intersected with reefs which are more or less permanently exposed. The waters between reefs and the shoreline are normally very calm. Shores are partially formed of flat rocks covered sporadically with thin sand layers and partially of salt sandflats known as sabkhas. Sabkhas, although appearing as a solid surface, make approach to the water virtually impossible except on man-made tracks which are found in some places.

The remains of traditional fish traps indicate that this area was used in the past for fishing. Several fishing villages which existed in the area are now deserted.

The entire zone (approximately 40 km) from Ruwais to the south of Al-Zubarah can be described as heavily polluted (Photo 13). Virtually the entire shoreline is coated with oil which ranges in thickness from less than a millimetre up to several centimetres. In those places where sand was not completely covered with oil it was heavily mixed with it (Photos 14 - 16). The fact that in some places several layers of oil can be distinguished suggests that these shores have been coated by oil several times. As far offshore as the eye can see the bottom also appears to be covered with oil.

Photo 9. Massive deposits of tarry materials on Al-Zubarah beach

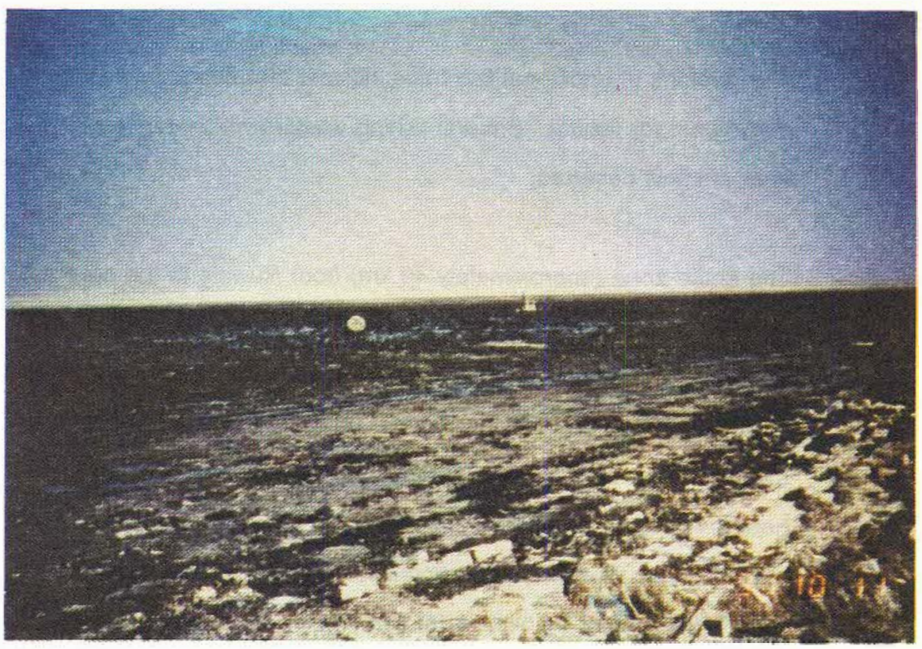

Photo 10. Tarry materials and marine litter covering Al-Zubarah beach

Photo 11. Weathered tar mat on Al-Ariech beach

Photo 12. Massive tarry deposits and marine litter covering Abu-Dhuluf beach

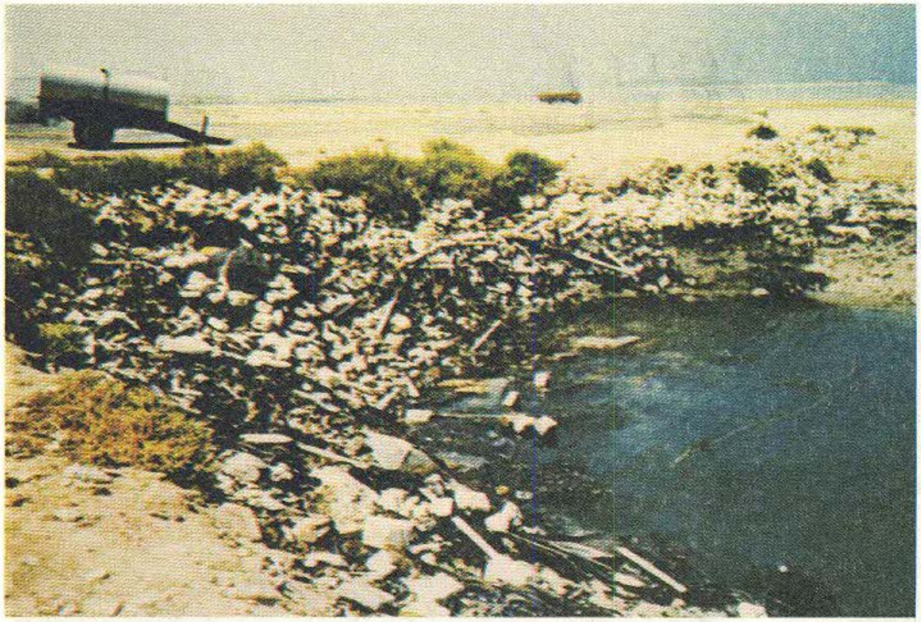

Photo 13. Marine litter on Ruwais shore

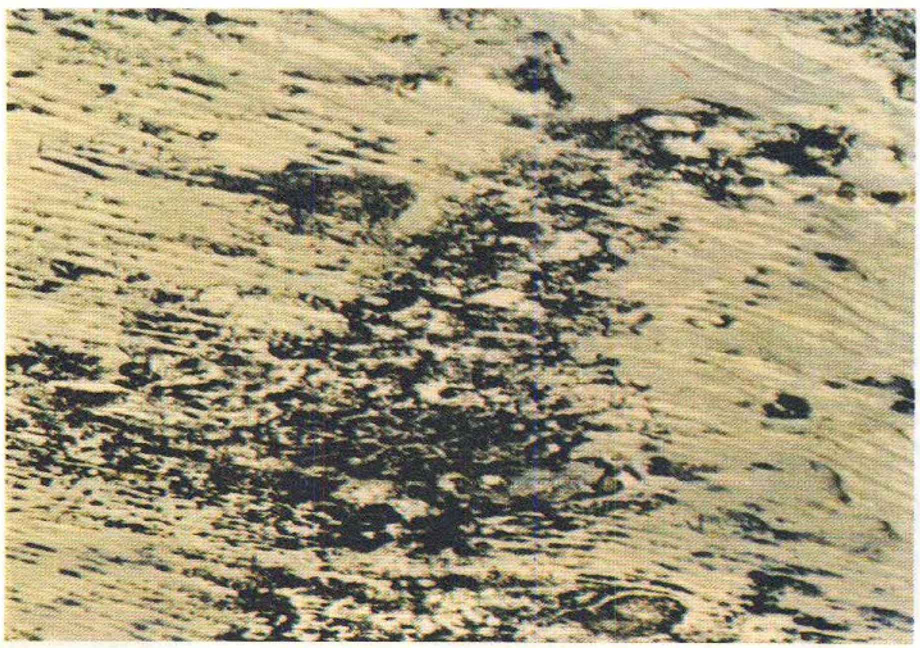

Photo 14. Beach sand heavily mixed with tarry deposits at Al-Zubarah area

Photo 15. Tarry deposits covered with sand at Al-Zubarah beach

