



Research Paper

Heavy metals distribution and assessment in coral reefs of area between Quseir and Hamata, Red Sea, Egypt

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ABSTRACT

Concentrations of seven heavy metals (Fe, Cu, Zn, Pb, Cd, Ni and Co) were measured by Atomic Absorption Spectrophotometry (AAS) during summer and winter in four species of coral reefs (*Stylophora pistillata*, *Acropora humilis*, *Porites solida* and *Platygyra daedalea*) at six sites along the Red Sea coasts: I (Shouni), II (Asalaya), III (Tondoba), IV (Wadi El Gemal), V (Abu Ghsoon) and VI (Hamata). The studied heavy metal contents were measured in the hard skeleton of the coral reef species. The results showed the highest values of Fe, Mn and Pb in the different coral reef species which are strongly attributed to the land filling and the different anthropogenic impacts in the locality. Also, the results were compared with those of the other studies conducted in other areas of the Red Sea and the world, as well as, the existing guidelines of metals. Some heavy metal concentrations in coral reefs in the study areas are higher compared to that in the impact areas of the Egyptian Red Sea coast. The highest metal contents in the different species are strongly attributed to natural inputs, landfilling and the different anthropogenic impacts in the study areas.

M. Nageeb Rashed^{1*}, Hashem A. Madkour²
and Shimaa H. Mohammed³

¹Faculty of Science, Aswan University,
Egypt.

²National Institute of Oceanography and
Fisheries, Red Sea Branch, 84511
Hurghada, Egypt.

³Egyptian Environmental Affairs Agency,
Red Sea protectorates, Marsa Alam Office,
Egypt.

*Corresponding author. E-mail:
mnrashed@hotmail.com.

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INTRODUCTION

The Egyptian Red Sea includes several of the world's most unique and various marine and coastal habitats, so the Red Sea is considered one of important storehouses of marine biodiversity in the world. The ecosystems of Red Sea make it internationally significant where the largest and very beautiful coral reefs are inhabited by many species which occur nowhere else in the world. Today, these reefs are attracting tourists in ever-increasing numbers. However, if this increasing tourism industry is not well controlled we are in danger of losing a great and sustainable resource. There are many risks threatening marine resources in Red Sea which include habitat destruction, non-sustainable use of living marine resources, navigation risks and risks from petroleum production and transport, urban and industrial hotspots and rapid expansion of coastal tourism. Other risks may involve the illegal elimination of pollutants by transiting vessels (Gladstone et al., 1999; UNEP, 2006; Persga, 2005).

One of the common marine pollutants is heavy metals emitted from sources such as industrial and sewage treatment discharges and antifouling paints (Mitchellmore et al., 2003). On a daily basis, the pollution of aquatic ecosystem with heavy metals is increasing at a great rate and has become an important worldwide problem (Malik et al., 2010).

Many studies have been concerned with the determination of heavy metal concentrations in the skeleton and tissue of hard corals (Howard and Brown, 1984; Brown, 1987; Guzman and Jimenez, 1992; Mitchellmore et al., 2003; Madkour, 2013). The increasing of heavy metals in coral skeleton may reflect the environmental factors besides the anthropogenic impacts (Shen et al., 1987; Esslemont et al., 2000). In addition, the corals can adjust the concentration of some trace metals in the tissues, which limits the usefulness of coral tissues for bio-assay purposes to a few metals and may modify how trace metals are transferred to

skeletons. Moreover, the trace metals in coral skeletons had been metabolized and biologically precipitated in substitutional solid solution with calcium.

Anu et al. (2007) found that the concentration of heavy metal in the coral forms is based on the morphological features of massive, branching and/or fallacies. They also observed that Pb, Ni, Mn and Cd in tissues showed highest concentrations within the branching-type corals. Barakat et al. (2015) concluded that corals are suitable for use as proxy tools for assessing environmental pollution.

The scope of the present study is to measure heavy metals (Fe, Mn, Zn, Cu, Pb, Ni and Cd) in four species of coral reef. The results are used as fingerprints to locate sites of polluted coral reefs and to identify heavy metals sources and understand the impacts of human activities and pollutant sources in the area between Quseir and Hamata. The metal levels in the present study were further compared with those found at Quseir area and other areas along the Red Sea coast and the world.

Study areas

Six locations were selected along the area between Quseir and Hamata to represent different conditions. These sites being arranged from north to south illustrate the various human activities probably found in the areas (Figure 1).

Site 1: Shouni bay lies north to the Marsa alam city with longitude lines 25° 28' 9.31" and latitude lines 34° 40' 50.16" and is exposed to diving and snorkeling activities.

Site 2: Asalaya bay is located between longitude lines 24° 57' 46.38" and latitude lines 34° 56' 15.87". This area is exposed to snorkeling and diving activities.

