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Contamination of Coral Reef by Heavy Metals Along the Egyptian Red Sea Coast

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Over the last decades, severe damage to coral reefs from pollution and over-exploitation has been noted, over the world (Wilkinson 1992). The coral reefs of Egyptian Red Sea Coast are currently undergoing such severe deterioration, and it has been suggested that pollution may be responsible. The generally accepted explanations for the severe damage of coral reefs tend to certain anthropogenic disturbances (i.e. sewage, mariculture farms, dredging and phosphate spill). However, various effects of pollution on coral reef organisms and communities have been documented (Wood and Johannes 1975; Loya and Rinkevich 1980; Hatcher et al. 1989; Hughes 1994).

Coral reef was used over the last four decades as proxy tools to record the environmental pollution, such as inorganic pollution (Livingston and Thompson 1971; Goreau 1977; Dodge and Gilbert 1984; Hanna and Muir 1990; Scott 1990; Guzman and Jimenez 1992; Guzman and Jarvis 1996; Bastidas and Garcia, 1999), particulate organic matter (Isdale 1984), pollution with hydrocarbons (Readman et al. 1996), organochlorine pollution (Glynn et al. 1989). Incorporation of heavy metals with the coral reef skeleton via calcium substitution with metals or through association with particulate organic matter within skeletal pores are widely documented (Howard and Brown 1984). Few researchers have studied metal incorporation under different regimes of metal exposure in corals (Harland and Brown 1989; Jones 1997). However, no systematic studies have been conducted on coral reef in the Egyptian part of the Red Sea (DANIDA 1996; EIMP 1996). Therefore, we provide for the first time an assessment of concentrations for several heavy metals (Cd, Cr, Cu, Fe, Hg, Pb, Sn and Zn) in coral reef collected from large geographical area of the Egyptian Red Sea coast.

MATERIALS AND METHODS

The coral reef sampling stations were located along the Red Sea coast (Figure 1) starting from Marsa Alam to Taba (about 900 km). The *Acropora* sp. was collected at 20 sites within a period of two weeks from April 1999. At each site, 10 large pieces (8-10 cm) of coral reef were collected within a reef area of 1 km^2 at each of the 20 sites with collection depths ranged from 2-5 m.

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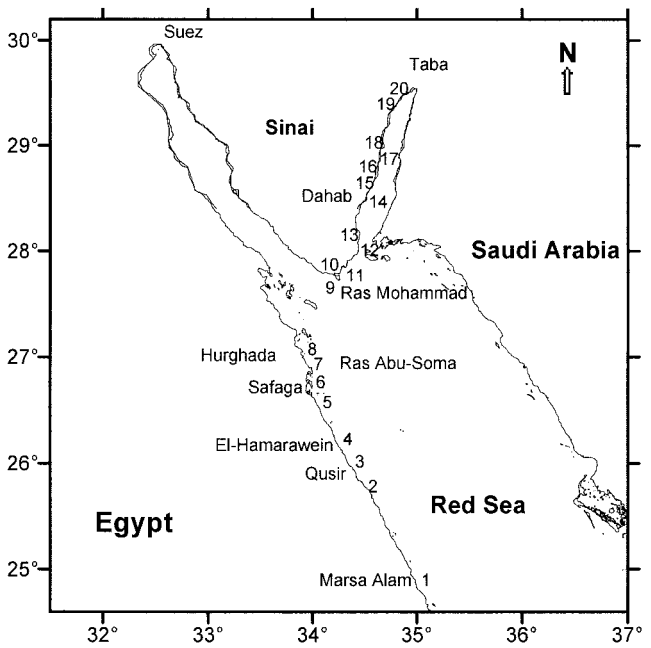

Figure 1. Stations where the coral reef samples were collected.

Coral samples were sun-dried, placed in plastic bags, and transported to the laboratory. Coral samples were cleansed in 5% sodium hypochlorite solution for 24 hr, washed in distilled water, and oven dried at 40°C for 72 hr. Subsamples (30-50 g) of coral skeleton were crushed and homogenized before the digestions with acids (Shen and Boyle 1988).