Photo 16. Oily deposits covered with sand at Al-Ariech beach

The thickness of this bottom oil layer was difficult to estimate. Besides oil, enormous quantities of debris have been found on these shores particularly at high water line but not only there (Photo 17). It included timber, wooden crates, oil drums, ropes, various plastic objects, cable reels, seaweed, etc. Some dead fish and birds have been observed stranded on these shores.

An effort to clean-up approximately 10 km of the shore to the west of Ruwais has been made by the Environment Protection Committee, Qatar. The results were visible but a lot of debris has been left, oil has been removed only from relatively narrow width of the beach (most of the intertidal zone remains coated) and a lot of damage has been done to the rocky substrata (Photo 18).

3.1.1.4 Fuwairet - Al-Ghariyah

These beaches are made of coarse sand with sand banks extending for tens and hundreds of metres offshore especially near Fuwairet. Back shores are also made of sand with scarce desert vegetation surrounding waters are very shallow and parts of these shoals are exposed at low tides (Photo 19). In some parts, the bottom near the shore is made of flat rocks which are covered with a thin layer of sand. Access to the beaches is generally good, although heavy vehicles may face some problems. Load bearing capacities of the beaches do not seem to be sufficient for any heavy vehicles and this observation should be determined precisely prior to planning any clean-up operations involving mechanical means of oily deposits removal. At low tide it is possible to drive on the partially exposed sea bottom near the shore but this practice should be avoided because of possible damage to the intertidal zone.

