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Pollution in the Bay of Bengal: Impact on Marine Ecosystem

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Abstract

The study focused on heavy metal concentration in sea water, sea sediment and their toxic effect on sea shells, and on oyster along the east coast of the Bay of Bengal. The hierarchy of heavy metals in sea sediment of the bay showed as: Fe > Zn > Ni > Cr > Pb > Cd. The average concentration of nickel exceeded ERL (20.9 $\mu g \cdot g^{-1}$) value and the incidence of adverse effects on biological components exceeded 16.7%. The present study showed that the concentration of Cd, Fe, Pb and Cu in sea water were relatively higher than the standard concentration. The study showed a considerable amount of heavy metals (0.035%) such as Zn, Pb, Cu, Fe, and Mg in sea shells, and oyster which may make them toxic. The toxic effect of Pb and Zn may reduce their growth which is a great threat to marine ecosystem.

Keywords

Bay of Bengal, Heavy Metal, Effects Range-Low (ERL), Effects Range-Medium (ERM), Marine Organisms

1. Introduction

The coast of Bangladesh is known as a zone of multiple vulnerabilities as well as opportunities. It is prone to severe natural disasters like cyclones, storm surges, floods, erosion, soil salinity etc. Main rivers and lake of this region are the Karnaphuli, Halda, Sangu, Matamuhuri, Bakkhali, Naf, Kasalong, Chingri, Mayani and Kaptai Lake. A large number of chemical and fertilizer industries have been established on both the banks of the Karnaphuli River. Effluents from these industries are reportedly being directly discharged from river to sea. Huge amount of solid wastes and effluents are discharged through Chaktai, Sundari, Noakhal, Mazirghat, Gupta, Mohesh, Shikalbhaha and Ferighat canals into the Karnaphuli River; as a result pollution of this river is increasing day by day [1]. A number of industries namely fertilizers, cement, pulp and paper, food processing, pharma-

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ceuticals, metal, textile, chemical, petroleum, lubricant plants, etc. discharge heavy metals into the coastal water [2]. Reference [2] mentioned that the Bay of Bengal and Karnaphuli River are heavily polluted in areas close to Chittagong port channel due to discharge of oil and chemical waste leaked from ships. Plastic bottles and other plastic products are most common forms of litter in the coastal water. The rapid and unplanned increase in shrimp culture is also becoming a concern. The use of antibiotics and other chemicals used in shrimp fields is causing pollution in the water, which may harm other aquatic lives. Shrimp culture in Cox's Bazar uses 620 tons of urea annually. It also generates 15 tons of waste daily, which comes into sea [3].

Many studies have been conducted on water pollution in rivers of Bangladesh. Reference [4] conducted a study for the determination of some trace metal (Cr, Mn, Zn, Ni, Cu, Pb, Cd and Fe) concentrations in water of the Karnaphuli River estuary and found that the estuary has been polluted from domestic sewage, land washout, river run-off and shipping activities. Reference [5] mentioned that elevated concentrations of ^{226}Ra and ^{40}K values observed in river sediment may be due to the anthropogenic input of phosphate fertilizers into the estuarine zone from agricultural lands and wastes in the vicinity. A few studies have, however, been done on sea water and marine sediment pollution of the bay [2] [6]. The present research was conducted to study the sea water as well as sea sediment pollution and their impact on marine ecosystem.

2. Methods and Materials

The continental shelf, extending up to 36 nautical miles (about 67 km), of the north-eastern part of the Bay of Bengal was selected as the study area (**Figure 1** and **Figure 2**). Thirty sea surface water (upper 40 m), eight sea sediment samples at different depths which varied from 10 to 20 m, and twenty eight sea shells, oyster and coral reef samples were collected by using different sampler such as Water Level sampler, Sediment Grab sampler, Ecobeam sounder with the help of BNS ANUSHANDHAN (Roebuck Class Hydrographic Survey vessel with 5 m

