Qatar Univ. Sci. J. (1995), 15 (1): 215 - 221

MARINE ALGAE AS BIOINDICATORS OF POLLUTION LEVELS IN THE ARABIAN GULF

By

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الطحالب البحرية ككاشفات حيوية لمستويات التلوث في الخليج العربي

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التوزيع المكثف لعدد من الطحالب البحرية في الخليج يلعب دوراً كبيراً في استخدامها ككاشفات حيوية لرصد تركيزات بعض الملوثات في المنطقة . وتوضح الدراسة الحالية أهمية تواجد وانتشار بعض أجناس الطحالب في تقدير مستويات بعض الفلزات الثقيلة والهيدروكربونات البترولية حول السواحل القطرية والسعودية . أبرزت النتائج تراكم تلك الملوثات في هذه الأجناس بصورة واضحة وكذلك امكانية تطبيق برنامج رصد مكثف مشابه في أماكن أخرى بمنطقة الخليج . كما ألقت الدراسة الضوء على أهمية التخلص الطبيعي من الملوثات البحرية عند انجراف الطحالب بعد موتها بكميات كبيرة على شواطئ المنطقة .

Key Words: Algae, Bioindicator, Metals, Hydrocarbons, Concentration factor, Arabian Gulf.

ABSTRACT

The extensive distribution of several marine macroalgal species makes them a potential bioindicator tool for monitoring existing levels of different types of marine pollutants in the region. The present work illustrates the importance of a few widely distributed species of marine algae in depicting the levels of some toxic heavy metals and hydrocarbons along the Qatari and Saudi Arabian shores. Results indicate a strong bioaccumulation potential in these species for both heavy metals and hydrocarbons. A similar monitoring scheme using these identified species could very well be extended to other areas in the Gulf in order to form a comprehensive monitoring plan for the region. This field study also highlights the potential for removal of pollutants by algae as they are washed ashore in large quantities in the region.

INTRODUCTION

The use of biological indicator organisms is a very attractive tool toidentify and demarcate areas of aquatic contamination [1]. Some of these organisms not only accumulate certain contaminants from the surrounding milieu, allowing inexpensive and relatively simple contaminant analysis, but they may also represent a moving time-averaged or integrated value of the relative biological availability of these chemicals at each site studied. However, the use of indicator organisms introduces biological variables which are not present in physico-chemical studies of water or sediments. These variables merit consideration in as much as they affect the result of indicator surveys for trace pollutants like metals and hydrocarbons [2].

It was mainly the capability of certain bivalves to bioconcentrate some priority pollutants, where concentration factors of several orders of magnitude higher than the ambient environment were noticed, and the cheap and relatively easy analytical techniques employed that a global "Mussel Watch Program" was initiated in 1976 [3]. This program, though being very successful world wide, left certain areas, like the Arabian Gulf where natural populations of an ideal bivalve were scanty and uneven, unrepresented in terms of the use of an ideal indicator organism for monitoring studies. The semi-enclosed nature of this water body and the peculiar environmental conditions of not only high temperature and salinity, and also petroleum exploration and exploitation processes which have increased the pace of industrialization along the west coast, has rendered this area very susceptible to the dangers of pollution. Recent events like the Nowruz spill and the Gulf War oil spills are a few examples of the dangers of environmental disasters that this area can be subjected to. Thus, it is felt that there is a real need for an ideal bioindicator organism which fulfills the major requirements and is widespread in its distribution.

With this in mind, attention was drawn to the use of macroalgal species in the Arabian Gulf in depicting pollution levels at various coastal sites. The recent Gulf War oil spill of 1991 offered an opportunity to investigate two different sites affected to a great extent by the spill; one along the southeastern coast of Saudi Arabia (i.e. Tanagib, Abu Ali and Jubail) and the other along the entire coast of Qatar.

Total aromatic hydrocarbons and some heavy metals were analyzed in macroalgae collected from these sites with a view to determine the state of the environment in these areas, especially before and after the oil spill. Our study was also useful for determining the potential of these macroalgal species to bioaccumulate these pollutants to levels which could render them ideal biological indicators. This objective assumes greater importance since these macroalgal species are widely distributed all along both coasts of the Gulf as has been reported by several authors [4-8].

