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Distribution of Dissolved Petroleum Hydrocarbon in the Southern Arabian Gulf

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ABSTRACT. Sea water samples collected from the southern part of the Gulf during September 1985 showed that, according to the standard used, the concentration of petroleum hydrocarbons is variable. The variations in the results for the references: Kuwait crude oil, Qatar crude oil (from Dukhan and Halul Island) and chrysene standards are usually in an average ratio of 1:1.26:2.6 : 1.51 respectively.

The concentration of dissolved petroleum hydrocarbons varied from 7.7 $\mu g\ l^{-1}$ to 32 $\mu g\ l^{-1}$ during September 1985. High levels (69-373 $\mu g\ l^{-1}$) were recorded around the beaches of Halul island indicating oil contamination. The total concentration of petroleum hydrocarbons dissolved in the Gulf waters was found to be 406×10^3 ton which is 2.7 times as higher as the estimates of oil pollution in the Gulf area during 1985. Dissolved oxygen levels decrease with increasing the concentrations of petroleum hydrocarbons ($r = -0.55$).

The potential for oil pollution in the Gulf Region is alarming because more than half of all the oil transported in the world passes through this area. Nearly 100 oil tankers pass though the strait of Hormuz every day (Oostdam 1980). Estimates made in 1979 showed that 144,000 metric tons of oil polluted the Gulf region and that during the 10 years from 1980 to 1989, more than 1.5 million metric tons will pollute the region (Golob and Brus 1984). Although these figures are not optimistic, yet, the estimated flushing time, that is the time for all the water in the basin to be exchanged with water from the open sea, is 5.5 years (Hughes and Hunter 1979).

The present work is a part of the programme that deals with studying the state of oil pollution in the Gulf area in general and in the Qatari water in particular.

Materials and Methods

Sea water samples were collected during the period 17-26th September 1985 from 15 stations of which 8 stations lie in the United Arab Emirates water and 7 stations in the Qatari water (Fig. 1). An additional 4 stations in the Qatari water were collected by a small boat around the beaches of Halul Island. The other samples were collected using R/V Mukhtaber Al-Bihar at 1-m depth with a glass bottle of capacity 2.8 l.

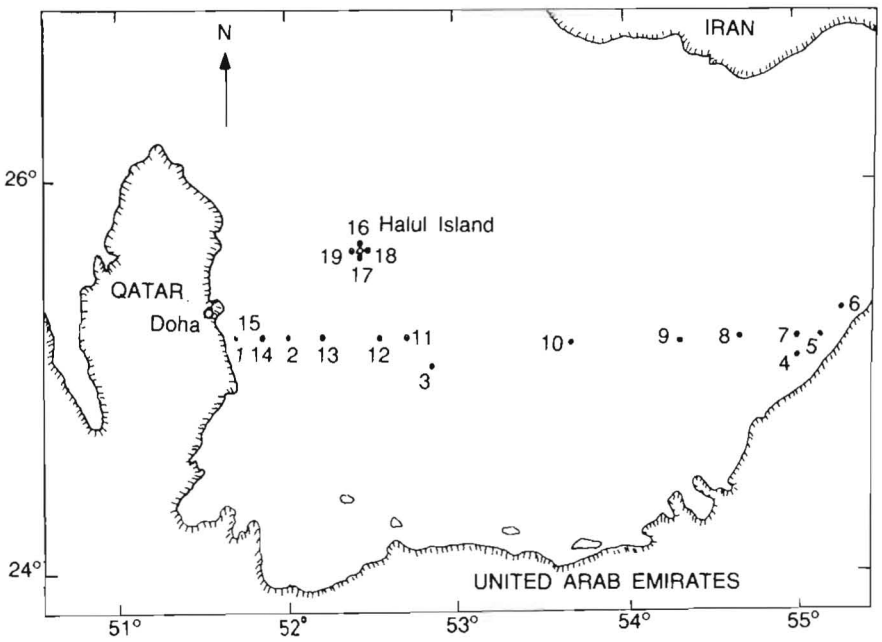

Fig. 1. Area of investigation

Dissolved/dispersed petroleum hydrocarbons were measured by UV spectrofluorometry (Turner 430) according to the method given in the "Manual for monitoring of oil and petroleum hydrocarbons in marine waters and on beaches UNESCO (1977). Kuwait crude oil, Qatar crude oil from Dukhan and Halul Island and chrysene were used as standards to evaluate the best reference standard.