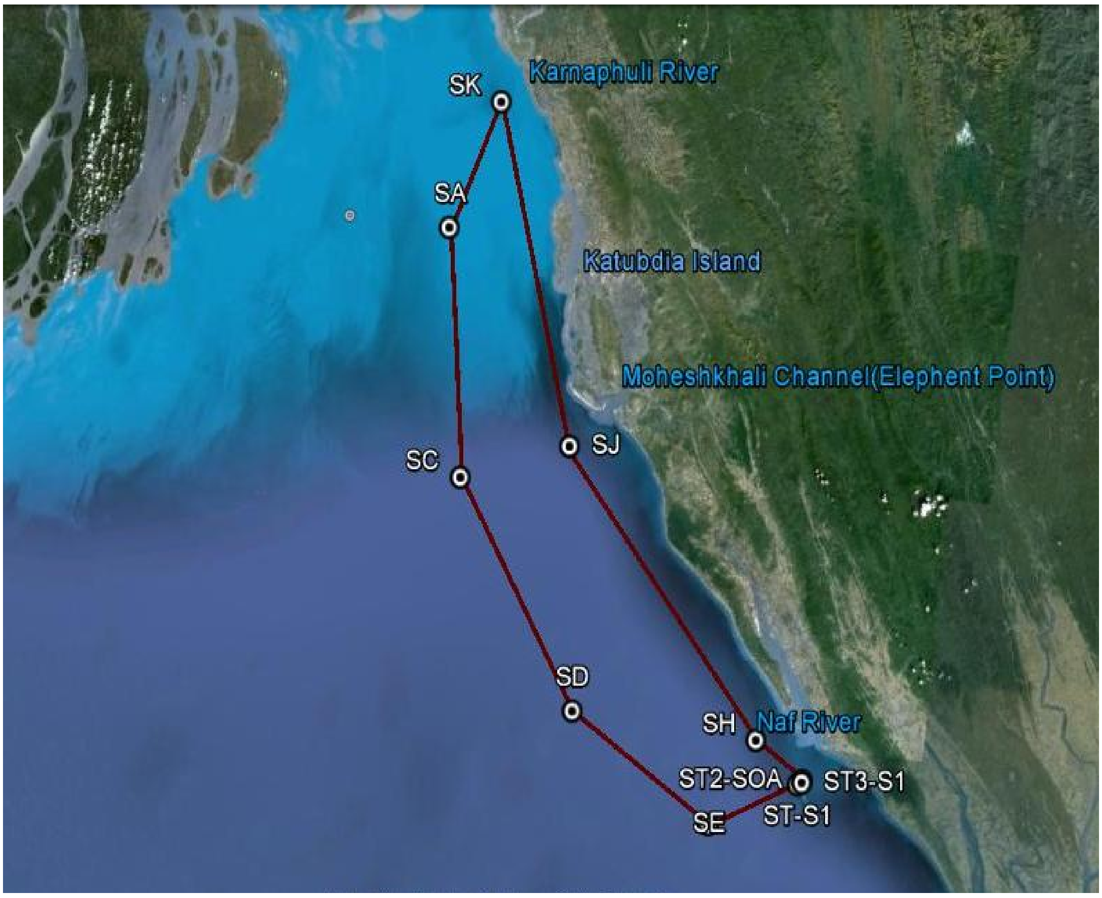

Figure 1. The study area and location of water sample.

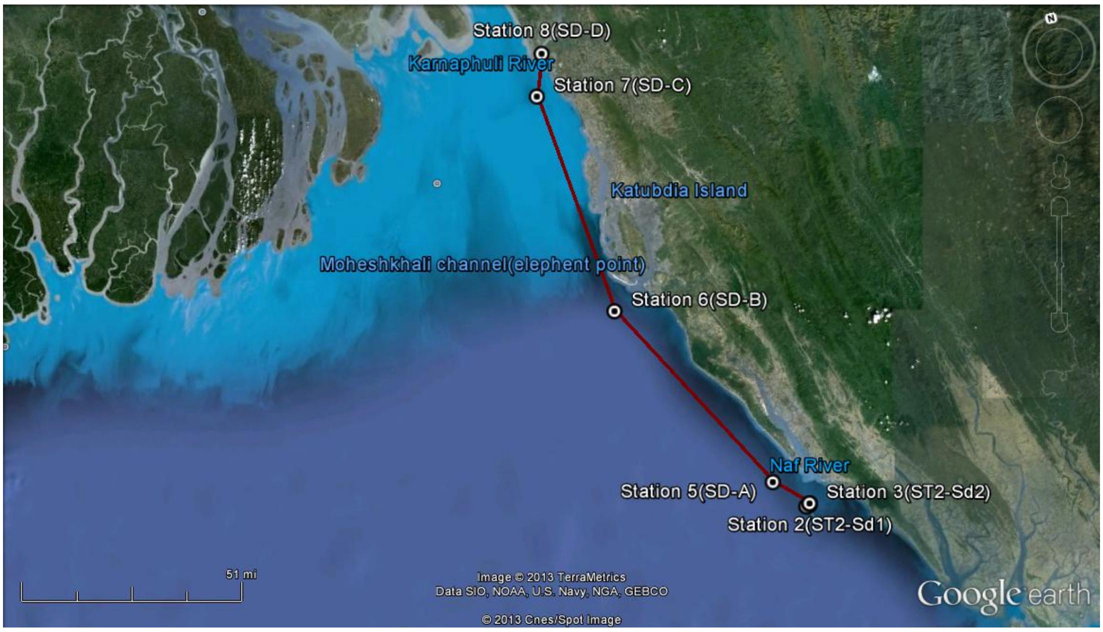

Figure 2. The study area and location of sediment samples.

