Comparative Assessment of Water Quality in the Major Rivers of Dhaka and West Java

Md. Tajuddin Sikder[1], Masaomi Yasuda[1], Yustiawati[1], Suhaemi M. Syawal[2], Takeshi Saito[3], Shunitz Tanaka[1,4], Masaaki Kurasaki[*4]

[1]Graduate School of Environmental Science, Hokkaido University, Japan

[2]RC for Limnology, Indonesian Institute for Sciences, Indonesia

[3]Faculty of Health Sciences, Hokkaido University, Japan

[4]Faculty of Environmental Earth Science, Hokkaido University, Japan

[*1]kura@ees.hokudai.ac.jp

***Abstract*-A comparative study of general water quality has been extensively studied in some major rivers of West Java, Indonesia and Dhaka, Bangladesh. Water quality assessment based on physiochemical investigation along with heavy metal concentration in water and sediments is presented. The results indicate that maximum sampling sites in the rivers of Dhaka are severely impaired in comparison with the rivers of West Java. And, the pollution gap in the rivers of Dhaka is evident in respect of the season where pollution in winter is eminent in comparison with rainy seasons. All rivers were severely polluted with NO_x, PO_4^{3-} and *Escherichia coli* (E-coli). The heavy metal concentration of Al and Mn exceeded whereas, Cu, Zn and Pb were found to be below the international guidelines in most of the sampling points. And, Cd and Fe approached the threshold limit in Dhaka. With the enrichment study, every metal was found predominant in both the Ciliwung and the Cikaniki River; while rivers of Dhaka comprise little enrichment value adequately report noteworthy difference in metal sources along with elevated accumulation trends of metals into the bed sediments. The re-suspension experiment also suggests identical trends of metal swelling into the sediments. High health risks were envisaged due to the presence of toxic mercury in sediments (0.83-1.07 µg/g) of the Cikaniki River and paddy samples (0.08 µg/g) close to the baseline value of Indonesia. Based on the results, it is evident that metal, organic and fecal pollution in the rivers of West Java and Dhaka are in somewhat dreadful condition that requires immediate remediation step.**

Keywords-Pollution; Wate Quality; West Java; Dhaka; Mercury Contamination

I. INTRODUCTION

Pollution, nowadays, has become a serious concern for human life due to the industrial burst in the world. And, the rivers are the main choices to hold and bear the responsibility of pollutants, especially in the developing worlds. Water pollution caused by chemical substances such as heavy metals affects tropical rain forest and River ecology [1]. Heavy metals can accumulate from water to sediments through settling process and some particles can also find their ways into the biota [2]. Once in Japan, the pollution caused by Cd and Hg took huge live toll in Toyama and Minamata such as itai itai diseases and Minamata diseases, respectivly [3].

Development activities mostly depend on the rivers for the cleaning and disposal purposes. So, it urges a systematically monitoring study to assess the status of pollution to suggest some management strategies. This study focuses on Indonesia and Bangladesh because, in West Java and Dhaka, the rivers play vital roles as traffic arteries in economic activities. Most of the industrial growth is occupied in those areas particularly in Dhaka and spread out on the banks of some major rivers; Buriganga, Shitalakshyaa, Turagh and the Bongshi River. In the Jakarta gulf, Hg contamination has been reported [4], [5]. Besides, the seasonal variations along with the geographic and geomorphologic disparity also direct a fluctuation of pollution among the rivers of these two countries. Thus, detailed studies of the quality of water and sediments are needed to evaluate environmental conditions. Although many studies have been performed to understand the water quality and heavy metal distribution, a few approaches have been found to compare the pollution status among the rivers in different countries. Our previous study attempted to investigate the metal concentrations in water and sediments of some important rivers in West Java, Indonesia [1]. In this study, the authors tried to focus on the general water quality and heavy metals in relation with a comparative view to make clear the pollution sources. Sometimes, metal concentration in water appears very low though the actual pollution is obvious there because of metal partitioning with some other components. From this viewpoint metal concentrations in sediments were also measured. Besides, we tried to understand the pollution severity in respect to the difference of industrial setup along with reference value recommended by World Health Organization (WHO) [6]. Hg concentration was determined in both sediments and water of the rivers of West Java, because gold mining is widely practiced and related with the rivers especially, the Cikaniki River. Therefore, this study is targeted to examine the water environment of both Dhaka and West Java to evaluate equally the pollution status and health of biota.

