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Pinctada radiata (Pearl Oyster): A Bioindicator for Metal Pollution Monitoring in the Qatari Waters (Arabian Gulf)

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Bivalves are extensively used in monitoring programmes in the marine environment due to their ability to concentrate pollutants to several orders of magnitude above ambient levels in sea water. Commonly, the levels of contaminants accumulated in the tissues has been used to indicate the degree of chemical contamination in the environment.

Trace metals are the main sources of metals toxicity in the marine environment by entering the food chain and thus affecting the ecosystem. The marine ecosystem off Qatar has been recently subjected to the direct release of urban and industrial runoff from major centres. Such inputs are known to contain trace metals which lead to increased metals concentrations in the coastal zone, some of which are toxic and can endanger human health.

A wealth of knowledge exists for heavy metals in bivalves in many areas of the world while little appears for the Arabian Gulf species. In the present study an attempt has been made to analyse the metal accumulation in the abundant bivalve *P. radiata* in order to test its potentiality as sentinel accumulator of heavy metals from the marine environment around Qatar. It could be considered as a first step in developing a regional programme for monitoring metals in the Gulf environment.

MATERIALS AND METHODS

Eight Qatari pearl oyster beds were visited during 1992-1993 (Figure 1) namely Palm Island (PI), Doha Harbour (DH), Al-Edd, Al-Gharby (AG), Umm Al-Ezzam (UZ), Ras Laffan (RL), Umm Al-Orooq (UO); all located between longitudes 25° 01' 30" N and 25° 56' 19" N and latitudes 51° 39' 26" E and 52° 28' 91" E. Two more beds were sampled around Halul island (HI) and opposite Messaieed industrial area (MS) (Figure 1). The first two beds lie in the intertidal area. Oysters population densities in these beds were about 85 ind./m^2 for Palm island, between 60 ind./m^2 and 55 ind./m^2 for Ras Laffan and Umm Al-Ezzam beds, 114 ind./m^2 for Al-Edd Al-Gharby, 41 ind./m^2 for Umm Al-Orooq. Off Messaieed industrial area, receiving discharge from steel, fertiliser, petrochemical industries as well as oil terminals, few organisms were collected.

Dead beds were observed in Ras Laffan and Doha harbour (17 ind./m^2) which could be due to suffocation of oysters as a result of continuous dredging and ship traffic activities taking place in the area hindering settlement and creation of beds. However, very few live oysters were recorded around Halul island due to the presence of oil pollution resulting from the production and storage of crude oil on the island as well as its proximity to main oil fields. Above the beds temperature ranged between 25 and 29°C, salinity between 40.1 - 44.8 psu, pH between 8.2 and 8.3, and oxygen saturation between 90 and 114%.

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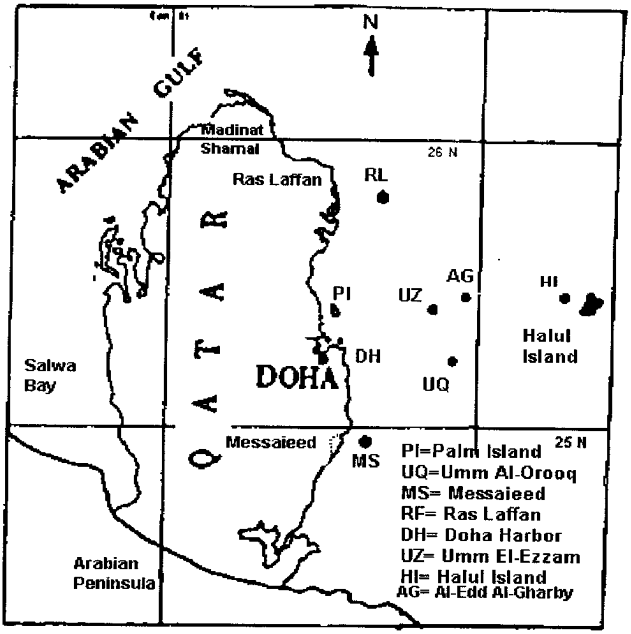

Figure 1. Locations of pearl oyster beds along the Qatari coast

Table 1. Determination of trace metals in oyster tissue NBS 1566 a

Material	Cd	Cu	Pb	Ni	V
	$\mu g\ g^{-1}$				
Oyster 1566a	4.15 ± 0.38	66.3 ± 4.3	0.371 ± 0.014	2.25 ± 0.44	4.68 ± 0.15
This study	4.09 ± 0.40	65.0 ± 3.0	0.38 ± 0.100	2.20 ± 0.39	4.79 ± 0.30

