Seasonal Distributions, and Risk Assessment of Polychlorinated Biphenyls (PCBs) in the Surficial Sediments from the Turag River, Dhaka, Bangladesh

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Title

Seasonal Distributions, and Risk Assessment of Polychlorinated Biphenyls (PCBs) in the Surficial Sediments from the Turag River, Dhaka, Bangladesh

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Abstract

Polychlorinated biphenyls (PCBs) assessment in sediments of Turag River, Dhaka, Bangladesh has been conducted for the first time. This River provides critical ecological services to agriculture, industry, and transportation. However, the Turag River is one of the most industrially polluted rivers surrounding Dhaka in Bangladesh. In this study, six PCB congeners namely PCB 10, PCB 28, PCB 52, PCB 138, PCB 153, and PCB 180, were analyzed in surface sediments by GC-ECD at 9 sampling sites. Pre-monsoon and post-monsoon season sampling were collected in this study. The total concentrations of PCBs varied from 344.49 to 0.22 ng/g dw and 10.6 to 1.68 ng/g dw in pre-monsoon and post-monsoon, respectively. The paramount contributor congener to the total PCBs was PCB 180 and was found at all sites. The ecological risk assessment indicated a high potential risk in pre-monsoon (E_r^i = 277.32) and low potential risk in post-monsoon (E_r^i = 25.69). Sediment quality guideline quotients (SQGQs) showed that PCBs in pre-monsoon would cause no or moderate biological effects on organisms at most sampling sites except in surface sediments of

site S5 (high biological effects), while no adverse ecotoxicological effect was observed in post-monsoon. Considering both probable effect level (PEL) and threshold effect level (TEL), the new sediment quality guideline quotient (NSQGQ) showed that in post-monsoon PCBs contamination would cause moderate biological effects, while in pre-monsoon the findings remained consistent with the findings of SQGQ. This study gave a quick look at the PCB contamination scenario in the Turag River sediments and also allowed for a comparison between the investigated River and other rivers worldwide.

Keywords: Bangladesh; PCBs; Sediments; Risk assessment; Turag River

1. Introduction

Polychlorinated biphenyls (PCBs) are a type of man-made chlorinated compounds consisting of 209 congeners known as persistent organic pollutants (POPs) originally appended in the Stockholm Convention on POPs. In the 1930s-1980s, PCBs were widely manufactured around the world as commercial mixtures because of their low flammability, thermal and chemical stability, and electric insulating properties (Kampire et al. 2017). For many years, PCBs were extensively used as dielectric fluids in capacitors and transformers, pesticide and wax extenders, printing ink, carbonless copy paper, hydraulic oils, flame retardants, coolants, adhesives, and in various applications (ATSDR 2000; Habibullah-Al-Mamun et al. 2019). Though PCBs have been banned in the late 1970s, worldwide they are still reported in environmental matrixes e.g., water, air, sediments, etc., in various studies.

Sediments serve as reservoirs for PCBs as being absorbed by them (Ranjbar Jafarabadi et al. 2019). When PCBs are transported into the aquatic environment through the diverse paths, they tend to deposit on the surface sediments and a small portion of PCBs adsorbed on the suspended particulate matter in water (Mechlińska et al. 2010). Then, these sediments bound contaminants are carried away through incorporating with trophic level e.g., consumption of benthic organisms by fish (Bjermo et al. 2013). Again, sediment can resuspend with changes in environmental components, and then be released back into the water and begin another cycle of environmental contamination and may end up in the food chain (Cui et al. 2020). Therefore, the surface sediments show the current PCBs contamination levels in the river (Baqar et al. 2017).

Bangladesh is a signatory country to the Stockholm Convention on POPs, 2001. But environmental quality guideline on PCBs has barley been set in Bangladesh. However, in Bangladesh, some studies have been carried out to evaluate the PCBs contamination in environmental media and biota at the coastal areas. Yet, no researches have been conducted on PCBs pollution on any river body. Also, the occurrence and ecotoxicological risks of this compound in various river sediments are remained unknown.

