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Assessment of Pb, Cr, Ni contamination in water from different selected sites of the Karnaphuli river, Chattogram, Bangladesh

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ABSTRACT

Heavy metal pollution of water arising from anthropogenic sources continues to become a great challenge to human and aquatic population. The Karnaphuli is the principal and the largest river in Chattogram, Bangladesh. The biggest contributors of heavy metals in the Karnaphuli water arising from industrials wastages, a growing population without proper sewerage facilities, increase in the number of aging automobiles, fertilizers and pesticides from the agricultural farms in the highlands of Chattogram. These potential sources of heavy metal have continued to increase in the environment and posing detrimental impacts on human and aquatic life system, hence an effective monitoring of the river water is very important. The present study involves the determination of metals included Lead (Pb), Chromium (Cr) and Nickel (Ni) in the Karnaphuli River. Ten sampling stations were selected for collecting water from different locations of the Karnaphuli at dry seasonal period. The water samples were digested by acid digestion for the quantification of heavy metals using Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES). The data was analyzed using ANOVA with the level of significance (≤ 0.05). From the findings, means of lead were found below detection limit (BDL) in several stations viz. Patenga sea beach, Shipping Corporation, Chaktai New Bridge, Lamburhat and Rangunai sadar. The highest mean of Pb was 0.131±0.0014 in Sadarghat jetty, followed by 0.072±0.0014 mg/L in Kalurghat industrial area (west side) which exceeds the permissible limits of WHO standards. The mean levels of Cr were found BDL in the Patenga sea beach, Lamburhat and Rangunai sadar. Within the detection level, the highest concentration of Cr 0.115±0.00212 and 0.092±0.0014 mg/L were found in Sadarghat jetty and Kalurghat industrial area respectively. Nickel (Ni) was found below the permissible limit of WHO standard of drinking water (0.07 mg/L) in all locations throughout the study period. The level of these heavy metals showed variation from one place to another and it was considerably higher in industrial sites than that of non-industrial sites in most of the sampling locations.

INTRODUCTION

Heavy metal pollution of river has become a serious concern in Bangladesh which is mainly caused by the disposal of untreated toxic effluent, sewage discharges, industrial pollutants, land washout, city run-off and urban wastages into rivers. Being a fast growing country, Bangladesh is experiencing rapid industrial developments and unplanned urban growth in recent years (Mia et al., 2015). But pollutants produced by these activities are triggering environmental problems on an unprecedented scale, primarily due to different toxic heavy metal pollution (Tareq et al., 2003; Bhuiyan et al., 2011; Islam et al., 2015; Sharifuzzaman et al., 2016). Chattogram is the second largest city, main seaport and economic nerve-center of the country, whose ecosystems is under multiple stresses due to discharge of effluents from various heavy industrial sites. These industrial effluents are distributed into the Karnaphuli through several ways. In Chattogram, industries like oil refineries, ship recycling, textile and cement industries, tanneries, paint manufacturing and dyeing plants, paper and rayon mills, naval and merchant ships, steel and engineering factories, food and fertilizer industries, chemical industries and other small-

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scale and agro-based industries as well as disposal of sewage and solid wastes are directly discharged into the adjacent of Karnaphuli River (KR) and coastal waters of Bay of Bengal (Chowdhury et al., 1999; Hossain and Khan 2002; Ali et al., 2016).

The people of Chattogram city depends on the Karnaphuli river for variety of aspects. The river originates from the Lushai Hills of Mizoram of India, flows through Rangamati and the port city of Chattogram and discharges into the Bay of Bengal at latitude 22°12´N and longitude 91°47´E near Patenga (Dey et al., 2015). Most of the industries in Chattogram are located mainly at Sagorika, Fauzdarhat, Kaptai, Nasirabad, Barabkunda, Bhatiary, Sholashahar, Patenga and Kalurghat, Oxygen, Kotwali. The wastewater from these heavy industrial sites is discharged into surface drains that ultimately carry it to the Karnaphuli River. Especially it was noticed that wastewater from Nasirabad and Kalurghat industrial area (mainly chemical, leather, textile and steel re-rolling industries) drain that wastewater into drainage canals, which is ultimately discharged into the Karnaphuli River after primary or without any treatment (Dey et al., 2015). Moreover, as the business capital of Bangladesh, Chattogram is becoming more populated day by day. Hence, the potential sources of contamination do not only come from the industrial sites but also from municipal and household wastage materials through different sewage and drainage system ultimately polluting the Karnaphuli River (KR).