Animals were collected by scuba diving and transported to the laboratory frozen in plastic bags. After taking biometric measurements, specimens were opened and dissected using all acid washed plastic tools over clean PVC sheets. Freeze dried tissue samples were digested in concentrated Aristar HNO_3 at 80°C using teflon beakers (MOOPAM, 1989). The mean dry weight: wet weight ratio was 0.21 as determined for five oysters collected from each location.

Trace metals (Cd, Cu, Pb, Ni and V) were determined in the diluted digests using Graphite Furnace Atomic Absorption Spectrophotometer Model 238 Perkin Elmer with HGA 400 Graphite Furnace. All analysis were carried out in duplicate and the mean value was reported. The accuracy of the determination procedure was assessed by analysing the Oyster Tissue Standard Reference Material NBS 1566a (Table 1). Replicate analyses were carried out to allow assessing precision being 3% for Cd, 5% of Pb, 4% for Cu, 6% for Ni and 8% for V. Detection limits were 5 ng g^{-1} (Cd), 15 ng g^{-1} Cu, 8 ng g^{-1} Pb, 25 ng g^{-1} Ni and 10 ng g^{-1} V. No contamination was detected during analysis as appeared from undetectable metals in blanks.

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For calculations of bioconcentration factors, water samples were collected in acid washed teflon bottles. Bottles were rinsed several times with seawater before use. Sea water was filtered using 0.4 pm acid cleaned nuclepore filters acidified to pH 2.0 and kept frozen at -20°C for analysis. Dissolved metals were determined according to different polarographic techniques using the EG&G PAR 174A Polarographic analyzer in conjunction with a model 303 A SMDE (Anon, 1988). Ni and V were measured using the standard addition technique (Abdel-Moati, unpublished data) while those for dissolved Cu, Cd and Pb were used after Abdel-Moati and Kureishy (1997). Analysis of t-test was applied to check the level of significance site wise.

RESULTS AND DISCUSSION

The size (shell height) categories of fished pearl oyster *Pinctada radiata* are divided into 3 groups: small (SH < 40 mm), medium (SH 40 - 60 mm) and large (SH > 60 mm). Most fished shells were of medium size (Table 2). The average concentration of Cu, Pb, Cd, V and Ni in pearl oyster collected from different locations are presented in the same table. Only a few samples were caught from Messaieed (n = 4) and Halul areas (n = 6), even though these locations were well known producers of this species in the past. For all samples, cadmium was the metal observed in lowest concentrations followed by copper < vanadium < lead < nickel. Cadmium elevated concentrations were observed for oysters caught from Doha harbour and Ras Laffan as well as Messaieed area i.e. averages 0.85 ±0.18 µg g^{-1}, 0.72 ±0.22 µg g^{-1} and 0.61 ±0.09 μg^{-1}, respectively. These locations are subjected to increased dredging activities for harbours expansions and navigational channel deepening during the past five years. These averages are significantly higher ($p < 0.05$) than those observed for other beds which show insignificant difference in between. Increased concentrations of labile and total dissolved Cd were observed by Abdel-Moati & Kureishy (1997) in the bottom water layers opposite these areas rendering the metal more bioavailable to benthic organisms.

On the other hand, the concentrations of Cu were insignificantly different between oysters collected from different locations with an average ranging between 2.13 ± 0.46 µg g^{-1} for Umm Al-Ezzam bed to 3.76 ±0.98 µg g^{-1} around Halul island (Table 2). Eisler (1979) observed that molluscs contained more copper in tissues and soft parts than any other group. He added that some species could exhibit high Cu residues attributed to either proximity to anthropogenic source or to biotic/abiotic factors capable of modifying Cu uptake and retention. The disappearance of Cu variations between beds could reflect the absence of a point source for Cu to the marine ecosystem around Qatar. The concentrations of lead in oysters followed a different pattern. The highest lead concentrations recorded for oysters was 8.64 µg g^{-1} caught from Messaieed marine area. This area receives about 300 x 10^{6} m^{3} of effluent as well as cooling water discharge from the industrial areas harbouring several industries. Elevated Pb concentrations were observed in water (av. 2.04 µg /ℓ), surface sediments (av. 10.84 µg g^{-1}), zooplankton (av. 3.66 µg g^{-1}) and phytoplankton (av. 2.07 µg g^{-1}) collected from this area (Abdel-Moati and Flamarzi, 1996). The significant increase of Pb in specimens collected from Doha harbour bed (average 4.79 ± 1.61 µg g^{-1}) could be related to the presence of the harbour in the close proximity of a main highway, fishing boats and yachts anchorage all of which could be a source for combusted leaded gasoline used as fuel. Except of the high average value recorded for oysters collected near Halul island (Table 2), variations in concentrations between other locations seemed insignificant lying between 2.25 ± 1.01 µg g^{-1} for Umm Al-Orooq to 3.15 ± 0.89 µg g^{-1} near Palm Island.

