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The effect of the Banton 300 oil-spill accident on marine life in Umm Al-Quwain in the Arabian Gulf (northern United Arab Emirates)

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ABSTRACT
This study reports on the effects of the accidental spillage of 10,000 tons of Iranian crude oil that resulted from the sinking of the oil tanker "Banton 300" during January 1998, 5 miles from Umm Al-Quwain on the Arabian Gulf. The oil slick spread to cover a huge area of the coastal waters and shores of the United Arab Emirates, with a total length of about 15 km and total width of about 30-50 m. Different effects of oil on marine organisms of Umm Al-Quwain are categorized as: direct lethal toxicity (diatoms, sponges, acorn barnacles, copepods, echinoderms and fish); sub-lethal disruption of physiological and/or behavioural activities (bacterioplankton, heterotrophic flagellates, and tintinnid ciliates); effects of direct coating (birds and mangroves); incorporation of hydrocarbons in organisms (crabs, scallops, edible mussels, large fish and plants), which may cause tainting and/or accumulation of hydrocarbons in food chains, and finally changes in microhabitats (amphipods and worms), especially alteration of substrate characteristics.

KEYWORDS: oil pollution, Arabian Gulf, UAE, marine organisms

INTRODUCTION

The Arabian Gulf is shallow with an average depth of about 35 m and maximum depth of about 100 m. The Gulf is connected through the Strait of Hormuz to the Arabian Sea, which forms the northern part of the Indian Ocean. Weather has an important effect on the seawater of the Gulf. Continuous sunlight, particularly in summer, warms the water surface, causing an increase in evaporation rates, and consequently the Gulf water is hyper-saline. The Gulf's marine environment is becoming increasingly important in fulfilling social, economic, development and strategic objectives of the region, playing a vital role in providing most of the population with fresh water from desalination plants, and providing fisheries and artisanal fisheries of a multi-million dollar industry. The Gulf region is a unique environment especially for marine organisms, which are in many cases living at the extreme limits of their environmental tolerances and effects of additional stresses imposed by man, including those arising from oil pollution.

The discovery of oil in the Gulf during 1930's and 1940's was principally responsible for the current immense economic wealth and geopolitical importance of the region, leading to a massive increase in shipping. In consequence, oil pollutants became a problem in several parts of the Gulf. The marine environment of the United Arab Emirates along the Gulf is subjected to increased quantities of oil, which may cause human health problems (Ponat 1988). The response of the Gulf biota to oil pollution is still not well understood, because few assessments of the effects of oil on marine environment and community structure in the Gulf have been undertaken (but see Sheppard 1993; El-Serehy 1998 &1999; Shriadah 1998; Youssef *et al.* 1998).

Petroleum hydrocarbons reach the Gulf water by many routes, and tanker accidents are by no means the essential source of oil pollution. On January 7, 1998, an accidental oil spillage was detected on the UAE shore at Umm Al-Quwain in the Arabian Gulf. The source of spillage was found to be the sinking of the oil tanker "*Banton 300* ", 5 miles from

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the Umm Al-Quwain coastline. Based on the amount of oil that had leaked from the tanker, it was estimated that 10000 tons of Iranian crude oil spilled into the environment. This oil spread to cover a huge area, with a total length of about 15 km and total width of about 30-50 m of the coastal waters and shores of United Arab Emirates, and reaching the coasts of Ajman and Sharja Emirates to the south and Ras Al-Khima Emirate to the north.

Immediate steps were initiated to try to treat the spilled oil physically. However, the rapidly moving winds and water currents at the site of the accident, and the old and damaged state of the oil tanker, defeated efforts by facilitating the rapid expansion of the oil spill.

Shortly after detection of the spillage, a research programme was launched to study the response of the marine organisms to the impact of the contaminating oil. The present work is a part of this programme and deals with the impact of oil pollution on the living resources of the Gulf. Although assessment of effects on higher levels of biological organization is ultimately essential, it is necessary to begin with the impacts on individuals.