MATERIAL AND METHODS

Samples from the Saudi and Qatari coasts were collected from areas shown in Figure.1. Utmost care was taken to avoid contamination and samples were deep frozen immediately after collection. Before analysis, samples were thawed, washed with distilled water to remove extraneous material, dried at 50 °C and powdered. Aliquots of the powdered samples were analyzed for heavy metals using the methods described previously [9]. Total aromatics (chrysene equivalent) were analyzed using a modified method [10]. The methods used were tested by analyzing TORT-1 Reference Material from NRC Canada for heavy metals while for total aromatics, ROPME and IAEA Monaco Reference Materials was used. Recoveries ranged from 89 to 98% for heavy metals and were more than 97% for total aromatics. Coefficients of variation for all analyses ranged between 3 and 13%. Data for dissolved and dispersed hydrocarbons as well as for heavy metals concentrations in sea water were used to calculate concentration factors for the algae inhabiting the Qatari coast (Kureishy, unpublished data).

RESULTS AND DISCUSSION

Total aromatics were determined as chrysene equivalents in several species from Qatari intertidal zones as well as in those from Abu Ali and Tanagib areas along the Saudi Arabian coast. Samples from the Qatari coast have been divided into three time periods i.e. pre-spill, spill and post Gulf War spill periods. As can been seen from Table 1, the pre-spill total aromatics levels were very low, but they increased several fold during the spill time (period referred here as February 25 to April 10, 1991) although the dissolved/dispersed values of total aromatics did not show any significant increase during this period. In fact, dissolved/ dispersed petroleum hydrocarbons values monitored fortnightly for a two year period (October 1989-December 1991) along the Qatari shores showed a narrow range of 13 - 18 µg/l in the majority of the areas with no significant increase attributable to the Gulf War oil spill (Kureishy, unpublished data). However, this trend is not evident for total aromatic levels in algae (Table .1). The levels during the pre-spill were low (average 0.024 µg/g; range 0.007 - 0.04 µg/g), but they increased several orders of magnitude during the spill period (average 0.77 µg/g; range 0.46 - 1.21 µg/g). The levels did show a marked decrease during the post spill period with an average of 0.34 µg/g (range 0.13 - 0.62 µg) which , though high, are much lower than the levels measured during the spill. The levels for total aromatics show a significant bioaccummulation potential in macroalgae even though the dissolved concentrations did not change significantly. This increase could be attributable to an input of some dissolved fractions in between sampling periods for the dissolved/dispersed fractions.

Total aromatics were also analyzed in three most common species of macroalgae from three different localities along the Saudi Arabian coast (Figure 1). The sampling period was roughly one year after the spill (March 1992), and the areas covered were Tanagib, Abu Ali and its inner bays where the maximum impact of the spill was felt. In addition, an area south of Abu Ali Island (Jubail), where the impact of the spill was minimal, was also sampled. It is interesting to note that levels of total aromatics in these three macrolalgal Species varied significantly between the three areas (Table 2). It is evident that the highest levels were recorded in macroalgae around Abu Ali and inner bays where submerged oil spill leaches into the overlying waters. Tanagib samples showed lower values mainly because of the fact that this area is open and is easily flushed. South of Abu Ali, algae displayed the lowest value which are similar to pre-spill levels recorded along the Qatari coast,

Some heavy metals were also analyzed in macroalgae collected from the same locations. It is important to mention here that all three areas have different environmental characteristics and peculiarities which have a very significant effect on the heavy metal levels found in the algae. Table 3 depicts the values of Hg, Cd, Pb, Cu, Co and Ni in the three areas along the Saudi Arabian coast. it is interesting to note that while there is no significant difference

Table 1
Total hydrocarbons (chrysene equivalent μg/g dry wt.) in marine algae and seaweeds collected from Oatari Beaches

