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Metal Accumulation in the Edible Marine Snail *Turbo Coronatus* (Gmelin) from Different Locations in Bahrain

تراكم العناصر الكيميائية النذرة في الحلزون البحري *Turbo Coronatus* من مناطق مختلفة حول مملكة البحرين

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Abstract: The concentration of seven trace metals (Fe, Ni, Zn, Mn, Pb, Cu, Cd) in the soft tissue of *Turbo coronatus* (Gmelin) from five nearshore areas were studied. The mean concentration of each trace metal in the edible marine snail exhibited significant spatial variations. The highest concentration of Zn, Mn, Cu and Cd occurred at Jazirat Al-Shaikh (Askar), Al-Jadoom, Al-Qulayah, and Fasht Al-Jarim, respectively. However, maximum Fe level was recorded at Fasht Al-Jarim. In addition, the metal concentration showed significant seasonal variation. The highest concentration of Zn and Cd was in September and March, respectively, when algae was assumed to be abundant. The elevated values of Zn (47.77 $\mu g\ g^{-1}$) and Cd (1.29 $\mu g\ g^{-1}$) could be associated with spawning season.

Key words: Turban shell, spatial, temporal, metal accumulation, Bahrain.

المستخلص: تمت دراسة تراكيز سبعة أنواع من العناصر الكيميائية النذرة مثل الحديد (Fe)، النيكل (Ni)، الزنك (Zn)، المنجنيز (Mn)، الرصاص (Pb)، النحاس (Cu)، والكادميوم (Cd) في أنسجة الحلزون البحري من نوع *Turbo Coronatus* من خمس مناطق ساحلية. لقد وجد أن هناك اختلافاً إحصائيا متابيناً في متوسط تراكيز هذه العناصر الكيميائية بين المناطق البحرية المختلفة . وجد أن مناطق جزيرة الشيخ والجادوم والجليعة وفشت الجارم تحتوي على أعلى تركيزات لعناصر الزنك (Zn)، المنجنيز (Mn)، والنحاس (Cu)، والكادميوم (Cd). كما وجد أن أعلى التركيزات لعناصر الزنك (Zn)، والكادميوم (Cd) كانا خلال شهري سبتمبر ومارس على التوالي، وذلك عندما يكون هناك وفرة من الطحالب . وقد أرجع سبب ازدياد تراكيز هذين العنصرين إلى موسم التكاثر لهذا الحيوان .

كلمات مدخلية: الحلزون البحري، *Turbo Coronatus*، تراكم لعناصر الكيميائية، مملكة البحرين .

Introduction

During the past ten years, the state of Bahrain marine environment has become a matter of growing concern for government and local municipalities as well as non-governmental organizations. The shallowness of the sea, the restricted water circulation, the increasing local population and rapid industrial development especially along the eastern coastline are conducive to water pollution. Several studies have been carried out in Bahrain to monitor trace metal pollutants in the marine environment (Linden, *et al.* 1988; Fowler 1990; Fowler, *et al.* 1993). Marine sediments have always been reported to contain greater metal concentration than seawater.

Various members of the local benthic marine biota, namely the pearl oyster, *Pinctada radiata* and the clams, *Marcia flammae* and *Protapes* sp. have been monitored by Linden (1988), Al-Sayed et al. (1996), Dairi *et al.* (1998), and Fowler *et al.* (1993) to evaluate bioavailability and accumulation of trace metals. Furthermore, several commercial edible fishes have also been evaluated by Al-Sayed *et al.* (1996), Madany *et al.* (1996) and Fowler (1990) for their ability to accumulate trace metals in their bodies. In these investigations, oil-related industries and domestic discharges have been implicated as the main anthropogenic sources of metal pollution in Bahrain.

The gastropod *Turbo coronatus* is among the few remaining inhabitants of the rocky shore community which have economic value. At present *T. coronatus* is popular as seafood delicacy among local and expatriate people. However, there is a lack of information with regard to their ability to concentrate trace metals and their accumulation pattern.

Shellfish commonly accumulate trace metals in higher concentration than finfish (Canli, *et al.* 1992). Accumulation of metals, especially non-essential ones, is greatly dependent on concentration in ambient water and the period that animals are exposed to that concentration, though there are other factors which affect accumulation, such as temperature and salinity (Canli, *et al.* 1992; Sadiq, *et al.* 1992).

Several studies on accumulation of heavy metals in invertebrate have been conducted. For example, Nicolaidou (1994) worked on the digestive gland of three species of invertebrate *Monodonta mutabilis*, *Cerithium vulgatum*, and *Murex trunculus* as prey tissue, and hermit crabs *Clibanarius erythropus* as predators. This author analyzed the digestive glands and faecal pellets from the animals investigated. Most metals detoxified by the snails were unavailable to the crabs and passed straight through the gut and appeared in the faecal pellets. Cadmium (Cd) and chromium (Cr) on the other hand were transferred to the crabs (Nicolaidou, 1994). The little available information on the turban shell (*T.coronatus*) is concentrated on ecological aspects as well as its distribution pattern (Jones, 1986; Smyth, 1972; Basson, *et al.* 1977; Vousdon 1985).