II. MATERIALS AND METHODS

A. Study Area and Sampling

In Dhaka, Bangladesh, samples were collected from the Buriganga River, the Turag River; the Shitalakshyaa River and the Bongshi River. The Buriganga River is one of the most polluted rivers in Bangladesh. Most of the industries and factories in Dhaka are situated along the bank of this river or very close to the river system. The Shitalakshyaa River links with the Buriganga on the northwestern side of the capital and is considered the second most polluted river in Bangladesh (Fig. 1). The Ciliwung and Cikaniki Rivers are also important rivers in West Java, where the capital city, Jakarta, is located (Fig. 1).

Samples were collected 2 times from June 12–19, 2007 and September 8–15, 2007 at 8 sampling sites in the Ciliwung River and the Cikaniki River in West Java, Indonesia. In addition, paddies and soil samples in a rice paddy field were obtained near a gold amalgamation plant in the upstream area of the Cikaniki River (Cisarua Village). In this manuscript, sampling station from 1-6 and 7-8 were referred as Ciliwung (1-6) and Cikaniki (1-2), respectively. And, each sampling was conducted 2 times from December 20-27, 2010 and September 21-23, 2011 at 9 sampling sites; Buriganga (1-2), Shitalakshyaa (1-2), Turagh (1-2) and Bongshi (1-3), the major 4 rivers in Dhaka, Bangladesh (Fig. 1). Sampling bottles were kept at 4°C and were transported to the laboratory for further processing.

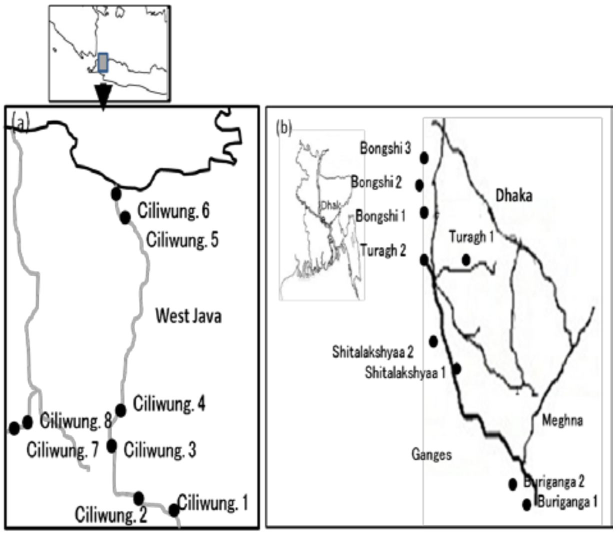

Fig. 1 Sampling sites in West Java, Indonesia and Dhaka, Bangladesh

B. Water Quality Parameters

The physicochemical parameters (pH and conductivity) of the samples were measured immediately at each sampling point with a U-51 multi-parameter water quality meter (Horiba, Kyoto, Japan) according to the instruction manual.