The uncontrolled dumping of huge wastes from heavy industrial sites is even extremely poisonous when the pollutants are heavy metals which can't be treated easily by conventional methods. Moreover some industries are discharging untreated waste water directly to the main water body of the river causing serious damage to marine ecology and aquatic lives along with the health of peoples who are exposed to this environment for a long term. Since the heavy metals in the river water have continued to increase, there is need to determine their levels in the Karnaphuli River for understanding suitability of water for human and aquatic life system. Therefore, the purpose of the study is to determine the levels of toxic heavy metals (Pb, Ni, Cr) from ten selected stations of the Karnaphuli River and to evaluate the water quality parameters in aspects of heavy metal contamination of KR as affected by industrial pollution. The research is also designed to analyze the samples collected from some non-industrial sites viz. residential, households, populated area to compare the degree of pollution between industrial and non-industrial sites of KR flows throughout the Chattogram.

METHODOLOGY

Study areas

Water samples were collected from ten selected sites of the Karnaphuli river during dry winter season in January 2019 and tested for toxic heavy metals (Pb, Cr, and Ni) content in water. Ten sampling stations were selected before collecting the samples (Table 1). Standard procedures were used to analyze the parameters of the water sample. All primary lab works were performed at Chattogram Veterinary and Animal Sciences University, Bangladesh.

Table 1
The sampling locations and its tidal condition.

Sampling stations	Sample ID	Condition
Patenga sea beach	S-1	High tide
15 No. ghat, (opposite of the KAFCO)	S-2	High tide
Shipping corporation	S-3	High tide
Sadarghat jetty	S-4	Low tide
Banglabazar ghat	S-5	Low tide
Firingibazar ghat	S-6	Low tide
Chaktai New Bridge	S-7	High tide
Kalurghat industrial area (west side)	S-8	High tide
Lamburhat	S-9	Low tide
Rangunai sadar (nearby CUET)	S-10	Low tide

Study period

The study was conducted from January to May, 2019 and the sampling sites were previously selected for collecting raw water samples.

Preliminary treatment of samples

In Primary, the water samples were collected in 1.5 liter polypropylene bottles. Before using, all bottles were washed with dilute acid followed by distilled water and were dried in an oven. For heavy metal analysis the primary sampling point was in the surface water layer (0-5 cm from the surface) at main flow. Before taking final water samples, the bottles were rinsed three times with the water to be collected. The sample bottles were labeled carefully with date and sampling source and chilled immediately to 3º to 4ºC for laboratory analysis.

During lab analysis, at first 100 ml of each sample was measured and taken to 250 ml beaker. The water samples were agitated very carefully to obtain homogeneous suspension of solids and transferred to an evaporating dish. Then 5 ml HNO_3 was added into the sample to acidify and evaporate on a steam bath to 20 to 25 ml. After evaporation, the sample was cooled and transferred to a 150 ml conical flask together with any solids remaining in the dish. Additional 5 ml HNO_3 and 10 ml H_2SO_4 with few glass beads (to prevent bumping) were added into the solution. Then it was returned to hot plate and continued evaporated until dense fumes of SO_3 appear in the flask. The remaining HNO_3 was removed and a clear solution was observed. The solution was cooled to room temperature and carefully diluted to about 50 ml with distilled water. The solution was filtered through Whatman filter paper to remove silicate and other insoluble materials. Then the filtrate was transferred to a 100 ml volumetric flask and made up to the mark with deionized water. Finally, an aliquot of this solution was taken for the determination of metals.

Analytical techniques of sample

The samples were analyzed by using Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES, Shimadzu 9820, Japan). The inductively coupled argon plasma is a spectroscopic source, which was used for the determination of heavy metals. All the spectroscopic measurements of the sample solutions as well as the standard metal solutions were performed at their respective wavelength of maximum absorptions λ_{max}.

To generate plasma, first, argon gas was supplied to torch coil, and high frequency electric current was applied to the work coil at the tip of the torch tube. Using the electromagnetic field created in the torch tube by the high frequency current, argon gas was ionized and plasma was generated. This plasma has high electron density and temperature (10000K) and this energy was used in the excitation-emission of the sample. Solution samples were introduced into the plasma in an atomized state through the narrow tube in the center of the torch tube.

