International Convention and Prevention of Marine Pollution: Heavy Metal Concentration in the Bay of Bengal

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Abstract
International convention on marine pollution provided less attention for the protection of the marine environment and of the high seas beyond coastal areas. The Stockholm Declaration on the Human Environment determined the concern regarding the whole marine environment, and emphatic reflection was done in the provisions of the Law of the Sea Convention. Eight heavy metals were analysed from both water and sediment samples of the Bay of Bengal (BoB). The decreasing trend of metals were observed in water samples: Zn (0.91±8.11) > Ni (0.78±0.72) > Cr (0.56±0.18) > Cu (0.16±0.24) > Pb (1.32±0.21) > As (1.14±0.95) > Hg (1.00±0.04) > Cd (0.07±0.03) µg/L and in sediment samples: Zn (46.53±23.57) > Cr (22.58±7.81) > Ni (21.17±12.17) > Pb (14.64±6.65) > Cu (13.04±8.19) > As (4.06±1.62) > Hg (0.03±0.02) > Cd (0.02±0.01) mg/kg. For the sustainability of the marine resources, the integration of Ecosystem Based Management and Marine Spatial Planning (EBM-MSP) provides a platform for different levels of governing bodies and stakeholders for the transparent, smooth and progressive decision-making process, that enables monitoring and surveillance in order to manage with future uncertain conditions.

Keywords: Marine pollution; Heavy metal; Bay of Bengal; Ecosystem Based Management; Marine Spatial Planning.

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1. Introduction

The causal effect of the unsustainable utilization and exploitation of ocean resources is the deterioration of marine environment where the impacts of released pollutants into the oceans are also play a significant role (Timagenis, 1980). The fundamental policy of Sustainable Ocean Governance (SOG) is to the protection of living organisms from depletion and the sustainable utilization of species and ecosystems, and the prevention and control of marine pollution. Nowadays, pollution is considered as one of the most significant threats to the health of the living resources in the oceans. Therefore, for the conservation of marine species and ecosystems, marine pollution control along with its prevention of is one of the most sensitive benchmarks.

Over the decades the significance of International Environmental Law has progressively improved – encompassing the subjects associated to the environmental conservation, pollution and protection as well as incorporating significant issues regarding the impact of trade on sustainability of marine environmental and the versatile usage of natural resources, energy policies and so on. In general, the legal perspective of International Convention is accredited that legislation concerning to marine pollution should be founded on scientifically derived standard efforts. These legislation efforts at international and national levels are struggling with insufficiencies in the scientific understanding of marine pollution i.e. the legal framework – set by ideological, ethical and social contemplations - which enables the working parties to restrict their attention to the scientific aspects of the marine pollution problem (Tomczak, 1984).

The crucial point is that the water body characterized by the slow rate of exchange in comparison to their robust volume, for instance, semi-enclosed estuaries and embayment like Bay of Bengal (hereinafter BoB), are the most susceptible to contaminant inputs. The pollutant assimilation capacity for these systems typically is very limited. Thus, the cumulative effects due to the prolonged accumulation and persistence of particular unassimilated materials, for example, synthetic toxic organic compounds, heavy metals will be imposing a potential long-term threat to marine food webs (Yi et al., 2011; Islam et al., 2014; Martin et al., 2015; Islam et al., 2015b, d; Ahmed et al., 2015c). Consequently, it turns into not only a global concern but also a multi-folded critical issue with interlocking political, technological, economic and legal aspects (Schachter, 1971).

Unfortunately, the major contaminants, for instance, heavy metals, plastic litter, nutrients, siltation, oil and radioactive wastes severely deteriorate the marine environment in the BoB. Most of the coastal areas of BoB are deadly affected by industrial and municipal effluents as well as by indiscriminate development of brackish-water culture systems (Holmgren, 1994). Specially, the metal pollution in the marine ecosystems is enhancing because from urbanization and industrialization (Sekabira et al., 2010; Zhang et al., 2011; Bai et al., 2011; Grigoratos et al., 2014; Martin et al., 2015).