Photo 17. Enormous quantities of debris and seaweeds on Al-Zubarah beach

Photo 18. Piles of collected oily deposits and marine debris on Al-Ariech beach

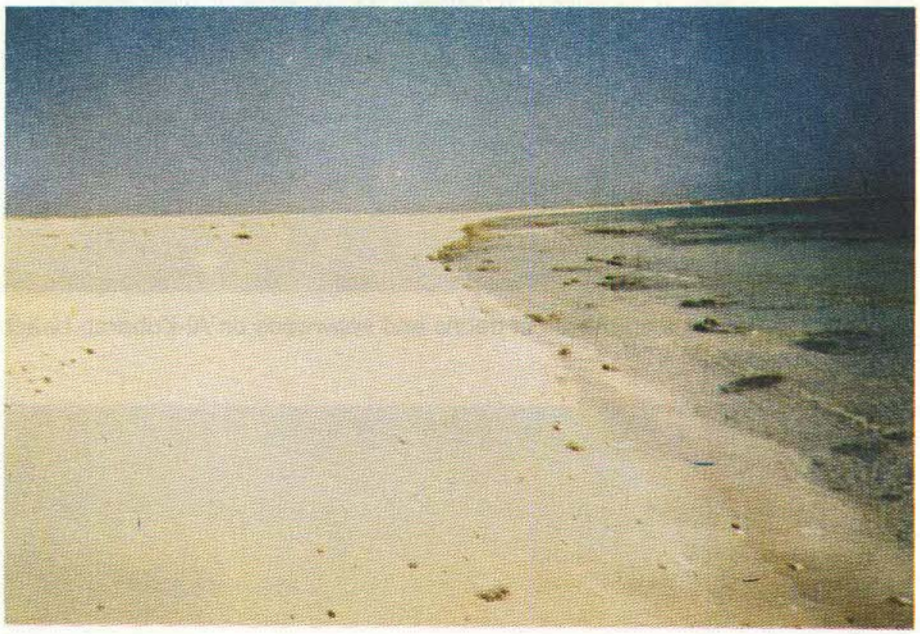

Photo 19. Fuwairet beach

Fishing is a traditional trade in the area and some old style fish traps made of stone were found near the shore. Nowadays the area is generally not inhabited, the only ones left are a few houses or groups of houses belonging to local fishermen. Al Ghariyah which used to be the largest settlement in this part of the Qatari coast, is now deserted. Local people occasionally visit these beaches for recreational purposes.

The beaches visited in the north-eastern part of the peninsula includes beaches which have not been cleaned up and others which have.

The beaches which were found in their original state were moderately polluted with various sized tar balls and lumps of oiled sand (Photo 20). The size of the tar balls observed range between shell nodules of 10 - 20 mm in diameter and large cakes of more than 200 mm in diameter. The average size of tar balls found was approximately 100 mm. These showed different degrees of weathering, ranging from hard, heavily weathered lumps to agglomerations of rather fresh oil and this may indicate constant exposure of these beaches to oil pollution (Photo 21). Since larger surfaces of beaches were not covered with continuous layers of oily material it suggests that this part of the coast was not affected by an accidental oil pollution of significant size.

Photo 20. Tarry deposits on Fuwairet beach

Photo 21. Tar balls and oily deposits on Fuwairet beach

Moderate quantities of natural (seaweed) and man-made (wood, plastic bottles, etc.) debris were found mixed with the described tar balls (Photo 22). It may be of importance to mention that the colour of dried seaweed and tar balls is practically the same so that aerial surveillance of these shores may result in false reports.

The sea bottom near the shore is sporadically coated with oil but otherwise the water appears to be clear and clean (Photos 23 and 24).

The beaches which were cleaned-up some time before this study obviously appeared to be less polluted than the others. However, deposits of dry seaweed and some tar balls were found on these beaches too. The change in beach profile could also be noticed in cleaned areas, due to removal of sand.

3.1.1.5 Doha

Beaches in the Doha area consist mainly of coarse sand, shell, and carbonate rock fragments. The area is relatively shallow with a gentle slope towards the east. This area includes the major Qatari commercial harbour (Doha harbour) and is considered the most popular area in Qatar. Small amounts of weathered and fresh small-sized tar balls were found on these beaches.