The multi-parameter water quality meter was calibrated every time at each sampling point with two standard solutions of pH 4 and pH 7. An ion selective pack test (Kyoritsu Chemical-check Lab, Corp, Tokyo, Japan) was employed to measure chemical oxygen demand (COD), NO_2^-, NO_3^- and PO_4^{3-} according to their instruction manuals. The detection limits of the ion selective pack were COD (2 ppm), PO_4^{-3} (0.02 ppm), NO_2^- (0.02 ppm), and NO_3^- (1 ppm). *Escherichia coli* (E-coli) were measured with simple detection paper (Shibata, Japan). Dissolved organic carbon (DOC) was measured with a TOC analyzer (TOC-5000A, Shimadzu, Kyoto, Japan). For this procedure, 25 mL of the filtrated sample was mixed with 0.1M HCl and made up to 50 mL with distilled water. Phthalic hydrogen potassium was used for TOC standard sample. Sodium carbonate and sodium bicarbonate were used for inorganic carbon standard samples. The detection limit of the TOC analyzer was 4 ppb. Internal quality control was used in the measurement of the physicochemical parameters and heavy metals of the samples in each region. Analytical quality control was assured by replicate analysis of samples. Three replicates of each sample were prepared and their physicochemical parameters were analyzed simultaneously.

C. Heavy Metal Analysis

Firstly, river water samples were filtered to remove the insoluble materials by Millipore membrane filters (Omnipore™, Ireland) with 0.45 µm pores followed by acid digestion with grade conc. HNO_3 for 1.5 h to keep the pH below 2. The digested samples were then prepared to measure the metal contents with inductively coupled plasma–mass spectrometry (ICP-MS, Seiko SPQ-6500, Tokyo, Japan). In case of sediment, 50 mL of 0.1 M HNO_3 were added to 10 g of dried sediment, and subsequently the mixture was agitated for 24 h followed by centrifugation at 3,000 rpm for 15 min. Twenty paddy samples (about 0.4 g each) were completely digested with 10 mL of conc. HNO_3, and supplemented up to 100 mL with distilled water. To remove the insoluble materials, the digested solution was filtered with a 0.45 µm Millipore filter (USA). The contents of Mg, Mn, Al, Co, Cd, Pb, Fe, Cu and Zn were then measured with the ICP-MS. In addition, inorganic Hg contents in the same samples were measured by using a Hiranuma HG 300 Mercury Analyzer (Hiranuma Sangyo Co., Ltd., Japan: detection limit 0.1 ng/mL). Total Hg contents were determined as follows: to degrade the organic compounds, 1 mL of conc. H_2SO_4, 1 mL conc. HNO_3 and 2 mL $KMnO_4$ (50 g/L) were added to 30 mL of the above-mentioned acidified sample. The mixture was shaken for 15 mins, and heated at 95°C for 2 hrs. After cooling, 1 mL of hydroxylamine chloride was added to neutralize the excess $KMnO_4$. The neutralized solution was filtered with a 0.45µm Millipore filter. The filtered solution was diluted up to 100 mL with distilled water and the Hg contents were measured using a Hiranuma HG 300 Mercury Analyzer [1]. The concentrations of metals were detected at the ng/mL (ppb) level. The detection limits of ICP-MS were Al (0.005 ppb), Mn (0.03 ppb), Fe (0.005 ppb), Zn (0.05 ppb), Cu (0.005), Cd (0.03 ppb), and Pb (0.005 ppb). Standard solutions were prepared from 1,000 mg/L stock solutions of different metals of interest (Wako Pure Chemicals Industries Ltd., Kyoto, Japan) by dilution with ultrapure water. The glassware was washed with nitric acid followed by distilled water. All the experiments were carried out in triplicate. The results were reproducible within an error limit of ±5%.

D. Statistical Analysis

To analyze the differences among the sampling stations for different metal levels, one-way ANOVA was applied followed by the student t-test to identify the homogeneous type of the data sets. Pearson's correlation matrix was also calculated for different metals to trace the common sources of pollutants. Regression coefficients were calculated between metals and organic C contents in sediments. The significance level in this study was $P < 0.05$.