Turag is one of the most polluted rivers running through west-north and north of Dhaka City (Islam et al. 2018; Ferdousi et al. 2020). This River is directly affected by various industries ranging from small to large scale garments, textile, pharmaceuticals, chemicals, pesticides, jute, metal industries, tobacco, ink, pulp and paper mills, food processing, tanneries, etc. (Sarkar et al. 2016; Aktar and Moonajilin 2017; Islam et al. 2018). The heavy discharge of pollutants by the industries adjacent to the River banks causes a dangerous level of water abysmal (Begum et al. 2018). The Department of Environment (DoE) declared it as an ecologically critical area (ECA) in September 2009 (Rahman et al. 2018; Majed and Chawdhury 2018).

69 The process of urbanization, industrialization, and medium to large-scale landfills using industrial
70 sludges, open burning of industrial and municipal waste, e-waste, etc., and many other polluting
71 activities on riverbanks might be the key sources of PCBs in this River. Besides, the tropical
72 climate of Dhaka causes frequent rainfall with an annual average temperature of 25 °C might
73 attribute to the transportation of contaminants to this River. Thus, the contamination status of PCBs
74 and its harmful consequences are paramount to evaluate seasonally and spatially in the River
75 sediments. Very few studies have been carried out regarding organic pollutants on the River, and
76 ecological risks due to organic pollutants are still unknown. Hence, the consensus-based sediment
77 quality guideline (SQG) given by Long and MacDonald (1998) has been extensively used to assess
78 PCBs induced ecotoxicological risks in sediments (Barakat et al. 2013; Zhang et al. 2016; Liber et
79 al. 2019). Therefore, the prime objectives of this study were to assess the seasonal and spatial
80 distribution of sedimentary PCBs pollution and to evaluate the ecological and ecotoxicological
81 risk of PCBs in sediment.

82 **2. Materials and Methods**

83 **2.1 Study area and sample collection**

84 The study area consists of the part of the Turag River. The Turag River is one of the most
85 prominent floodplain regions generates from the Bangshi river at Kaliakoir Upazila (Hossain and
86 Chowdhury 2018). The Turag River is active and has a small flow only in the dry season. It joins
87 the Buriganga River near Mirpur (Dhaka) (Aktar and Moonajilin 2017; Hossain and Chowdhury
88 2018). It is navigable by boats throughout the year (Islam et al. 2018).

89 Two sampling trips were undertaken in pre-monsoon (March-May) 2019 and in post-monsoon
90 (November-February) 2020 to collect surface sediments on the bank of the Turag River (Fig. 1).

During low tide, a total of 18 sediment samples were collected during this time from nine sampling sites. From the top surface (0 – 6 cm) of the riverbank, around 200g of sediments were collected from each location by a hand Trowel as a sampler. In polyethylene (PE) ziplock bags the samples were carried and transferred in an airtight ice-filled insulating box.

The samples were stored at −8 °C. All the samples were air-dried for two days, and foreign objects such as leaves, shells, plastic fragments, and other visible impurities were discarded. Subsequently, a mortar and a pestle were used to ground the dried sediments. Then, these were sieved for homogenization by using a stainless-steel sieve (Testing Sieve, Chung gye, Seoul, Korea) (1 mm) and resulted in fine powder. The powder was then transferred into polyethylene (PE) ziplock bags and kept in a freezer at −20 °C before extraction.

2.2 PCBs Extraction and Clean-up

The APA 6431B method was followed to extract the target compounds from the sediment samples. Briefly, 50 mL of n-hexane and 50 mL of acetone were introduced into a 250 mL conical flask containing 10.0 g of the sediment sample and sonicate vigorously for 60 minutes. The sample was filtered into a 250 mL round bottle flask. The procedure was repeated twice. The extracts were later combined to make a whole and concentrated to 1 mL using a rotary evaporator in a water bath at 35 °C. The remains were moved into a 10 mL test tube with 5 mL n-hexane with anhydrous Na_2SO_4. Here, clean-up was done by adding 1 mL of Sulphuric acid with 10% water; shaken vigorously using a vortex mixer for 1 min, and then centrifuge at 3000 r/min to separate the two layers recording the volume collected in GC vial for the run.