Photo 22. Moderate quantities of seaweeds and man-made litter on Fuwairet beach

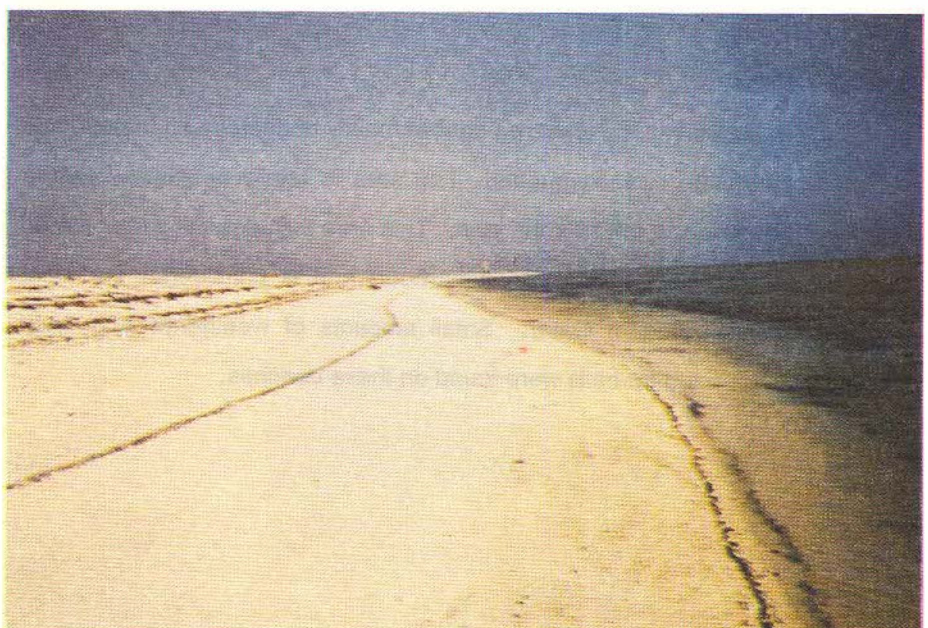

Photo 23. Nearshore sea bottom sporadically coated with oil at Al-Ghariyah shore

Photo 24. Apparently clear and clean sea water over weathered oily deposits at Al-Ghariyah shore

3.1.1.6 South of Umm Said

The south-eastern part of the Qatari peninsula is arid and sandy, with virtually no vegetation. High sand dunes are a predominant landscape feature (Photo 25). These start from Umm Said industrial zone and extend southward. The shores are very flat consisting mainly of salt sandflats called Sabkhas (Photo 26). Areas of sabkhas which stretch for kilometres into the land are intersected by sand dunes which in places practically reach the sea. At high tides sabkhas are flooded. Although from a distance sabkha resembles solid ground, it cannot support any traffic. Narrow tracks have been made in sabkhas which enable approach to the water. Surrounding waters are shallow with a number of exposed sand banks, coral heads and small islands.

The area is becoming very popular among the local population as a recreational area. Favourite forms of pastime include driving on sand dunes, swimming, diving (especially near offshore islands) and sailing.

Very few traces of apparent oil pollution could be seen on these shores. The man-made debris which has been observed is most probably the result of the above mentioned recreational activities on these beaches (Photo 27 and 28).