Among all the pollutants, heavy metal contamination in the marine environment has pointed comprehensive attention owing to its abundance, persistence and environmental toxicity (Islam et al., 2015a; Ahmed et al., 2015a, b) – both natural and anthropogenic events are responsible for it (Wilson and Pyatt, 2007; Khan et al., 2008). Though, anthropogenic actions can readily introduce heavy metals in sediment and water (Sanchez-Chardi et al., 2007). The group of metals and metalloids of atomic density greater than 5 g/cm^3 is recognized as 'Heavy metals' – toxic even at low concentration, accumulate in suspended particulates and sediment, persistent, ubiquitous and non-biodegradable in nature (Ali et al. 2019; Bhuyan and Islam, 2017). They include lead (Pb), cadmium (Cd), zinc (Zn), mercury (Hg), arsenic (As), silver (Ag), chromium (Cr), copper (Cu), iron (Fe) and the platinum group elements (Duruibe, 2007).

At present, in many developing countries like Bangladesh, contamination of heavy metal is becoming a fundamental problem because of unplanned urbanization and industrialization (Islam et al., 2015c). The discharge of untreated industrial effluents, various urban wastes and agrochemicals in the marine environment has generated a shocking condition in Bangladesh – incessant increment of the metal concentration in the BoB, such as As, Cr, Cd and Pb causing intensive deterioration of water quality (Khadse et al., 2008; Venugopal et al., 2009; Islam et al., 2015a, c).

Therefore, the objectives of this study are to denote the International Conventions for the prevention of marine pollution by defining pollution as well as to determine the levels of heavy metals in the sediment and water of the catchment area of Bangladesh; and to assess the heavy metal pollution status in the BoB.

2. Pollution Definition and Convention

The elementary fact regarding the marine environment indicates that the simple and categorical specification from the onset what constitutes pollution. The chore responsibility is to involve the alignment of an intricate sequence of natural phenomena with diverse activities of deliberate or accidental man-made intervention, and economic, legal and political deliberations. Taking into account all these factors, the most authoritative definition of marine pollution was adopted by the Inter-governmental Oceanographic Commission (IOC), and outlined by the Joint IMCO/FAO/UNESCO/WMO/WHO/IAEA Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP, 1969) as part of the basic framework of the UN Convention on the Law of the Sea (UNCLOS) 1982 (Article 1.4). This definition specifies marine pollution as being:

'The introduction by man, directly or indirectly, of substances into the marine environment (including estuaries) resulting in such deleterious effects as harm to living resources, hazards to human health, hindrance to marine activities including fishing, impairment of quality for use of seawater and reduction of amenities'.

The UNESCO's *Intergovernmental Oceanographic Commission (IOC)* utilised same definition to receive further attention from the *United Nations Conference on Human*

Development in 1972 (Stockholm Conference) by adopting the word 'energy':

'The introduction by man, directly or indirectly, of substances or energy into the marine environment (including estuaries), resulting in such deleterious effects as harm to living resources, hazards to human health, hindrance to marine activities, including fishing, impairment of quality for the use of seawater, and reduction of amenities' (Pontaviae, 1973).

Countries like Belgium proposed the use of the term 'waste' (Tomczak, 1984). The United Nations Conference on the Law of the Sea subsequently adopted the GESAMP and UNESCO-IOC definitions in functional terms but polished them by referencing to the 'likelihood' of harmful effects, using the broader spectrum of 'marine life' and 'other legitimate uses of the sea'. The UN Convention on the Law of the Sea (hereinafter LOSC) defined marine pollution:

'Pollution of the marine environment' means the introduction by man, directly or indirectly, of substances, or energy, into the marine environment, including estuaries, which results or is likely to result, in such deleterious effects as harm to living resources and marine life, hazards to human health, hindrance to marine activities including fishing and other legitimate uses of the sea, impairment of quality for use of sea water, and reduction of amenities' (UNCLOS, 1982).

The LOSC definition was also followed by UN Environment Programme (UNEP) Guidelines on Protection of the Marine Environment Against Pollution from Land-based Sources 1985 (Montreal Guidelines). In addition, a number of regional conventions, for instance, the Convention on the Protection of the Marine Environment of the Baltic Sea Area (replaced by the Baltic Convention, 1992), the Barcelona Convention for the Protection of the Mediterranean Sea Against Pollution (1976), the Kuwait Convention, the Lima Convention, the Jeddah Convention, the Cartagena Convention, the Nairobi Convention, the Noumea Convention and the Bucharest Convention (1992), defined marine pollution in a similar manner. For example, Article 2 of the Convention on the Protection of the Marine Environment of the Baltic Sea Area states:

'Pollution' means introduction, by man, directly or indirectly, of substances, or energy, into the sea, including estuaries, which are liable to create hazards to human health, to harm living resources and marine ecosystems, to cause hindrance to legitimate uses of the sea including fishing, to impair the quality for use of the sea water, and to lead to a reduction of amenities' (Sands, 1988).