2.3 GC-ECD Analysis

The quantification of polychlorinated biphenyls (PCBs) was performed by injecting 1.0 µl aliquot of final extract into a gas chromatograph (Simadzu 2010 plus) equipped with a ^{63}Ni electron capture detector (ECD) and a moving needle-type injection system and injection mode was splitless. The column consisted of SH Rtx-5, 30 m long, 0.32 mm i.d.0.25 µm film thickness. Here, the column temperature was started from 120 °C (1 min hold) at a rate of 20 °C / min to 210 °C (4 min hold) and then at a rate of 5 °C / min to 290 °C (3 min hold). Detector and injector temperatures were maintained at 300 °C and 200 °C respectively. Nitrogen gas was the carrier gas

Data acquisition and processing were carried out by a chromatogram, named GCsolution Postrun, Version 2.41.00 with a workstation (GCsolution), and a computer. PCBs were quantified by comparing the individual peak areas between the sample and the standard.

2.4 Quality assurance and quality control

For the study of linear range, a diluted PCBs standard mixture solution series of 2.5, 5, 10, 50, 100, and 200 ng/mL were prepared and injected onto the GC-ECD. The results show that the relation is linear up to 200 ng/mL and the coefficients of determination (R^2) values showed good linearity ranging between 0.9844 and 0.9971.

All solvents were of analytical grade for PCBs analysis. Quality assurance (QA) and quality control (QC) measures are baking all glassware at 400 °C and rinsing them with solvent before use, running method blanks, and matrix blanks for every batch of 10 samples. An S/N (signal-to-noise) ratio equivalent to 10 was applied to set the limit of detection (LOD) for each analyte. The limit of detection (LOD) was ranged from 0.01 ng/mL (dw) to 200 ng/mL (dw). <0.001ng/g levels were taken as not detected in the PCB calculations. Moisture content was assessed to present data on a dry weight basis.

2.5 Data analysis

For statistical analyses, IBM SPSS Statistics (Version 22.0) and Microsoft XL (Version Microsoft Office Professional Plus) were employed. The Shapiro-Wilk W test was conducted for data normality test. One-way ANOVA test was conducted to find the variations among the concentrations of PCBs and seasonal differences. The Arc-GIS software (Version 10.5) was used for site identifications and the spatial variations of PCBs in sediments.

2.6 Sediment quality guideline quotient (SQGQ)

SQGQ was carried out to identify the adverse biological effects of PCBs in sediments. Firstly, the probable effects level quotient (PELQ) was calculated by applying the following formula (Long and MacDonald 1998):

$$PELQ_i = \frac{C_i}{PEL} \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where PEL is the guideline value for the target contaminant (i), and C_i is the measured concentration of the target contaminant. For each site, the SQGQ was calculated as:

$$SQGQ = \frac{\sum_{i=1}^{n} PELQ_i}{n} \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where n is the total number of measured contaminants having sediment quality guideline values. Three ranges of SQGQ were categorized based on potential adverse biological effects of sediment contamination. They are: no biological effects (SQGQ < 0.1), moderate biological effects ($0.1 \leq$ SQGQ < 1), and high biological effects (SQGQ ≥ 1) (Tian et al. 2013; Wang et al. 2019; Lv et al. 2020).

2.7 New sediment quality guideline quotient (NSQGQ)

According to Wang *et al.,* 2019, SQGQs might depreciate the risks of PCBs for not taking into consideration the TEL effects. Thus, considering both PELs and TELs, they introduced a new sediment quality guideline quotient (NSQGQ) (Long and MacDonald 1998; Zhang et al. 2016). At first, NSQGQ for total PCB congeners was derived from the following formula (Wang et al. 2019):

$$NSQGQ_i = \frac{\sqrt{\frac{C_i}{TEL}+(\frac{C_i}{PEL})^2}}{2} \text{.....(3)}$$

Finally, the combined toxic risk index of total PCBs and other contaminants could be assessed based on the following equation:

$$NSQGQ = \frac{\sum_{i=1}^{n} NSQGQ_i}{n} \text{.....(4)}$$

Where $NSQGQ_i$ is the new SQGQ of a certain contaminant; C_i denotes the measured concentration of the target contaminant; n denotes the total number of the measured contaminants having sediment quality guideline values and NSQGQ refers to the combined new sediment quality guideline quotient.