Results and Discussion

The concentrations of dissolved petroleum hydrocarbons in sea water of the southern part of the Gulf between Qatar and UAE are given in Table 1. The measured aromatic hydrocarbon contents vary significantly depending upon the standard used. The concentration of petroleum hydrocarbons in samples collected during September 1985 are scattered in the ranges (7.7-32), (9.8-40.5), (20.2-83.5) and (12.4-51.1) $\mu g.l^{-1}$ when Kuwait, Qatar (Dukhan and Halul) crude oils and chrysene were respectively used as standards. For samples collected around the beaches of Halul Island the petroleum hydrocarbon levels were significantly much higher. (Table 1).

Table 1. Concentrations of dissolved oxygen and dissolved dispersed petroleum hydrocarbons in sea water of the southern Arabian Gulf*

St. No.	Areas	Oxygen $ml.l^{-1}$	Petroleum hydrocarbons ($\mu g.l^{-1}$)			
			Kuwait	Qatar		Chrysene
				Dukhan	Halul	
1	Qatar	3.30	24.4	31	63.8	39.1
2	Qatar	3.21	18	22.9	47.1	28.8
3	UAE	3.46	17	21.5	44.4	27.2
4	UAE	3.20	15.8	20	41.3	25.2
5	UAE	3.60	18	22.9	47.1	28.8
6	UAE	3.40	19.6	24.9	51.3	31.4
7	UAE	3.20	32	40.5	83.5	51.1
8	UAE	3.30	18.8	23.8	49.1	30
9	UAE	3.57	19.5	24.8	51.1	31.2
10	UAE	4.10	9.8	12.4	25.5	15.6
11	Qatar	4.00	24.1	30.5	62.9	38.4
12	Qatar	4.10	15.2	19.2	39.7	24.3
13	Qatar	3.40	18.3	23.2	47.9	29.3
14	Qatar	4.10	7.7	9.8	20.2	12.4
15	Qatar	3.65	14.1	17.8	36.7	22.5
16	Qatar Halul[1]	–	373	469	969	540
17	Qatar Halul[2]	–	136	171	354	197
18	Qatar Halul[3]	–	68.8	86.7	179	126
19	Qatar Halul[4]	–	191	240	497	277
	Mean		54.8	69.1	142.7	82.9
	Ratio		1	1.26	2.6	1.51

* Using Kuwait, Qatar (Dukhan, Halul) Crude oils and chrysene as standards.
1 Halul Island N. beach
2 Halul Island S. beach
3 Halul Island E. beach
4 Halul Island W. beach

The variations in the results for the references Kuwait, Qatar (Dukhan and Halul) and chrysene standards are usually in an average ratio of 1: 1.16: 2.6: 1.51 respectively. The calculated inverse values for the slopes (concentrations) of the calibration curves for the four reference standards (Fig. 2) were found to be similar (1:1.25:2.5:1.67) to the ratio mentioned above.