The wavelengths used for element contents determination and the values obtained for ICP-OES analytical technique were Pb 228.802 nm, Cr 267.716 nm and Ni 231.604 nm.

Statistical analysis of sample

All data was collected in Microsoft Excel 2007 spread sheet. Afterwards data were exported to SPSS 17 (SPSS Inc., 233 South Wacker Drive, 11th Floor, Chicago, IL 60606-6412). Data were sorted, coded and recorded before statistical analysis in SPSS 17 software. Then, data was analyzed by one way ANOVA test to assess the significant level of variation at 95% confidence interval.

RESULTS AND DISCUSSION

The present study revealed the mean concentrations of trace metals like lead (Pb), nickel (Ni), chromium (Cr) which have been estimated in samples collected from the mentioned zones (Table 1) on one occasion only in the winter season. Findings of this study along with the recommended standards of World Health Organization (WHO) have been summarized in Table 2. Most of the dissolved heavy metals were found to be in slightly higher concentrations in heavy industrial sites than that of lower industrial sites of the Karnaphuli river. Table 1 shows, the concentration levels ranged from BDL (Below Detection Limit) to 0.131±0.0014 mg/L for Pb, form BDL to 0.050±0.0014 mg/L for Ni and that of BDL to 0.115±0.00212 mg/L for chromium (Cr).

Table 1
Mean concentration of heavy metals in water of KR at selected sites

Sample ID	Chromium (mg/L)	Nickel (mg/L)	Lead (mg/L)
	Mean ± SD	Mean ± SD	Mean ± SD
S-1	BDL	BDL	BDL
S-2	0.0264±0.00015	BDL	0.0455±0.00015
S-3	0.0123±0.00015	BDL	BDL
S-4	0.115±0.00212	0.012±0.003	0.131±0.0014
S-5	0.0091±0.0003	0.0072±0.00015	0.0152±0.00015
S-6	0.024±0.0015	0.012±0.0015	0.0172±0.00014
S-7	0.0186±0.00014	0.016±0.0015	BDL
S-8	0.092±0.0014	0.050±0.0014	0.072±0.0014
S-9	BDL	BDL	BDL
S-10	BDL	BDL	BDL
p-value	<0.001	<0.001	<0.001
WHO standard	0.05	0.07	0.01

BDL=Below Detection Limit (Detection limit of the instrument was 0.001 mg/L)

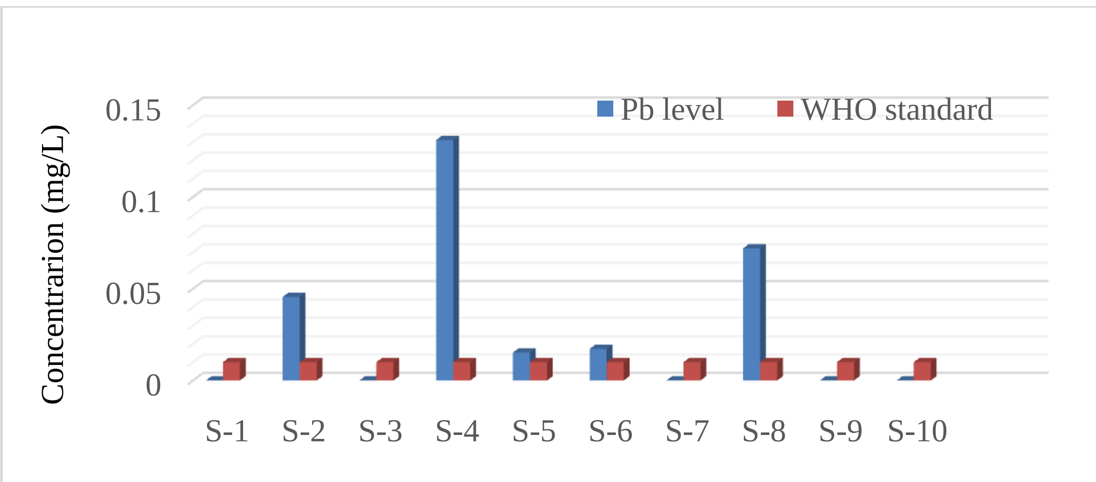

Figure 1
Mean concentration of lead (Pb) in the samples compared with WHO standard