3. Results and discussion

3.1 Composition and occurrence of PCBs in sediments

In the present study, detectable levels of PCBs were noticed in all sedimentary samples. The PCB congeners concentration in sediments from Turag are presented in Table 1. The PCB concentrations ranged from 0.217 to 344.49 ng/g and 1.68 to 10.6 ng/g dry weight (dw) in pre-monsoon and post-monsoon, respectively in the surface sediments.

In pre-monsoon, the highest concentration (344.49 ng/g) was observed in sediments collected from Site 5 with the only presence of PCB 180 (344.412 ng/g dw) and PCB 52 (0.074 ng/g dw) (Table 4.1). Followed by Site 5, both Site 3 and 8 were higher in PCB concentrations. For Site 8 and 3, the concentrations were 124.82 ng/g and 121.18 ng/g, respectively.

The percentage composition of six PCB congeners is shown in Fig. 2. In pre-monsoon, PCB 180 was the most abundant among the analyzed congeners with an average concentration of 67.67 ± 115.6 ng/g in the investigated samples, followed by PCB 28 (0.786 ± 2.17ng/g) and PCB 138 (0.441± 0.68 ng/g). PCB 180 alone contributed more than 97% to the total PCBs in the analyzed sediments. PCB 180 showed predominance at all sites. From Fig. 2(a), PCB 52 was the second dominant congener at Sites 7 and 9. PCB 28 was the second dominant congener at Sites 1 (> 40%) and 2. Also, PCB 138 was the second dominant congener at Sites 4 and 6 (> 15%).

Whereas, in post-monsoon (Fig. 2(b)), PCB 180 was the most abundant congener with an average concentration of 4.38 ± 2.78 ng/g, followed by PCB 28 (.86 ± 2.48 ng/g) and PCB 52. Here, PCB 180 alone contributed more than 68% to the total PCBs in the analyzed sediments. From Fig. 4.1(b), PCB 180 showed predominance at all sites except Sites 1 and 8. PCB 10 showed predominance at Site 8 (> 40%), and PCB 28 showed predominance at Site 1 (> 60%). PCB 52 was the second dominant congener at Sites 4, 5, 6, and 7.

High abundance and dominance of PCB 180 had been observed in both seasons. In the past, increased concentrations of PCBs 170 and 180 have been reported to be evidence of the presence of Aroclor 1260 (Ormerod et al. 2000). Aroclor 1260 was a usual constituent of capacitor oils and transformer (Erickson and Kaley 2011). This would be consistent with the release from the disassembling of transformers and other types of electrical equipment at Sites 3, 5, and 8 in the

pre-monsoon season. Both Sites 5 and 8 were in the vicinity of landfills. Especially at Site 5, several transformers were observed along the roadsides. Leakage from these transformers may be concentrated due to heavy rainfall accompanied by Cyclone Fani in the same month and lead to the high contamination of PCB 180.

PCBs are conclusively a significant source of environmental pollution because of leakage from installations at storage or disposal, operating installations, and considered a great source of environmental pollution by PCBs in several emission inventories (Kakareka and Kukharchyk 2005). During the site visit, it was observed that maximum sites direct in contact with landfills. Landfills are a potential source of PCBs emission, as they contain municipal and industrial wastes. The type of PCB wastes in the landfills highly affects the levels of PCBs emissions (Kakareka and Kukharchyk 2007). Municipal waste burning is another potential source of PCBs pollution in this study. A variety of wastes are burnt into large bonfires such as paper, packaging material, paperboard, polyethylene film, plastic bottles, contaminated wood, waste food, rags, etc. Street sweep which contains a significant share of domestic wastes is burnt down often. Sanitary landfills of solid wastes and in other places of their unofficial accumulation cause unavoidable spontaneous fires.

3.2 Seasonal and spatial differences of PCBs in sediments

In the study area, the seasonal and spatial dissemination of PCBs in sediments are shown in Fig. 3. Seasonally, neither the levels of total PCBs nor the identified congeners distribution patterns differ significantly ($p > 0.05$).