The present investigation of trace metal concentrations in the edible marine snail *T. coronatus* populations living at different sites around Bahrain is reported with the aim of obtaining a background level for performing interaspecific comparison. The response of the edible marine snail in contaminated sites was studied in order to gain more information on the possible use of the animal as a biomonitor for the Bahrain marine environment.

Materials and Methods

1. Study area

Individuals of *T. coronatus* were collected on three occassions from five locations with different degrees of pollution along the coastline of the Kingdom of Bahrain (Fig. 1). Samples were collected at Fasht Al-Jarim and at Al-Jadoom Island a part of Fasht Al-Jarim, located at the northern part of Bahrain. The island is largely uninhabited and lacks any industrial activities. This island is man-made formed by dredging and reclamation.

Samples were also collected from the Marina Club a site usually used for mooring of leisure boats and yachts and at Al-Qulayah close to Mina Salman, the main harbour in the country, which appeared to be contaminated by naval traffic emission and domestic waste disposal. Finally, samples were also collected from Jazirat Al-Shaikh an island at Askar which lies at the east coast of Bahrain. Jazirat Al-Shaikh is a rocky island located downstream of major industrial areas, especially those associated with oil- related industries such as oil refinery and petrochemical.

2. Sampling

Turban shell, *T. coronatus* samples were collected from the five localities between March 2002 and October 2002. About 30 snails from each site were collected to investigate the bioaccumulation of Pb, Cu, Mn, Zn, Fe, Ni, and Cd. The animals were hand picked and carefully kept in clean seawater. All precautions were taken in order to avoid metal contamination.

3. Preparation of Specimens for Metal Analysis

In the laboratory *T.coronatus* were washed and cleaned with sterilized distilled water. All plastic containers and tools used in preparation of samples were acid washed. Turban shell dissections were carried out with ultra clean tools on polythylene covered work surfaces in order to minimize sample contamination. Soft tissue of at least 5-10 individuals were mixed together to form a composite sample. For each site 3 composite replica were prepared for elemental analysis.

4. Analytical Procedures

Turban shell samples were dried at 105°C to constant weight and then ground into powder using a mortar and pestle. Weighed samples were then digested in a nitric perchloric hot acid mixture until a clear solution was obtained. Dilutions were then made to 100 mls. using double distilled deionised water. Metal extraction was carried out according to the method of Bryan and Humerstone (1973). SP9 Pye-Unicam atomic absorption spectrometer with a detection limit range of 0.003-0.01 $\mu g\ ml^{-1}$ was used for elemental determinations in samples of turban shell. All values are reported as $\mu g\ g^{-1}$ wet weight of soft flesh.

5. Quality Assurance Experiments

In order to assess the precision and accuracy of the results, replicated analyses of the blank, standard solutions, as well as the samples, were carried out.