To determine the Cd, Cr, Cu, Fe, Pb, Sn and Zn concentration for each sample, 1g of coral reef skeleton was digested in 25 ml of HCl and 15 ml of HNO_3-$HClO_4$ 5:1 at 80°C (triplicate digestion were made for each sample). Metal content determinations were performed with Unicam 909 atomic absorption spectrophotometer using standard reference material (SRM 2974, provided by EIMP-IAEA). The laboratory results showed recovery efficiency ranged from 95-103 % for the heavy metals with coefficient of variation (CV) 6-10 % for all studied heavy metals. To assure the quality of analysis all procedures were made following the guidelines recommended in the Unicam 909 manual. Detection limits in mg kg^{-1} were Fe 0.1; Cd, Cr, Cu, Pb, Sn and Zn 0.05. All calculations were carried out on a Microsoft Excel program for Win XP 2002.

Mercury analysis was conducted using cold vapor atomic absorption (SOLAAR 32). In which 1 g of the homogenized air dried sample was weighed accurately into a previously pre-cleaned Teflon vial, 4 ml of HNO_3-HCl (9:1) mixture was added and heated for 2 hour at 50°C. After cooling to room temperature, the

Table 1. Concentration (mg kg^{-1}) of heavy metals (Cd, Cu, Fe, Hg, Pb and Zn) in coral reef skeleton.

Site No.	Location Name	Cd	Cu	Fe	Hg	Pb	Zn
1	Marsa Alam	0.55	4.07	51.26	0.64	2.66	2.09
2	Qusir	1.09	18.64	94.61	1.07	1.97	11.05
3	Qusir Ref	1.99	1.17	52.25	1.21	1.24	4.04
4	El-Hamarawien	1.15	9.76	161.20	0.97	7.25	5.76
5	Safaga	0.26	2.41	37.62	0.63	1.77	0.22
6	Safaga (Pub. Beach)	1.90	3.87	107.76	0.52	34.30	8.28
7	Ras Abu-Soma	2.06	15.49	214.05	1.18	3.00	5.06
8	Hurghada NIOF	2.22	36.25	111.64	0.53	3.82	20.76
9	Ras Mohammad	1.14	12.90	133.90	0.51	2.24	11.64
10	Sharm El-Mina	2.49	10.72	70.38	1.01	2.18	9.23
11	Sharm El-Maya	0.58	1.14	92.31	1.13	2.46	1.68
12	Na`ama Bay	0.32	0.91	62.38	0.66	4.11	0.90
13	Nakhlat El-Tel	2.56	2.83	158.82	0.78	18.93	10.50
14	Dahab	0.77	1.18	64.01	0.55	1.07	2.00
15	Ras Mamlah	0.53	1.77	26.23	0.44	1.47	1.77
16	Hibeiq Ras Nabar	0.94	7.77	280.05	1.18	5.58	6.79
17	Nuweiba, El-Siadin	1.73	3.74	206.47	0.88	5.90	10.24
18	Nuweiba	1.57	5.70	270.35	0.60	8.53	7.93
19	Marsa Muqibila	0.92	1.99	52.14	0.49	0.97	0.90
20	Taba	1.43	9.35	290.97	1.30	1.67	8.63
Mean		**1.31**	**7.58**	**126.92**	**0.81**	**5.56**	**6.47**
Median		**1.15**	**3.97**	**101.19**	**0.72**	**2.56**	**6.28**

volume was diluted, by using di-distilled water, filtered and complete to 25 ml; then subjected to Hg-determination with duplicate analysis (UNEP/IAEA 1985). To evaluate the accuracy and precision of the analytical methodology, reference material DORM-2 (provided by EIMP-IAEA) was run parallel with the samples. Our recovery was 98.5 for total Hg. A check standard and blank were run after every 8 samples. Detection limit for Hg was 0.005 mg kg^{-1}.