MATERIALS AND METHODS

Three sites of the contaminated water along Umm Al-Quwain shore were chosen for this study (Fig. 1). The first site was heavily contaminated and located at Umm Al-Quwain Creek, where condensed mangrove trees cover a big area forming many islands as a transitional habitat between terrestrial and marine ecosystems. The second site showed moderate visible contamination and lay along the Umm Al-Quwain shore, in front of the "Marine Biology Research Center" of the Ministry of Agriculture. The third site was a mildly contaminated area along the coast of Umm Al-Quwain in front of the desalination plant, the main source of fresh water. Three weeks after the spill had been detected, the sediment in this area showed no visible contamination and no surface slick was observed.

Seawater samples were collected in pre-cleaned amber 4-l bottles. Petroleum hydrocarbons in seawater samples were extracted using a mixture of fluorescence-free hexane-dichloromethane (7:3; v/v) on board. Seawater extract was evaporated using a Rota vapour, taken up in 10 ml n-hexane into a vial and then cleaned by silica gel and aluminum oxide column chromatography to remove biogenic lipid compounds (Law *et al*., 1988). Petroleum hydrocarbon levels were determined by fluorescence using fixed excitation (310 nm) and emission (360 nm) on a Shimadzu RF-5000 Spectrophotometer. Iranian crude oil was used as a standard reference compound for the calibration of the spectrofluorometer.

Sediment samples were collected during March 1998 using a core (0.01 m^2) to a depth of 15-20 cm at the mean low tide of each site. Three core samples per site were taken for sediment grain size. The grain-size distributions of sediment samples were analyzed using standard methods (ASTM Standards, 1973). Median diameters were derived from the cumulative curves of total size distribution. Within one day of the accident, a programme for sampling and collecting marine fauna and flora was started on the basis of weekly sampling for 16 weeks.

Bacterioplankton were collected in sterile glass containers. The collected bacterioplankters were fixed in 2.5 % final concentration glutaraldehyde and kept in the dark at 4 ^{o}C. Planktonic bacteria were counted using the method developed by Porter & Feig (1980), using an Olympus BH-2 microscope fitted with a reflection fluorescence attachment (x1000 magnification). Phytoplankton samples were collected using 4-l van-Dorn water bottle, and three replicate samples were taken from 0.5 m depth at each sampling site. The collected phytoplankters were fixed immediately in 1% final concentration Lugol's Iodine and kept in the dark.