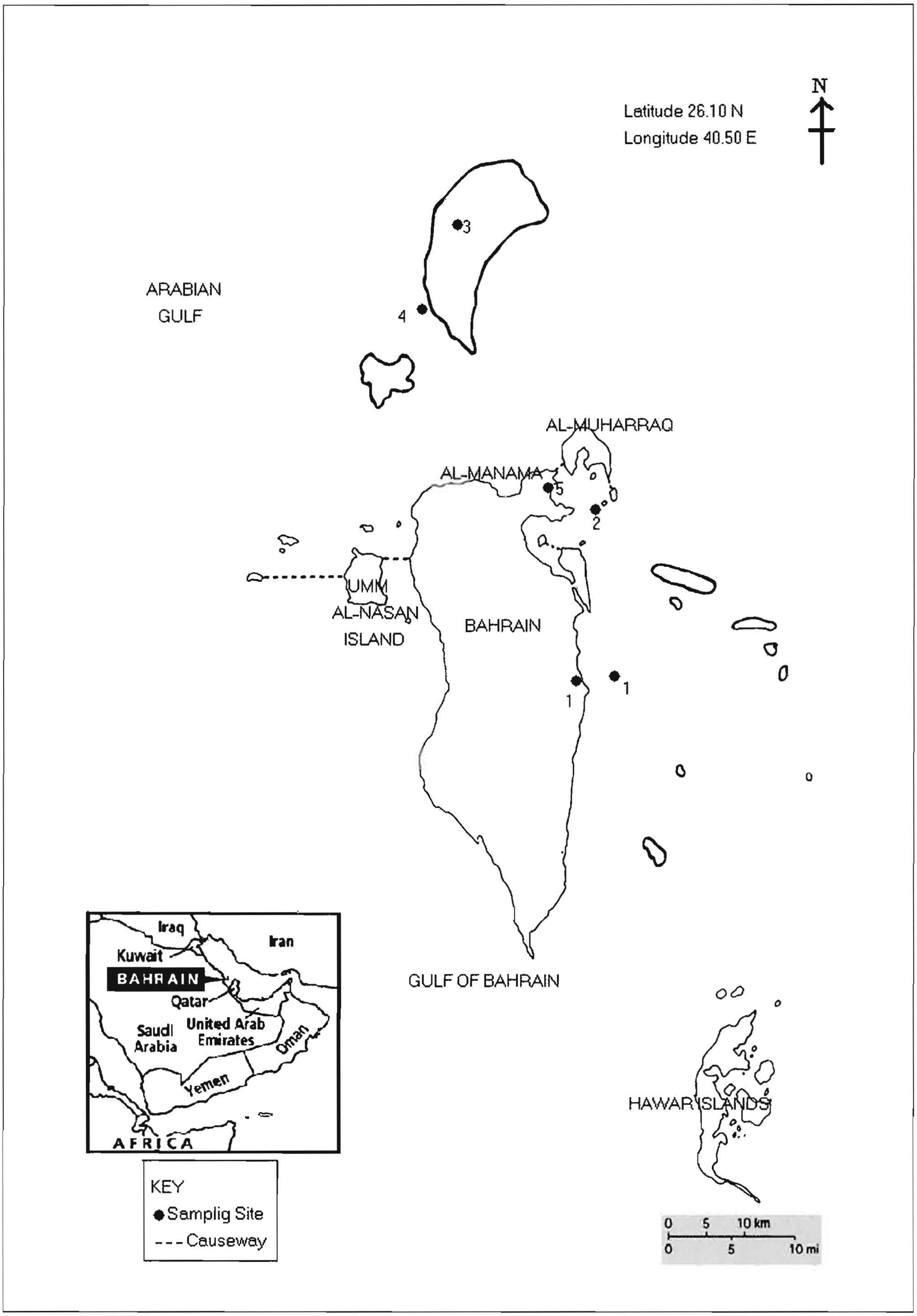

Fig. 1. Bahrain map showing sampling sites, where (1) Jazirat Al-Shaikh (Askar), (2) Al-Qulayah, (3) Fasht Al-Jarim, (4) Al-Jadoom, and (5) Marina Club.

Table 1. Trace metal levels (µg g^{-1} wet weight) in the edible snail, *T. coronatus* collected from different sites in Bahrain during 2002, (Mean ± S.E.). Figures in the same columns having different superscript are significantly different at $P \leq 0.05$.

Sites	Trace metal						
	Fe	Ni	Zn	Mn	Pb	Cu	Cd
Jazirat Al-Shaikh (Askar)	878.50^{ab} ±108.68	1.11 ±0.25	47.77^{a} ±5.23	6.00^{ab} ±0.51	1.83 ±0.44	33.61^{a} ±2.48	0.68^{a} ±0.09
Al-Qulayah	856.28^{ab} ±116.60	1.09 ±0.27	37.75^{b} ±2.06	4.77^{a} ±0.10	2.13 ±0.50	38.70^{a} ±1.89	0.13^{b} ±0.03
Fasht Al-Jarim	1124.06^{b} ±138.66	1.51 ±0.25	26.15^{c} ±1.30	4.50^{a} ±0.41	1.66 ±0.29	20.82^{b} ±2.27	1.73^{c} ±0.23
Al-Jadoom	1098.65^{b} ±92.59	1.97 ±0.38	33.75^{b} ±1.72	6.79^{b} ±0.94	3.03 ±0.41	35.21^{a} ±4.55	1.60^{c} ±0.12
Marina Club	716.80^{a} ±46.18	1.84 ±0.49	30.50^{bc} ±2.06	1.57^{c} ±0.52	2.54 ±0.43	33.41^{a} ±4.48	0.54^{a} ±0.08
Average	934.858	1.505	35.185	4.726	2.239	32.352	0.936
F-ratio	2.83*	1.28	10.08*	12.18*	1.77	4.09*	28.60*

* Indicates statistically significant at $P \leq 0.05$.

6. Data Analysis

Data analysis was performed using a STATIGRAPHIC computer program Version 5. Data was reported as arithmetic Mean ± S.E. and range. Analysis of Variance (ANOVA) was employed to measure differences between mean levels of metals in various stations, and compared using Duncan's Multiple Range Test.

Results

Trace metal levels in the edible snail *T. coronatus* collected from the five sites of Jazirat Al-Shaikh at Askar, Al-Qulayah, Fasht Al-Jarim, Al-Jadoom, and Marina Club in Bahrain are shown in Table 1. It can be seen that the averages of iron (Fe), zinc (Zn), manganese (Mn), copper (Cu), and cadmium (Cd) were statistically different between sites at ($P \leq 0.05$). However, no significant differences were found for Ni and Pb between the different sites.

Iron levels in *T. coronatus* varied from one site to another. Fasht Al-Jarim had the highest level of Fe (1124.06 µg g^{-1} wet weight) compared to Al-Jadoom, Jazirat Al-Shaikh, Al-Qulayah, and Marina Club which had a concentration of 1098.65, 878.50, 856.28, and 716.80 µg g^{-1} wet weight, respectively.

In addition, Zn levels differed from one site to another with the highest concentration in Jazirat Al-Shaikh (47.77 µg g^{-1} wet weight) and the lowest Zn concentration in the Fasht Al-Jarim (26.15 µg g^{-1} wet weight). The concentration of Zn was 37.75, 33.75, 30.50 µg g^{-1} wet weight in the other sites of Al-Qulayah, Al-Jadoom, and Marina Club, respectively.