draft, 64 m length, 30 m width and displacement 1450 ton) provided by Bangladesh NAVY. The samples were collected during March 20 to 23, 2012. In this study lab experiments are performed in BCSIR (Bangladesh Council for Scientific and Industrial Research), Department of Soil, Water and Environment, and Department of Geography and Environment in Dhaka University.

Sediment quality guidelines (SQGs) [7] have been followed to know the toxic effect of heavy metal on marine ecosystems. The study calculated the average concentration of heavy metal and ERL and ERM guideline values for trace metals (ppm, dry wt.) and percent incidence of biological effects in concentration ranges defined by the two values [7]: ERL = Effects Range-Low and ERM = Effects Range-Median.

The pollution load index (PLI) has been calculated by obtaining the n-root from the n-CFs that obtained for all the metals. This CF is the quotient obtained by dividing the concentration of each metal [8]. The formula of PLI is:

$$\text{PLI} = \sqrt[n]{\left(\text{CF1} \times \text{CF2} \times \text{CF3} \times \cdots \times \text{CFn}\right)}$$

$$\text{CF} = \text{C metal}/\text{C background value}$$

where,

CF = contamination factor; n = number of metals;

C metal = metal concentration in polluted sediments;

C background value = background value of that metal.

The world average concentration of Cu (45 µg/g), Ni (68 µg/g), Mn (900 µg/g), Pb (20 µg/g), Zn (95 µg/g), Fe (46,000 µg/g), Cr (90 µg/g) and Cd (0.3 µg/g) reported for shale [9] were considered as the background value.

3. Results

3.1. Heavy Metal Concentration in Sea Sediment

The concentrations of the metals such as Cu, Pb, Cd, Zn, Cr, Ni, Mg, and Ca were measured. The concentration of Pb in sea sediments varied from 5.26 $\mu g \cdot g^{-1}$ to 22.54 $\mu g \cdot g^{-1}$ with an average (n = 8) value of 12.71 $\mu g \cdot g^{-1}$ (α-8.38). The highest concentration was found at ST2-Sd1 point, which is 1.31 nautical mile east from St. Martin Island (**Figure 3**, **Table 1(a)**). The Cd concentration varied from 0.015 $\mu g \cdot g^{-1}$ to 5.98 $\mu g \cdot g^{-1}$ with an average (n = 8) of 0.85 $\mu g \cdot g^{-1}$ (α-2.1). The highest concentration of Cd was found near Karnaphulli River (**Figure 4**, **Table 1(a)**). The second highest concentration of Cd was 0.704 $\mu g \cdot g^{-1}$ in St. Martin coast (**Figure 4**, **Table 1(a)**). The concentrations of Cr varied between 0.73 $\mu g \cdot g^{-1}$ and 31.13 $\mu g \cdot g^{-1}$ with an average (n = 8) of 14.51

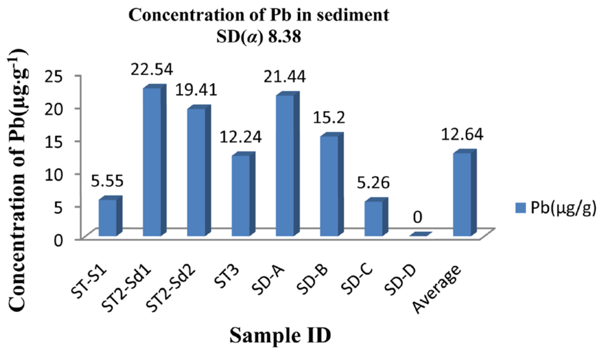

Figure 3. Concentration of Pb in sediment.