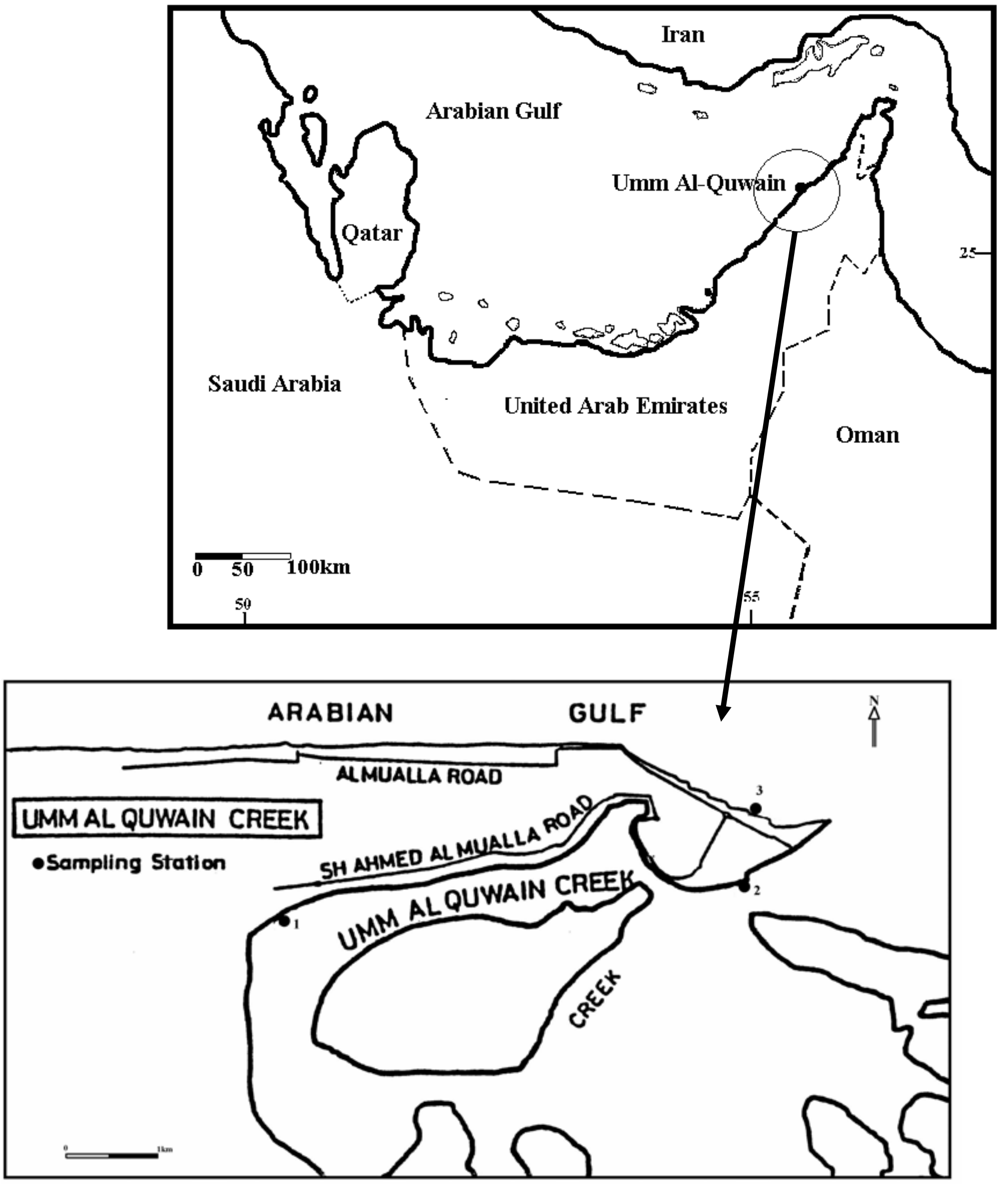

Fig. 1: Location of sampling sites in Umm-Al-Quwain at northern United Arab Emirates on the Arabian Gulf.

Zooplankton samples were collected using a plankton net with a mesh size of 100 µm. The net was hauled horizontally behind a boat for 5 minutes at each site. The collected zooplankters were fixed immediately in 5% formalin. Zooplankton as well as phytoplankton organisms were counted under a Wild M40 inverted microscope provided with phase contrast. Phytoplankters were counted after settlement by the Utermohl method (Utermohl 1958). Many marine plant and animal species were also collected by hand from the area of the accident along the Umm Al-Quwain shores during the study.

Temperature, salinity, pH, dissolved oxygen were determined at time of collection from each site. Chlorophyll *a* values were determined in the samples collected from the three sites according to Parsons *et al*. (1984).

RESULTS

The sedimentary composition at the three sites is shown in Table 1. The sediments at site I are mainly (86.5-89.2 %) fine sand. Consequently the median grain sizes of these sediments ranged from 138 to 155 μm. Sediments at the other two sites (II & III) are coarse (26.2 – 48.3 %) and fine (51.1-89.7 %) sands. The median grain sizes ranged from 395-540 μm.

Table 1: Sedimentary composition at the three sites along Umm Al-Quwain shores during March 1998. (500–2000 μm = coarse sand, 63-500 μm = fine sand).

Site	*sample*	*% coarse sand*	*% fine sand*	*median diameter*	*calcium carbonate*
I	1	9.6	88.4	155	77.0
	2	8.9	86.5	142	71.4
	3	6.8	89.2	138	69.6
II	1	41.5	54.6	460	96.2
	2	35.7	65.1	452	95.1
	3	43.3	52.0	505	93.8
III	1	35.7	58.3	430	96.1
	2	48.3	46.1	544	97.9
	3	25.7	68.0	398	95.2

Temperature, salinity, dissolved oxygen, hydrogen ion concentration, chlorophyll *a* and petroleum hydrocarbon values varied at the three selected sites (Table 2). The highest temperature was recorded at site I, while the lowest was at site III. The highest oxygen percentage saturation was recorded at site II, while the lowest was at site I. Fluctuations in pH around a slightly alkaline mean value were generally limited. Chlorophyll *a* levels tended to be high at site I and low at site II. Concentrations of petroleum hydrocarbons were low at site III and very high at site I while site II was intermediate.