As shown in Table 1, Mn showed the highest concentration in Al-Jadoom followed by Jazirat Al-Shaikh, Al-Qulayah, and Fasht Al-Jarim, with the lowest concentration in Marina Club (6.79, 6.00, 4.77, 4.50, and 1.57 µg g^{-1} wet weight, respectively).

Cu had a concentration of 38.70, 35.21, 33.61, 33.41, and 20.82 µg g^{-1} wet weights in Al-Qulayah, Al-Jadoom, Jazirat Al-Shaikh, Marina Club, and Fasht Al-Jarim, respectively.

Cadmium also showed variations in its concentration in different sites, ranging from 1.73 to 1.60, 0.68, 0.54, and 0.13 µg g^{-1} wet weight in Fasht Al-Jarim, Al-Jadoom, Jazirat Al-Shaikh (Askar), Marina Club, and Al-Qulayah, respectively.

The overall mean concentration levels of Fe, Zn, Cu, Mn, Pb, Ni, and Cd in the snail *T. coronatus* samples were 934.858, 35.185, 32.352, 4.726, 2.239, 1.505 and 0.936 µg g^{-1} wet weight, respectively.

Iron demonstrated the highest concentration of all the metals tested in the five sites, that of 934.858 µg g^{-1} wet weight, Cd was the lowest in all sites except Al-Qulayah in which Ni showed the lowest concentration, that of 1.51 µg g^{-1} wet weight. The decreasing concentration patterns of different metal used were as follows: Fe> Zn> Cu> Mn> Pb> Ni> Cd.

However, the order of concentration of metals in Jazirat Al-Shaikh was Fe> Zn> Cu> Mn> Ni>

Table 2. Trace metal levels (μg g^{-1} wet weight) in the edible snail, *T. coronatus* collected in different months in Bahrain during 2002, (Mean ± S.E.). Figures in the same columns having different superscript are significantly different at $P \leq 0.05$.

Months	Trace metal						
	Fe	Ni	Zn	Mn	Pb	Cu	Cd
March	979.84 ±66.37	1.77 ±0.22	30.13[a] ±1.14	4.29 ±0.56	2.41 ±0.24	29.81 ±2.51	1.29[a] ±0.14
September	878.50 ±108.68	1.11 ±0.25	47.77[b] ±5.23	6.00 ±0.51	1.83 ±0.44	33.61 ±2.48	0.68[b] ±0.09
October	856.28 ±116.60	1.09 ±0.27	37.75[c] ±2.06	4.77 ±0.10	2.13 ±0.50	38.70 ±1.89	0.13[c] ±0.03
F-ratio	0.57	2.13	15.99*	1.25	0.58	2.20	14.09*

* Indicates statistically significant at $P \leq 0.05$.

Pb> Cd. The pattern for metal concentration Fasht Al–Qulayah and Jadoom was as follow; Fe> Cu> Zn> Mn> Pb> Ni> Cd. Metal concentration for Fasht Al-Jarim and Marina Club showed the following pattern Fe> Zn> Cu> Mn> Cd> Pb> Ni and Fe> Cu> Zn> Pb> Ni> Mn> Cd, respectively.

Table 2 shows the results of trace metals in the edible snail *T. coronatus* collected in different months in Bahrain during 2002. All metals, with exception of Zn and Cd did not show any monthly variation. The concentrations of Zn and Cd were significantly different at $P \leq 0.05$.

The results showed seasonal variations in Zn concentration, with the Zn level at 47.77 μg g^{-1} wet weight in September (end of summer). It dropped to 37.75 μg g^{-1} wet weight in October. A further drop occurred in March with a concentration of 30.13 μg g^{-1} wet weight. Cadmium concentration, on the other hand showed different pattern compared to Zn. Its concentration was highest in March that of 1.29 μg g^{-1} wet weight, compared to its lower concentration of 0.68 and 0.13 μg g^{-1} wet weight in September and October, respectively.

Table 2 shows variation between months in the concentration of the same metals. In September, the concentration of Zn and Mn showed the highest level compared to lowest level of Pb during the same month. Most of the metals showed the highest concentration in March (Cd, Fe, Ni and Pb) with exception of Zn, Mn and Cu (with concentration of 1.29, 979.84, 1.77, 2.41, 30.13, 4.29, and 29.81 μg g^{-1}, respectively). Copper with a concentration of 38.70 μg g^{-1} showed its highest concentration only in October, while Cd, Fe and Ni recorded the lowest in the same month.

Discussion

The results of the present study which compares the metal concentration in the five sites in Bahrain of Jazirat Al-Shaikh (Askar), Al-Jadoom, Al-Qulayah, Fasht Al-Jarim and Marina Club clearly demonstrate significant spatial variations in the edible snail. While the highest concentration of Zn, Mn, Cu, and Cd was observed in Jazirat Al-Shaikh, the highest level of Fe was found in Fasht Al-Jarim. Jazirat Al- Shaikh is located downstream of the main oil refinery outfall which still represents a major source of trace metals despite it recent claims of improvements of effluent quality, according Linden *et al.* (2004).