Table 2. Mean and standard deviation of different metal concentrations in Pearl oyster *P. radiata* (µg g^{-1} dry wt) collected from the coastal waters of Qatar (n = number of samples).

LOCATION		Shell height (cm)	Trace Metals				
			Cu (µg g^{-1})	V (µg g^{-1})	Pb (µg g^{-1})	Cd (µg g^{-1})	Ni (µg g^{-1})
Palm Island (n = 14)	(PI)	5.2 – 7.4	3.57 ± 1.25	2.7 ± 0.74	3.15 ± 0.89	0.41 ± 0.07	4.94 ± 0.83
Doha Harbour (n = 19)	(DH)	4.2 – 6.9	3.05 ± 1.94	5.6 ± 0.31	4.79 ± 1.61	0.85 ± 0.18	6.18 ± 1.96
Al-Edd Al-Gharby (n =21)	(EG)	4.9 – 6.7	2.2 ± 0.37	1.75 ± 1.66	1.74 ± 1.01	0.30 ± 0.14	4.72 ± 1.43
Umm Al-Ezam (n = 21)	(UZ)	5.2 – 7.7	2.13 ± 0.46	3.44 ± 1.94	1.43 ± 0.81	0.34 ± 0.12	3.88 ± 1.75
Ras Laffan (n = 16)	(RL)	3.9 – 6.3	2.44 ± 1.10	2.34 ± 1.39	2.96 ± 1.28	0.72 ± 0.22	7.54 ± 0.86
Umm Al-Orooq (n = 17)	(UQ)	5.2 – 6.4	2.12 ± 0.79	1.89 ± 0.28	1.25 ± 1.01	0.32 ± 0.16	4.95 ± 1.76
Halul Island (n = 6)	(HI)	4.9 – 6.1	3.76 ± 0.98	8.13 ± 2.01	5.59 ± 0.93	0.43 ± 0.28	13.2 ± 2.41
Messaieed (n = 4)	(MS)	5.3 – 5.8	3.11 ± 1.03	7.32 ± 2.26	7.17 ± 1.47	0.61 ± 0.09	11.23±1.50

Table 3. Range and/or mean concentrations of different metals (µg g^{-1} d wt) in oysters from the Gulf region

Location	**Cu** (µg g^{-1})	**V** (µg g^{-1})	**Pb** (µg g^{-1})	**Cd** (µg g^{-1})	**Ni** (µg g^{-1})	**Reference**
Bahrain (91/92)	0.4 – 3.4 (1.52)	-	1.25 – 14.0 (6.75)	0.25 – 3.8 (1.65)	0.2 – 8.95 (3.25)	Al-Sayed *et al.* (1994)
Bahrain (91)	3.3 – 4.6	1.0 – 1.9	0.32 – 3.9	3.9 – 9.9	0.44 – 1.24	Fowler *et al.* (1993)
UAE (83)	-	-	-	11 - 34	-	Fowler (1985)
UAE (91)	3.0	1.24	0.14	11.1	1.64	Fowler *et al.* (1993)
Oman** (91)	20 - 165	0.34 – 2.3	0.08 – 0.37	4.9 – 15.3	0.41 – 1.69	Fowler *et al.* (1993)
Saudi Arabia* (91)	16	1.4	0.43	0.66	2.6	Fowler *et al.* (1993)
Kuwait (90)	0.38 – 2.29	-	0.44 – 0.64	0.77 – 1.93	0.96 – 1.33	Bou-Olyan *et al.* (1995)
Kuwait (92)	1.01 – 1.18	-	10.68 – 18.66	1.85 – 3.16	0.94 – 1.33	Bou-Olyan *et al.* (1995)
Permissible limit	10	1.0	2.0	2.0	2.0	GESAMP (1991), UNEP/FAO/WHO 1988
Australia	17.6 – 58.3	-	nd – 1.9	0.25 – 0.78	0.49 – 2.6	Peerzada & Dickinson (1989)
Qatar	2.79 ± 0.99	4.14 ± 1.32	3.88 ± 1.12	0.49 ± 0.16	7.08 ± 1.57	Present study