Generally, these definitions narrated the nature and effects of marine pollution for the formulation of fundamental legal and policy framework for the marine environmental protection. Serious destruction of the living resources and the marine ecology has been held owing to the pollution of the seas by oil, chemicals, nuclear waste and the effluent of urban industrial society. Thus, in the contemporary Law of the Sea, marine pollution has become one of the significant issues in order to control, reduction and elimination. For the marine environment protection, the Geneva Conference in 1958 had very little mentioned:

i) Geneva Convention on the Continental Shelf (1958): in generally addresses pollution from oil and pipelines (Article 24) and radioactive materials (Article 25) but does not reflect other areas.

ii) Geneva Convention on Fishing and Conservation of the Living Re- sources of the High Seas (1958): only protection from overexploitation of marine resources by international agreement; activated in 1966 but has had very negligible impact on deep-sea fishing.

For the protection of the marine environment from all forms and sources of pollution, the United Nations Conference on the Human Environment, held at Stockholm in 1972, perceived the insufficiencies of the existing legal and policy framework as well as suggested the significance of a more comprehensive approach (Boyle, 1985). Following two international conventions are implemented under the auspices of the International Maritime Organization and directly address the problem of plastics and marine debris (United Nations, 1982) where:

i) the 1978 Protocol to the International Convention for the Prevention of Pollution from Ships (1973) (MARPOL): came into action in 1983 – suggests substantial developments in structure: the text functions solely on ‘harmful substance’ (Canyon, 1978);

ii) the Convention on the Prevention of Pollution by Dumping of Wastes and Other Matter (1972), (London Dumping Convention – LDC): became activated on August 30, 1975.

In order to pursue the conservation and sustainable development of marine and coastal environments along with its living and non-living resources, Agenda 21 of the 1992 United Nations Conference on Environment and Development highlights the rights and obligations of states and delivers the international basis. For the prevention of coastal and open ocean areas from marine pollution, the United Nations Environmental Program (UNEP) approaches the general framework of action by means of involving three hermetically interlinked components: marine environment, regional seas, and its living resources (Kennish, 1996).

Regional Agreements

Besides international convention and legal framework, regional initiatives focus this global pollution concerns as well. Thus, numerous regional agreements propose incumbent strategies for the salvation of the sustainable marine environment by diminishing pollution issues. UNEP Regional Seas Program patronized a series of agreements at the regional level, for example:

i) The Barcelona Convention – The Convention for the Protection of the Mediterranean Sea against Pollution, done at Barcelona 1976, with protocols, Athens 1980 and Geneva 1982;

ii) The Kuwait Regional Convention for Co-operation on the Protection of the Marine Environment from Pollution, Kuwait, April 24, 1978;

iii) The Convention for the Conservation of the Red Sea and Gulf of Aden Environment, Jeddah 1982, reprinted in New Directions (Simmonds loose-leaf ed. 1983);

iv) The Convention for the Protection of the Marine Environment and Coastal Area of the South-East Pacific, Lima 1981;

v) The Convention for the Protection and Development of the Marine Environment of the Wider Caribbean, Cartagena 1982;

vi) The Convention for Co-operation in the Protection and Development of the Marine and Coastal Environment of the West and Central African Region, Abidjan 1981

encompasses the west African coastal zones and inland waters from Mauritania to Namibia; aims at ecosystem-based management of the aquatic environment.

There are other regional legal and policy frameworks, such as,

i) Helsinki Convention – Convention on the Protection of the Marine Environment of the Baltic Sea Area (1974): runs exclusively on the term 'hazardous substance';

ii) Arctic Waters Pollution Prevention Act (Canada) (1970);

iii) The Oslo Convention for the Prevention of Marine Pollution by Dumping from Ships and Aircraft (1972) for the North Sea;

iv) Convention on the Protection of the Environment between Denmark, Finland, Norway and Sweden (1974): regulates several categories of pollution including marine pollution;

v) Draft Rules on Sea Pollution (International Law Association, 53rd Conference, 1968): was not provided sufficient concentration at the time;

vi) Draft Articles on Marine Pollution of Continental Origin (International Law Association, 55th Conference, 1972);

vii) Paris Convention for the Prevention of Murine Pollution from Land-Based Sources (1974).