The study recorded that the mean of lead (Pb) showed variation from one place to another. This might be due to the degree of deterioration of water quality which may differ from one place to another of the Karnaphuli river. In addition, the degree of deterioration of water quality largely influenced by the seasonal variation, human activities and catastrophic events exists in the sites of the river. The concentration of Pb levels showed huge variation which ranging from BDL to 0.131±0.0014 mg/L. The highest Pb contents of 0.0131±0.0014, 0.072±0.0014 and 0.0455±0.00015 mg/L were found in samples collected from Sadarghat jetty, Kalurghat industrial area and 15 no. ghat (opposite of the KAFCO) respectively. However, Pb was found below detection limit (BDL) in several stations during analysis. This might be due to low solubility of Pb containing compound in water. This finding is in well agreement with the findings of Venugopal et al. 2009 who also found non-detectable level of Pb in their study. The overall concentration profiles of Pb in all sampling points are displayed in Figure 1 comparing with WHO standard (0.01 mg/L).

The level of Cr were found to be within the detection level in most stations and also in several sampling stations it showed below the permissible limit of WHO standard (WHO, 1993, 2004 and 2011). However, the concentration of Cr exceeds the permissible limit in samples collected from the Sadarghat jetty (0.115 mg/L) and Kalurghat industrial area (0.092 mg/L) which is shown in Figure 2. This finding is also compliance with Islam et al. (2013) they also found a notable amount of Cr content (0.09 mg/L) in their study from kalurghat west industrial area. Rashid et al., (2012) also found a prominent amount of Cr in their studies. This might be due to the presence of potential sources of Cr contamination from those sites. The potential sources of Cr include wastes from tannery waste, waste from chemical laboratory, textile waste and earth's crust. A field survey study under Sarwar et al., (2010) recorded that from Kalurghat to the Chattogram Port around 713 industries directly or indirectly throwing their untreated waste or wastewater in Karnaphuli River. Out of that around 156 are situated very close to the Karnaphuli. However, the level of Cr in Patenga sea beach, Lamburghat and Rangunai were found Below Detection Limit (BDL) in the present study which is agreed with the findings of some previous authors in which they also demonstrated that Cr content was below the detection level in KR (Mamun, 2013; Dey et al., 2015).