III. RESULTS AND DISCUSSION

The general water quality in the samples from river water of West Java, Inodnesia and Dhaka, Bangladesh is listed in Table 1. In case of West Java and Dhaka, each number is the average value for the 2 sampling times. The pH maintained by a well-buffered river can be attributed to the fact that, normally, running water is influenced by the nature of the deposits over which the water flows [7]. The pH value was ranging from 7.1–8.4 for the sampling points in both countries. It can be seen that the ionic environment in rivers are identical and lies within the standard range recommended by the WHO [6]. Conductivity is a measurement of the ability of an aqueous solution to carry an electrical current. High conductivity values ranges from 60-375 µS/cm in West Java and 303-919 µS/cm in the rivers of Dhaka, indicating high ionic pollution in Dhaka and West Java as compared with the WHO guideline. Besides, the rivers of Dhaka also possess high conductivity value in comparison with the conductivity

TABLE 1 GENERAL WATER QUALITY OF THE RIVERS IN DHAKA, BANGLADESH AND WEST JAVA, INDONESIA

Sampling point	pH	Conductivity (μS/cm)	COD (mg/L)	NO_2^- (mg/L)	NO_3^- (mg/L)	PO_4^{-3} (mg/L)	E-coli (num./mL)	TOC (mg/L)
Dhaka, Bangladesh								
Buriganga 1	7.4	397.3	28.3	0.1	0.6	1.1	213	7.1
Buriganga 2	6.8	393.0	30.0	0.0	1.0	0.8	255	6.3
Shitalakkha 1	8.1	919.3	70.0	0.1	1.3	1.1	171	19.2
Shitalakkha 2	7.2	331.5	69.3	0.0	0.9	0.2	144	28.2
Turagh 1	7.2	378.1	21.0	0.7	7.0	0.8	146	7.5
Turagh 2	8.4	297.6	82.5	0.1	0.6	3.3	260	21.4
Bongshi 1	8.4	303.6	78.3	0.0	0.6	3.1	78	16.6
Bongshi 2	7.8	424.5	33.5	0.3	8.0	0.8	201	5.5
Bongshi 3	7.1	359.5	20.3	0.5	8.0	0.3	42	3.1
West Java, Indonesia								
Ciliwung 1	7.5	70.0	4.5	0.0	1.0	0.0	23.5	n.d.
Ciliwung 2	7.8	130.0	14.5	0.0	1.4	0.5	21.5	n.d.
Ciliwung 3	7.2	210.0	13.0	0.7	30.0	1.1	64.5	n.d.
Ciliwung 4	7.1	190.0	20.0	0.3	15.0	0.6	115.5	n.d.
Ciliwung 5	7.3	375.0	40.0	0.1	1.0	2.0	117.0	n.d.
Ciliwung 6	7.4	335.0	35.0	0.0	1.0	2.0	128.5	n.d.
Cikaniki 1	7.6	60.0	14.0	0.0	1.0	0.1	57.0	n.d.
Cikaniki 2	7.5	105.0	7.5	0.2	8.5	0.5	57.5	n.d.
WHO	6.5-8.5	250	255	0.5	0.45	.01	0	~

n.d. means not detected; ~ means not known

TABLE 2 METAL CONCENTRATIONS IN RIVER WATER OF DHAKA

Sample sites	Al	Mn	Fe	Cu	Zn	Cd	Pb
Dhaka: Water sample (μg/L)							
Buriganga 1	59.85	0.88	25.59	5.28	2.49	3.03	3.00
Buriganga 2	92.69	32.50	41.93	2.52	3.74	2.54	4.00
Shitalakkha 1	9.81	40.74	35.73	26.33	1.54	3.51	4.00
Shitalakkha 2	69.52	49.51	144.00	5.93	3.73	3.03	5.00
Turagh 1	69.40	0.66	28.77	11.36	1.23	3.06	5.00
Turagh 2	28.66	43.56	57.30	11.46	5.81	2.54	4.00
Bongshi 1	13.14	45.51	82.92	12.16	35.43	3.04	3.00
Bongshi 2	7.49	0.29	16.99	6.43	1.51	2.01	4.00
Bongshi 3	30.08	17.39	8.64	2.73	0.44	3.02	5.00
West Java: Water sample (μg/L)							
Ciliwung 1	29.40	35.63	n.d.	35.07	38.01	29.23	7.22
Ciliwung 2	57.97	35.28	n.d.	36.30	59.49	28.94	7.23
Ciliwung 3	29.18	35.40	n.d.	35.65	47.03	28.68	7.16
Ciliwung 4	33.13	35.13	n.d.	35.71	40.46	28.80	7.13
Ciliwung 5	44.59	250.75	n.d.	34.96	43.93	28.66	7.17
Ciliwung 6	39.29	290.69	n.d.	35.33	42.62	28.64	7.18
Cikaniki 1	212.52	35.36	n.d.	35.21	38.94	28.70	7.73
Cikaniki 2	167.01	36.28	n.d.	36.35	51.38	28.69	7.84
WHO	50	10	50	2000	3000	3	10