Elevated trace elements of Ni, Mn, Pb, Cu, and Cd were found at Al-Jadoom, which could be related to repeated oil spills normally originating from the offshore northern sea area. In this regard, the data is consistent with other studies which relate the accumulation of metals to water pollution.

In Bahrain, the concentration of metals was attributed to water pollution and the transfer of metal bioaccumulators such as the clam, a filter feeder molluscan species. Dairi *et al.* (1998) studied the concentration of trace metals in the gills of two edible clams namely *Marcia flammea* and *Protopes sp.* from Tubli Bay, Bahrain. They found that Pb represented the highest concentration of 7.93 ppm and 4.00 ppm in *M. flammea* and *Protopes* sp., respectively, while Ni showed the lowest concentrations of 1.2 ppm and 1.89 ppm in *M. flammea* and *Protopes* sp., respectively.

Another study on trace metals in Bahrain showed that the metal concentrations were high in

Table 3. Trace metal concentration (µg g^{-1}) in tissues of *T. coronatus* from different sites in Bahrain compared to trace metal concentrations (µg l^{-1}) in seawater.

Sites	**Trace metals**						
	Fe	**Ni**	**Zn**	**Mn**	**Pb**	**Cu**	**Cd**
Jazirat Al-Shaikh (Askar)	878.50	1.11	47.77	6.00	1.83	33.61	0.68
Al-Qulayah	856.28	10.9	37.75	4.77	2.13	38.70	0.13
Fasht Al-Jarim	1124.06	1.51	26.15	4.50	1.66	20.82	1.73
Al-Jadoom	1098.65	1.97	33.75	6.79	3.03	35.21	1.60
Marina Club	716.80	1.84	30.50	1.57	2.54	33.41	0.54
Seawater	0.03	0.31	0.84	0.07	0.16	0.20	0.11
Months							
March	979.84	1.77	30.13	4.29	2.41	29.81	1.29
September	878.50	1.11	47.77	6.00	1.83	33.61	0.68
October	856.28	1.09	37.75	4.77	2.13	38.70	0.13

the pearl oyster, *P. radiata* in all the stations measured and the levels of Pb (7.64 µg g^{-1}) and Cd (2.48 µg g^{-1}) exceeded the WHO limits (Al-Sayed, *et al.* 1994).

In the Gulf region a comparative study was made in Bahrain, UAE and Oman by Fowler *et al.* (1993). They reported that trace metal levels in sediments and bivalves collected in 1991 were not greatly different from those measured in earlier years at the same sites. One exception was higher Pb value compared to previous records from the same locations (38 µg g^{-1} dry Pb) detected in rock scallops from Askar.

The spatial variation could be attributed to differences in element uptake or variation in the level of pollution in different regions (Companella, *et al.* 2001).

The bioaccumulation of metals was also related to the level of water pollution. For example, Companella *et al.* (2001) studied the concentrations of Cd, Cr, Cu, Pb and Zn in four marine organisms, namely the seagrass, *Posidowa oceanica*, the brown algae, *Padina paronica* and two gastropod mollusks, *M. turbinate* and *Patella caerula* in Sicily, Italy, in the Mediterranean area. These authors found that the region where the harbour was located had the highest concentration of metal, while the lowest values were recorded at clean stations.

Furthermore, in gastropods, it was found that the concentrations of metals (Co, Cr, Cu, Fe, Mn, Ni, and Zn) in the viscera of *C. vulgatum* and *M. mutabilis* were significantly higher in the animals from the polluted site.

In addition Shiber *et al.* (1978), measured Pb, Cu, Ni, and Fe levels in limpets, *Patella coerulea*, mussels, *Brachydontes variabilis*, and snails, *M. turbinate*, from the coast of Ras Beirut in Lebanon which appeared to be high in relation to levels reported by investigators from other clean coastal areas.

The results of the present study are in agreement with Sadiq *et al.* (1992) which suggests that bioaccumulation of metals is positively correlated with size. The highest growth of shell and body wet weight occurred in March (2002) as did the accumulation of Zn and Cd. This suggests a possible relationship between the growth of the animal and its ability to accumulate trace metals.

Bioaccumulation of trace metals in molluscan species was attributed to several factors such as the size of the animal, method of feeding, level of water pollution, spawning season, salinity and temperature changes, and the ability of the animal to concentrate different metals.

The relationship between the concentration of trace metals and the size of mollusks is not fully understood. Some authors believe that there is a positive relationship between the weight of the animals and its accumulation of metals (Cubadda, *et al.* 2001; Catsiki, *et al.* 1994; Sadiq, *et al.* 1992). The latter related the metal accumulation to the

Table 4. Heavy metal concentrations (μg g^{-1}) in different marine organisms.

