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Impact of Ship Breaking Activities on the Water Quality at the Coastal Area of Chattogram, Bangladesh

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The ship breaking area of Chattogram is one of the most ecologically effective regions in Bangladesh. It includes wealthy biodiversity that consists of numerous species which are endemic to this region. The impact of various physico-chemical parameters on pollution is a significant concern for both the environment and biodiversity. In order to evaluate the potential ecological impact, water samples were obtained using standard procedures from several sites within ship breaking yards. The values of physico-chemical parameters like, temperature, EC, TDS, TSS, pH, DO, BOD, salinity, oil and greases were found 29.65 ºC, 2028.87 µS/cm, 1014.89 mg/L, 7392.42 mg/L, 8.03, 7.28 mg/L, 4.03 mg/L, 12.83 ppt, 7166.64 mg/L, respectively. A decreasing trend in the amount of trace elements present in water and sediment: Pb (0.46 mg/L) > Cr (0.49 mg/L) > As (0.205 mg/L) > Cd (0.049 mg/L). The concentrations of toxic metals, however, exceeded the permissible thresholds in both regions. Lead and chromium had no seasonal effects, whereas arsenic and cadmium significantly varied with the seasons. The evaluation of the heavy metal pollution index (HPI) and contamination factor (CF) showed that the study area had a critical score of water quality (HPI > 100). The metal concentrations had an elevated contamination effect (CI > 3). According to the study's findings, the ship breaking site is moderately polluted with heavy metals and posed a risk to the ecosystem.

Keywords: Heavy metals, Ship breaking activities, Ecological risk, Impact on health.

INTRODUCTION

Growing industrialization and urbanization causes water pollution, particularly in the areas where rivers and the ocean meet and is currently on the rise [1-4]. Sources from many, including runoff from agriculture, inappropriate application of dangerous element pesticides or fertilizers, disposal of metropolitan garbage, including shipping the introduction of dangerous metals into the aquatic environment of the coastline is caused by a number of important factors [5-8]. Ship breaking activities are contaminating the seawater environment along the coastal area. Bangladesh is currently the most productive and promising nation, both for the home steel industry and the global ship breaking business. The ship breaking sector contributes between 2.2 and 2.5 million tons of the nation's steel production. There are between 250 and 350 re-rolling mills and at least 40 active ship breaking yards in Bangladesh [9,10]. Because in the long run prevalence of toxic metals in aquatic water bodies, they may have negative impacts on the aquatic biota, particularly fish determination, toxicology of the environment [11-14] and a considerable effect for bioaccumulation [15-18]. Metals that are poisonous to aquatic life pose dangers to the health of people and aquatic organisms [2,19-21]. The majority of hazardous metals are then discharged back into the water body as a result of depletion through the sediment as well as the environment in the water [22-26]. As harmful metal contamination rises, it immediately affects human health through the chain of food [27-29], having substantial adverse effects on fish or invertebrate's species as well [28,30,31].

Toxic metals such as arsenic, lead, chromium, or mercury are present in the ballast water, as well as electrical cables containing copper protective electrodes and steel in the frame of the ship. Fluorescent light coils, light fixtures, temperature sensors, batteries, electrical panels and fire detectors also contain these hazardous materials [32-34]. In ship breaking places, particularly in Bangladesh, arsenic, chromium, cadmium and lead are mainly found as poisonous metals [35-37]. Pentachloro benzene (PCB) containing sealants are another risky contaminant present on ships [38], thousands of litters of oil and up to 7.5 tons of different kinds of asbestos (bilge oil, engine oil, oil lubricants, grease and hydraulics). Moreover, tankers may transport as much as 1,000 cubic meters of used oil. According to the Basel convention, the majority of these goods are classified as hazardous wastes.

Concerns about the harmful effects on the environment and the long-term impact of ship breaking activities for both the discharge of hazardous materials have been raised in several studies [39-41]. Scrapped vessels leak and spill a variety of disposable items and trash, which frequently mingle with beach sand and water, endangering the coastal ecology and wildlife [42,43]. The ship-breaking industry generates a variety of pollutants, including heavy substances, aromatic hydrocarbons, perfluoroalkyl acids (PFAAs) and microbiological contamination. The pH of the soil and saltwater may be raised as a result of the addition of ammonia, oils and lubricants.