n.d. means not detected

TABLE 3 METAL ENRICHMENT FACTORS (%) IN ALL SAMPLING RIVERS

Rivers	EF (Al)	EF (Mn)	EF (Fe)	EF (Cu)	EF (Zn)	EF (Cd)	EF (Pb)
Buriganga	41	25	38	34	42	43	88
Shitalakshyaa	26	46	26	30	29	46	50
Turag	37	26	35	50	30	44	50
Bongshi	26	23	21	51	17	46	50
Ciliwung (Water)	33	30	~	40	33	30	50
Cikaniki (Water)	50	50	~	50	50	7	46
Ciliwung (Sediment)	62	45	n.d.	71	37	50	47
Cikaniki (Sediment)	50	50	n.d.	45	54	70	72

n.d. means not detected; ~ means not known

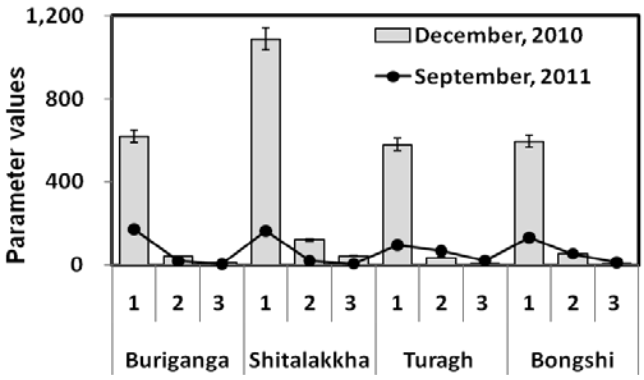

Fig. 2 Variation of general water quality in the rivers of Dhaka, Bangladesh 1= Conductivity (µS/cm); 2=COD (mg/L); 3=DOC (mg/L)

value in the rivers of West Java. The high conductivity values also make sure of the presence of high dissolve solids contents in water that is approximately 70% of the conductivity in µS/cm. Elevated level of conductivity along with high dissolved solids can cause certain physiological effects on desirable food plants and habitat-forming plant species; gives a "mineral tastes" in drinking water and can be a problem in water used for irrigation. NO_2^- and NO_3^- in the samples range from 0-0.7 mg/L both in Dhaka and West Java for NO_2^- and, 0.6-8 mg/L and 1-30 mg/L in Dhaka and West Java, respectively for NO_3^-. The NO_2^- concentrations exceeded the WHO guideline in Dhaka (Turagh 1 and Bongshi 3) and in West Java (Ciliwung 3) whereas; NO_3^- exceeded all sampling points in both countries. It was interesting that comparatively low concentration of NOx was observed downstream in the Ciliwung River in the city of Jakarta (Ciliwung 5 and 6). Non-point pollution sources such as agriculture and livestock may have contributed to the increased NO_2^- and NO_3^- in the rivers of developing countries especially in Bangladesh and Indonesia. Furthermore, NO_2^- and NO_3^- can be disseminated in the aquatic environment due to acid rain and exhaust gases [8]. Surprisingly, every sampling site in both countries possesses low COD value. The highest COD value of 40 ppm and 82.5 ppm were recorded in the downstream of the Ciliwung River (Ciliwung 6) and the Turagh River (Turagh 2), respectively. If effluent with high biological oxygen demand (BOD) levels is discharged into a water body then it generally speeds up bacterial growth along with the COD that can diminish the dissolve oxygen level in water causing lethal effects for most fish and many aquatic insects. Re-aeration due to atmospheric mixing may be assumed in this case of low COD in the sampling rivers to add oxygen and thus, oxygen levels will slowly increase in downstream.