Site 3: Tondoba area lies south to the Marsa alam city with longitude lines of 24° 57' 46.38" and latitude lines 34° 56' 15.87". It is exposed to diving and snorkeling activity and used as a small port for tourism and fishing boats.

Site 4: Wadi El-Gemal area (50 km south Marsa Alam) lies south to Marsa alam city with longitude lines 24° 41' 16.96" and latitude lines 35° 5' 7.90". It is exposed to diving and snorkeling activity and used as a small port for tourism and fishing boats and in addition to a control site which is Qola'an Reefs (in Hamata area south Wadi El-Gemal area).

Site 5: Abu-Ghsoon bay (1600 m south of Abughsoon mining port) is lying south to Marsa alam city with longitude lines 24° 26' 21.24" and latitude lines 35° 12' 43.64" and is exposed to diving and snorkeling activities; used as a port.

Site 6: Hamata bay lies south to the Marsa Alam city with longitude lines 24° 17' 26.11" and latitude lines 35° 22' 39.70" and is exposed to tourism activity.

MATERIALS AND METHODS

Field work

The materials used in this study were collected in the year, 2016 and 2017. Coral reef samples were collected from the studied areas during summer and winter by Scuba diving. Four species of coral reefs were selected for the present study. They include two species of branching (elkorn) coral (*Stylophora pistillata* and *Acropora humilis*) and brain coral (*Porites solida* and *Platygyra daedalea*). The collected samples were washed severally with bidistilled water to remove any adhering materials; thereafter, the samples were oven dried at 105°C for 24 h and placed in label bags until analysis.

Laboratory methods and treatment of data

10 g of each dry coral reef specimen were powdered using automatic agate mortar. 0.5 g of each powdered sample was digested according to the method described by Chester et al. (1994) using a 10 ml mixture of nitric acid (HNO₃) and perchloric acid (HClO₄) (3:1) for complete dissociation. The samples were digested in a hot plate. The residue of each sample was dissolved in 2 ml of 12 N HNO₃, diluted to 25 ml with bi-distilled water and filtered using filter paper. The concentrations of the metals were determined by AAS (Flame Atomic Absorption Spectrophotometry, GBC 932AA) and the results expressed as ppm.

RESULTS AND DISCUSSION

Concentration of the heavy metals in the coral reef at different study areas during summer season.

Seven heavy metals (Fe, Cu, Zn, Cd, Pb, Ni and Mn) were measured in four types of coral reef species (*S. pistillata*, *A. humilis*, *P. solida* and *P. daedalea*) during summer and winter from the studied areas. Table 1 and Figures 2 to 8 shows the summer data. The results showed that the coral species in Hamata area, especially *P. solida*, exhibited the highest value of Fe, Mn and Cu (330.25, 13.15 and 3.65 mg/L, respectively), while the highest value of Ni (10.35 mg/L) was presented in *S. pistillata* and the highest value of Zn (7.55 mg/L) presented in *P. daedalea*.

At Wadi El-Gemal area, Fe, Mn, Zn, Cu, Pb and Cd (741.35, 11.35, 9.55, 2.80, 66.25 and 0.20 mg/L, respectively) presented in the coral specie (*P. daedalea*) in the highest value, while the highest value of Ni (0.20 mg/L) was presented in *P. solida*.

Elements Fe, Mn, Cu and Pb were presented in high concentrations (316.20, 17.05, 2.15 and 780.25 mg/L, respectively) in the coral specie (*P. daedalea*) at Abu-Ghsoon area, while *A. humilis* showed the highest content of



Figure 1: Location map of the study areas between Quseir and Hamata.

Zn and the species *S. pistillata* showed the highest content of Ni (11.20 mg/L) and Cd (0.50 mg/L).