RESULTS AND DISCUSSION

Two elements Cr and Sn, were not detected in coral skeleton from 20 sites, probably because our analytical method can not detect low concentrations or traces. Table 1 presents the concentration of the other six metals in the coral reef skeleton samples. All metal levels detected were generally in low concentration except iron was detected in high concentration relative to the other studied metals.

The concentration of Zn ranged from 0.2 to 12 mg kg^{-1} with an average 5.6 mg kg^{-1}. The concentration of Cu ranged from 1 to 19 mg kg^{-1} with an average 6.5 mg kg^{-1}, while the concentration of Cd was ranged from 0.3 to 2.5 mg kg^{-1} with an average 1.3 mg kg^{-1}.

The highest concentration level of lead was recorded at Safaga (St. 6; 34 mg kg^{-1}) and the lowest concentration was recorded at Marsa Muqibila (St. 19; 1 mg kg^{-1}). The iron was recorded the highest concentration level at Taba (291 mg kg^{-1}) with an average concentration 127 mg kg^{-1}.

Most of the metal levels measured at Stations 2, 9, 13, and 17 were higher than the range observed in the coral from other stations. However, the concentration of heavy metals measured in this study were generally much lower than the other areas (Table 2). The concentration of the measured heavy metal Cd, Cu, Pb and Zn recorded almost the same lower range in most studied locations.

Table 2. Average heavy metal concentrations (mg kg^{-1}) in coral reef skeletons taken from the open literature.

Site	Cd	Cr	Cu	Fe	Hg	Pb	Zn	reference
1	7.5	7.3	2.0	113.0	NA	31.0	10.2	Guzman and Jimenez (1992)
2	7.6	9.9	3.8	70.8	NA	32.3	8.9	
3	7.6	9.3	3.3	81.9	NA	0.0	9.2	
4	0.09	29	3.8	NA	NA	0.33	28	Esslemont (2000)
5	0.19	67	7.2	NA	NA	0.24	37	
6	0.18	31	14	NA	NA	8.2	447	
7	NA	0.8	16.33	62.05	2.5	1.4	10.67	Bastidas and Garcia (1999)
8	NA	2.0	12.52	18.09	5.2	1.1	9.12	

1: Costa Rica; 2: Panama; 3: Central America; 4: Pioneer Bay; 5: Nelly Bay; 6: Townsville Harbor; 7: Punta Brava; 8: Bajo Caiman; NA: Not available.

The concentration of heavy metals observed for Zn at stations 2, 9, 13 and 17; Cu at stations 4, 7, 10 and 20 and Pb at stations 6 and 13 suggested a presence of sources for heavy metals (natural and/or anthropogenic) and an effective mechanism for distributing the metals at the above stations. Possible pollution sources in region include: 1- point sources (e.g. refineries, oil terminals, power plants, ports, dockyards, domestic and industrial sewage); 2- non-point sources (e.g. domestic and industrial sewage, agriculture activities, soil erosion); 3- unpredictable point sources (e.g. oil waste at sea by tankers, major oil spills) (Table 3). In general, point-sources can be identified and some actions can be taken to manage the problem.

Table 3. Sources and the main sites of marine pollution in the Red Sea and the Gulf of Aqaba.

Sources of Pollution	Main Sites of Pollution
Sewage from cities and tourist resorts	Hurghada, Sharm El-Sheikh, Dahab, Nuweiba and Taba
Shipment of mineral products (mainly phosphate)	Safaga, El Hamarawein and Quseir
Oil pollution from ships and offshore and onshore oil production and transport facilities	Agaba in Jordan and Eilat in Israel (tourism, oil terminals, phosphate loading operations)
Coral reef damage (anchor damage, boat grounding snorkeling or SCUBA-diving tourists)	Sharm El-Sheikh, Na'ama Bay, Ras Nasrani, Dahab, Nuweiba and Taba

Comparison of the Cd, Cu, Pb and Zn (Table 1) suggested that Cu and Zn may have local sources input into stations 2, 8, 9, 13 and 17. However the level of Pb at stations 6 and 13 suggested that, Pb may also have local sources input at those locations. Urban sources of heavy metals from municipal waste water discharges and others may be involved.