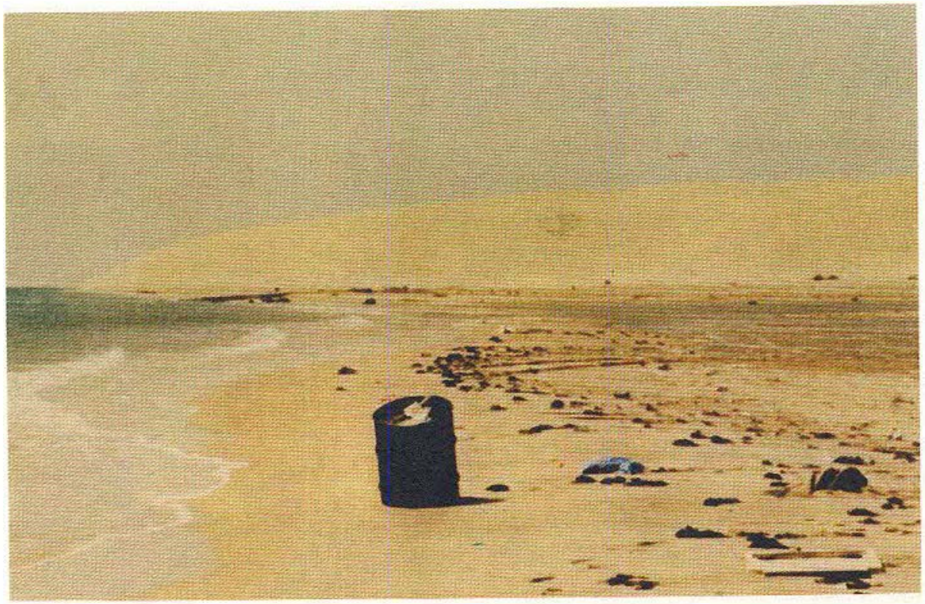

Photo 25. High sand dunes south of Umm Said

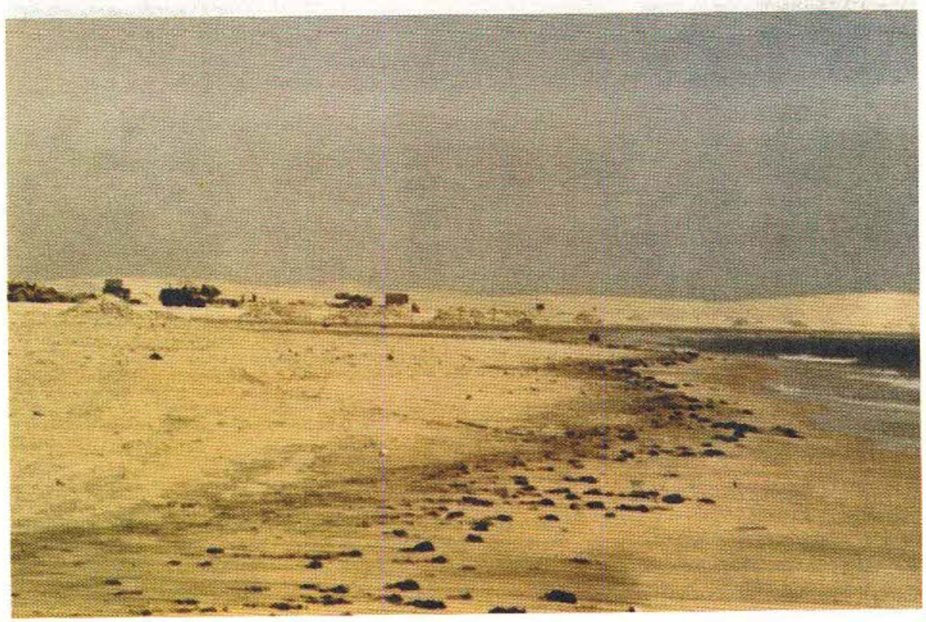

Photo 26. Flat shore south of Umm Said

Photo 27. Man-made debris on the beach south of Umm Said

Photo 28. Marine litter south of Umm Said

3.1.2 Rates of tar deposition on beaches

The results of deposition of tar at the selected Qatari beaches are given in Table 1.

Table 1

Tar deposition at selected Qatari beaches (gm^{-1} $month^{-1}$)

Beach	Dates									
	9/91	10/91	11/91	12/91	1/92	2/92	3/92	4/92	5/92	6/92
Abu Samra	326	193	441	211	298	188	245	176	231	199
Umm Bab	169	78	390	287	319	114	289	168	380	281
Dukhan	99	275	138	389	219	238	252	363	161	185
Bir Zikrit	240	288	251	314	242	200	290	341	306	288
Al-Zubarah	Difficult to assess*									
Al-Ariech	Difficult to assess*									
Al-Ghariyah	771	313	770	473	507	579	427	678	601	780
Fuwairet	413	499	1013	518	689	725	389	1132	797	924
Doha	189	287	210	310	225	318	411	280	215	136
South of Umm Said	109	284	250	58	149	213	146	221	248	150

*Difficult to assess because the whole beach was covered with massive tar mats.

Average and range of the rates for tar deposition on Qatari beaches ($g\ m^{-1}$ $month^{-1}$) are given in Table 2.

Table 2

Average and range of the rates for tar deposition on Qatari beaches ($g\ m^{-1}$ month)

Beach	Average	Range
Abu Samra	251	176 - 441
Umm Bab	248	78 - 390
Dukhan	232	99 - 289
Bir Zikrit	276	200 - 341
Al-Ghariyah	600	313 - 780
Fuwairet	710	389 - 1132
Doha	258	136 - 411
South of Umm Said	183	58 - 284

The average rates of tar accumulation during the period of study at Al-Ariech and Al-Zubarah beaches were roughly estimated to be more than 5000 g^{-1} m^{-1} $month^{-1}$.

The state of oil pollution and rates of tar deposition on Qatari beaches during the period of study were highly variable in space and time. This variability becomes more understandable if the location of Qatar peninsula and meteorological and hydrological conditions in the region are considered.