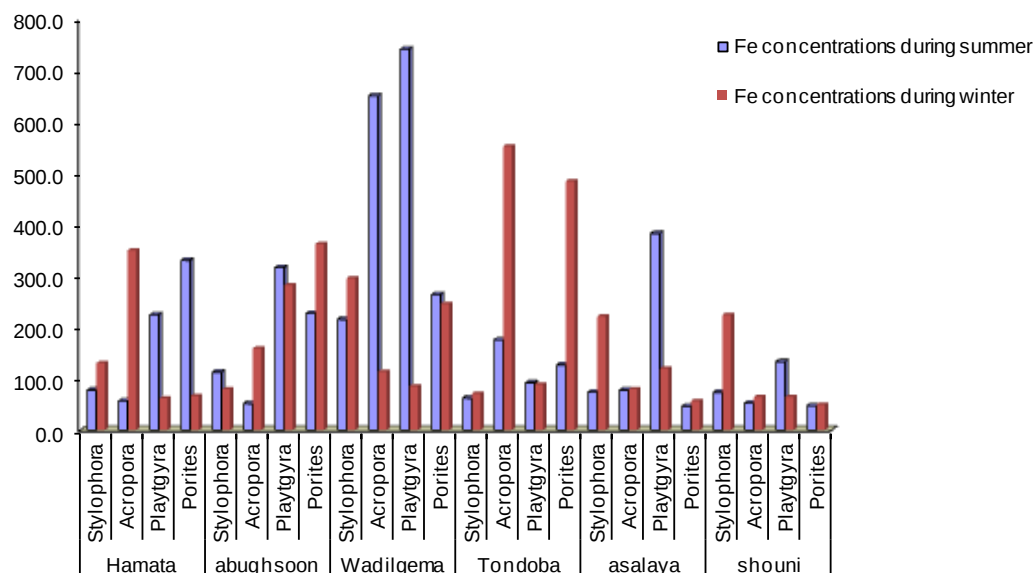
Coral specie (*A. humilis*) from Tondoba area showed the highest value of Fe, Mn, Zn and Cu (175.40, 2.85, 9.85 and

7.15 mg/L, respectively), while *P. solida* showed the highest content of Pb (57.40 mg/L) and Ni (8.15 mg/L).

At Asalaya area, the coral species (*P. daedalea*) showed the highest content of Fe, Mn and Pb (382.70, 25.05 and

Table 1: The results of heavy metals of coral reef species at the studied localities during summer.

Sites	Species name	Fe	Mn	Zn	Cu	Pb	Ni	Cd
Hamata	Stylophora pistillata	77.60	1.60	6.75	2.25	0.01	10.35	0.05
	Acropora humilis	56.60	1.45	5.30	1.65	13.70	4.00	0.05
	Playtgyra Solida	224.25	12.05	7.55	3.45	123.10	7.40	0.20
	Porites daedalea	330.25	13.15	6.35	3.65	109.80	3.30	0.20
Wadilgema	Stylophora pistillata	215.20	3.05	7.40	2.75	11.60	1.60	0.05
	Acropora humilis	650.65	8.70	3.15	1.35	16.60	1.50	0.05
	Playtgyra Solida	741.35	11.35	9.55	2.80	66.25	7.95	0.20
	Porites daedalea	263.55	9.55	3.25	1.50	52.30	9.35	0.05
Abughsoon	Stylophora pistillata	112.50	1.35	5.30	2.10	5.50	11.20	0.50
	Acropora humilis	51.15	2.05	7.05	1.45	20.55	1.85	0.05
	Playtgyra Solida	316.20	17.05	3.40	2.15	780.25	2.05	0.05
	Porites daedalea	227.30	12.90	5.95	1.85	212.23	2.15	0.25
Tondoba	Stylophora pistillata	61.85	1.30	4.90	2.15	4.75	1.35	0.05
	Acropora humilis	175.40	2.85	9.85	7.15	35.25	1.40	0.05
	Playtgyra Solida	91.85	2.80	4.55	1.65	15.05	4.70	0.05
	Porites daedalea	126.85	1.85	6.05	5.25	57.40	8.15	0.05
Asalaya	Stylophora pistillata	73.75	1.25	4.65	1.10	0.01	3.35	0.30
	Acropora humilis	77.80	1.70	6.25	1.40	45.55	2.35	0.15
	Playtgyra Solida	382.70	25.05	6.25	1.90	265.75	2.35	0.05
	Porites daedalea	46.20	1.25	7.10	1.95	18.90	1.40	0.05
Shouni	Stylophora pistillata	73.35	2.60	23.05	3.95	32.20	1.15	0.05
	Acropora humilis	52.45	1.20	6.50	1.85	10.90	2.25	0.05
	Playtgyra Solida	132.85	8.70	6.05	2.40	117.20	11.65	0.05
	Porites daedalea	47.15	2.00	4.10	0.90	34.10	5.25	0.15