Organisms	Fe	Ni	Zn	Mn	Pb	Cu	Cd	References
Grouper fish *Epinephelus coioides*	3.20 (w)	4.40 (w)	499 (w)	2.20 (w)	10.80 (w)	3.90 (w)	1.20 (w)	Al-Sayed *et al.*, 1996
Pearl oyster *Pinctada radiata*	46.80 (d)	3.70 (d)	8.70 (d)	2.90 (d)	5.90 (d)	1.63 (d)	0.90 (d)	Al-Sayed *et al.*, 1994
Bivalve *Marcia flammea*	2.33 (w)	1.20 (w)	1.24 (w)	- -	7.93 (w)	- -	4.87 (w)	Dairi *et al.*, 1998
Protapes species	2.60 (w)	1.89 (w)	2.50 (w)	-	4.00 (w)		1.7 (w)	Dairi *et al.*, 1998
Meretrix meretrix	11420-157770 (w)	360-4310 (w)	2550-9030 (w)	490-354620 (w)	30-7630 (w)	90-3920 (w)	50-970 (w)	Sadiq *et al.*, 1992
Brachydontes variabilis	24.20-152.30 (w)	1.00-19.50 (w)	-	-	6.10-11.30 (w)	4.50-30.60 (w)	0.04-0.70 (w)	Shiber *et al.*, 1978
Chiton *Acanthopleura hadoni*	1957.00 (d)	-	199.60 (d)	14.90 (d)	- -	26.20 (d)	6.10 (d)	Wahbeh, 1990
Limpet *Cellana radiata*	1109.20 (d)	-	93.30 (d)	10.30 (d)	- -	26.80 (d)	5.50 (d)	Wahbeh, 1990
Snail *Nerita forskalii*	643.90 (d)	-	86.40 (d)	19.70 (d)	-	- -	11.30 (d)	Wahbeh, 1990
Nerita polita	257.70 (d)	-	116.50 (d)	21.22 (d)		-	10.00 (d)	Wahbeh, 1990
Mesodesma glabrum	937.80 (d)	-	537.50 (d)	1824.40 (d)	- -	82.10 (d)	5.30 (d)	Wahbeh, 1990
Gastropods *Monodonta turbinate*	- -	- -	10.1-61.2 (d)	-	0.06-0.87 (d)	3.10-28.3 (d)	0.10-5.89 (d)	Cubadda *et al.*, 2001
Monodonta mutabilis	- -	- -	10.7-40.4 (d)	-	0.06-0.30 (d)	6.00-34.70 (d)	0.28-4.11 (d)	Cubadda *et al.*, 2001
Patella carulea	-		2.2-19.10 (d)	-	0.06-0.51 (d)	0.47-3.79 (d)	1.70-11.80 (d)	Cubadda *et al.*, 2001
Patella lusitanica	-	-	5.80-22.80 (d)	-	0.10-1.02 (d)	1.42-3.90 (d)	2.00-6.60 (d)	Cubadda *et al.*, 2001
Patella carulea	442.30-1283.70	0.20-18.50 (w)	- -	- -	1.40-27.50 (w)	2.70-9.7 (w)	0.10-1.10 (w)	Shiber *et al.*, 1978
M. turbinate	30.60-232.10 (w)	1.00-13.60 (w)			1.60-8.40 (w)	9.60-25.50 (w)	0.10-0.50 (w)	Shiber *et al.*, 1978
Turbo coronatus	716.80-1124.06 (w)	1.09-1.97 (w)	26.15-47.77 (w)	1.57-6.79 (w)	1.66-3.03 (w)	20.82-35.21 (w)	0.13-1.73 (w)	Present study
Marine algae a. Chlorophyceae	1000-5200 (d)	4 (d)	-	37 (d)	-	-	1-3 (d)	Basson *et al.*, 1992
b. Phaeophyceae	300-3200 (d)	3-25 (d)	-	22-80 (d)	-	-	<1 (d)	Basson *et al.*, 1992
c. Rhodophyceae	700-2700 (d)	6-17 (d)	-	29-5 (d)	-	-	1-305 (d)	Basson *et al.*, 1992
WHO limits	-	-	1000	-	2.0	10.0	2.0	Al-Sayed *et al.*, 1994

(w) = wet weight, (d) = dry weight.

method of feeding and the amount of ingested materials grazed by herbivorous gastropods. Contrary to previous studies, some scientists believe that a negative correlation exists between the concentration of some trace metal and the size of the animal, while other metals showed no correlation. For example Catsiki *et al.* (1994) studied metal accumulation in gastropods such as *C. vulgatum* and *M. turbinata* and reported that the larger animals had lower concentration of Cr, Mn, and Ni metals in their tissues than the smaller ones. These authors believe that the older animals have the ability of detoxification more than the younger ones. Moreover, these authors also reported that some metals such as Zn, Fe, and Cu showed less relation with the size of the gastropod.

Table 5. Concentration factors[a] calculated with reference to sites and months metal concentrations in seawater.

Sites	Trace metals						
	Fe	**Ni**	**Zn**	**Mn**	**Pb**	**Cu**	**Cd**
Jazirat Al-Shaikh (Askar)	29283.33	3.58	56.87	85.71	11.44	168.05	6.18
Al-Qulayah	28542.67	3.52	44.94	68.14	13.31	193.50	1.18
Fasht Al-Jarim	37468.67	4.87	31.13	64.29	10.38	104.10	15.73
Al-Jadoom	36621.67	6.35	40.18	97.00	18.94	176.05	14.55
Marina Club	23893.33	5.94	36.31	22.43	15.88	167.05	4.91
Months							
March	32661.33	5.71	35.87	61.29	15.06	149.05	11.73
September	29283.33	3.58	56.87	85.71	11.44	168.05	6.18
October	28542.67	3.52	44.94	68.14	13.31	193.50	1.18

[a]CF = Co/Csw, where Co = concentration in the organism ($\mu g\ g^{-1}$ wet wt) and Csw = concentration in seawater ($\mu g\ l^{-1}$).