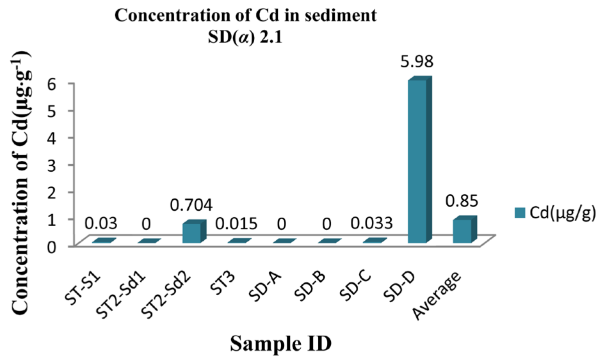

Figure 4. Concentration of Cd in sediment.

Table 1. (a) Location of sediment sample; (b) Location of water sample.

(a)

Station No.	Sample ID	Time & Date	GPS Position	Depth (m)	Distance from Shore (Nautical Miles)
1.	ST-S1	21.3.12 (9.50 am)	20˚37'51"N 92˚19'03"E	0 m	St. Martin Island
2.	ST2-Sd1	21.3.12 (1.20 pm)	20˚38'17"N 92˚19'52"E	10 m	1.2 Nautical Miles from St. Martin Island
3.	ST2-Sd2	21.3.12 (1.20 pm)	20˚38'17.30"N 92˚19'51.99"E	10 m	1.31 Nautical Miles from St. Martin Island
4.	ST3	21.3.12 (1.50 pm)	20˚37'58"N 92˚19'45"E	3.5 m	St. Martin Island Jeti
5.	SD-A	22.3.12 (0905)	20˚44'14"N 92˚13.42'E	20 m	5.77 Nautical Miles from Naf River
6.	SD-B	22.3.12 (1440 pm)	21˚24.35'N 91˚49.63'E	11 m	6.61 Nautical Miles from Moheshkhali Channel
7.	SD-C	22.3.12 (2045 pm)	22˚09'033"N 91˚44.55'E	17 m	4.57 Nautical Miles from Karnaphuli Estuary
8.	SD-D	23.3.12 (9 am)	22˚17.018'N 91˚47.72'E	13 m	Karnaphuli River Estuary

(b)

Sample No.	Sample ID	GPS Position	Depth (m)	Distance from Shore (Nautical Mile)
1	SA	21˚53.948'N 91˚34.619'E	0 m, 10 m	15 Nautical Mile from Kutubdia
2	SC	21˚22.20'N 91˚32.49'E	0 m	25 Nautical Mile from Cox's Bazar
3	SD	20˚06.19'N 91˚38.26'E	0 m, 40 m	27 Nautical Mile from Cox's Bazar
4	SE	20˚50.89'N 91˚45.93'E	0 m, 10 m, 40 m	34 Nautical Mile from Cox's Bazar 36.5 Nautical Mile from St. Martin
5	SH	20˚44.14'N 92˚13.42'E	0 m	5.5 Nautical Mile from Shahpuri Dip
6	SJ	21˚24.35'N 91˚49.63'E	0 m, 10 m	Elephant Point (Mohesh Khali Channel)
7	SK	22˚09.033'N 91˚44.55'E	0 m	Karnaphuli River Estuary
8	ST-S1	20˚37'51"N 92˚19'03"E	0 m	St. Martin Island
9	ST2-SOA	20˚38'17"N 92˚19'52"E	0 m	1.2 Nautical Mile from St. Martin
10	ST3-S1	20˚37'58"N 92˚19'45"E	3.5 m	St. Martin Island Jeti

μg·g^{-1} (α-12.08). Cr has a high loading at point SD-A which is 5.77 nautical mile east from Naf River (**Figure 5**, **Table 1(a)**). The average (n = 8) Ni concentration was found to be 36.65 μg·g^{-1} with α-16.32. The Ni concentrations varied from 9.025 μg·g^{-1} to 56.38 μg·g^{-1} in the study area. The highest concentration was 56.38 μg·g^{-1} at St. Martin coast which is 5.77 nautical mile east from Naf River (**Figure 6**, **Table 1(a)**). The concentration of Zn varied from 16.372 μg·g^{-1} to 178.705 μg·g^{-1} with an average (n = 8) of 184.56 μg·g^{-1} (α-66.89) in the study area. Zn showed two high loading on Moheshkhali channel and St. Martin Island (5.77 nautical miles east from Naf River) (**Figure 7**, **Table 1(a)**) which were 178.705 μg·g^{-1} and 159.80 μg·g^{-1} respectively. In the present study, the average (n = 8) concentration of Fe was found to be 808.27 μg·g^{-1} with α-316.05. The concentrations of Fe varied from 82.73 μg·g^{-1} to 1015.34 μg·g^{-1}. The major pollution source of Fe was observed at Station 2 (1.21 nautical miles from St. Martin Island) (**Figure 8**, **Table 1(a)**), which had the highest concentration of Fe (1015.34 μg·g^{-1}). In the present study the concentration of Ca varied from 0.0369 μg·g^{-1} to 3.2704 μg·g^{-1} with an average (n = 8) of 1.01 μg·g^{-1} (α-1.16). The highest concentration of calcium (3.270 μg·g^{-1}) was found at St. Martin Island Jeti (**Figure 9**, **Table 1(a)**).