**Figure 2:** Fe concentration in coral species during summer and winter.

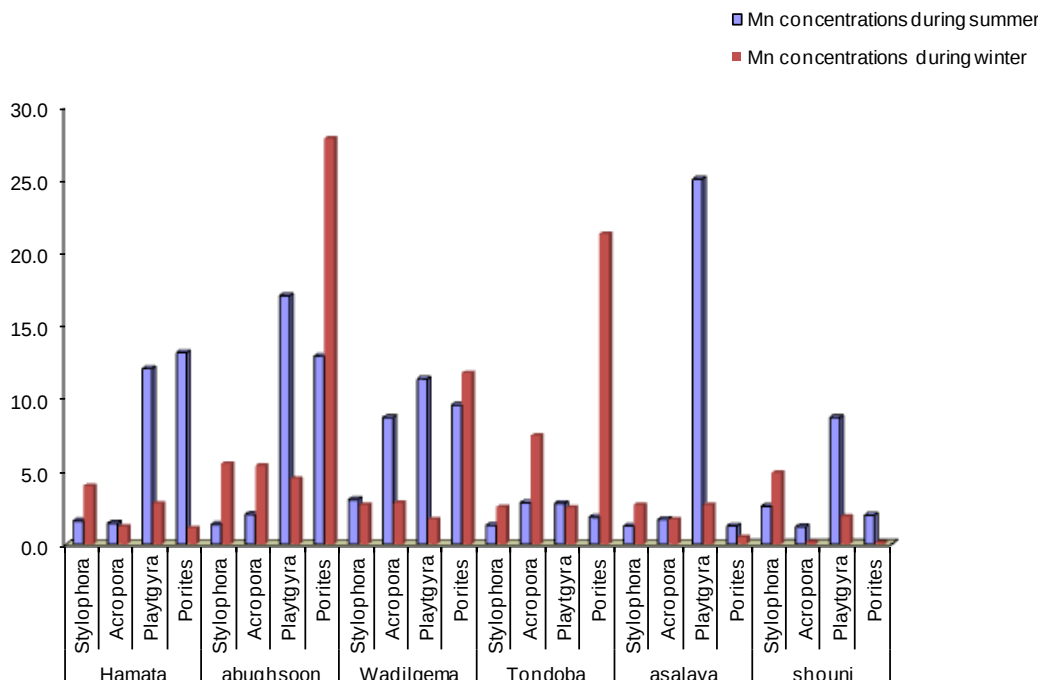


Figure 3: Mn concentrations in coral species during summer and winter.

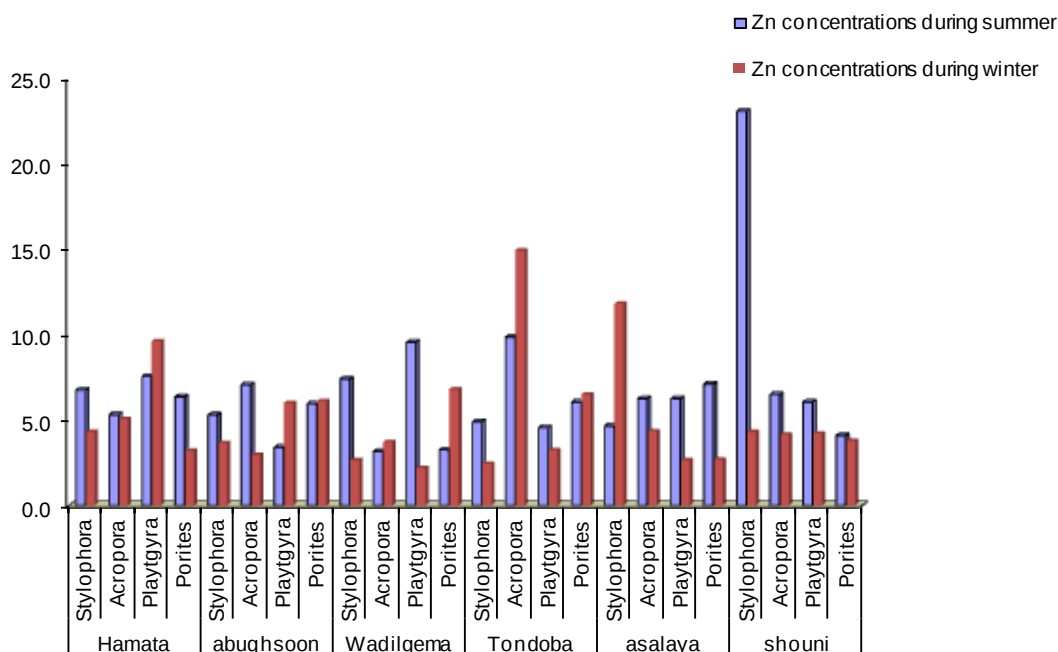


Figure 4: Zn concentrations in coral species during summer and winter.