The density of planktonic bacteria was high, ranging between 0.5, 3.4 and 6.8 (x 10^7 organism/ml for sites III, II and I, respectively. Phytoplankton densities ranged between 4 x 10^4 (site III) and 4 x 10^5 cell/l (site I), and consisted only of the dinoflagellate taxa of *Noctiluca* and *Protoperidinium*.

The oil slick was pushed into a mangrove area of *Avicennia marina* at site I by waves and rising tides. It became deposited in pools as the tide fell, leaving a high-water oiled mark visible on the mangrove prop and stocks, and splashing onto leaves and limbs. Up to 130 cm of crown height was coated with oil film and a considerable number of leaves were dead. Lenticles on the aerial roots were also coated with oil film, thought to affect the respiration efficiency of these roots. Small individual mangroves (one to two years old) were killed.

The marine organisms of Umm Al-Quwain showed five categories of responses to the spilled oil, as shown in Table 3. According to data presented in Table 3, these five responses of marine organisms can be categorized as follows: (1) direct lethal toxicity, referring to interference by hydrocarbons with cellular and sub-cellular processes, especially membrane activities, leading directly to organism death; (2) sub-lethal disruption, also referring to interference with cellular and physiological processes but not including effects causing immediate death, although death may follow due to abnormal behaviour or through other indirect causes; (3) direct coating, occurring as smothering, mechanical interference with activities such as movement and feeding, or loss of insulative properties of feather of birds and fur of mammals; (4) tainting, which indicates oily or petroleum flavours of edible marine organisms and (5) habitat changes, which include effects of alterations in the physical or chemical environment resulting in significant shifts in species composition and geographic distribution in the region of the accident.

Table 2: Umm Al-Quwain sampling sites and their averages values of temperature (ºC), salinity (‰), dissolved oxygen (ml/L), oxygen percentage saturation (O_2%), hydrogen ion concentrations, (pH), chlorophyll *a* (μg/L) and petroleum hydrocarbon (μg/L).

Site	Temp	Salinity	DO	O_2%	pH	Chl *a*	Petr. Hyd.
I	23	39	5.6	133	8.23	1.28	4.5 x 10^6
II	22.6	40	7	147	8.20	0.42	3.4 x 10^5
III	22.4	40	6.7	141	8.15	0.81	5.15 x 10^4

A sharp increase in the bacterial population density from 0.5 x 10^7 to 6.8 x 10^7 organism/ml was recorded during the period of sampling. Generally, site I recorded the highest number, while site III sustained the lowest numerical abundance of planktonic bacteria. An increase in phytoplankton, especially those species belonging to Dinophyceae, and a disappearance of meta-zooplankton (copepods) were recorded during the first 6 weeks of sampling. The highest densities of phytoplankton were recorded at site I.