* *Malleus regula* ** Rock oyster = *Saccostrea cucullata*

Table 4. Bioaccumulation factor (metal concentration in tissue mg kg^{-1} dwt/metal concentration mg l^{-1} in sea water) for *P. radiata* collected from Qatari waters.

Location	**Trace Metals**				
	Cu	**V**	**Pb**	**Cd**	**Ni**
Palm Island	1785	1688	2423	2158	2744
Doha Harbour	1326	2745	2482	4473	4414
El-Edd Al-Gharby	2444	2917	12429	4286	9077
Umm Al-Ezzam	2130	4914	8938	3090	6467
Ras Laffan	1627	1950	9864	973	4435
Umm Al-Orooq	2356	3150	6250	3556	9167
Halul Island	2212	1452	12590	1194	3000
Messaieed	1944	1772	5975	2033	2955

Vandium and Nickel concentrations in oysters increased significantly several times in *P. radiata* collected from areas affected by oil loading activities eg. Halul island (av. 13.2 ± 2.41 µg g^{-1} Ni and 8.13 ± 2.01 µg g^{-1}V), Messaieed (av. 11.23 ± 1.53 µg g^{-1}Ni and 7.32± 2.26 µg g^{-1}V). Other areas exhibited significantly ($p < 0.01$) lower averages (Table 2) though insignificant differences appeared in between.

According to the guidelines set by GESAMP (1991) and UNEP/FAO/WHO (1988) oysters could be considered unfit for human consumption.Due to their high retention of V and Ni. However, Pb values are higher or close to permissible recommended concentrations (Table 3).

The ability of oysters to accumulate metals to several orders of magnitude higher than background medium has been reported by Forstner and Wittmann, 1983; Talbot, 1985. Higher metal contents were observed along Indian ocean coasts in relation to low pH and salinity and increase in the precipitated form of metal (Bryan & Uysal, 1978). Al-Sayed *et al.* (1994) attributed the increased concentrations of metals in oyster flesh to the rise in temperature leading to increased filtration and feeding rates of filter feeding oysters. However, despite the variations in salinity during the present study, bioaccumulation of metals occurring in *P. radiata* seems to be more affected by manmade activities rather than environmental factors. This could be supported by the fact that concentrations of metals showed a decreasing trend with increasing distance from land based activities, suggesting that such activities may have enhanced metal bioaccumulation in oysters.

Comparing metal concentrations in oysters in this study with those collected from other sampling areas in the Gulf revealed generally that V, Pb and Ni concentrations are higher than other Gulf regions while those of Cu fall within those observed off Bahrain and UAE but lower than those recorded off Saudi Arabia and Oman. Cd levels were remarkably lower than other Gulf samples.

Metal concentrations in oysters reflected the variations of their concentrations in water. A highly significant correlation appeared with Pb ($r = 0.963$, $p < 0.001$), Ni ($r = 0.843$, $p < 0.05$), V (0.793, $p < 0.05$), Cd (0.771, $p < 0.10$) and Cu ($r = 0.684$, $p < 0.2$). Inter-elemental associations in oysters were investigated showing strong correlations ($p < 0.0001$) between Ni and V from one hand and Cd and Pb from the other, though with less magnitude ($p < 0.05$). This could to a great extent reflect their common sources. Sadiq *et al.* (1992) suggested that bioaccumulation of some metals by clams may be influenced by others in the tissue.