265.75 mg/L, respectively). *P. solida* represented the highest contents of Zn (7.10 mg/L) and Cu (1.95 mg/L). The species *S. pistillata* showed the highest content of Ni (3.35 mg/L) and Cd (0.30 mg/L). The coral species (*P. daedalea*)

from Shouni area showed the highest content of Fe, Mn, Pb and Ni (132.85, 8.70, 117.20 and 11.56 mg/L, respectively). *S. pistillata* showed the highest contents of Zn (35.05 mg/L) and Cu (3.95 mg/L). The highest level of Cd (0.15 mg/L)

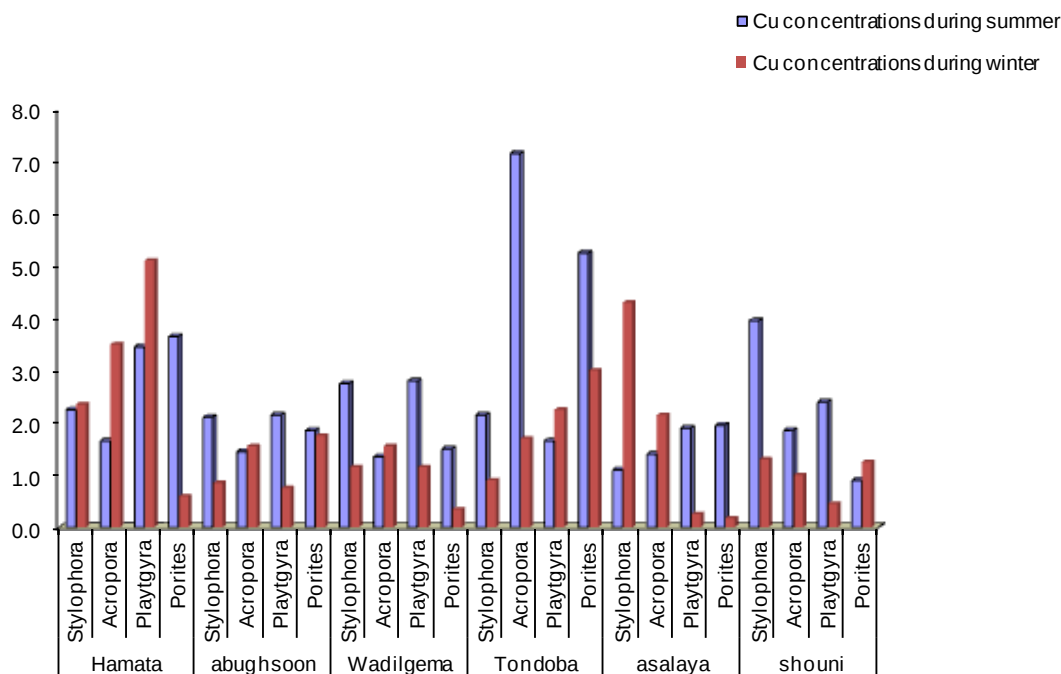


Figure 5: Cu concentrations in coral species during summer and winter.

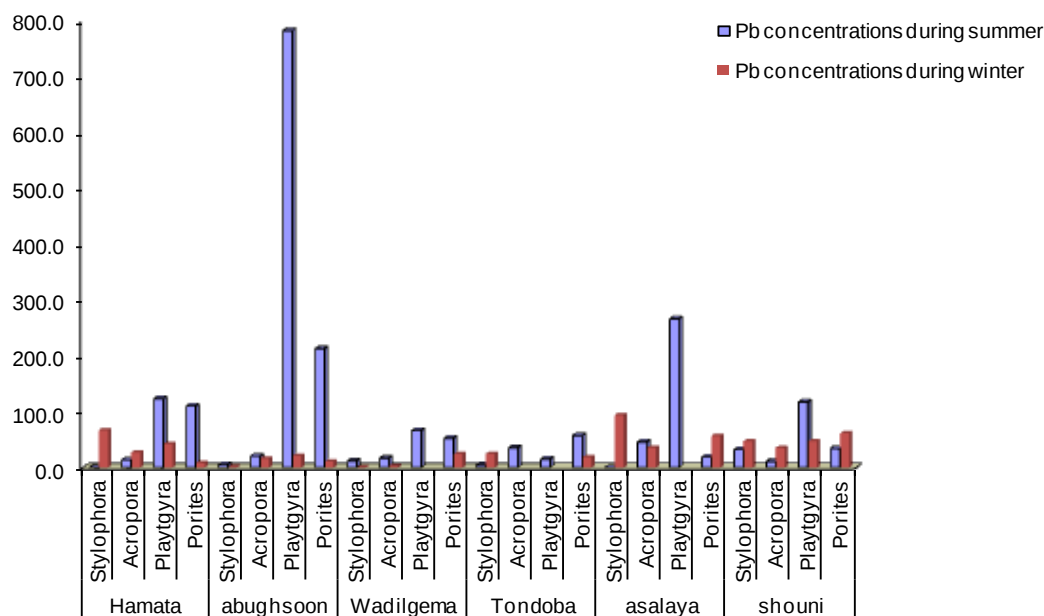


Figure 6: Pb concentrations in coral species during summer and winter.

was presented in *A. humilis*.