High levels of phosphate as compared with the WHO guidelines were recorded in every sampling point of West Java (0-2 mg/L) and Dhaka (0.2-3.3 mg/L). Phosphates generally enter water from phosphorus-rich bedrock and from human and animal waste, including that from laundry, cleaning, industrial effluents, and fertilizer runoff. Phosphate usually stimulates eutrophication that may enhance the growth of primary producers resulting in reduced stability of the ecosystem and the overwhelming of natural cycles. The presence of high NO_x combining with high level of phosphate are resulting a wide variety of problems ranging from anoxic waters (through decomposition) to toxic algal blooms and decrease food supply and boost up habitat destruction in the sampling countries. It was thought that river water in West Java contained high levels of organic compounds and agricultural chemicals because of the limited availability of sewage system in the area. Total organic carbon (TOC) was measured for the rivers of Dhaka and a high content of organic carbon (3.1-28.2 mg/L) was found in each river. The results attained from the microbial study indicated that all rivers contained high microbial rupture in comparison with WHO, causing widespread fecal pollution. These results indicated the fecal pollution caused by human activities and livestock, as domestic and agricultural waste as well as human excreta were directly discharged into rivers. There is some risk of infectivity of the food web when vegetables are eaten raw [9]. Kido et al. [8] also reported severe fecal pollution in the rivers of Indonesia.

The above observation of general water quality suggests water pollution in those rivers in comparison with the WHO standard values. The results have also shown that the physiochemical pollution scenario in the rivers of Dhaka is in elevated level in comparison with the rivers of West Java (Table 1). The catchment areas of the rivers of Dhaka are full of residential, agricultural and industrial entities, distributing huge amount of pollutants every day. Besides, Indonesia is a tropical country with high rainfall and the temperature there may contribute low pressure on their rivers while Bangladesh is a low-lying and overpopulated country along the equator characterized by a monsoon climate which contributes high pressure on the rivers in respect to pollution. It was also observed from the results of West Java that the Cikaniki River is more polluted than the Ciliwung River. The pollution status was compared in the rivers of Dhaka in respect of season and obvious pollution gaps were recorded. It is evident from

Figure 2 that water quality parameters are in maximum in winter (December, 2010) in comparison with the values in rainy seasons (September, 2011). The excess rain water may dilute the pollution level of the entire river system in the rainy seasons and climatic variability reduces the original concentrations of pollutants in these rivers.

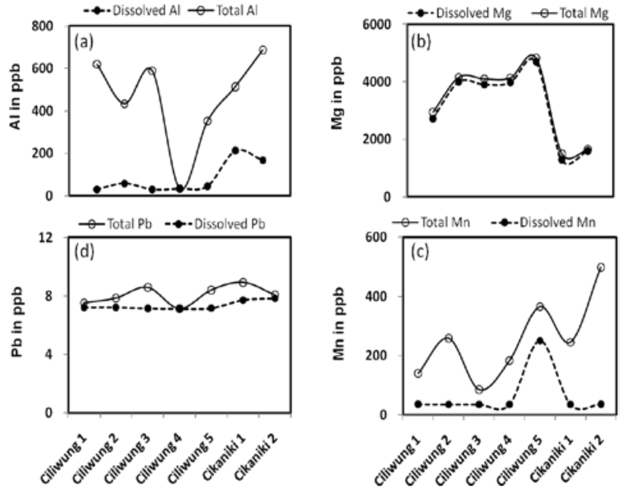

Fig. 3 Trends of accumulation/exchange of heavy metals between water and sediments in Ciliwung and Cikaniki Rivers of West Java, Indonesia