Because of lower labour costs and laxer environmental restrictions for disposal, the majority of ship-breaking yards today operate in south Asian nations due to inadequate development, management and an absence of appropriate regulations [44,45]. Recent years have seen the emergence of reviews that perform a systematic synthesis of the research findings focused on the pollution of Bangladesh water and sediment by toxic substances [46-50]. The main goals of the current study are to address the physico-chemical and corrosive metal issue by looking at the water condition of ship breaking sites, to assess the quality of the water using various geochemical contamination indices. These studies will also offer some suggestions for meaningful and sustainable ship breaking operations.

EXPERIMENTAL

Study area: The ship breaking yard in Chattogram, the second-largest ship breaking hub in the world, is confined to an 18 km^2 extending along Sitakundupazilla's coastline, particularly from Bhatiary to Kumira situated in Chattogram district, which is in Bangladesh's southeast. The research region is located outside of the city of Chattogram between latitudes 22.48078ºN and longitudes 91.70726ºE. The geomorphological layout of Sitakunda, which would be 70 km (43 miles) large and 10 km (6 miles) large and is among the Chittagong Hill Tracts' western most systems in Bangladesh, is defined as north of the Feni river, within the south the Karnaphuli river, within the east the Halda river, the Sandwip channel towards the west as well [2,4]. The Sandwip channel and the Halda valley are separated from one another by the Sitakunda range. The Halda is one of the six banks of the Karnafuli, the same principal river in the region and it flows approximately 88 km (55 miles) through Khagrachari to the Gulf of Bengal [10,50,51]. The Sandwip channel turns up the northern terminus of the Chittagong-Tripura folded belt (Fig. 1) [52].

Water sampling: About 1 L of water using plastic containers with a pair of stoppers was randomly gathered from the area to be tested for water quality. The bottles were cleaned, rinsed and treated using 5% HNO_3 for an overnight period prior to sampling. After drying, deionized water was used to rinse the bottles. The bottles were carefully screwed after sampling and the corresponding identification number was written on them. All water samples had their collection sites tested for temperature, EC, pH and TDS. BOD, COD, DO, TSS, salinity, alkalinity, chloride, total hardness and turbidity were measured at the laboratory.

Analysis of water quality

Determination of heavy metal pollution index (HPI): The level of water pollution was assessed for its fitness for human consumption, with a critical score of 100 applied to cases of contamination with heavy metals of drinking water. To determine the calibre of river water, the following formula was employed to determine the water pollution index [53]:

Heavy metal pollution Index formula constitute of two different parts: 1. Units weight, and 2. Sub-indwx value

1. Units weight (Wi) is represented as:

$$\mathrm{Wi}\alpha\frac{1}{\mathrm{Si}} \tag{1}$$

$$\mathrm{Wi}=\frac{\mathrm{K}}{\mathrm{Si}} \tag{2}$$

where, K = Constant, Si = standard permissible limit value of the ith parameters,

2. Sub-index value (Qi) of the parameters was calculated by the following formula:

$$\mathrm{Qi}=\sum_{i=1}^{n}\frac{|\mathrm{Mi}-\mathrm{Ii}|}{(\mathrm{Si}-\mathrm{Ii})}\times 100 \tag{3}$$

where, Mi = Monitored value of heavy metals of the ith parameters, Ii = Ideal value of the ith parameters, Si = Standard value of the ith

$$\mathrm{HPI}=\frac{\sum_{i=1}^{n}\mathrm{WiQi}}{\sum_{i=1}^{n}\mathrm{Wi}} \tag{4}$$

where, Wi = Unit weight of the ith parameters, Qi = sub-index value of the parameters. Pb, As, Cr and Cd each have tolerable limits of 0.01 (mg/L), 0.01 (mg/L), 0.05 (mg/L) and 0.003 (mg/L) respectively, according to WHO [54].

Determination of contamination index (CI): The contamination index (CI) was utilized to determine the relative pollution attributable to metals within the research field. The following formula can evaluate the index's ability to indicate the overall impact on all of the metal concentrations:

$$\mathrm{CI}=\sum_{i=1}^{n}\mathrm{CFiw} \tag{5}$$

$$\mathrm{CFiw}=\left(\frac{\mathrm{CMi}}{\mathrm{CHi}}\right)-1 \tag{6}$$

where, CFiw is the individual metal's contamination factor in water; CMi is the metal's measurement concentration; and CHi is the element's highest permeability limit; CHi is recognized as an acceptable value that was used in the HPI equation.