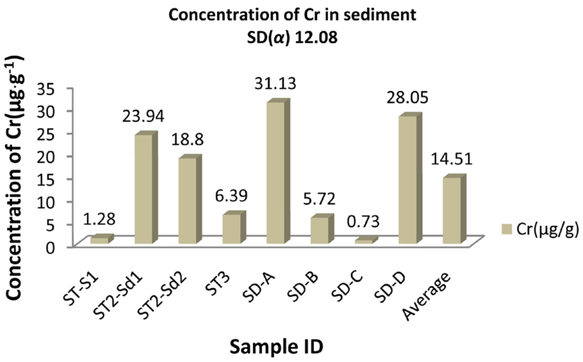

Figure 5. Concentration of Cr in sediment.

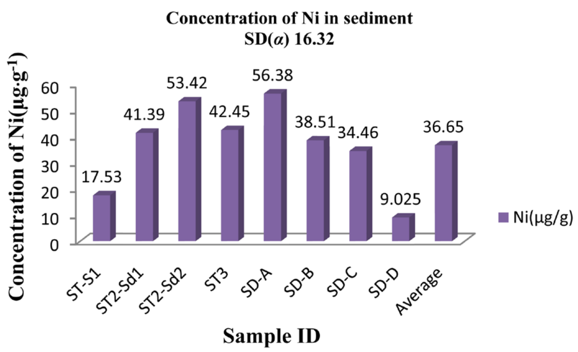

Figure 6. Concentration of Ni in sediment.

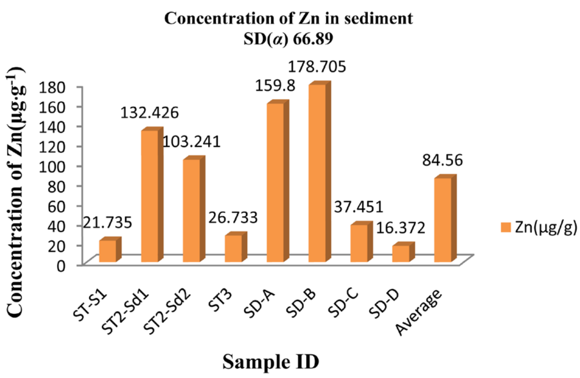

Figure 7. Concentration of Zn in sediment.

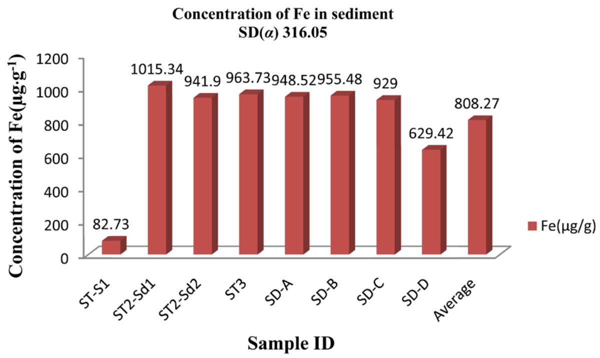

Figure 8. Concentration of Fe in sediment.

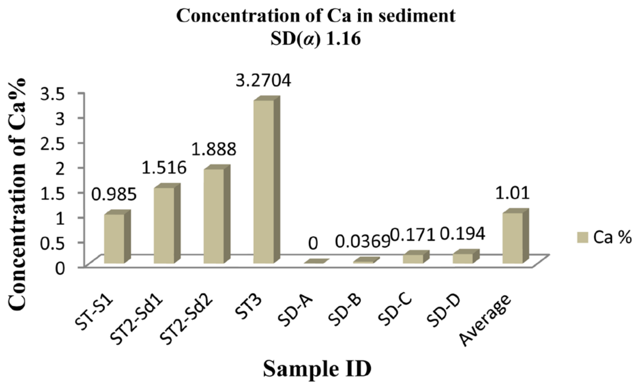

Figure 9. Concentration of Ca in sediment.

Therefore, the hierarchy of heavy metals in sea sediments of the bay was found as follows: Fe > Zn > Ni > Cr > Pb > Cd.