Table 3
The effect of the spilled oil on marine organisms of Umm Al-Quwain

Species	**Effect of spilled oil**					
	Group	**Lethal**	**Sub-lethal**	**Coating**	**Tainting**	**Habitat change**
Plants						
Coscinodiscus radiatus	Diatom	■				
Protoperidinium sp	Dinoflagellate		■			■
Noctiluca sp	Dinoflagellate		■			■
Halophila ovalis	Sea grass				■	
Sargassum sp	Sea weed	■				
Avicennia marina	Black mangrove	■		■		
Animals						
Favella brevis	Tintinnid		■			
Clathria sp	Sponge	■				
Dysidea sp	Sponge	■				
Siphonochalina sp	Sponge	■				
Liriope tetraphylla	Trachymedusae	■				
Ceratonereis costae	Polychaete					■
Tylonereis bogoyawlenski						
Balanus amphetrite	Polychaete					■
Tetraclita sp	Acorn barnacle	■				
Murex sp	Acorn barnacle	■				
Oliva bulosa	Mollusk	■				
Conus textile	Mollusk	■				
Strombus textile	Mollusk	■				
Strombus decorus	Mollusk	■				
Cerithidea cingulata	Mollusk	■				
Cypraea turdus	Mollusk	■				
Elysia sp	Mollusk	■				
Pinctda radiata	Mollusk	■				
Sepia sp	Mollusk				■	
Paracalanus parvus	Mollusk				■	
Corycaeus ovalis	Copepod					
Acartia erythraea	Copepod	■				
Hyperia sp	Copepod	■				
Ocypode saratan	Amphipod	■				■
Matuta sp	Ghost crab	■			■	
Portunus pelagicus	Swimming crab				■	
Lycopodes sp	Blue crab				■	
Echinometra mathaei	Hermit crab					
Echinodiscus auritus	Echinoderm					
Astropecten sp	Echinoderm	■				
Luidia maculata	Echinoderm				■	
Argyrops spinifer	Echinoderm				■	
Lethrinus miniatus	Fish		■		■	
Lutjanus fulviflamma	Fish		■		■	
Nemipterus japonicus	Fish		■		■	
Unidentified sea birds	Sea bird			■		

DISCUSSION

The sedimentary composition of site I, with its fine sands (138 –155 µm) of median grain sizes which could hold very small interstitial spaces, explains the formation of oil pools and surface oil slick at this site. This also explains the fast disappearance of visible contamination and surface slicks at site III, which was characterized by coarse sand with large grain sizes and consequently big interstitial spaces.

Based on the average values of temperature, salinity, pH, dissolved oxygen, oxygen (% saturation), chlorophyll *a* and petroleum hydrocarbons measured during the present study, the three sites show a high degree of similarity in temperature, salinity and pH values, similar to those given by Banat *et. al*. (1993). Thus, temperature, salinity and pH were nearly identical before and after the oil spill and could not account for any differences as a response to the spilled oil. Similar findings were recorded by Machil *et al*. (1978) and Dahl *et al.* (1983) for the impact of oil spills in the marine ecosystem. However, the three sites reflect some differences in the values of dissolved oxygen. The changes in oxygen concentration can be related to changes in plant growth, since the respiratory rate increases with temperature and the decline in solubility of oxygen in water with rising temperature and salinity. It is therefore helpful to calculate the percentage saturation of water with oxygen at the three sites throughout the period of study. There were differences among the three sites in the values of dissolved oxygen (% saturation) and chlorophyll *a*: the highly contaminated area (site I) had a lower value of dissolved oxygen (5.6 ml/l) and higher values of chlorophyll *a* (1.28 µg/l) when compared by moderate (site II) and lightly (site III) contaminated areas. These findings might reflect the impact of the spilled oil on the physico-chemical properties controlling the ecosystem on one hand and the effect of the increased nutrients and detritus from mangrove trees at this site on the other. Chlorophyll *a* has been found to increase while dissolved oxygen decreases in seawater after addition of crude oil (Dahl *et al*. 1983).

The concentration of petroleum hydrocarbons reported here (range: 5.15×10^4 to 4.5×10^6 µg/l) is much higher than other parts of the Arabian Gulf: El-Samra *et al*. (1986) gave values of 2.95, 4.14 and 3.29 µg/l as the mean concentrations of total hydrocarbons in seawater of Kuwait, Saudi Arabia and Qatar, respectively. Thus the accidentally spilled oil on the Umm Al-Quwain shores dramatically increased the concentrations of petroleum hydrocarbon.

The data presented in Table 3 are interesting in classifying oil effects as lethal toxicity, sub-lethal toxicity, coating, habitat alteration and incorporation. Actually, marine organisms of different species vary widely in sensitivity to oil. Unfortunately, data describing the sensitivity of species to oil exists for a very small number of marine species. For example, among more than 100 species found in Atlantic coastal habitats, data on effects of oil exist for less than a third (Moore *et al*. 1974). Results in Table 3 demonstrate the lack of information on species-by-species basis. More importantly, the summary presented in Table 3 does not indicate the limited nature of the present data. A check (■) in Table 3 merely implies that some data are available. In fact most of the available data on oil effects are still questionable, since they are mostly based on laboratory studies of individual species in the form of LD_{50} values (LaRoche 1973).