Statistical analyses: In order to tabulate and process the data, MS Excel 2010 was utilized. The acquired data were then

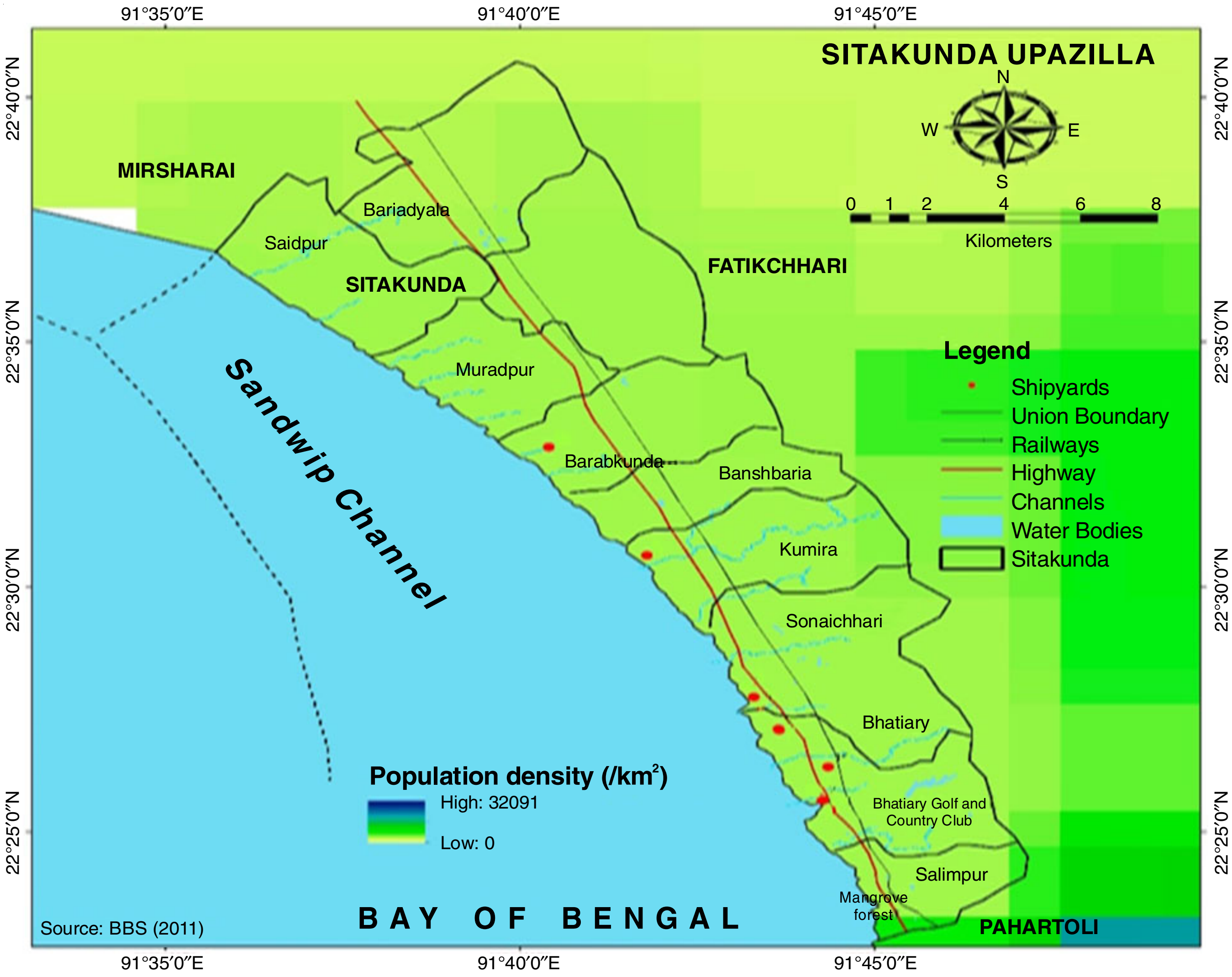

Fig. 1. Map of the study area (Ship breaking yard, Sitakunda, Chattogram, Bangladesh)

analyzed and displayed using techniques from statistics, such as descriptive statistics, column charts, line charts and error bars. To determine the significant change in harmful metal concentration in water of the ship breaking area, an ANOVA was conducted. The research site map was altered and the distribution of additional metal-related data was shown in a counter graph made with ArcGIS (v.10.1).