SPECIES	location	pre-spill oct-dec 90	spill feb 91	post - spill march 92
Sargassum binderi	Umm Said	0.007	0.73	0.42
S. heteromorphum	Umm Said	0.023	0.89	0.36
Cystoseira myrica	Umm Said	0.031	-----	0.39
S. binderi	Al-Wakra	0.017	0.67	0.29
C. indica	Al-Wakra	0.040	-----	0.27
S. heteromorphum	Al-Gharya	0.025	0.46	0.13
S. binderi	Al-Gharya	0.034	1.09	0.62
Hormophsa triquetra	Al-Gharya	0.180	0.73	0.38
C. indica	Al-Gharya	0.022	0.48	0.16
S. boveanum	Al-Gharya	0.035	----	----
Cystophyllum sp.	Al-Shamal	0.032	----	----
S. heteromorphum	Al-Shamal	0.029	1.21	0.62
H. triquertra	Al-Shamal	0.025	0.59	0.18
S. binderi	Al-Shamal	0.022	0.83	0.35
H. triquetra	Zikreet	0.150	----	----
H. triquetra	MH. Zikreet	0.017	----	----
H. triquetra	10 km N Zikreet	0.025	-----	----
H. triquetra	Dohat Al Hussain	0.017	----	----
H. triquetra	Umm Bab	0.028	0.68	0.32
H. triquetra	7km N umm Bab	0.026	----	----
H. triquetra	Al -Sarriya	0.026	----	----
H. triquetra	Dukan	0.028	0.76	0.39
H. triquetra	N Salwa	0.013	----	----
H. triquetra	S Salwa	0.022	0.91	0.29

Table 2
Total aromatic hydrocarbons in macroalgae fromTanagib, Abu Ali and south of Abu Ali Island (Saudi Arabia), March 1992.

location	species	total aromatic hydrocarbon (μg/g dry wt.)
TANAGIB		
	Sargassum binderi	0.210
	Hormophysa triquetra	0.170
	S. boveanum	0.097
	Seagrass (unidentified)	0.046
ABU ALI AND INNER BAYS		
	Sargassum binderi	0.430
	Hormophysa triquetra	0.330
	Seagrass (unidentified)	0.084
ABU ALI SOUTH (JUBAIL SIDE)		
	Sargassum binderi	0.019
	Hormophysa triquetra	0.012
	S. boveanum	0.009