Sediments are heterogeneous in constituents, and the different elements of sediments show different interactions with the pollutants (Kampire et al. 2017). It may highly affect the

composition of PCBs concentration spatially and seasonally. Only Site 1 exhibited a little bit consistent during two seasons (14.86 ng/g and 10.6 ng/g in pre-monsoon and post-monsoon, respectively). It indicates the sources of PCBs might be similar in both seasons (Dodoo et al. 2012; Habibullah-Al-Mamun et al. 2019).

The seasonal difference in the PCBs concentration might be caused by the variations of the precipitation amount in these two seasons (Li et al. 2012). The elevated levels of PCBs in pre-monsoon samples, especially at Sites 3, 5, and 8 might be caused by heavy rainfall and floods which triggered surface runoff from highly contaminated sites. This reason is suspected because heavy rainfalls took place due to Cyclone Fani before sampling from these sites. This tropical cyclone caused medium to heavy rainfall over the country, and Dhaka experienced 10 to 70 mm rainfall accompanied by the tropical cyclone (The Daily Star 2019; OCHA 2019). Large water bodies show higher contamination during and immediately after rainstorms (Awwa Research Foundation 2008). An increase in precipitation intensity triggers inputs of pollutants, especially severe nutrients, pathogens, hazardous substances, organic material, and other dissolved contaminants (e.g., pesticides) (Ching et al. 2015). On the day of sample collection in the pre-monsoon season, at Mirpur station (SW302) the water level was 2.86 m with regular water flow. Intense shipping and fishing activities during the pre-monsoon season might be another reason for PCBs contamination.

In premonsoon, higher levels of PCBs were observed at Site 2 (10.54 ng/g), Site 4 (9.67 ng/g), and Site 6 (5.38 ng/g). Co-evaporation of PCBs with water might be one of the reasons (Dodoo et al. 2012). Another reason might be excessive sedimentation from low mixing effects in the dry season because of relatively weaker wave action and decreased upstream rivers inflow (Habibullah-Al-Mamun et al. 2019). It is important to note that the dry flow during post-monsoon decreased the

240 water height to such extent that some of the samples were stored from the river bed and the water
241 level was 1.52 m with low water flow at the Mirpur station (SW302).

242 Despite sampling sites in the study area, the mean concentration of ∑PCBs in pre-monsoon (69.33
243 ng/g dw) was much higher than in post-monsoon (6.42 ng/g dw). The findings were compatible
244 with earlier research conducted by Lai *et al.,* in 2015 at Pearl River, China which reported that the
245 wet season has a higher mean concentration of ∑PCBs than the dry season, and which was not
246 significant ($P > 0.05$). In several studies, PCBs concentration remains the same or slightly changes
247 over seasons (Baqar et al. 2017; Habibullah-Al-Mamun et al. 2019).

248 The spatial distribution of ∑PCBs deviated highly from the mean concentration of ∑PCBs in pre-
249 monsoon (SD = 115.12 ng/g). High tidal influence, high precipitation, changes in river dynamics
250 might affect the spatial distribution of pollution in pre-monsoon. Besides, agricultural and surface
251 runoffs, dumping of industrial wastes, intense dredging operations, and atmospheric depositions
252 might speed up the extent of PCB contamination in this season. Whereas, in post-monsoon, the
253 spatial distribution of ∑PCBs did not deviate highly from the mean concentration of ∑PCBs (SD
254 = 3.37 ng/g). Weak tidal influence, low water flow, low or no precipitation, static river dynamics
255 might affect the spatial distribution of pollution in this season. During the monsoon season (June
256 to Mid-October), the surface sediments generally are worn out and new sediments are settled down
257 thereafter. It takes time to accumulate organic pollutants in new sediments. Consequently,
258 relatively very lower concentrations of PCBs were observed in the post-monsoon season.

259 The incomplete burning of e-wastes is a potential source of PCBs in the study area. Other potential
260 sources of PCBs in the study area might contain paint industry, burning of e-waste for metal
261 recovery, vehicular fuels, PVC (polyvinyl chloride) industries (Syed et al. 2014; Baqar et al. 2017),

dumping and discharges of oils and waste material (Farooq et al. 2011), coal combustion and industrial waste (Chi et al. 2007), and recycling units and steel production (Biterna and Voutsa 2005),.