RESULTS AND DISCUSSION

Physico-chemical parameters: Water being polluted or not can be easily determined by its physical aspects of water quality. Colour, taste, smell and solid in the water and rise of temperature always indicate water pollution.

Temperature: In water bodies, the temperature of the water has a profoundly significant effect on the biological, chemical and physical activities that take place. The dissolution rate of gases in water exhibited a negative correlation with increasing water temperature, resulting in a subsequent rise in oxygen consumption and an accelerated decomposition process [55].

In this investigation, an average temperature was 29.65 °C (Fig. 2). The highest temperature (31 °C) was recorded at yard-3 whereas the lowest temperature (28.44 °C) was observed at yard-4. The temperature readings of the present study were all observed to be within the permitted range of 30.5 °C [56].

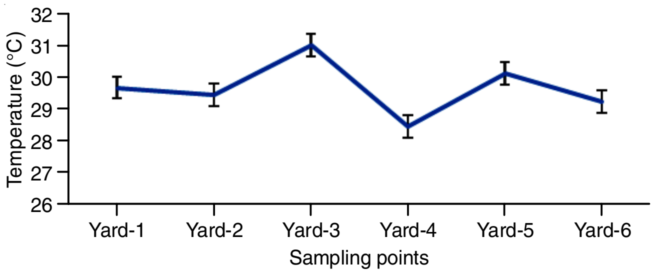

Fig. 2. Variation of temperature at different sampling points of the ship breaking area

Electrical conductivity (EC): The quantity of electrical current and the sum of all dissolved ions in water bodies are known as electrical conductivity [57,58]. In the current investigation, the average EC value was 2028.87 µS/cm. The lowest value was 1215.67 µS/cm at yard-2, while the highest value was 3512.22 µS/cm at yard-1 (Fig. 3). All of the results above the 3000 µS/cm acceptable limit for surface water [59]. The water

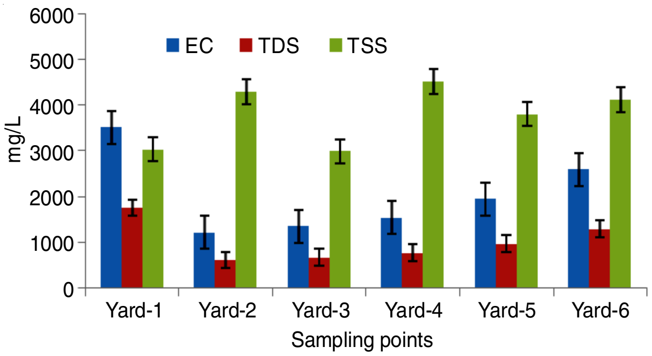

Fig. 3. Variation of EC, TDS and TSS at different sampling points at ship breaking area

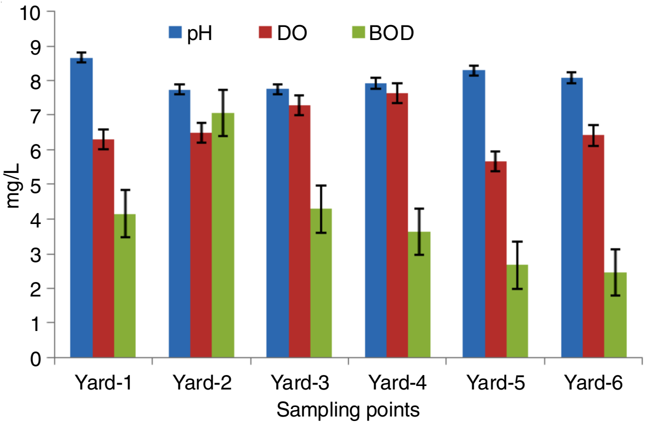

Fig. 4. Different sampling point of pH, DO and BOD in Chattogram ship breaking area

in a ship breaking yard became extremely hard as EC levels increased posing several health risks.