Concentration of the heavy metals in the coral reef at different study areas during winter season

Table 2 and Figures 2 to 8 show the data of heavy metal concentrations in the coral reef at the different study areas

during winter season. The results revealed that in Hamata area the coral species (*S. pistillata*) showed the highest contents of Mn, Pb and Cd (4.0, 66.65 and 0.79 mg/L, respectively), while the highest value of Fe (350.05 mg/L) was found in *A. humilis*. *P. daedalea* showed the highest level of Zn (9.60 mg/L) while *P. solida* showed the highest content of Ni (9.29 mg/L).

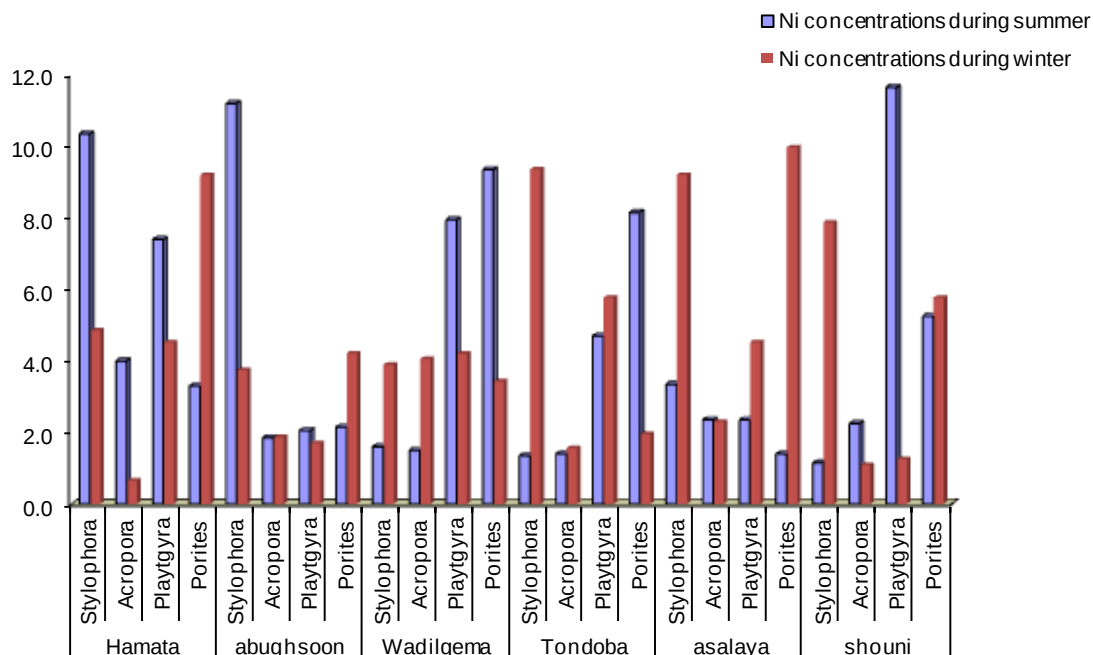


Figure 7: Ni concentrations in coral species during summer and winter.