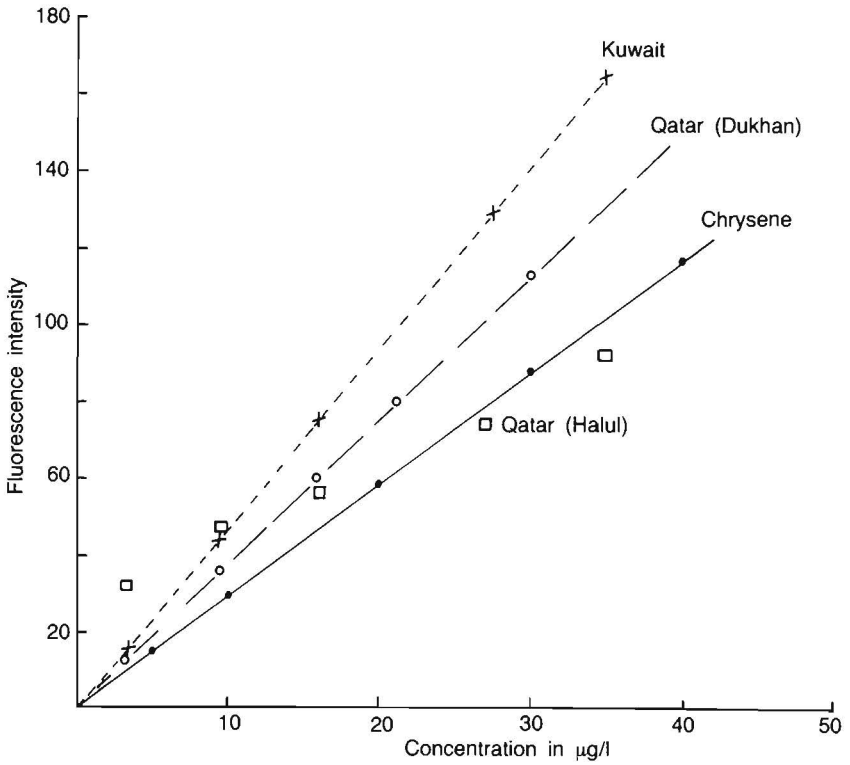

Fig. 2. Calibration curves for the four standards

Using the data of IAEA (1985) for sea water from Bahrain, UAE and Oman, we calculated the ratio of the standard used Kuwait, chrysene and fuel oil. The ratio was 1:1:11. It may thus be concluded that the measured oil content in sea water is variable according to the standard used (Awad 1982) and the best method by which comparison of results of petroleum hydrocarbons in the Gulf area may be made is either to use the same standard or to establish the concentration

fluorescence calibration curves for the main crude oils in the Gulf area. On the basis of these limitations, it seems that Kuwait crude oil and possibly Qatar crude oil from Dukhan can be used as a reference standard for estimating petroleum hydrocarbons in the Gulf water. The physical and chemical characteristics of each type of crude oil are given in Table 2.

Table 2. General characteristics of Qatar (Dukhan) and Kuwait Crude oils (personal communication)[1]

Crude Characteristics	Qatar	Kuwait
Specific gravity	0.8175	0.875
Apl gravity	41.5	30.4
Viscosity cS at 10°C	4.5	30
Pour Point °C	−12	−20
Reid vapor pressure at 37.8°C	10.2	8.0
Carbon content (wt. %)	85.6	−
Hydrogen content (wt. %)	12.7	−
Sulfur content (wt. %)	1.19	2.62
Nitrogen content (wt. %)	0.032	−
Water content (Vol. %)	0.0	0.05
Ash content (wt. %)	0.001	0.003
Conradson carbon residue (wt. %)	1.2	5.3
Asphalt content (wt. %)	< 0.05	1.79

1 Qatar National Petroleum Company

Based on Kuwait crude oil as standard the concentration of dissolved petroleum hydrocarbons in the southern part of the Gulf (Fig. 3) between Qatar and UAE during September 1985 varied from 7.7 $\mu g\ l^{-1}$ at St. No. 14 in the Qatari waters to 32 $\mu g\ l^{-1}$ at St. No. 7 in the UAE waters. The mean value of petroleum hydrocarbons in the Qatari water is lower than that of the UAE waters by 1.4 $\mu g\ l^{-1}$.

On the other hand, the samples collected from the beaches of Halul Island in the Qatari waters showed extremely high levels (69-373 $\mu g\ l^{-1}$), particularly in the case of the northern beach of the Island. This is not surprising since this site is an oil production and exportation area which is subjected to frequent spills.

Comparison of the values in Table 3 with concentrations in other areas of the world ocean suggests that with the possible exception of Halul shore waters,

current levels of petroleum hydrocarbons in the southern part of the Gulf are not exceptionally high.