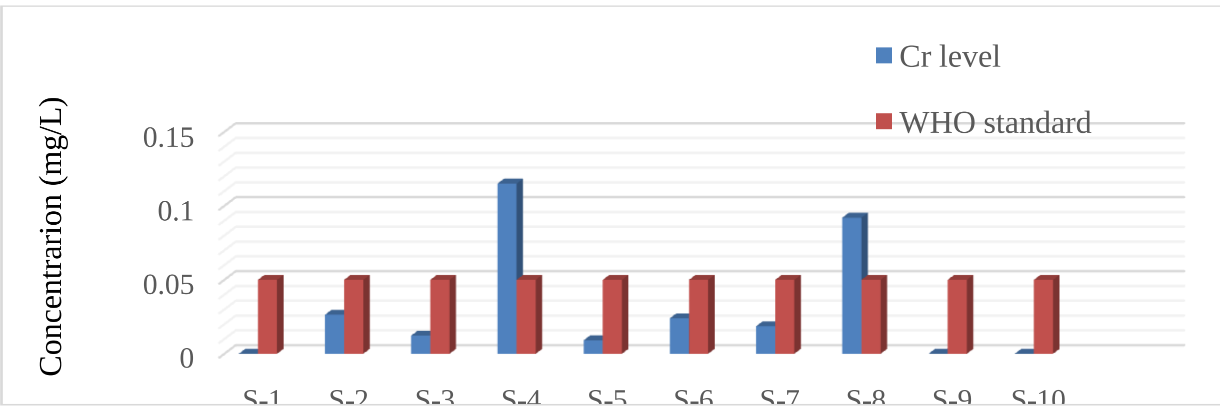

Figure 2
Mean concentration of Cr in the samples compared with WHO standard

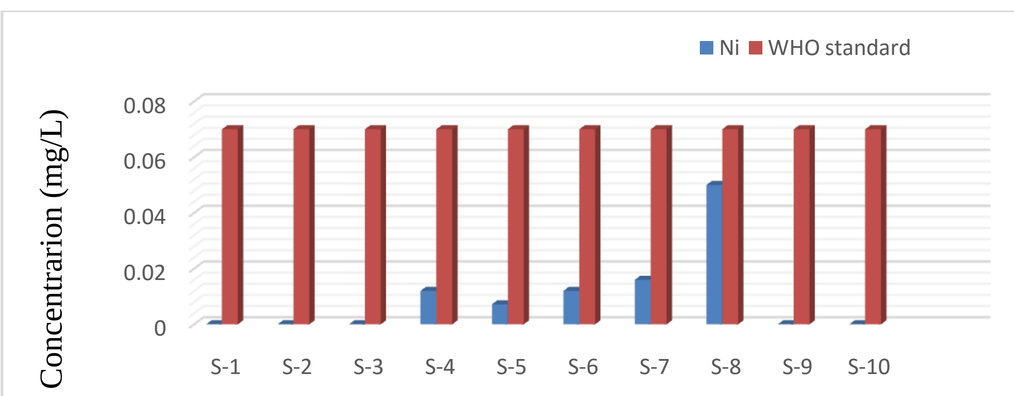

Figure 3
Mean concentration of Nickel (Ni) in the samples compared with WHO standard

The present study also revealed the mean status of Nickel (Ni) in the Karnaphuli which is summarized and mentioned in the Table 1 and figure.3. The concentration of Ni was found below the permissible limit of WHO standard of drinking water (WHO, 1993, 2004 and 2011) in all sampling stations. The peak concentration of Ni (0.050±0.0014 mg/L) was found in sample collected from Kalurghat industrial area and followed by 0.016 and 0.012 mg/L in Chaktai New Bridge and Sadarghat jetty respectively. This might be due to the presence of higher potential sources of nickel from industrial activities around these respected areas. The findings by Sarwar et al., (2010) have reported that about 98 and 71 industries are located in the Kalurgaht and Sadarghat areas respectively.

The average mean concentration of these three metals (Pb, Ni and Cr) were found in the present study along with the recommended standards of World Health Organization (WHO) have been summarized in the Table 2. The findings showed that total mean concentration of Ni and Cr were 0.0108 and 0.0331 mg/L respectively found below the permissible limit of WHO standard of drinking water (WHO, 1993, 2004 and 2011). This finding is similar to the findings of Dey et al. (2015) who also claimed that Ni and Cr were below the permissible limit of WHO standard in their study. However, the average mean of Pb (0.04242±0.0627 mg/L) was found above the permissible limit of WHO drinking water standard. A previous study by Islam et al. 2013 in the Karnaphuli River also stated that the average lead concentration was above the WHO standard limit (0.01mg/L).

Table 2
Comparing total mean concentration of metals in all stations compared with WHO standards

Heavy metals	No. of samples (N)	Concentration (mg/L) Mean ± SD	WHO standard (mg/L)
Pb	10	0.04242±0.0627	0.01
Cr	10	0.0331±0.043	0.05
Ni	10	0.0108±0.0155	0.07

CONCLUSION

Day by day, the river Karnaphuli is losing its water quality like other river belts in Bangladesh. Several studies also revealed that the river is under severe pollution threat. This is mainly due to various human activities and catastrophic events on it. The results of the present study represents that among three metals (Pd. Cr and Ni) only Ni was within the recommended values for all sampling stations but Pb and Cr were found beyond permissible limits of WHO in several stations. However, in the overall concentration of these three metals only Pb (0.04242±0.0627 mg/L) exceeded the recommended values. This might be due to the presence of higher Pb contributors around the respected sites of the Karnaphuli River. This exceeded level of Pb recommends a sign of presence of metal pollution which is an alarming environmental issue. If this trend continues, it may make an impact on the quality of the Karnaphuli water and in the long run can cause a serious threat for human and aquatic ecosystems. In this study, the mean concentration of these three metals (Pb, Cr, Ni) were found considerably higher in heavy industrial sites than that of lower industrial sites. This situation indicates that the Karnaphuli water is being highly contaminated with untreated effluents which are discharged by the industries located in the bank of the river resulting in the heavy metal pollution. The concentration of metals found in samples collected from the Sadarghat jetty and Kalurgaht area were showed considerably higher than that of other sampling stations in this study. This is because the Sadarghat jetty and Kalurgaht area are heavily industrialized than other sampling sites selected in the present study. The findings of the study convey a strong message for the government and local policy maker to establish environmental laws and regulations on the industries and to enforce installation of effective effluent treatment plants for preserving the environment of the River Karnaphuli and other important rivers in Bangladesh.

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