3.2. Sediment Quality Analysis

From the study it can be seen that the average concentration of the heavy metals were below ERL level, except nickel (**Table 2**). The concentration of Ni was greater than ERL value. The Stations 3 and 5 of St. Martin Island coast have been detected high concentration of Ni. The average (n = 8) concentration of Ni exceeded ERL value. The incidence of adverse effects exceeded 16.7% for nickel. The concentration of nickel exceeded ERL and ERM value at Station 5 (5.77 nautical mile from Naf River) (**Table 1(a)** and **Table 2**, **Figure 6**).

3.3. Pollution Load Index

The values of Pollution Load Index (**Table 3**) were found to be generally low (<1) in all stations of the study area. The results of the present study showed that the CF values of some of the metals such as Cr, Ni and Fe were low (<1) (**Table 3**) but Pb shows higher (>1) values at St. Martin's Island (Station 2), and at near Naf River (Station 5); Cd showed higher (>1) values at St. Martin's Island (Station 3) and Karnaphuli River (Station 8); and Zn showed higher (>1) values at St. Martin's Island, Naf River and Karnaphuli River (Stations 2, 3, 5, 7) (**Figure 1(a)**, **Table 3**).

3.4. Water Results

Concentration of Heavy Metals in Sea Water

The study found that the average (n = 30) concentration of Cd, Fe, Pb and Cu were relatively higher than the standard concentration in sea water (**Table 4**). The average (n = 30) Pb concentration (0.161 ppm) in sea water was detected near St. Martin Island. The concentration of Cd (n = 30; 0.005 ppm) was higher at Elephant Point (Mohesh Khali Channel) as the sampling point was situated in inner part of the estuary zone. The average (n = 30)

Table 2. Average concentration of heavy metal in present study and ERL and ERM guideline values for trace metals (ppm, dry wt.) and percent incidence of biological effects in concentration ranges defined by the two values (from Long, *et al*., 1995). ERL = Effects Range-Low; ERM = Effects Range-Median.

Chemical	Average con. of heavy metal ($\mu g \cdot g^{-1}$) in present study	Guidelines		Percent (ratios) incidence of effects*		
		ERL	ERM	<ERL	ERL-ERM	>ERM
Cadmium	0.85	1.2	9.6	6.6	36.6	65.7
Chromium	14.51	81	370	2.9	21.1	95.0
Copper	14.28	34	270	9.4	29.1	83.7
Lead	12.64	46.7	218	8	35.8	90.2
Nickel	36.65	20.9	51.6	1.9	16.7	16.9
Zinc	84.56	150	410	6.1	47.0	69.8

*Number of data entries within each concentration range in which biological effects were observed divided by the total number of entries within each range.

Table 3. Pollution Load Index (PLI) of heavy metals in sea sediment.

Station No.	Sample ID	CF Pb	CF Cd	CF Cr	CF Cu	CF Ni	CF Zn	CF Fe	PLI Index
1	ST-S1	0.28	0.1	0.014	0.0004	0.26	0.23	0.0018	0.03
2	ST2-Sd1	**1.13**	0	0.27	0.39	0.61	**1.39**	0.022	0.4
3	ST2-Sd2	0.97	**2.35**	0.21	0.35	0.79	**1.09**	0.02	0.44
4	ST3	0.61	0.05	0.07	0.18	0.62	0.28	0.021	0.15
5	SD-A	**1.07**	0	0.35	0.53	0.83	**1.68**	0.021	0.49
6	SD-B	0.26	0.11	0.06	0.17	0.51	0.39	0.020	0.15
7	SD-C	0.76	0	0.31	0.78	0.57	**1.88**	0.021	0.40
8	SD-D	0	**19.93**	0.008	0.15	0.13	0.17	0.014	0.14

concentration of cadmium was 0.002 ppm in sea water, whereas the standard value of Cd in seawater is 0.0001 ppm. Zn concentrations of seawaters in the study area showed lower values compared to other areas of the world. The average (n = 30) concentration of copper in sea water was 0.003 ppm and this value was higher than the standard value of copper (0.0009 ppm). The average (n = 30) concentration of iron was much higher (0.414 ppm) in sea water of the bay than the standard value.

3.5. Biological Samples

The oyster creates its own environment by secreting a shell composed of ninety-five percent (95% - 97%) of calcium carbonate [10]. The remainder of the shell is made up of organic material and trace amounts of manganese, iron, aluminum, sulfate and magnesium [10]. The present study found a considerable amount (0.035%) of heavy metals such as Zn, Pb, Cu, Fe, and Mg in their shells which may make them toxic (**Figure 10**).