The investigation of trace metal concentration in the tissues of gastropods which are grazers may provide useful information about the transfer of toxic elements from water and sediment (abiotic component) to primary producers, then to grazers and gradually to higher consumers including humans (Campanella, *et al.* 2001). Campanella *et al.* (2001) stated that the highest concentrations of Cd and Zn occurred in the seagrass leaves compared to rhizomes and therefore assumed that the uptake of these metals preferentially occurred from the water to photosynthetic tissues of the seagrass. Other studies also related the concentration of metal to the transfer of metals between different organisms. For example, Zhang *et al.* (1990) found that the accumulation of Selenium (Se) by the clam, *Puditapes philippnarum* was mainly from ingested phytoplankton with lesser amounts being accumulated directly from seawater. Furthermore, the variation in concentration of trace metals among different regions could be related to the differences in the growth rate. Similar results were reported by Frias-Espericueta *et al.* (1999) who stated that bioaccumulation of metals could be attributed to spawning season.

The results of our study showed significant variation in the metal levels in different periods of time. The concentration of most metals, for instance Cd, Fe, Ni, and Pb was high during September and March 2002 which could be the prespawning period. In addition, March, which is the spring month, showed highest growth of the edible snail, as was clear from the results. The shell height (18.88 mm), the shell width (20.89 mm) and the wet weight (2.19 g) were in their highest level during March.

When compared to values reported in the literature (Linden, *et al.* 1988; Al-Sayed, *et al.* 1994; Al-Sayed, *et al.* 1996) trace metal levels in *T. coronatus* appear to be relatively higher than some element in other marine organisms. Iron (Fe) for example was low in ambient seawater but elevated within the animal. Similarly Cu concentration was found to be consistently higher within the animal tissue overtime. In general, concentration of trace metal within the animal has the following pattern Fe, Cu, Mn, Zn, and Pb (Table 3).

The level of some trace metals such as those investigated in this study was higher than that reported for snails and other marine organisms studied in Bahrain or in other regions of the world. For example, Fe and Cu levels were higher in *T. coronatus* than the grouper fish. In addition, Fe, Cu, and Cd were much higher in the present study than is reported for *B. variabilis* and *M. turbinate.* However, *Patella carulea* has lower levels of Cu and Cd while Fe was higher than *T. coronatus* (Table 4). It was found that the level of Cu and to some extent Pb were higher than the WHO acceptable limits for marine organisms.

Further analysis involved calculation of concentration factors of different trace metals (Table 5). The results clearly indicate the snail's ability to concentrate selected trace metals to varying degree.

The edible snail seems to be an efficient accumulator of Fe, Mn, and Cu as evident from high concentration factors. The animals are moderate accumulators of Zn and Cd. However, no net accumulation took place with regard to Ni and Pb.

Accumulation of high levels of metals even in unpolluted areas must be related to feeding habits of the snail which is primarily herbivorous. Therefore, it may be possible to suppose that the metal concentrations in the soft tissue of *T. coronatus* are substantially influenced by metal accumulation in the algae on which they graze as evident from high metal content of some macroalgae in Bahrain as reported by Basson *et al.* (1992) and Dairi *et al.* (2002).

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References

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

Al-Sayed, H.A., Al-Saad, J., Madanmy, I., and Al-Hooti, D. (1996) Heavy metals in the grouper fish *Epinephelus coioides* from the coast of Bahrain: an assessment of monthly and spatial trends. Intern. J. Environ. Stud. **50:** 237-246.

Basson, P.W., and Abbas, J.A. (1992) Elemental composition of some marine algae from the Bahrain coastline (Arabian Gulf). Ind. J. Mar. Sci. **21:** 59- 61.

Basson, P.W., Burchard, J.E., Hardy, J.T. and Price, A.R.G. (1977) Biotopes of the western Arabian Gulf. Aramco Department of Loss Prevention and Environmental Affairs, Dharan, Saudi Arabia.

Bryan, G.W. and Humerstone, L.G. (1973) Brown seaweed as an indicator of heavy metals estuaries in South-West England. J. Mar. Biol. Ass.UK. **53**: 705-720.

Campanella, L., Conti, M.E., Cubadda, F., and Sucapane, C. (2001) Trace metals in seagrass, algae and mollusks from an uncontaminated area in the Mediterranean. Environ. Poll. **111:** 117- 126.

Canli, M. and Furness, R.W. (1992) Toxicity of heavy metals dissolved in sea water and influences of sex and size on metal accumulation and tissue distribution in the Norway lobster *Nephrops norvegicus*. Mar. Environ. Res. **36** : 217- 236.

Catsiki, V.A., Bei, F., and Nicolaidou, A. (1994) Size dependent metal concentra-tions in two marine gastropod species. Neth. J. Aquat. Ecol. **28:** 157- 165.