Mercury concentrations measured in the coral reef skeleton samples ranged from 0.44 to 1.3 mg kg^{-1} with average 0.81 mg kg^{-1}. The highest concentration was recorded at station 20 (Table 1). However, there is no highly elevation of Hg was recorded overall studied locations. Mercury and copper are two of the three most toxic of the elements (with Ag) to invertebrates and algae in marine and estuarine ecosystems (Fisher et al. 1984). Mercury is introduced mainly from atmospheric deposition (Coal combustion and waste incineration) and industrial discharge (Clark 1994). Increases in Hg are of concern because of the potentially small margin of safety between background levels of exposure and concentrations that can cause harm in humans and other organisms (MESB 1993). Additionally, most

Table 4. Spearman (non-paramatic) rank order correlations.

	Cd	Cu	Fe	Hg	Pb	Zn
Cd	r = 1					
	p = 0.00					
Cu	r = 0.49	r = 1				
	p = 0.03	p = 0.00				
Fe	r = 0.54	r = 0.54	r = 1			
	p = 0.01	p = 0.01	p = 0.00			
Hg	r = 0.27	r = 0.13	r = 0.45	r = 1		
	p = 0.26	p = 0.58	p = 0.04	p = 0.00		
Pb	r = 0.38	r = 0.24	r = 0.55	r = 0.04	r = 1	
	p = 0.10	p = 0.31	p = 0.01	p = 0.86	p = 0.00	
Zn	r = 0.72	r = 0.73	r = 0.60	r = 0.10	r = 0.39	r = 1
	p = 0.00	p = 0.00	p = 0.01	p = 0.68	p = 0.09	p = 0.00

anthropogenic Hg deposited in water shields is retained in the soil and biota for more than a decade (Lindquist and Rode 1991). Moreover, some microorganisms can often tolerate greater concentrations of certain metal compounds than can higher forms of life. Therefore, metal toxicity passively can ascend a food chain, being concentrated in simple biota and thus rendering a toxic dose to the higher animal (Canli and Furness 1995). The toxicities of Cd and Hg are cases in point because these are concentrated via accumulation in shellfish and other related marine species before human consumption, often giving rise to serious toxic consequences.

Spearman (non-paramatic) correlations were studied and showed moderate correlation between Pb, Hg and Fe (r = 0.55 and 0.45) and good correlations were found between Cd, Cu and Zn (r = 0.72 and 0.73) (Table 4).

Cadmium induced hepatic and renal injury in chronically exposed rats, likely role of hepatic cadmium-metallothionein in nephrotoxicity (Dudley et al. 1985). Cadmium accumulated in liver, kidney rather than in muscle and may be replacing the zinc in some enzymes and has a long half-life time (10-30 years) (Kotsonis and Klaassen 1978). Severe contamination with cadmium leads to itai-itai disease (Yosumura et al. 1980). Copper is found in living organisms' enzymes to carrying oxygen. However, accumulation of copper in liver leads to cirrhosis; in brain leads to death of neurons and resulting neurological symptoms; and in kidney leads to renal tubular damage (Matta et al. 1999). Severe contamination with Pb leads to brain damage, anemia, liver, and kidney diseases (Goyer and Mushak 1977). Zinc is an essential metal for maximum activity of many enzymes and contributes to the development and maintenance of the thymus (Koller 1980).

The potential hazard to the marine environment of pollutants depends mostly on their concentration and persistence. Persistent pollutants such as heavy metals can

remain in the environment unchanged for several years and may thus pose a threat to man and other organisms. The pollutions levels reported here suggest that heavy metals must be considered for some stations as a various regional threat. The effect of heavy metal pollution on coral reef are still unknown (Howard and Brown 1984; Brown 1987a,b).

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