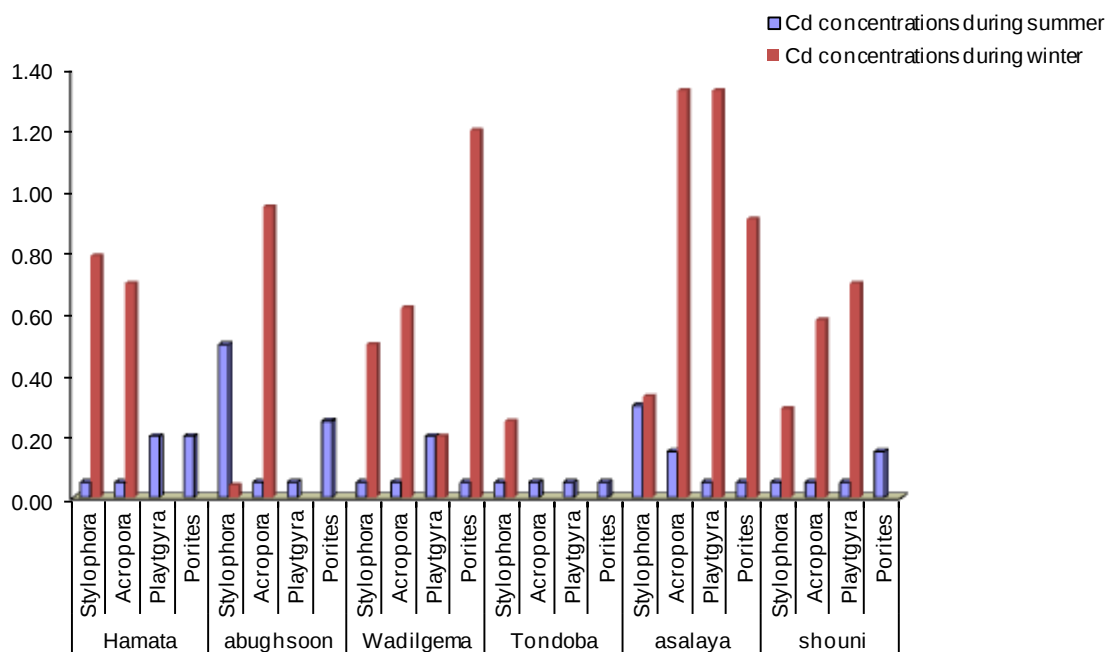


Figure 8: Cd concentrations in coral species during summer and winter.

S. pistillata from Wadi El-Gemal exhibits the highest concentrations of Fe (295.25 mg/L), while the species (*P. solida*) showed the highest contents of Mn, Zn, Pb and Cd (11.75, 6.80, 24.25 and 1.20 mg/L, respectively). The highest concentration of Cu (1.55 mg/L) was presented in

A. humilis, while Ni was presented in the highest concentration in *P. daedalea*.

At Abu-Ghsoon area, the coral species (*P. solida*) showed the highest level of Fe, Mn, Zn, Cu and Ni (362.20, 27.85, 6.10, 1.75 and 4.21 mg/L, respectively), while the highest

Table 2: The results of heavy metals of coral reef species at the studied localities during winter.

Sites	Species name	Fe	Mn	Zn	Cu	Pb	Ni	Cd
Hamata	Stylophora pistillata	130.00	4.00	4.30	2.35	66.65	4.85	0.79
	Acropora humilis	350.05	1.20	5.05	3.50	27.20	0.65	0.70
	Playtgyra Solida	61.55	2.80	9.60	5.10	42.15	4.52	ND
	Porites daedalea	66.20	1.10	3.20	0.60	7.90	9.20	ND
Wadilgemal	Stylophora pistillata	295.25	2.70	2.65	1.15	0.39	3.89	0.50
	Acropora humilis	113.45	2.85	3.70	1.55	2.65	4.05	0.62
	Playtgyra Solida	84.80	1.70	2.20	1.15	ND	4.20	0.20
	Porites daedalea	245.65	11.75	6.80	0.34	24.25	3.43	1.20
Abughsoon	Stylophora pistillata	79.20	5.53	3.65	0.85	1.19	3.74	0.04
	Acropora humilis	158.60	5.40	2.95	1.55	16.10	1.87	0.95
	Playtgyra Solida	282.30	4.50	6.00	0.75	21.10	1.70	ND
	Porites daedalea	362.20	27.85	6.10	1.75	10.85	4.21	ND
Tondoba	Stylophora pistillata	70.70	2.55	2.45	0.90	24.65	9.36	0.25
	Acropora humilis	552.10	7.45	14.90	1.70	ND	1.56	ND
	Playtgyra Solida	88.40	2.50	3.25	2.25	ND	5.77	ND
	Porites daedalea	484.65	21.30	6.50	3.00	18.45	1.95	1.16
Asalaya	Stylophora pistillata	220.85	2.70	11.80	4.30	93.90	9.20	0.33
	Acropora humilis	79.55	1.70	4.35	2.15	35.15	2.30	1.33
	Playtgyra Solida	119.95	2.70	2.65	0.26	ND	4.52	1.33
	Porites daedalea	56.60	0.48	2.70	0.17	56.16	9.97	0.91
Shouni	Stylophora pistillata	223.95	4.90	4.30	1.30	47.25	7.87	0.29
	Acropora humilis	64.10	0.15	4.15	1.00	34.90	1.09	0.58
	Playtgyra Solida	64.15	1.90	4.20	0.45	47.20	1.25	0.70
	Porites daedalea	49.10	0.11	3.80	1.25	61.20	5.77	ND

concentration of Pb (21.10 mg/L) was found in *P. daedalea*. The highest concentration of Cd (0.95 mg/L) was found in *A. humilis*.

Fe (552.10 mg/L) and Zn (14.90 mg/L) is presented in its highest concentrations in *A. humilis* from Tondoba area, while *P. solida* showed high Mn, Cu and Cd (21.90, 3.00 and 1.16 mg/L, respectively). *S. pistillata* in the same area showed the highest contents of Pb (24.65 mg/L) and Ni (9.36 mg/L).

At Asalaya area, *S. pistillata* showed the highest contents of Fe, Mn, Zn, Cu and Pb (220.85, 2.70, 11.80, 4.30 and 93.90 mg/L), while the highest concentration of Ni (9.97 mg/L) was presented in *P. solida*. The highest content of Cd (1.33 mg/L) was measured in both *A. humilis* and *P. daedalea*.