The present study showed that intertidal sessile species of the mangrove *Avicennia marina*; the bivalve *Pencidata radiata* and the diving birds were the primary groups that showed different degrees of coating. However, mobile organisms did avoid exposure and sub-tidal benthic species were protected because the oil does not occur as a film sub-tidally. Similar findings were recorded during Santa Barbara spill of crude oil (Straughan 1972). Although the thickness of coating necessary to cause mortality is not readily definable, most species exposed to coating from the main body of the oil slick were likely to be affected.

The effect of habitat alteration could of course prevent species normally present in or on a substrate from inhabiting the area. Thus the disappearance of the most common polycheate infauna such as *Certonereis costae* and *Tylonereis bagoyawlenski* and the amphipod *Heperia* sp. (Ismail 1993; El-Serehy 1999), from inhabiting the shore of Umm Al-Quwain can be explained by the previously mentioned hypothesis. Thus, species dependent on the substrate only for passive support, like those simply lying on the substrate such as amphipods, are more likely to be little affected by the physical presence of oil. However, species living in the substrate or otherwise more than passively dependent upon the substrate like polycheates seemed to be more vulnerable to this effect. Unfortunately, there are virtually no data on the relationship between the amount of oil present and the degree of suitability of the substrate for various species (Moore & Dwyer 1974; Clark 1997).

During the present study, the number of planktonic bacteria recorded in the samples collected from the three sites examined was very high. Bacterial densities were generally two orders of magnitude higher than those recorded by Banat *et al*. (1993) (average: 0.5 x 10^5) five years before the accident. The most obvious direct effect of oil addition to seawater is the rapid stimulation of bacterial growth (Lee *et al.* 1978; Dahl *et al*. 1983). This is probably due to the fact that the low-molecular-weight fractions become immediately available as carbon and energy sources without requiring any adaptation period (Lee *et al*. 1978). This could explain the increase in numbers of planktonic bacteria as a direct response to the spilled crude oil at the seawater of Umm Al-Quwain. Moreover, the formation of secondary, possiblly very toxic and water-soluble material increases very rapidly with decreasing thickness of oil film (Burwood and Speers, 1974). Consequently, the decrease in population density of planktonic bacteria at both areas of sites II and III compared to those recorded at site I is due to the fact that site I was more heavily contaminated with crude oil.

The increasing number of bacteria at the oil-polluted coasts of Umm Al-Quwain is thought to encourage the growth of bacterial-feeding planktonic organisms. Flagellates can graze on heterotrophic bacteria (Hass & Webb 1979) and these flagellates constitute a substantial fraction of microplankton biomass in the sea under natural condition (Throndsen 1970). Tintinnids also graze bacteria and flagellates (Spittler 1973; Heinbokel & Beers 1979). Both flagellates and tintinnids were more abundant in the sea water at the Umm Al-Quwain shore during the present study (Table 3). The rapid growth of bacteria and predominance of flagellates and tintinnids in oil-polluted ecosystems has already been noted (Lee *et al*. 1978).

The response of these microorganisms to the accidental spillage of 10,000 tons of crude oil might actually reflect the abundance of bacterioplankton and protozooplankton as oil-tolerant microorganisms. On the other hand, the zooplanktonic copepod community disappeared from samples collected during the first 6 weeks of the present study, which may reflect the lethal impact of the oil to these zooplankters. Davies *et al*. (1980) concluded that crude oil had a direct inhibitory effect on the development of copepod eggs and naupli.