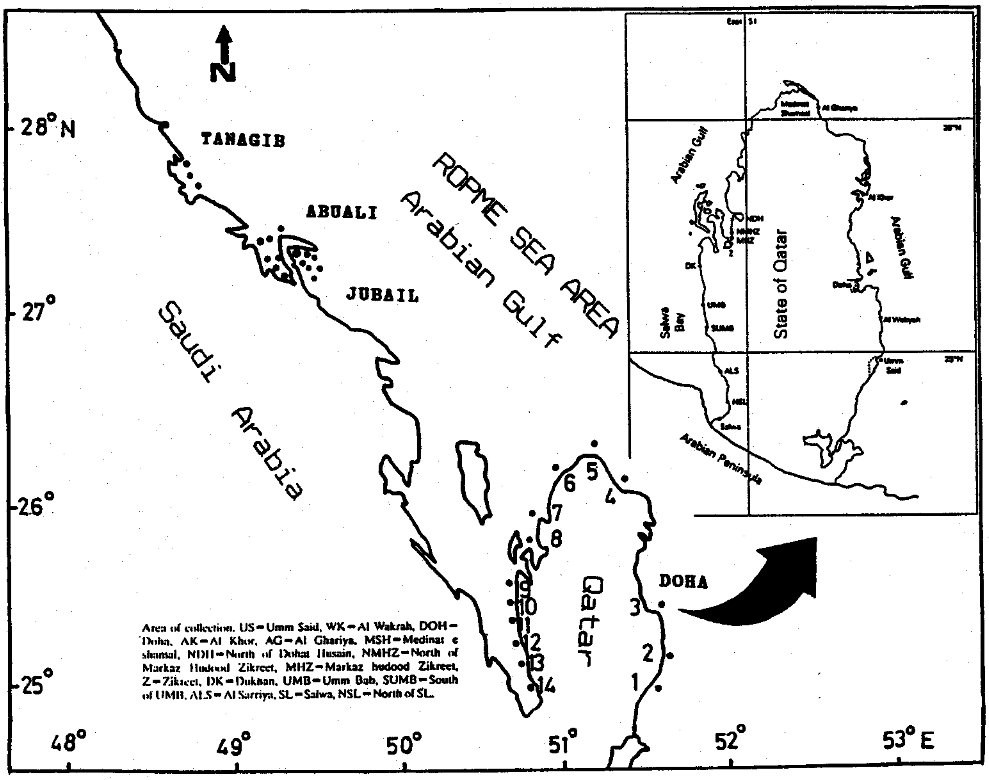

Fig. 1: Map of ROPME Sea Area (Arabian Gulf) Showing the sampling sites.

between the levels found in algae from the Tanagib and Abu Ali areas, samples from south of Abu Ali showed a marked increase in the levels of almost all the heavy metals. It is quite clear that these values are influenced largely by the outfalls of the city of Jubail which is heavily industrialized. It is also note worthy that no influence of the oil spill was evident from the levels measured at the other two sites, viz. Abu Ali and Tanagib, sampled in March 1992. A follow-up study of these heavy metals in the three macroalgal species from Qatar also showed interesting trends (Table 4). Around the industrial site at Umm Said and near the capital city of Doha, concentrations of practically all the heavy metals are higher compared to those from Al-Ghariah and Madinat Al -Shamaal which are non-industrial and non-urban areas. However, slightly higher values for practically all metals are observed in Dukhan (an important oil producing area) and Salwa areas for one species of macroalgae. The two sites are in Salwa bay, a semi-enclosed water body influenced by oil exploration activities. Our results clearly demonstrate the bio-accummulation efficiency of these macroalgae for depicting environmental levels of contaminants and more specifically the heavy metals.

Concentration factors were computed using measured levels of dissolved heavy metals and petroleum hydrocarbons. While the concentration factors for total aromatics are generally low reaching a maximum of 50, the factors for heavy metals are generally very high (Table 5). Concentrations factors near industrial and/or urban areas were significantly higher than those observed for samples collected from areas located away from land discharge. Concentration factors could not be established for algae from the Saudi coasts since corresponding concentrations of total aromatics and heavy metals in water are not available for that region.

As mentioned above, several species of macroalgae are widely distributed throughout the Gulf ranging in habitat from the lower intertidal to sub-littoral zone. Until the 1970's, macroalge were widely used in pollution surveys [2,11-13] at which time the Mussel Watch Program stressed the importance of using bivalves in monitoring programs. It is important to note that while bivalves accumulate both dissolved and particulate loads of pollutants, thus giving a measure of total pollutant levels in the waters, macroalgae species respond primarily to dissolved or soluble species of pollutants in the surrounding milieu. The present study advocates the need for renewed interest in macroalgae to be used in pollution monitoring programs, especially those in the Gulf (termed the ROPME Sea Area) as there is at present a limited program in having a Mussel Watch (bivalve) type program in this region. This is partly because of the patchy distribution of bivalve resources along the Gulf coasts and more specifically the lack of a single bivalve species which is found throughout the region to be used as an indicator species. Thus macroalgae species like e.g. Sargassum may be an excellent substitute due to their widespread distribution in the Gulf. Several species

Table 3
Selected heavy metals (µg/g dry wt.) in macroalgae from tanagib, Abu Ali and south of Abu Ali island, Saudi Arabia (March 1992)