P. daedalea from Shouni area showed the highest concentration of Cd (0.7 mg/L), while the coral specie (*S. pistillata*) showed the highest contents of Fe, Mn, Zn, Cu, Pb and Ni (223.95, 4.90, 4.30, 1.30, 47.25 and 7.87 mg/L, respectively).

Comparison of the results in the present study with the others published

Coral reef areas along the cost of Egyptian Red Sea are being heavily influenced by anthropogenic activities. In general, the most attractive and economically valuable reefs in the world are found in developing countries (Madkour, 2013). The main anthropogenic sources of heavy metals contamination in the studied coral reefs are antifouling and anticorrosive paints used to protect ships and coastal structures, shipment operations inside the harbor, domestic sewage, oil refineries, ship yards, power plants, desalination plants and landfill. Also, natural inputs may increase heavy metal concentrations of coral reef species in some areas.

Table 3 shows the comparison between concentrations of heavy metals in coral reef species of the present study and other areas of the Egyptian coasts. The concentrations of Fe recorded high values in the present study as compared to the previous study, but these values approach from the

Table 3: Comparison of the heavy metal concentrations (ppm) in coral reef species from the present work and other areas of the Egyptian Red Sea coast.

Site	Heavy metals concentrations (ppm)							References
	Fe	Mn	Zn	Cu	Pb	Ni	Cd	
The area between Quseir and Hamata	46.20-741.5	1.20-52.05	3.15-23.05	0.90-7.15	0.01-780.25	1.15-11.75	0.05-0.50	The present study
Al-Ghardaqa area	-	3.8-8.8	0.33-18.8	0.59-4.2	3.48-55	0.09-0.38	0.003-0.06	Hanna (1990)
South Hurghada Abu Soma Bay	1,380-4,280	-	5.9-56	18-88.9	0.01-4.9	1.4-6.7	0.01-0.05	Mohammed (2002)
Wadi El-Gemal	33.6-250.7	2.53-13.1	2.03-15.81	0.55-4.18	14.01-35.7	0.38-4.36	0.04-0.26	Madkour (2005)
Safaga lagoon	6.76-183.20	0.00-14.56	0.03-5.04	0.00-0.79	0.00-2.12	0.06-1.72	-	Dar and Abdel-Wahab (2005)
Hurghada Shipyard	39.6-731.7	1.9-7.7	13.8-36.3	1.1-6.4	4.7-20.9	0.3-2.1	0.04-0.26	Madkour and Dar (2007)
Different areas: Red Sea, Egypt	18.3-301.15	0.31-15.56	0.69-28.24	0.38-10.05	0.00-30.00	2.97-16.47	-	Mohammed and Dar (2010)
Different areas: Red Sea, Egypt	22.19-275.8	0.12-26.88	2.19-16.9	0.12-5.02	0.03-36.31	0.01-5.9	0.05-1.55	Madkour (2011)

values was measured by Madkour and Dar (2007).

The concentrations of Mn and Zn recorded high values in the present study as compared to the previous studies except in coral reefs measured by Madkour and Dar (2007), while the values of Cu recorded higher values as compared to the previous study except in coral reef measured by Mohammed (2002), while Mohammed and Dar (2010) recorded high values in some coral reef species as compared to the present study. In the same manner, lead concentrations recorded high concentrations in the natural inputs sites of the present study as compared to the previous studies.

The concentrations of Nickel recorded highest values in the coral reef species in the present study as compared to their concentrations in other studies of the Egyptian Red Sea coast except those measured by Mohamed (2010). However, the concentrations of Cd recorded high values as compared to the previous studies except that measured by Madkour (2013). The difference in the concentrations of heavy metals of coral reef species of the studied localities and other studies of the Egyptian Red Sea coast indicates that bioaccumulation of these metals is species specific. Generally,

the results showed that the heavy metals accumulated by coral reef species are not direct.

Conclusion

In this study, it was observed that most of the intended heavy metals appear to share the same anthropogenic sources of pollution. In general, the reef sites undergoing increased anthropogenic pressure exhibited elevated levels of heavy metals in coral reefs.

Heavy metals have a great effect on the marine life, especially coral reef. The high concentrations of these metals can accumulate in the skeleton of coral reef and have ability to kill a marine organism and destroy the marine system.

All the problems associated with heavy metals pollution in coral reef ecosystems will increase substantially in the incoming years, unless the interested Governmental and Non-governmental Organizations adopt sustainable management strategies to protect the coral reef areas and control the pollution sources in cooperation with the ecologists, scientists and other stakeholders.

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