4. Discussion and Conclusion

Many studies have been conducted on heavy metal pollution level, sources and their consequences on marine ecosystem in different coasts including Indian Ocean, China Sea, Pacific Ocean and so on. Reference [11] mentioned that the Indian coastal waters are subjected to considerable pressure from sewage and industrial wastes and therefore, the coastal sediment contains some heavy metals such as Cd, Cu, Pb and Zn. Reference [6] investigated the nutrient status and load of pollution for six heavy metals (Cu, Zn, Fe, Mn, Pb and Cd) in the sediment of Jagannath canal, which receives municipal sewage mixed brackish water from the Bidyadhari River of north Sundarbans, West Bengal and he found the concentration of different heavy metals hierarchy as follows: Fe >

Mn > Zn > Cu > Pb > Cd. In the present study, the hierarchy of heavy metals in sediment of the coast of the Bay of Bengal was found as follows: Fe > Zn > Ni > Cr > Pb > Cd. The study showed the average concentration of Fe, Zn, Ni and Cr were much higher compared to Pb and Cd. Reference [12] observed that cadmium as a pollutant should be given more weightage since it causes several adverse damaging effects on human body through its accumulation. Reference [13] observed that cadmium is the most harmful of all the heavy metal pollutants.

As per sediment quality analysis (SQA), the average concentration nickel was higher in sea sediment of the bay in all stations and it exceeded ERL (20.9 $\mu g \cdot g^{-1}$) and ERM values (51.6 $\mu g \cdot g^{-1}$). The incidence of adverse effects on biological components exceeded 16.7% for nickel. The St. Martin Island coast and Naf River are highly affected by this pollutant.

In the present study the value of Pollution Load Index in sea sediment was found to be generally low (<1) in all stations of the study area and the record reveals that the bay sediment is not yet polluted like many other rivers and canals of the region. Though, some heavy metals like Pb, Cd, Zn showed higher (>1) values in different stations of the study area due to the external discrete sources like industrial activities, agricultural runoff and other anthropogenic inputs. In Jagannath canal in India, the Pollution load index value the heavy metal was 1.71 [11].

The present study shows that the concentration of Cd, Fe, Pb and Cu in sea water were relatively higher than the standard concentration. The average concentration of copper in sea water of the study area was 0.003 ppm. Sewage contains large quantities of dissolved organic matter, which promote the mobility of copper. The average concentration of Fe was much higher (0.414 ppm) in the bay water compared to its standard concentration (0.0034 ppm). The average concentration of cadmium and Pb were 0.002 pm and 0.0908, respectively in bay water. Reference [14] observed a direct relationship between the heavy metal levels in seawater and the content in biological samples. Lead is taken up passively from the water and deposited in the organisms and hence the organisms contain more quantity of lead than water [15] [16].

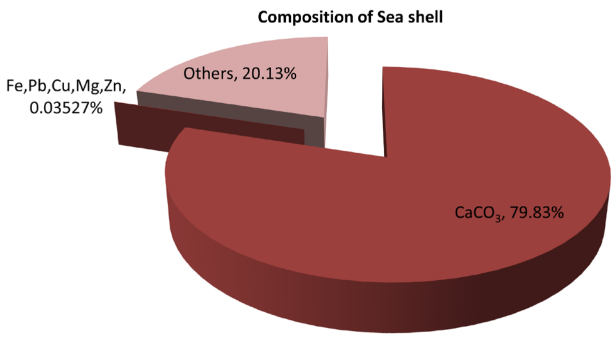

Figure 10. Chemical composition of sea shells.

Table 4. Comparisons between average concentration of heavy metal (ppm) in study area and the standard concentration of heavy metal in sea water at 3.5% salinity. ppm = parts per million.

Name of elements	Average con. of heavy metal (ppm) in present study	Standard concentration of heavy metal in sea water at 3.5% salinity (ppm = parts per million)
Pb	**0.0908**	0.0000300
Cu	**0.0026**	0.0009000
Cd	**0.00214**	0.0001100
Cr	0.00012	0.0002000
Fe	**0.41399**	0.0034000
Ni	0.0000	0.0066000
Ca	2.33595	411
Mg	1.122693	1290
Zn	BDL	0.0050000

Reference [17] mentioned that the average calcium carbonate of sea shells and oysters in St. Martin's Island was found 80%, whereas normal shells are composed of 95% - 97% of calcium carbonate. The present study determined that the shells and oysters in St. Martin's Island are being damaged due to heavy metals such as Zn, Pb, Cu, Fe, and Mg in their shells which may make them toxic. The toxic effect of Pb and Zn may reduce their growth which is a great threat to marine ecosystem as one trophic level is dependent on the next level. As these species are important ecosystem engineers in coastal ecosystems, they may make the next trophic level such as the mesopelagics, small squids more vulnerable. Consequently, the next trophic level (Misc. Fish, large squids) might be affected as they are dependent on the previous trophic levels. And finally the top trophic level (the tuna, bill fish, and marine mammals) will be affected due to the ocean pollution.