SPECIES	Hg	Cd	Pb	Cu	Co	Ni
			TANAGIB			
S B	0.083	0.72	0.93	2.21	0.19	0.97
H T	0.096	0.61	0.81	1.95	0.31	1.27
S BV	0.088	0.81	1.07	1.68	0.22	1.17
S G	0.035	0.48	0.76	1.09	0.17	0.93
			ABU ALI AND INNER BAYS			
S B	0.077	0.68	0.87	1.39	0.21	1.13
H T	0.088	0.75	0.99	1.26	0.27	0.79
S G	0.062	0.33	0.64	0.98	0.13	1.17
			SOUTH OF ABU ALI (JUBAIL			
S B	0.19	1.21	1.66	1.75	0.38	1.19
H T	0.24	1.07	1.37	2.31	0.27	1.32
S BV	0.33	1.37	1.41	2.64	0.52	1.03
S G	0.09	0.88	0.83	1.38	0.31	0.87

SB = *Sargassum binderi* HT = *Hormophysa triquetra*
SBV = *Sargassum boyeanum* SG = *Sea grass* (unidentified).

Table 4
Concentrations of selected heavy metals (µg/g dry wt.) in macroalgae from the Qatari Coast (Oct. 1990 - March 1992)

SPECIES	Location	Hg	Cd	Pb	Cu	Co	Ni
S B	UM	0.130	1.38	1.98	4.12	0.42	2.92
	DH	0.093	1.12	2.25	3.89	0.55	4.35
	GH	0.062	0.63	1.01	3.45	0.21	1.12
	MS	0.048	0.58	0.86	4.12	0.18	1.30
H T	UM	0.187	1.21	1.63	4.89	0.56	2.48
	DH	0.108	1.07	1.74	4.32	0.72	6.18
	AG	0.037	0.84	1.02	3.78	0.31	2.37
	MS	0.042	0.68	0.87	3.18	0.33	1.83
	DK	0.093	0.97	1.32	4.41	0.41	5.22
	SW	0.076	0.83	1.11	3.72	0.33	3.85
S BV	UM	0.099	1.81	1.23	4.95	0.47	5.17
	DH	0.110	1.28	1.44	4.56	0.52	8.02
	AG	0.052	0.94	0.80	3.21	0.28	2.16
	MS	0.033	0.54	0.81	2.62	0.19	3.12

SB = *Sargassum binderi* HT = *Hormophysa triquetra*
SBV = *Sargassum boveanum*
UM = UMM SAID DH = DOHA AG = AL-GHARIYA
MS = MADINAT AL-SHAMAL DK=DUKHAN SW=SALWA

Table 5
Concentration factors for Hg. cd and Pb in selected species of macroalgae from the Coast of Qatar

species	location	Hg	Cd	Pb
S. binderi	UMM SAID	6500	69000	26500
S. binderi	DOHA	5000	56000	30000
S. binderi	M. SHAMAL	2500	30000	13500
H. triquetra	UMM SAID	9000	60500	21700
H. triquetra	DOHA	5500	53500	23200
H. triquetra	M. SHAMAL	2000	37500	12600
H. triquetra	DUKHAN	4700	48500	17600
S. boveanum	UMM SAID	5000	90500	16500
S. boveanum	DOHA	5500	64000	19000
S. boveanum	M. SHAMAL	2000	35000	10800

S = *Sargassum* H = *Hormophysa*

can be identified as having a uniform distribution in sensitive locations in the ROPME Sea Area and, most importantly, some have shown a high concentration factors and good potential for bioaccummulation of heavy metals and, to some extent, total aromatics.

In addition, it is worth mentioning that these macroalgal species are washed ashore in huge quantities along the coast of the Arabian gulf . Preliminary estimates of the amounts deposited on some Qatari beaches range from several hundred kilograms to several tons per month. Given the existing concentrations of heavy metals and total aromatics, associated with algae, such detrital transport could be an effective way of accelerating the natural removal of dissolved contaminants from the Gulf water. However, accurate figures on depositional rates are required to make a viable and accurate estimate of this removal mechanism.

ACKNOWLEDGMENTS

We thank Prof. Ibrahim S. Al-Naimi; former Dean of the Faculty of Science; and at present The President, University of Qatar for his interest and support throughout this study. We would also record our thanks to Dr. Abdullah Al-Kobaisi; Dean, Faculty of Science, for his encouragement and help. Thanks are also due to Mr. Kamal Al-Deeb for his assistance with some hydrocarbon analyses.

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