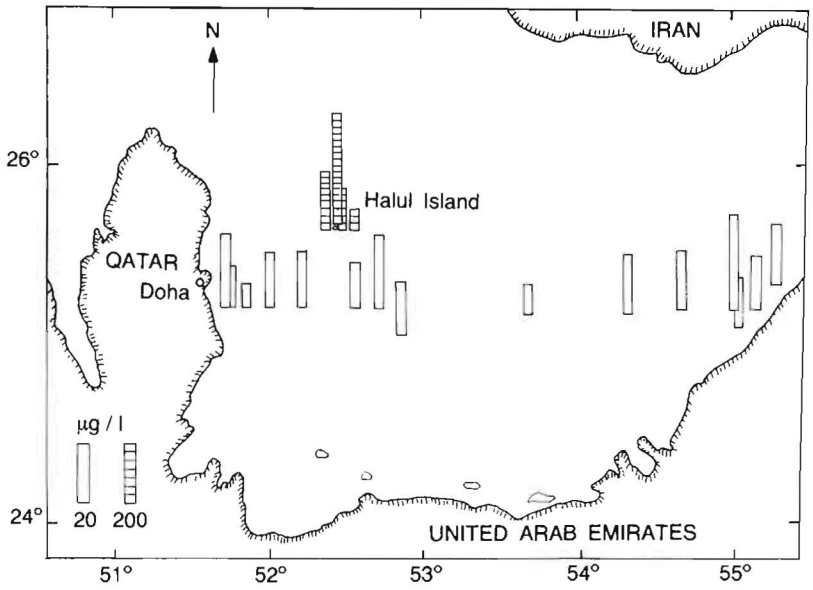

Fig. 3. Concentrations of dissolved petroleum hydrocarbon

Table 3. Hydrocarbon concentrations commonly found in oceanic waters (from Boehm *et al.* 1978)

Location	Concentration ($\mu g\ l^{-1}$)	Comments	References
Southern Arabian Gulf	7.7-373	Spectrofluorometry	The present study
Gulf of Mexico Loop Current	0-75	Gas chromatography	Iliffe and Calder (1974)
West African Coast	10-95	GC	Barbier *et al.* (1973)
Bedford Basin, Nova Scotia	1-60	Fluorescence	Keizer and Gordon (1973)
Open Ocean (Atlantic)	1-50	IR	Brown *et al.* (1973)
Open Ocean (N.W. Atlantic)	20	Fluorescence	Gordon *et al.* (1974)
Baltic Sea	50-60	Non-aromatics	Zsolnay (1972)

The advection of oil pollutants is directly affected by the speed of the wind and the wind-driven surface current. According to the prediction of Hunter (1983) there is a surface inflow of strength around 0.1 m/s along the Iranian coast and outflow of water along the bottom from the coastal areas of Saudi Arabia, Qatar and the United Arab Emirates (Fig. 4). The wind stress generates clear Ekman rotation and a surface inflow into the region North of the UAE. Thus the southern part of the Gulf is affected by oil pollution from different parts of the Gulf.

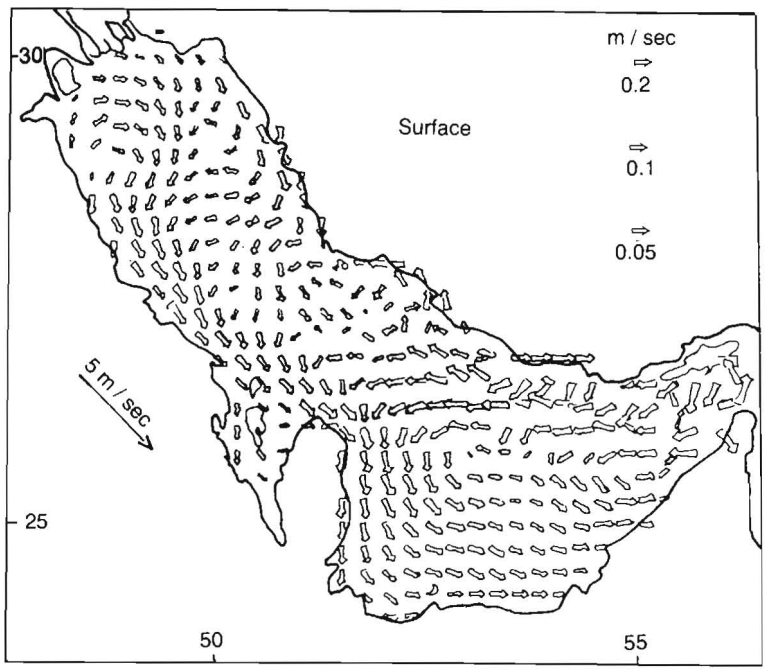

Fig. 4. Circulation of surface water in the Arabian Gulf (after Hunter 1983)

The surface current speed in the Qatari waters varied from 4.7 cm/sec. to 58.1 cm/sec., while at 5m depth it has the range 15.7-56.2 cm/sec (Beltagy 1983).