Among all of them, the most comprehensive narration is the LOSC (1982): for the realization of the principles and recommendations of the Stockholm Conference in order to have more efficient control of marine pollution since before the final acceptance of the definition of marine pollution reflecting development in environmental law, the LOSC experienced a series of changes, between the various sessions of the United Nations Law of the Sea Conference (UNCLOS) (Tomczak, 1984). In addition, a symbiotic relationship between the dynamic, evolving LOSC and other subject-wise environmental agreements is induced by articles 237 and 311. Therefore, to mitigate the increasing trend of marine ecosystem degradation and multi-stakeholder conflicts, to enhance the pursuit of sustainable coastal and open ocean development, to ratify comprehensive conservation and protection strategies, and to accentuate realistic initiative for the prevention of marine pollution, the proper integration and coordination of these issue-oriented agreements with the objectives of the LOSC is universally considered indispensable.

3. Materials and Methods

Study area and sampling

The collection of water and sediment samples was done on the western region in the northern BoB. Samples were collected between 89°39′ and 90°57′ East longitude and between 21° and 21°5′ North latitude in the BoB. 25 water samples were collected with the help of Niskin sampler at depths between 1 to 20 meter and 6 CTD station data has been recorded by a Sea-Bird Electronics CTD Machine (19 plus V2). Birge-Ekman grab sampler, a light weighted equipment (5–10 kg) with a sampling area of about 15 cm × 15 cm was used to collect a sample 3 L in volume. For pollution monitoring, a sampler that collects material at the water-sediment interface without loss or disturbance should be selected. The upper section of the sample (0–3 cm) was carefully taken to assess the most recent contributions of contaminants to the surface.

Analysis of Pollutants

In order to measure the metal pollution in the ocean water, sediment is considered as an environmental indicator (Islam et al., 2015c). The chemical composition of water and suspended sediment possess the principal component of metals (Mohiuddin et al., 2012). On the way of heavy metal transportation in the aquatic system, frequent changes will be held as a result of absorption, dissolution and precipitation phenomena (Abdel-Ghani and Elchaghaby, 2007), thus their performance and bioaccumulation will be affected (Nicolau et al.,2006; Nouri et al., 2011). Owing to diversity of marine habitats and environments, sediment is a crucial and dynamic portion in the ocean basin (Morillo et al., 2004). The study on heavy metals in water and sediments could be used to evaluate the risk factors due to harmful substance disposal in the marine ecosystems by anthropogenic and industrial implications (Zheng et al., 2008; Yi et al., 2011; Saleem et al.,2015). Therefore, the estimation of the concentrations of heavy metals in water and sediments from the BoB was done.

Chemicals and sample digestion

Sample digestion was done by ultrapure concentrated HNO_3. At first, water samples were filtered using 0.45 mm membrane filter and then acidified with HNO_3 to make a pH of <2. Properly mixed measured volume (50 ml) was taken in a beaker. By adding 5 ml of HNO_3, the sample was boiled at 130°C till the volume came to 25–30 ml. The process was not stopped until the solution becomes light coloured or clear. After cooling, the expected volume was prepared with deionized water. 2.0 g dried sediment and 15 ml of HNO_3 was taken in 100 ml beaker heated at 130°C till 2–3 ml remaining. The digested materials were passed through the filter paper washed with 0.1 M HNO_3 and made up to 100 ml volume with deionized water.

Analytical technique and accuracy check

All the heavy metals were analysed by Atomic Absorption Spectrophotometer (AAS) using (i) Cold vapor Mercury Technique (AA240FS), (ii) Flame process (AA240FS),

(iii) Graphite Furnace Atomic Absorption (AA280Z) and (iv) Hydride Generation Technique (AA240). The instrument calibration standards were made by diluting standard (1000 ppm) supplied by Sigma–Aldrich, Switzerland. The results were mentioned as μg/L and mg/kg for water and sediment samples, respectively. For the experimental procedure prior to use, all containers and glassware were cleaned by 20% nitric acid, finally rinsed with deionized ultrapure water for several times and oven-dried.

4. Result and Discussion

Heavy Metal Concentration in BoB

Heavy metal concentration was very high in all the stations specially Pb, Cd, Cu and Ni were concentrated much (Table 1). Total Dissolved Solids and Electrical conductivity was moderate throughout the stations. Major Ions were found in standard condition. Eight heavy metals were analysed from both water and sediment samples of BoB.