The main wind pattern in the whole area being north-westerly (Shamal) and predominant currents' pattern being counter-clockwise, one should normally expect the consequences of these unfavourable conditions to manifest in the northern parts of Qatar peninsula. The situation previously described for the area from Ruwais to Al-Zubarah confirms this assumption. Even if there was no oil on these shores, large quantities of deposited debris indicate that this is an area at high risk of pollution. Considering more or less regular occurrences of both accidental and chronic oil spillage in the sea to the north-west of Qatar, heavy oil pollution on the beaches of this area is not surprising. Oil which has been found on these shores originates mainly from known accidental oil spills registered in the past few years in the north-western part of the region. Precise data are not available, but most probably these coasts receive the first heavy coatings of oil during an oil spill accident which also affected the coasts of Bahrain in summer 1980 and Hazbah 6 blow-out in October of that year. The recent heavy coating of oil was formed due to the Gulf oil spill of 1991 during the Kuwait liberation war. Chronic discharges from the tankers bound for oil terminals in the western and north-western part of ROPME sea area only worsened the situation.

Small part of this oil have probably been reaching the north-eastern shores of Qatar (Al-Ghariyah and Fuwairet). Since these shores (NE) are more exposed to the direct influence of waves (they are not protected by coral reefs like those on the western side), higher wave energy encourages the self cleaning process. This is seen as a main reason for lower levels of pollution detected in the north-eastern area in comparison to the north and northwestern areas.

The south-western coast of the peninsula is far less exposed to the direct influence of tanker traffic. There are no oil terminals or ports in this area and the maritime traffic is only sporadic. The non existence of offshore oil fields further reduces the risk of oil spillage. Although this area can be affected by oil spilt in the northern parts of the ROPME sea area its impact will never be as severe as on the northern coasts of Qatar. Investigating the beaches to the south of Bir Zikrit clearly confirms this.

A comparison of the average quantities of tar on Qatari beaches (g m^{-1} of shoreline) with other ROPME sea area beaches is given in Table 3.

Table 3

Average quantities of tar on beaches in the ROPME

Sea Area (g m^{-1} of shoreline)

Area	Concentration range	Reference
Bahrain	14 - 858	Fowler, 1985
Kuwait	5 - 2325	Burns *et al.* 1982
Oman	1 - 906	Fowler, 1985
Saudi Arabia	0 - 28750	Stephen and Gunay, 1989
United Arab Emirates	4 - 233	Fowler, 1985
Qatar	58 - >5000	present study

3.2 Dissolved and dispersed petroleum hydrocarbons in Qatari coastal waters

Dissolved and dispersed petroleum hydrocarbons concentrations in samples taken at 1 m depth for each station along the Qatari coast during the two cruises are given in Table 4.

Table 4

Dissolved and dispersed petroleum hydrocarbons in samples taken at 1m depth for each station along the Qatari coast during the two cruises (May and December 1991)

Station No.	Petroleum hydrocarbons concentrations (μgl^{-1})			
	May 1991		December 1991	
	Chrysene equivalents	Kuwaiti oil equivalents	Chrysene equivalents	Kuwaiti oil equivalents
1	0.48	5.8	0.82	9.8
2	0.24	2.9	0.48	5.7
3	0.54	6.5	0.34	4.1
4	0.58	6.9	0.25	3.0
5	0.28	3.4	0.51	6.1
6	0.33	4.0	0.35	4.2
7	0.15	1.8	0.21	2.5
8	0.24	2.9	0.34	4.1
9	0.25	3.0	0.16	1.9
10	0.43	5.1	0.20	2.4
11	0.16	1.9	0.52	6.2
12	0.50	6.0	0.40	4.8
13	0.15	1.8	0.35	4.2
14	0.42	5.0	0.28	3.3
15	0.34	4.1	0.47	5.6
16	0.18	2.2	0.08	0.9
17	0.10	1.2	0.27	3.2
18	0.21	2.5	0.22	2.6

Average and range of concentrations of petroleum hydrocarbons in sea water of the studied areas are given in Table 5.

Table 5

Average and range of petroleum hydrocarbons concentrations in sea water samples from different Qatari coastal areas (μgl^{-1} Kuwaiti oil equivalents)

Area	Average	Range
Dukhan	2.1	0.9 - 3.2
Al-Zubarah	4.0	1.8 - 5.6
Ruwais	4.4	1.9 - 6.2
Fuwairet	2.7	1.8 - 4.1
Doha	4.6	3.0 - 6.9
Umm Said	5.8	2.9 - 9.8

The highest level (up to 9.8 µgl-1 Kuwaiti oil equivalents) was found in Umm Said waters on the southeastern side of the Qatari peninsula. The general trend shows a decreasing sequence of petroleum hydrocarbons levels in the following order: Umm Said > Doha > Ruwais > Al-Zubarah > Fuwairet > Dukhan. This may suggest that the possible main sources of dissolved and dispersed petroleum hydrocarbons in Qatari coastal waters are harbours and coastal activities (Umm Said, Doha and Ruwais) followed by leaching of dissolved oil from the deposited tarry materials (Al-Zubarah).