Total dissolved solids (TDS): TDS primarily showed the presence of several minerals, such as nitrite, nitrate, ammonia, phosphate, some acids, alkalis, metallic ions and sulfates, which contain dissolved and sticky particles in water [60]. TDS value for the samples obtained exceeded the machines from all sites (HACH® 378 digital) 10,000 mg/L is the detection limit, which is larger than the conventional value (500 mg/L) advised by [60-62]. The average value of TDS in the current study was 1014.89 mg/L (Fig. 3). Yard-1 had the highest reading (1756.11 mg/L), whereas yard-2 had the lowest reading (607.78 mg/L). From these results, it was found that the physico-chemical characteristics of seawater at the ship-breaking yard are experiencing deterioration, as indicated by increased TDS levels. These TDS values originate from the discharge and fragmentation of decommissioned ships and regularly mixed with the surrounding water.

Total suspended solids (TSS): The term TSS refers to solids that are suspended in water, both organic and inorganic matters. They might comprise plankton, silt and industrial trash. By absorbing light, water quality can be affected by excessive suspended sediment concentrations. The effect of water warming is a reduction in its ability to sustain the requisite oxygen levels for the survival of aquatic organisms. The process of photosynthesis in aquatic plants slows down, resulting in a reduced production of oxygen, due to a decrease in light availability [62]. Several types of life are rendered extinct by the interaction of warmer water, less light and lower oxygen levels. Moreover, suspended solids can obstruct fish gills, slow growth, weaken disease resistance and stop the development of eggs and larvae. Suspended solids can be produced by industrial waste, sewage discharges, algae growth, bottom feeders and erosion of the banks, as well as erosion from urban runoff and agricultural land. The average value of TSS in the current study was 3792.42 mg/L (Fig. 3). The lowest result was 2993.97 mg/L in yard-3 and the highest was 4515.69 mg/L in yard-4.

pH: The average pH in the current study was 8.03 (Fig. 4). The highest recorded value of 8.64 was detected in yard-1, while the lowest recorded value of 7.72 was observed in yard-2. The pH measurements of the study were found to be within the permissible range of 6-8.5. In the present study, pH changed as a result of lower photosynthetic activity. Photosynthetic activity was decreased as a result of ship breaking activities, which profoundly affected aquatic species' life cycles [63].

Dissolved oxygen (DO): Dissolved oxygen (DO) in water is produced by photosynthetic planktons and atmospheric air [62]. Any aquatic habitat with a healthy level of dissolved oxygen around 5.0 mg/L is considered to be free of pollution. Surface waters that are not contaminated typically have a high concentration of dissolved oxygen. Discharge of the wastes that require oxygen can quickly remove dissolved oxygen from the water [58]. The amount of dissolved oxygen in water is also generally reduced by other inorganic compounds such nitrites, ammonia, hydrogen sulfide, ferrous iron and other oxidizable chemicals. In general, high levels of organic matter contamination are correlated with low dissolved oxygen concentrations. The average DO in the current investigation was 7.28 mg/L. Yard-4 recorded the highest result (7.67 mg/L), while Yard-5 recorded the lowest value (5.66 mg/L) (Fig. 4). The presence of a significant quantity of metallic waste and a decrease in the breakdown capabilities of a microorganism resulted in the DO levels at all sample stations exceeding the average value (4-6 mg/L) recommended by WHO [59].

Biological oxygen demand (BOD): Microorganisms consume dissolved oxygen (DO), when organic wastes from sewage or other discharges is present in large amounts in the water. The exact amount of dissolved oxygen that is actually present in water is known as DO. The life forms in the water become unable to function normally when the DO falls below a specific point. An average BOD value in the current study was 4.03 mg/L. Yard-2 recorded the highest reading of 7.04 mg/L, while yards 6 and 5 recorded the lowest reading of 2.45 mg/L (Fig. 4). The levels of BOD observed in the surface water of the ship-breaking region were found to be consistently lower than the established water quality standard of 5 mg/L, as stipulated by WHO [59]. This outcome can be attributed to the regular accumulation of inorganic and metallic wastes in the vicinity.

Salinity: The types of aquatic organisms that occur as an ecological component are greatly influenced by salinity. The global ocean circulation is impacted by the salinity of oceans, as changes in density occur due to differences in both salinity and temperature at the ocean's surface. These variations in density affect buoyancy, leading to the sinking and rising of water masses [58]. Since more salinized waters become less soluble in CO_2, changes in ocean salinity are believed to be involved in changes in the amount of CO_2 in the atmosphere. The average salinity in the current study was 12.83 ppt. The highest recorded value of 17.79 ppt was found at yard-6, whereas yard-1 had the lowest value of 3.59 ppt (Fig. 5).