In considering the possible effects of natural and artificial surface films in modifying gas exchange across the air-sea interface, Garrett (1972) found that major release of petroleum hydrocarbons into the marine environment retards the gas exchange. This was evident from the oxygen concentrations in the surface

water of the southern part (Table 1) where the values decrease as the concentration of petroleum hydrocarbons increases ($r=-0.55$). The test of significance of the slope proved to be significant at the 95% confidence level.

Based on 58 observations recorded in the whole Gulf areas (Table 4) the average concentration of petroleum hydrocarbons was found to be 46.6 $\mu g\ l^{-1}$. The estimated volume of the Gulf water is 7910 km^3. These data enables us to calculate the total concentration of petroleum hydrocarbons dissolved in the Gulf waters which was found to be 406×10^3 tons. This value is higher by 2.7 times than the estimates of Golob and Brus (1984) for the oil pollution in the Gulf during 1985 from natural seeps, offshore production, tanker transport, etc. In addition to that, a strong correlation ($r=0.67$) exists between the levels of petroleum hydrocarbons in sea water and the oil production of the Gulf countries, Qatar, U.A.E., Saudi Arabia, Kuwait, Bahrain and Oman.

Table 4. Concentration of petroleum hydrocarbons ($\mu g.l^{-1}$) in different sea water areas and the average oil production (million barrels/year) of the Arabian Gulf countries during 1984 (Cooper 1986)

Area	Average oil production	Concentration		n[1]	References
		Range	average		
Qatar	137	7.7-373	81	11	Present study
		1.2-428	45.9	8	El Samra *et al.* (1986)
UAE	419	11-32	21.4	8	The present study
		0.1-30	7.6	6	IAEA (1985)
Saudi Arabia	1675	4.3-546	111	7	El Samra *et al.* (1986)
Kuwait	413	2.1-3.6	3.0	4	El Samra *et al.* (1986)
Bahrain	18.5[2]	0.4-5.7	1.7	6	IAEA (1985)
Oman	153	0.3-455	58.6	8	IAEA (1985)

n[1] Number of Samples
2 Average oil production of Bahrain was obtained by personal communication (Private source)

Conclusion

On the basis of the present discussion it seems that both Kuwait crude oil and Qatar crude oil from Dukhan, preferably the former, can be used as a reference standard for estimating petroleum hydrocarbons in the Gulf sea water.

The concentration of petroleum hydrocarbons in the sea water of the southern part of the Gulf showed values which are not exceptionally high in comparison with

other areas in the world's oceans. On the other hand, very high levels were recorded at those sites of oil production and exportation which are subject to frequent spills.

The petroleum hydrocarbon levels of sea water increase as the oil production of the Gulf countries increases.

The concentration of dissolved oxygen showed negative correlation with petroleum hydrocarbons in the sea water of the southern part of the Gulf area.

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توزيع الهيدروكربونات البترولية الذائبة في منطقة جنوب الخليج العربي

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خلال الفترة من ١٧ إلى ٢٦ أيلول (سبتمبر) ١٩٨٥م تم جمع عينات ماء بحر من ١٩ محطة من جنوب الخليج العربي، ٨ منها تقع في مياه الامارات العربية المتحدة و٧ محطات في المياه القطرية. وقد تم ذلك باستخدام سفينة الأبحاث القطرية «مختبر البحار»، بالإضافة إلى ٤ محطات جمعت حول جزيرة حالول في المياه القطرية باستخدام لنش صغير.