Cheung. S.G., Tai, K.K., Leung, C.K., and Siu, Y.M. (2002) Effects of heavy metals on the survival and feeding behavior on the sandy shore scavenging gastropod *Nassarius festivus* (Powys). Mar. Poll. Bull. **45** : 107- 13.

Cubadda, F., Conti, M.E., and Campanella, L. (2001) Size-dependent concentrations of trace metals in four Mediteranean gastropods. Chemospher. **45**: 561- 569.

Dairi, M., Al-Alawi, S.M., Al-Alawi, S.M., and Al-Sayed, H. (1998) Study of heavy metals in the gills of two edible clam species (*Marcia flammea* and *Protopes* sp.) in Bahrain. Reg. Confer. Mar. Environ.Gulf, Doha, Qatar, (Abstract).

Dairi, M. and Al-Sayed, H.(2004) The reproductive biology of two clam species *Marcia flammea* and *Protapes* species from Tubli Bay. 2nd Symp. Wild. Protec. Nat. Hab. GCC Arab. Gulf, Kingdom of Bahrain.

Frias-Espericueta, M.G., Osuna-Lopez, J.I., and Paez-Osuna, F. (1999) Gonadal maturation and trace metals in the mangrove oyster *Crassostrea corteziensis*: seasonal variation. Sci. Total Environ.; **231**: 115- 123.

Fowler, S.W., Readman, J.W., Oregioni, B., Villeneuve, J.P., and 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. Poll. Bull. **27:** 171- 182.

Fowler, S.W. (1990) Critical review of selected heavy metal and chlorinated hydrocarbons in the marine environment. Mar.Environ. Res. **29:** 1- 64.

Jones, D.A. (1986) A field guide to the seashores of Kuwait and the Arabian Gulf. University of Kuwait Publication.

Linden, O., Larsson, U., and Al-Alawi, Z.S. (1988) Effects of chronic oil pollution in a shallow sub-tropical mar.environ. Oil and Chem. Poll. **5:** 65-79.

Mandany, I., Wagab, A., and Al-Alawi, Z. (1996) Trace metals concentrations in marine organisms from the coastal areas of Bahrain , Arabian Gulf Water, Air and Soil Pollut. **91**: 233-248 .

Morley, N.J., Crane, M., and Lewis, J.W. (2003) Cadmium toxicity and snail-digenean interactions in a population of *Lymnaea* spp. J. Helminthol; **77**: 49- 55.

Nicolaidou, J.A.N.A. (1994) Variable transfer of detoxified metals from snails to hermit crabs in marine food chains. Mar. Biol. **120:** 369- 377.

Sadiq, M., Alam, I.A., and Al-Mohanna, H. (1992) Bioaccumulation of nickel and vanadium by clams (*Meretrix meretrix*) libvin in different salinities along the Saudi coast of the Arabian Gulf. Environ. Poll. **76**: 225- 231.

Salice, C.J. and Miller, T.J. (2003) Population-level responses to long-term cadmium exposure in two strains of the freshwater gastropod *Biomphalaria glabrata* results from a lifetable response exp. Environ. Toxicol. Chem; **22**: 678- 688.

Scheifler, R., Gomot-de Vaufleury, A., and Badot, P.M. (2002) Transfer of cadmium from plant leaves and vegetable flour to the snail *Helix aspersa*: bioaccumulation and effects. Ecotoxicol.. Environ. Safty. **53**: 148- 153.

Scheifler, R., Schwartz, C., Echevarria, G.D.E., Vaufleury, A., Badot, P.M., and Morel, J.L. (2003) "Nonavailabla" soil cadmium is bioavailable to snails: evident from isotopic dilution exp. Environ. Sci. Technol. **37**: 81- 86.

Shiber, J.G. and Shatila, T.A. (1978) Lead, cadmium, copper, nickel and iron in limpets, mussels and snails from the coast of Ras Beirut, Lebanon.Mar. Environ. Res. **1:** 125-134.

Statgraphics. (1991) Statistical graphics system by statistical graphics corporation. Version 5, Reference Manual, Vol 1. printed in the United States of America.

Smythe, K.R. (1972) Marine mollusca from Bahrain island, Persian Gulf. J. Conch. **27**: 491-496.

Vousden, D.H. (1985) The Bahrain marine habitat survey .Environ. Proteect. Commit. Kingdom of Bahrain.

Wade, T.L., Garcia-Romero, B., and Brooks, J.M. (1991) Oyster as biomonitors of Butyltins in the Gulf of Mexico. Mar. Environ. Res. **32:** 233- 241.

Wahbeh, M.I. (1990) Levels of zinc, manganese, copper, cadmium, iron, and magnesium in soft tissue of some intertidal mollusks from Aqaba, Jordan. Mar. Mesopotanica. **5**: 27-39.

Zhang, G.H., Hu, M.H., Huang, Y.P., and Harrison, P.J. (1990) Se uptake and accumulation in marine phytoplankton and transfer of Se to the clam *Puditapes philippnarum*. Mar. Environ. Res. **30:** 179-190.

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