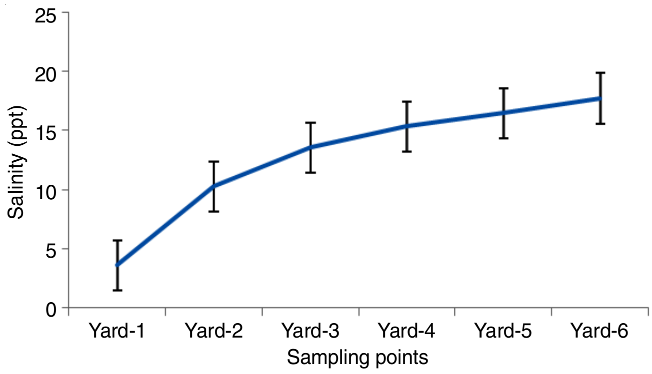

Fig. 5. Variation of salinity at different sampling points in the ship breaking area

Oil and grease: Grease and oil are major impediments to sunlight reaching the aquatic environment, which is one of the main factors regulating the marine aquatic ecosystem. In current investigation, Yard-1 had the highest value of 10120.09 mg/L, while yard-4 had the lowest value (1284.46 mg/L) (Fig. 6).

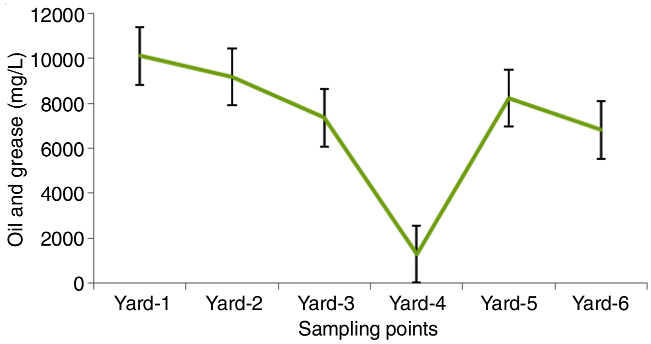

Fig. 6. Variation of oil and grease at different sampling points of ship breaking area

Concentration of metals in water: The metal concentrations have been found to decrease in the water bodies in the following order: Cr > Pb > As > Cd. In the water samples under study, Cr concentration was greater than that of the other metals (Fig. 7).

Arsenic: The hazardous component arsenic is found on the ocean's surface at a permissible limit of 0.002 mg/L [64,65]. The accumulation of arsenic in marine creatures is mostly derived from the saltwater environment in which they reside. This phenomenon is particularly evident in the photosynthetic organisms, which retain arsenic inside their bodies. Consequently, the metabolic processes occurring within these organisms can lead to alterations in arsenic concentrations, thereby influencing species dynamics. Aquatic algae contain arsenosugars [66] as well as aquaculture uses for arsenobetaine are the of organisms that are both inorganic and organic species that are present [67]. The highest concentration of 0.543 mg/L (As) was found in yard-5, whereas yard-1 had the lowest concentration of 0.034 mg/L (Fig. 7). In this work, the mean arsenic value was three times greater than the premissible value as suggested by WHO [54].