Metals are concentrated in organisms to detectable levels where accumulated doses reflect the bioavailable form of the metal. Their concentration in tissue of organisms depends on the
exposure to metal level in a particular environment either in water or sediment. No significant differences were observed for metal concentrations in water between Al-Edd Al-Gharby, Umm Al-Ezzam and Umm Al-Orooq locations i.e. average 0.9 µg kg^{-1} Cu, 0.6 ± 0.11 µg kg^{-1} V, 0.14 µg kg^{-1} Pb, 0.08 µg kg^{-1} Cd and 1.2 ± 0.3 µg kg^{-1} Ni. However, elevated concentrations of vanadium appeared around Halul island 5.6 µg kg^{-1}, Messaieed area 4.13 µg kg-1 and Doha harbour 2.04 µg kg^{-1}. Lead was also high in these locations ranging between 0.44 - 1.93 µg kg^{-1} while Cd was significantly high around Ras Laffan (av. 0.74 µg kg^{-1}, Doha harbour (av. 0.59 µg kg^{-1}) and around Halul island (av. 0.36 µg kg^{-1}). The concentrations of Ni were characteristically elevated ($p < 0.001$) around Halul island (av. 4.4 µg kg^{-1}) and Messaieed area (av. 3.8 µg kg^{-1}). The bio-concentration factor K_b (metal concentration in soft tissue as mg kg^{-1} d wt/ metal

concentration as mg ℓ^{-1} in seawater) was calculated for different locations (Table 4). The K_b values for Pb were high reaching about 10 -12 folds higher concentrated than Cu and V specially near Halul island. This bioaccumulation factor in oysters generally decrease in the order Pb > Ni > Cd > V > Cu. This could be related to their ability to pass through membranes and stored in lipids.

From the present study it is apparent that *P. radiata* possesses the requisites to be used as a bioindicator for metal pollution monitoring programmes in the Gulf. They are widely distributed, dominant, having benthic existence, relatively long life cycles and good response to wide range of environmental changes. They are easily identified and abundant under favourable conditions facilitating quantitative analysis. Oysters are suspension feeders pumping and filtering sea water at a rate of >4 litre hr^{-1} thus increasing their exposure time to different types of contaminants. Although previous studies proved no clear seasonality in the discharge of pollutants from landbased sources to the coastal zone, information on the seasonality of pollutants accumulation could be of importance in designing future monitoring programmes, for better understanding of metal variations in the area. Recent attempts are focused on transplanting and caging these organisms at several sites of interest.

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REFERENCES

Abdel-Moati MAR, Flamazi M (1996) Accumulation of lead in Messaieed marine area (Qatar) Arabian Gulf. Fresenius Environ Bull 5:196-201.

Abdel-Moati MAR, Kureishy T (1997) Dissolved copper, cadmium and lead in the coastal waters of Qatar (Arabian Gulf). Ind J Mar Sci 26 (2):143-149

Al-Sayed, H.A.; A.M. Mahasneh, and J. Al-Saad (1994). Variations of trace metal concentrations in seawater and Pearl Oyster *Pinctada radiata* from Bahrain (Arabian Gulf). Mar Pollut Bull, 28 : 370-374.

Anonymous (1988) Methods for the examination of waters and associated materials. University of Liverpool, Oceanography Laboratory, Liverpool L693BX, UK, p 144.

Bou-Olyan AH, Al-Mater S, Al-Yakoob S, Al-Hazeem S (1995). Accumulation of lead, cadmium, copper and nickel by pearl oyster *Pictada radiata* from Kuwait marine environment. Mar Pollut Bull 30:211-214.

Fowler S (1985) Coastal baseline studies of pollutants in Bahrain, UAE and Oman. Regional symposium for the evaluation of marine monitoring and research programmes. Al Ain, UAE, 1985.

Fowler S, Rendman JW, Oregioni B, Villeneuve JP, McKay K (1993) Petroleum hydrocarbons and trace metals in nearshore Gulf sediments and biota before and after the 1991 War. An assessment of temporal and spatial trends. Mar Pollut Bull 27:171-182.

GESAMP (1991) (IMO/FAO/UNESCO/WHO/IAEA/UNEP). Review of potentially harmful substances - carcinogens. Reports and Studies No. 46, Geneva.

MOOPAM (1989) Manual of oceanographic observations and pollutant analysis methods, ROPME, Safat, Kuwait, p 337-355.

Peerzada N, Dickinson C (1989) Metals in oysters from the Arnhem land coast, Northern Territory, Australia. Mar Pollut Bull 20:144-145.

UNEP/FOA/WHO (1988) Assessment of chemical contaminants in food, Global Environmental Monitoring Systems, London.