Previous studies for the determination of dissolved and dispersed petroleum hydrocarbons in Qatari coastal waters gave an average of 45.9 μgl^{-1} and a range fluctuating from 1.2 μgl^{-1} to 428.0 μgl^{-1} (Hassan and El-Samra, 1988).

Petroleum hydrocarbons concentrations in sea water in the northwestern region of ROPME sea area were reported to be in the range of 0.10 - 0.33 µgl-1 (EPD, 1986). Another study reported the concentration level at the surface, at ten meters depth, and at the bottom to be in the range of 0.7 - 4.6, 0.7 - 8.81 and 1.1 - 4.8 µgl-1 respectively (Literathy *et al*, 1986). From the western central region hydrocarbon concentrations in sea water were reported in the range of 0.12 - 1.4 µgl-1 (KFUPM/RI, 1987), while the corresponding figures from the southwestern region were in the range of 0.48 - 16.8 µgl-1 (Fowler, 1985).

3.3 Petroleum hydrocarbons in Qatari coastal sediments

The results for organic carbon and petroleum hydrocarbons in the sediments studied are given in Table 6.

Table 6

Petroleum hydrocarbons concentrations

(µg-1 dry weight in chrysene and Kuwaiti-crude-oil equivalents)

in Qatari coastal sediments (May 1991)

Station no.	Water depth (m)	Sediment type	TOC %	Concentration	
				Chrysene equivalents	Kuwaiti oil equivalents
1	8	Mud and sand	1.3	6.0	72.3
2	10	Fine sand	0.8	9.2	110.2
3	8	Sand	1.1	6.9	83.0
4	7	Mud and sand	1.4	4.0	48.0
5	8	Mud and sand	0.9	5.4	64.3
6	8	Mud and sand	0.8	4-2	50.1
7	6	Sand and mud	1.2	7.5	89.8
8	7	Sand and mud	0.9	6.4	76.4
9	7	Sand	0.9	6.5	77.7
10	8	Sand	0.8	8.4	100.9
11	7	Sand	1.0	7.2	86.2
12	9	Sand and mud	0.7	11.3	135.4
13	10	Sand	1.1	17.8	211.1
14	8	Sand	1-3	20.9	248.3
15	8	Sand	1.0	15.6	186.6
16	9	Sand	1.0	12.4	148.4
17	7	Sand	0.6	10.5	125.2
18	10	Mud and sand	0.9	13.1	156.0

The Ultraviolet Fluorescence Spectroscopy (UVF) method involves the excitation of electrons in the UV region of the electromagnetic spectrum and affects only those compounds with excitable electrons. Within a mixture of petroleum hydrocarbons, these are the polycyclic aromatic hydrocarbons (PAH's), i.e. those agents whose harmful effects on living organisms are well known (Law, 1981). Unlike many aliphatic hydrocarbons, aromatic compounds are a component of crude oils that have not been found to be produced biogenically, and their presence in marine samples is therefore taken to indicate the presence of petroleum hydrocarbons (Farrington & Meyer, 1975). For these reasons, as well as reasons of simplicity, sensitivity, and speed, UVF has found general acceptance for the determination of petroleum hydrocarbons in environmental samples from the Arabian Gulf region. However, one has to bear in mind that the reporting of results obtained with the UVF method in equivalents of a specific crude oil is based on the assumption that hydrocarbon mixtures extracted from sediments contain fluorescent aromatic hydrocarbons in roughly the same proportion as this crude oil. This assumption may not be always correct.

From the results of this work, it is evident that all sites along the Qatari coastline are contaminated to some extent with petroleum hydrocarbons (Table 6). Petroleum-hydrocarbon concentrations were markedly higher along the total length of the western side of the peninsula than on the eastern side (Table 6). The highest levels (>187 $\mu g g^{-1}$ dw Kuwaiti crude oil equivalents) were found in the Al-Zubarah area on the north-western side of the Qatari peninsula. The general trend shows a decreasing sequence of petroleum-hydrocarbon levels in the following order: Al Zubarah > Dukhan > Ruwais > Umm Said > Fuwairet > Doha (Table 7). These spatial variations can be explained in view of the location of the Qatari peninsula and the prevailing meteorological and hydrological conditions in the region. The main wind pattern in the whole area is north-westerly (Shamal), and the predominant water current is counter-clockwise, so one should expect the consequences of these conditions to appear in the northern parts of the peninsula (Linden *et al.,* 1990). Considering the frequent accidental and chronic oil spillage in the sea to the north-west of Qatar, heavy oil pollution in the north-western area (Al-Zubarah) is expected. North-eastern and eastern coasts of Qatar are not protected by coral reefs like those on the western side. They are therefore more exposed to the influence of waves, which may accelerate the oil degradation process. This may be considered one of the important reasons for the lower levels of oil pollution detected on the eastern side. The considerably higher concentrations of petroleum hydrocarbons in sediments of the Umm Said area, rather than other areas on the eastern side, could be attributed to local sources of pollution, such as wastes of the industrial zone and the heavy traffic arriving at and leaving Umm Said port.