Proper industrial planning and the safe disposal of ship oil, industrial and urban waste can reduce the high levels of pollutants into coastal ecosystem and would save our enormous marine resource of the country.

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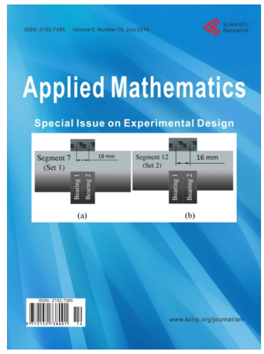
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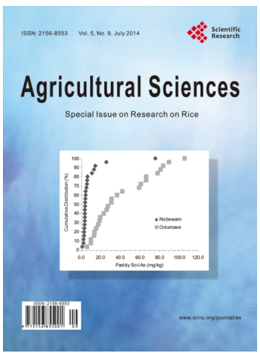
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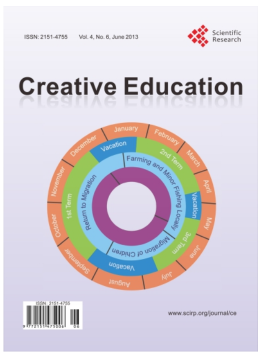
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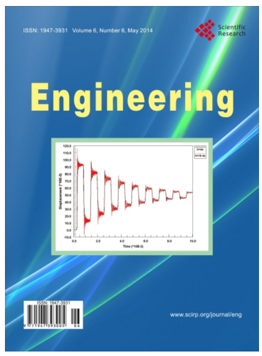
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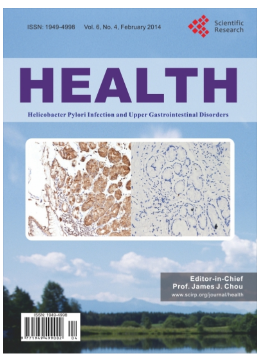
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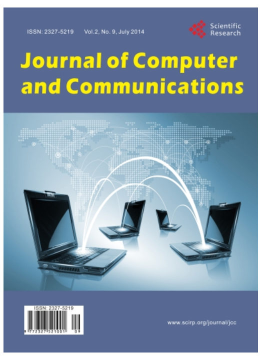
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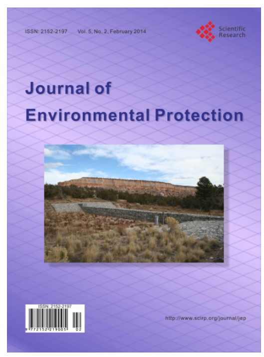
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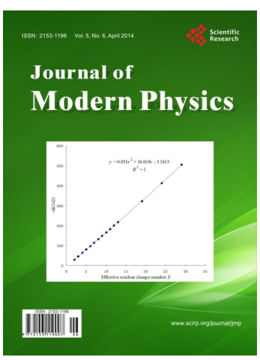
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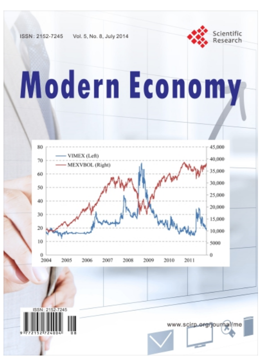
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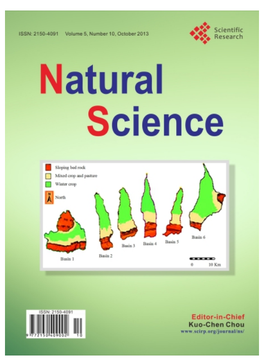
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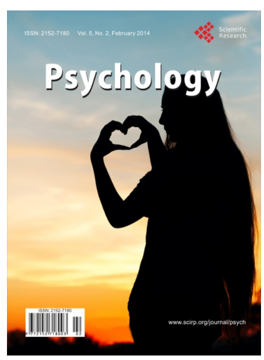
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