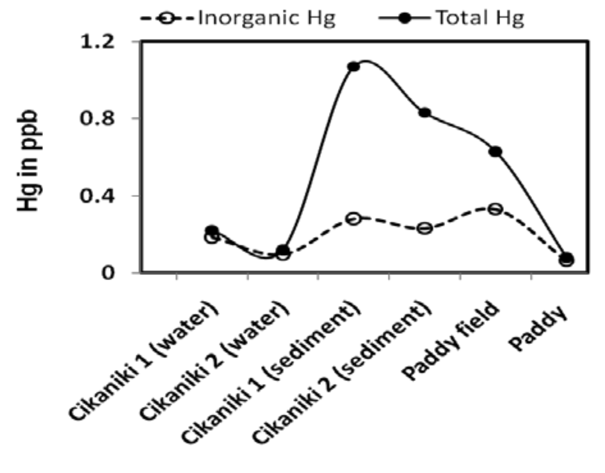

Fig. 4 Total and inorganic Hg contents in water (μg/L), sediments (μg/g) and paddy of Cikaniki River

Concentrations of metals in river water of Dhaka and of West Java are listed in Table 2. By considering the high metal levels in water samples in the rivers of West Java, sufficient metal transfer was expected into the sediment. So, a metal content in sediment was measured in both the Ciliwung and the Cikaniki River. Al and Mn concentration in each water sample of all sampling points of the Ciliwung and the Cikaniki River were found higher in comparison with the WHO guide lines, except the upstream for the Ciliwung River for Al. In addition, high concentration of Mn was found in the downstream of the Ciliwung. Although, Mn is an essential trace element, excess uptake of it may results in some nerve disorders [10]. And, Cu, Zn and Pb in all rivers were recorded as low in comparison with WHO values depicting the overall low level metal pollution in the rivers of West Java and Dhaka. In the Ciliwung 4, concentrations of all metals were lower than in other sampling sites. The reason for this is assumed to be the presence of a filtration plant near the Ciliwung 4. The Ciliwung and Cikaniki River contained high concentration of Cd ions whereas; rivers of Dhaka just approached the threshold limit (3 ppb) for Cd. The elevated levels of toxic Cd pointed to the severity of industrial pollution in West Java whereas, in case of Dhaka, it can be considered that this metal was naturally present in the environment rather than due to contamination. Moreover, other metal levels were also low in the rivers of Dhaka in comparison with the levels of West Java. Alike West Java, Cu, Zn and Pb, concentration in the rivers of Dhaka were much lower than the standard value recommended by WHO. Al, Mn and Fe concentrations were also documented as lower than the reference values of WHO and also lower than the metal contents in water and sediments (data not shown) in the rivers of West Java, except some points in downstream. These results indicated the discrete heavy metal status (source and distribution) in both countries. The pH value plays a key role in metal pollution and higher pH keeps low concentration of metals especially in the rivers of Dhaka. Besides, it was obvious from the results of West Java that the metal concentrations in the sediments were more than 10-fold those in river water [1].

Urban runoff could be a source of metals for river water, especially in the rainy seasons and all sampling regions had high annual rainfall. Contamination due to different metals was analyzed for the rivers of all sampling points according to the enrichment factor (EF). The EF (%) is usually used to determine water and sediment chemistry in relation to natural and anthropogenic pollution sources [11]-[13]. The EF was calculated as follows.