Table 7

Spatial concentrations of Petroleum hydrocarbons in Qatari coastal sediments (µg g^{-1} dw chrysene and Kuwaiti crude oil equivalents)

Area	Standard type	Petroleum hydrocarbons concentrations	
		Mean	Range
Umm Said	Chrysene	7.4	6.0 - 9.2
	Kuwaiti oil	88.5	72.3 - 110.2
Doha	Chrysene	4.5	4.0 - 5.4
	Kuwaiti oil	54.1	48.0 - 64.3
Fuwairet	Chrysene	6.8	6.4 - 7.5
	Kuwaiti oil	81.3	76.4 - 89.8
Ruwais	Chrysene	9.0	7.2 - 11.3
	Kuwaiti oil	107.5	86.2 - 135.4
Al-Zubarah	Chrysene	18.1	15.6 - 20.9
	Kuwaiti oil	215.3	186.6 - 248.3
Dukhan	Chrysene	12.0	10.5 - 13.1
	Kuwaiti oil	143.2	125.2-156.0

No significant correlation was found between the percentage of organic carbon (0.6-1.4%) and petroleum-hydrocarbon concentrations in the Qatari coastal sediments (r = +0.08).

The composition of petroleum hydrocarbon mixtures changes owing to different sources and physical, chemical, and biological influences. For this reason, results originating from various areas, even those obtained under identical conditions, are only conditionally comparable. A summary of some published petroleum hydrocarbon concentrations of the marine sediments from the Arabian Gulf is given in Table 8. Generally speaking, Qatari coastal sediments showed a low level of petroleum hydrocarbons concentration in comparison with the sediments of Kuwait and a higher level of petroleum hydrocarbons than the sediments of Oman, United Arab Emirates, Bahrain, and Iraq (Table 8).

Table 8

Concentrations of petroleum hydrocarbons in sediments from ROPME sea areas (determined by applying fluorescence technique and using Kuwaiti crude oil as a standard)

Area	Concentration range ($\mu g g^{-1}$ dw)	Reference
Oman	0.1-119.0	Fowler (1985)
United Arab Emirates	0.1-14.7	Fowler (1985)
Bahrain	0.5-8.5	Fowler (1985)
Kuwait	13.7-375.0	Literathy *et al.* (1986)
Iraq	0.4-44.0	Douabul *et al.* (1984)
Qatar	48.0-248.0	Present study

4. CONCLUSIONS

4.1 Petroleum hydrocarbons are ubiquitous in Qatari coastal waters and sediments.

4.2 While the impact of the 1991 Gulf oil spill was not clearly shown in levels of dissolved and dispersed petroleum hydrocarbons in Qatari coastal waters, it was obvious in covering the northern and northwestern beaches with tar mats.

4.3. The state of the tar pollution along the Qatari coastline is characterized by significant variations in levels. This varies from heavily polluted northern and northwestern shores to virtually pollution-free shores in the southeast. These variations can be attributed to the location of Qatar peninsula and to the meteorological and hydrological conditions in the region.

4.4 The highest levels of oil in any sediment from the area investigated were found in the sandy northwestern area, suggesting that accidental oil spills and chronic discharges from tankers bound for oil terminals in the northern part of the Arabian Gulf provide Qatari coasts with considerable amounts of oil wastes.

4.5 The spatial distribution of dissolved and dispersed petroleum hydrocarbons in Qatari waters suggests that harbours and coastal activities followed by leaching of dissolved oil from tarry deposits are the main sources of oil pollution in waters of the coastal belt.

5. RECOMMENDATIONS

5.1 Clean-up of Qatari beaches should begin as soon as possible according to a carefully prepared strategy which includes several phases and start from lesser polluted and better protected beaches (southern parts).

5.2 Mitigation and rehabilitation programmes are urgently required for the northern and northwestern beaches.

5.3 Oil pollution monitoring in Qatari coastal belt should be continued.

5.4 Qatari authorities should start the implementation of oil pollution prevention measures.

5.5. Qatar should sign regional and international conventions on oil pollution abatement and support their implementation.

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