وقد جمعت العينات تحت السطح مباشرة على عمق متر واحد وكانت سعة كل عينة حوالي ٢,٨ لتر. واستخدم في تعيين تركيز الهيدروكربونات البترولية جهاز التحليل السبكتروفلورمتري (تيرنر ٤٣٠) وباستخدام أربعة محاليل قياسية من البترول الخام الكويتي، القطري من منطقة دخان وحالول وكذلك من الكريسين وذلك لتقييم أحسن محلول قياسي من هذه الزيوت يمكن استخدامه في منطقة الخليج العربي.

وقد اتضح من الدراسة أن الهيدروكربونات البترولية المقاسة تختلف في تركيزاتها معتمدة على المحلول القياسي المستخدم. فهي تقع في الحدود (٧,٧ ـ ٣٢)، (٩,٨ ـ ٤٠,٥)، (٢٠,٢ ـ ٨٣,٥)، (١٢,٤ ـ ٥١,١) . . . . . ميكروجرام/لتر عندما استخدم البترول الخام الكويتي والقطري من دخان وحالول وكذلك الكريسين كمحاليل قياسية.

أما العينات التي جمعت حول شواطىء جزيرة حالول فقد كانت تركيزاتها مرتفعة جدا. وقد كانت التغيرات في النتائج باستخدام المحاليل القياسية سالفة الذكر هى بنسبة ١ : ١,٢٦ : ٢,٦ : ١,٥١، وباستخدام نتائج البحوث التي أجرتها هيئة

IAEA (معمل النشاط الاشعاعي البحري العالمي بموناكو) عام ١٩٨٥م في مياه البحرين والامارات العربية المتحدة وعمان، وباستخدام محاليل قياسية من بترول الكويت والكريسين وزيت وقود كانت نسبة التركيزات ١ : ١ : ١١.

وعلى هذا يمكن استنتاج أن تعيين تركيزات الهيدروكربونات البترولية يتغير تبعا لنوع الزيت المستخدم كمحلول قياسي وأن أحسن طريقة للمقارنة بين نتائج تركيزات الهيدروكربونات البترولية في الخليج العربي هي باستخدام محلول قياسي واحد لكل المنطقة.

وعلى هذا الأساس يمكن استخدام زيت البترول الكويتي كمحلول قياسي في الخليج كله وكذلك زيت البترول القطري من دخان لاقتراب نتائج كل منهما من الآخر.

واعتمادا على زيت البترول الكويتي كمحلول قياسي تبين أن تركيز الهيدروكربونات البترولية الذائبة في منطقة الجنوب بين قطر والامارات يتراوح بين ٧,٧ إلى ٣٢ ميكروجرام/ لتر وأن متوسط التركيز في المياه القطرية منخفض عن مياه الامارات بمقدار ١,٤ ميكروجرام/ لتر.

وخلاف لذلك كانت تركيزات العينات التي جمعت حول جزيرة حالول مرتفعة جداً (٦٩ ـ ٣٧٣ ميكروجرام/ لتر) ويعزى هذا الارتفاع إلى إنسياب البترول في هذه المنطقة حيث أنها من مناطق انتاج وتصدير النفط.

وباستبعاد نتائج مناطق انتاج وتصدير البترول في المنطقة (جزيرة حالول) فإن التركيزات الموجودة في المنطقة ليست مرتفعة كثيرا عن مناطق أخرى من العالم.

وقد بيّنت الدراسة أيضا أن دخول البترول إلى البيئة المائية يقلل من عملية تبادل الغازات خلال الطبقة السطحية وهذا ما كان واضحا من انخفاض تركيز غاز الأوكسيجين الذائب في الطبقة السطحية نتيجة لزيادة تركيز البترول وقد كان معامل الارتباط بينهما (ر = - ٠,٥٥) متوسط.

وفي هذا البحث حسبت كمية الهيدروكربونات البترولية الذائبة في الخليج كله ووجدت تساوي ٤٠٦ × ١٠^{٣} طن. وهذه القيمة تعادل ٢,٧ قدر القيمة التي أوجدها الباحثون للتلوث بالبترول نظريا للمنطقة. بالاضافة إلى أنه قد وجد ارتباط قوي (ر = ٠,٦٧) بيم التلوث بالبترول في كل منطقة وبين الانتاج الكلي لكل دولة من دول الخليج: قطر، الامارات، السعودية، الكويت، البحرين وعمان.