Table 1: Measured heavy metal concentration (ppm) in BoB water and sediment

Station		Concentration (ppm)							
		Pb	Hg	Cr	Cd	Cu	As	Zn	Ni
Water	1	0.59	0.31	0.35	0.09	0.06	0.05	0.09	0.33
	2	0.45	0.01	0.006	0.01	0.0005	0.004	0.001	ND
	3	0.09	ND	0.56	ND	0.16	1.136	0.53	0.56
	4	ND*	1.00	ND	0.07	0.002	0.42	ND	0.78
	5	1.32	0.003	0.0005	0.05	ND	0.55	0.91	0.0005
	6	0.001	0.22	0.002	0.09	0.16	0.7	0.009	0.00
Sediment	1	14.64	0.03	22.58	0.02	13.04	4.06	46.53	21.17
	2	19.95	0.09	45.95	0.05	37.47	5.21	92.91	54.90
	3	6.47	0.07	35.28	ND	ND	0.85	ND	33.27
	4	8.23	ND	ND	0.45	8.94	ND	21.78	ND
	5	12.53	ND	ND	0.79	19.48	ND	32.41	ND
	6	3.12	ND	ND	3.12	76.26	ND	131.22	ND

*ND = Not Detected

Heavy Metal concentration in water

The decreasing trend of metals were observed in water samples: Zn (0.91±8.11) > Ni (0.78±0.72) > Cr (0.56±0.18) > Cu (0.16±0.24) > Pb (1.32±0.21) > As (1.14±0.95) > Hg (1.00±0.04) > Cd (0.07±0.03) µg/L. The decreasing trend of metals were observed in the estuarine water of Karnaphuli River in Bangladesh as Cr > As > Pb > Cd where the ranges were 13.31–53.87, 46.09–112.43, 2.54–18.34 and 5.29–27.45 µg/L, respectively (Ali et al. 2016). In water of Buriganga River, Bangladesh concentration of Pb, Cd, Ni, Cu and Cr varied seasonally and spatially from 58.17 to 72.45 µg/L, 7.08 to 12.33 µg/L, 7.15 to 10.32 µg/L, 107.38 to 201.29 µg/L and 489.27 to 645.26 µg/L, respectively (Ahmed et al. 2010).

Heavy Metal concentration in sediment

The decreasing trend of metals were observed in sediment samples: Zn (46.53±23.57) > Cr (22.58±7.81) > Ni (21.17±12.17) > Pb (14.64±6.65) > Cu (13.04±8.19) > As (4.06±1.62) > Hg (0.03±0.02) > Cd (0.02±0.01) mg/kg. Hossain *et al.* (2019) investigated Zn (88.97 ±58.97)>Ni (32.75 ±16.09)>Cu (29.2±10.78)>Cr (25.14 ±5.20)>Pb (19.57 ±7.01)>As (2.58 ±2.55) mg/kg from the sediment of Sangu River estuary (Hossain et al. 2019). Siddiquee et al. (2012) studied the trace metal concentration in sediments of ship breaking area in Bangladesh where the concentration of metals like Cr, Ni, Zn, Pb Cu, Cd and Hg was varied from 22.89 to 86.72; 23.12 to 48.6; 83.78 to 142.85; 36.78 to 147.83; 21.05 to 39.85; 0.57 to 0.94 and 0.05 to 0.11 µg/g, respectively (Siddiquee et al. 2012). There are major two reasons responsible for the chromium enrichment in sediment: (a) discharging Cr based oxidants (chromate, dichromate, and so on) as industrial effluents such as tanneries and textile factories and (b) abundance of Cr concentrated minerals (Facetti et al. 1998; Islam et al. 2014; Mohiuddin et al. 2011). Higher level of Cu indicates its higher input in the sites(station-6), which is originated from anthropogenic activities: car lubricants (Fu et al. 2014; Al-Khashman 2007) and the emissions from vehicle and coal combustion (Li et al. 2012; Zhu et al. 2011) as well as natural activities: metal contents of rocks (Yi et al. 2011; Yang et al. 2009; Li et al. 2008; Liu et al. 2003).

5. Conclusion

The sources of pollution are affecting the BoB significantly and they need to be controlled effectively through appropriate measures and strategies to improve the health of the BoB and to achieve the objectives of EBM-MSP for the SOG where the ultimate target is to benefit of the people of the region. Both natural and human-induced processes that are very much heterogeneous in nature coexist in the marine environment. Natural elements such as the ecosystems itself andits functions cannot be regulated or planned. So, it is only the human element that can be planned or regulated to restore and maintain the good order of the marine environment. In that case, it is essential to develop an integrated management regime to understand the interactions among multiple natural and human drivers and cumulative impacts generated from these integrations on the environment.

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