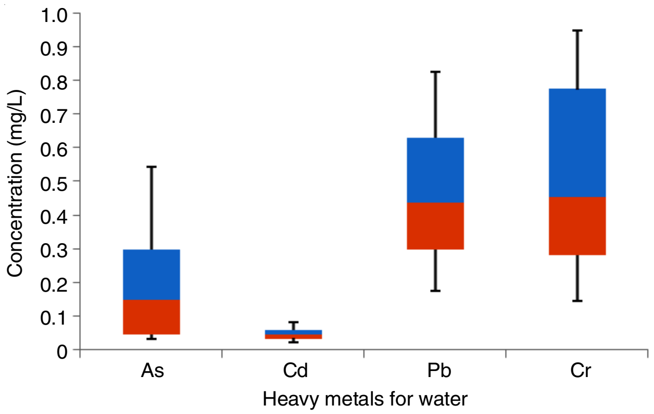

Fig. 7. Concentration of heavy metals in water at the ship breaking yard

Chromium: The amounts of chromium in natural waters in open oceans range from 2 to 5 mmol/kg. The chromium toxicity for aquatic species is often lower than that of Cd, Pb, Hg, Ni, Cu and Zn due to the harsh acidic nature of Cr ions [68]. A considerable growth inhibition is observed in aquatic plants with raising of Cr concentrations (0.5 to 5 mg of Cr (VI)/IV). Even though chromium is present in greater quantities in marine ecosystems compared to aquatic plants, it does not significantly pollute plant tissues. Intake from sediments directly is shown by the fact that sorption occurs nearly exclusively through the stems of sea grass [69]. Although there is little information on bioavailability in any species, chromium is mostly delivered to fish and invertebrates through food. According to Geisler & Schmidt [68], the rates are significantly greater when aquatic animals are captured at the commercial apprehended (approximately 0.26-1.55 and 0.5 mg/kg). Within the region under investigation, yard-1 exhibited the highest recorded value of 0.83 mg/L, whereas yard-4 displayed the lowest recorded value of 0.23 mg/L. The study observed an average chromium level of 0.49 mg/L (Fig. 7), which exceeds the WHO recommendation threshold by a factor of 2.4.

Cadmium: Hazardous metal cadmium can be found in ambient water at levels not more than 1 ng/mL [70,71]. Yard-1 recorded the highest value of 0.083 mg/L while yard-4 recorded the smallest value of 0.023 mg/L. The average value of cadmium concentration in the current investigation was 0.049 mg/L (Fig. 7). Unfortunately, the recorded concentration of cadmium(II) exceeded the upper limit advised by WHO.

Lead: The utilization of water sourced from the ship breaking zone is considered hazardous due to the presence of excessive levels of lead, as indicated by the toxicity reference values (TRV). These TRVs demonstrated that lead constitutes the primary constituent and significantly exceeds the permissible threshold for water quality. Yard-6 recorded the highest value of 0.824 mg/L, while yard-3 recorded the smallest value of 0.17 mg/L (Fig. 7). The analysis revealed that the average concentration of lead was determined to be 0.469 mg/L (Fig. 7). Most importantly, the average Pb levels exceeded the recommended limit set by the WHO by a factor of six.

Heavy metal pollution index (HPI): In present study, the heavy metal pollution index's average value was 178.16 (Fig. 8). The highest value was yard-6, while yard-4 had the lowest value. Based on the findings, it is evident that the the quality of the water within the examined region is degraded.

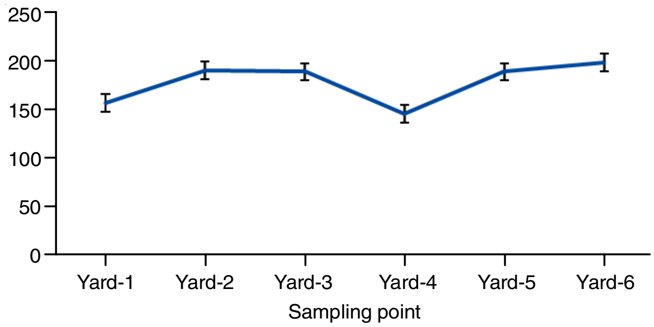

Fig. 8. Heavy metals pollution index at different point of ship breaking area

Water contamination index (CI): The winter measurements of the contamination index (CI) at site two exhibited the highest value, which is likely due to the local ship breaking activities and wastewater disposal plant. The CFw value in the winter was higher than it was in the summer. Similar results in an urban river in Bangladesh were also reported by other researchers [17,72].

Conclusion

This study focuses on the evaluation of water quality in response to ship breaking activities in the coastal region of Chattogram, Bangladesh. The results of this investigation indicate metal concentrations were above the environmentally safe upper limit. Water quality indicators such as contamination index (CI) and heavy metal pollution index (HPI) values indicated that drinking water had become contaminated in the research area, which affected the measured pollutant levels. According to the prospective environmental risk assessment and the risk index, the research region was exposed to high-risk lines as a result of the accumulation of pollutants, which had a major negative impact on the ecological productivity of the coastal environment. There were substantial environmental dangers related to hazardous pollutants from the ship-breaking process. The expansion of the ship breaking yard in the nation should only be authorized under the condition that pollution is effectively mitigated to the lowest possible levels.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this article.

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