It was very interesting to discover a marked increase in the phytoplankton population density in response to the accidentally spilled oil. This might be due to the complete absence of the grazing impact of zooplankton, which disappeared in response to the spilled oil. It is not confirmed whether the oil had any nutritional effect to phytoplankton or not. The Gulf region is a unique marine environment and the data generated from other areas cannot simply be extrapolated to this area. Azab (1995) listed

26 phytoplankton species from the Umm Al-Quwain shore, belonging to Bacillariophyceae (15 species), Dinophyceae (5 species), Cyanophyceae (3 species), Chlorophyceae (2 species) and Euglenophyceae (one species). Before the oil-spill accident, the most abundant phytoplankter was *Microcystis elabens* (Cyanophycaeae), followed by the centric diatoms (*Chaetoceros curvisetus*, *Thalassiosira decipiens* and C*oscinodiscus radiatus*), the pennate diatoms (*Navicula distans* and *Synedra undulat*) and then *Gymnodinium simplex* and *Prorocentrum micans* (Azab 1995).

After the spill, a sharp reduction in the phytoplankton community structure was recorded: *Noctiluca* and *Protoperidinium* (Dinophyceae) were the most abundant species, dominating the phytoplankton community. Both of these dinoflagellate species were absent from the list given by Azab (1995). Thus their occurrence during 1998 and for the first time in the present study is probably a direct response to the impact of crude oil on the phytoplankton ecosystem. This response may reflect the movement pattern of the oil, enrichment because of hydrocarbon usage, or selection for oil-pollution phytoplankton indicators.

In conclusion, oil pollution may be less harmful to the marine ecosystem of the warm climate areas, such as the Umm Al-Quwain marine ecosystem in the Arabian Gulf, than those of cold and temperate climates worldwide. This may be due partially to the rapid evaporation of the volatile components of crude oil at higher temperatures.

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الملخص العربى

تأثير حادثة انسكاب النفط من الناقلة بانتون 300 على الحياة البحرية بشواطئ أم القوين شمال دولةالإمارات العربية المتحدة على الخليج العربى

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أدى اكتشاف البترول فى الخليج العربى فى حقبة الثلاثينيات والأربعينيات لمظاهر الثراء وازدهار الملاحة البحرية . إلا أن ذلك صاحبه مشاكل متزايدة نتيجةً للتلوث البترولى الناجم عن ناقلات البترول للبيئة البحرية وقاطناتها من الأحياء البحرية والتى تعتبر ثروة طبيعية لها أهميتها . لذا استهدف هذا البحث دراسة تأثير انسكاب عشرة آلاف طن من النفط الإيرانى الخام من الناقلة بانتون " 300 " على حياة الأحياء البحرية التى تقطن مياه وشواطئ إمارة أم القوين شمال دولة الإمارات على الخليج العربى . ولقد أثمر البحث عن ظهور خمسة استجابات متباينة كرد فعل للأحياء البحرية تجاه النفط المنسكب - تم مناقشة كلاً منها على حدة . حيت أظهر البترول المنسكب سمية قاتلةً لبعض الأحياء مثل الدياتومات والاسفنجيات و الأطومات الجالسة ومجدافيات الأرجل وشوكيات الجلد وصغار الأسماك ، بينما أظهرت بعض الأحياء البحرية الأخرى قدرةً محدودةً على تحمل مثل هذا التأثير القاتل للزيت المنسكب مثل الهائمات الدقيقة البكتيرية والسوطية والهدبية الأولية - صاحبها خللاً فى النمط السلوكى لها ، وظهرت بعض الأحياء البحرية مثل الطيور البحرية وأشجار المنجروف وقد كسيت بطبقة من هذا الزيت المنسكب كان لها تأثير واضح على أداء هذه الكائنات فى النظام البيئى البحرى بمنطقة الحادثة . بينما أظهرت مجموعات السرطانات البحرية والرخويات والأسماك الكبيرة مقدرة على تخزين المشتقات الهيدروكربونية داخل أجسامها لتأتى برائحة وطعم غير مستساغين . وأخيراً جاءت تلك المجموعة من الأحياء البحرية وقد تأثرت بيئاتها ومرتكزاتها بالزيت المنسكب لينعكس ذلك عليها مثل القشريات مزدوجة الأرجل والحلقيات عديدات الأشواك.