$$EF(\%) = \{(C - C_{min})/(C_{max} - C_{min})\} \times 100$$

Where, C refers to the mean concentration of heavy metals in the water sample (ppb) and C_{max} and C_{min} refer to the maximum and minimum concentrations (range) in (ppb), respectively, determined during the study. The inclination of metals to accumulate in river sediments was assessed by determining the EF (%). Surprisingly, the analysis showed that the Buriganga and Shitalakshyaa River in Dhaka have high EF (%) for Pb and the Turagh and Bongshi River comprise high EF (%) for Cu and Pb (Table 3). In contrast, every sampling point for the Cikaniki River possesses high EF (%) for every metal. This may be due to the fact that the metal EF (%) for the rivers of West Java were calculated with the sediment samples indicating high transformation and accumulation of metal into the suspended river bed sediments. Besides, high pH values stimulate accumulation of metals in riverine sediments (geoaccumulation) [14]. However, lower EF values indicate unpolluted river water whereas similar EF values specify identical sources of pollution. So, the above results suggest that a heavy metal pollution source in the rivers of both Dhaka and West Java is different. To understand the re-suspension or exchange of metals between the sediment and water, Al, Mg, Pb and Mn were further analyzed (Figure 3). It is evident from the results that the possibility of exchange of metals is very low in case of Mn and Mg whereas, Pb possesses moderate possibility and Al has the high chance of re-suspension.

Of note, illegal gold mining in the Bogor area exploit large amount of Hg to purify the gold in the gold-amalgam method. No record about gold mining activities was found in Dhaka, Bangladesh. So, Hg concentration was determined only in the Ciliwung River and in the paddy, paddy field and upstream area of the Cikaniki River. However, Hg was hardly detecte in the Ciliwung River whereas Hg ranged from 0.119 to 0.218 ppb in the Cikaniki River where 80% of the total Hg was inorganic (Fig. 4). The Hg content of river water is lower than the base line value of Hg for Indonesia (below 1 ppb). The total Hg concentrations in sediments ranged from 0.63 to 1.07 µg/ g, and the inorganic Hg concentration ranged from 0.23 to 0.333 µg/g which remains very close to the base line value (1 ppm). These results suggest high risk of being adjacent to the mining area.

Organic Hg is generally more toxic than inorganic Hg. It is estimated that 4.8 tons of Hg per month discarded into the river find their ways through many villages into the downstream [1]. Hg-prone diseases commonly known as Minamata disease resulted severe malfunction to the human offspring of Minamata Bay in Japan [8]. Fortunately, the organic Hg was present at low levels in water but unfortunately in sediments, it accounts 50% to 70% of total Hg (Fig 4). So, there is high possibility for bioaccumulation of Hg in food chain [15]. In this study, the total inorganic Hg concentrations in the paddy samples were 0.08 µg/g and 0.065 µg/g, respectively (Fig.4). This value was about 16 times higher than that in the basin of the Agano River which became known as the second Minamata disease area in 1974 [16]. The total Hg intake from rice in Indonesia (500 g/day per person) is calculated to be around 0.040 mg Hg/day that exceeded the safe guideline and may affect human health [1].

IV. CONCLUSION

It is concluded from the present study that the rivers in West Java, Indonesia and Dhaka, Bangladesh have been considerably contaminated by heavy metals, physiochemical and biological pollutants. The biological pollution indicates anthropogenic sources caused by poor sewerage system whereas the heavy metals and physiochemical pollution indicate industrial sources. Some rivers have shown high tendency to transfer the metals into the suspended sediments and/or river bed sediments. No noteworthy interaction of pollution sources was possible to establish between the rivers of both countries. The rivers of West Java and its associated ecosystem are highly vulnerable due to the presence of elevated level of Hg in the rice grain. So, the consumption of Hg polluted rice must be studied elaborately. The results implicitly suggest the urgent need for systematic monitoring along with remediation to reduce pollutant inputs and by developing functional sewage treatment plant.

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Md. Tajuddin Sikder finished his Bachelor and Master degree in the department of Environmental Sciences, Jahangirnagar University in Bangladesh. He works as the faculty in the department of environmental science of Stamford University Bangladesh. And, he is at present a PhD candidate in Graduate School of Environmental Science, Hokkaido University, Japan. His PhD research is focused on the application of cyclodextrin polymer cross-linked with epichlorohydrin to remove heavy metals in solution.