4.4 Ecological risk assessment

It is highly important to assess the sediment-bound PCBs inducing potential risk of the Turag River. As there is still no uniform standard available, the risk assessment of PCBs in the riverine environment was carried out based on the ecological risk index (ERI) of Hakanson (1980) and implemented in previous studies (Cui et al. 2016; Baqar et al. 2017). Here, the risk assessment has been done by the following equations:

$$ERI = \sum E_r^i \quad \text{.....(5)}$$

$$E_r^i = T_r^i \times C_f^i \quad \text{.....(6)}$$

$$C_f^i = \frac{C_0^i}{C_n^i} \quad \text{.....(7)}$$

Where ERI is the summation of ecological risk factors of seven heavy metals and PCBs. As this study is about PCBs, so heavy metals were disregarded. So, in this calculation, ERI is equivalent to E_r^i (monomial potential ecological risk factor). T_r^i is the toxic-response factor for PCBs. C_f^i is the contamination factor, and C_n^i denotes reference value for ∑PCBs, and it is 0.01 ppm or 10 ng/g.

The potential ecological risk factor (E_r^i) had been graded into following five categories (Hakanson, 1980):E_r^i < 40, low risk; 40–79 E_r^i , moderate risk; 80–159 E_r^i , considerable risk; 160–319 E_r^i , high risk; and E_r^i> 320, very high risk.

The ERI was calculated using Eqs. (3) and (4). The ERI value indicated high potential ecological risk during pre-monsoon (E_r^i = 277.32) and low potential ecological risk during post-monsoon (E_r^i = 25.69). The ecological risk factor of the Turag River is shown in Table 2.

4.5 Ecotoxicological risk assessment

4.5.1 Sediment Quality Guideline Quotients (SQGQs)

The average values of SQGQ for both seasons are shown in Fig. 4.5. Six sampling sites of pre-monsoon are below 0.1. Besides, the SQGQs in two sampling sites, namely, Site 3 and Site 8 indicate the benthic organisms might suffer from moderate adverse biological effects due to sediment-bound PCBs. The SQGQ of PCBs at Site 5 is above 1, suggesting that this surface sediment of the sampling site was suffering from high adverse biological effects (Table 3). Whereas, the SQGQs of post-monsoon show that PCBs would not cause any effects on benthic organisms (Table 3).

4.5.2 New sediment quality guideline quotient (NSQGQ)

Wang *et al.,* 2019 showed in their study that there was a significant linear correlation (R^2 = 0.9869, $p < 0.01$) between SQGQs and NSQGQs while specifying that NSQGQs perhaps a valid method to evaluate the ecotoxicological risks of PCBs. They recommend NSQGQs can better estimate the ecotoxicological risks for PCBs. Here, the effect levels were divided into the following categories: NSQGQ < 0.2, no or low effects; 0.1 ≤ NSQGQ < 2, moderate effects; and NSQGQ ≥ 2, high adverse effects.

In pre-monsoon, the NSQGQs reflect that the PCBs contamination would cause low to moderate biological effects on the Turag River except Site 5 indicating a high adverse effect on biological organisms (Table 3). Whereas, in post-monsoon, the NSQGQs denote that PCBs contamination

caused moderate biological effects during the post-monsoon, while according to SQGQ, this season had no effects on aquatic species of the Turag River (Table 3).

4.6 Comparison with previous studies worldwide

A comparison of mean sedimentary ∑PCBs concentration of the Turag River with those recorded from other rivers around the world is presented in Table 4.

No data on PCB contamination in the Turag River is accessible to compare with the findings of other studies in sedimentary PCBs. In Bangladesh, the literature indicates no research on riverine sedimentary PCBs.

The comparison of mean PCBs concentration in sediments of Pre-monsoon with other studies (Table 4) presented that the ∑PCBs concentration of this study was comparable or lower than those reported from Huveane River, France (Kanzari et al. 2014); Umgeni River, South Africa (Gakuba et al. 2015); Pearl River Delta, China (Wang et al. 2019); and Pangani River and its tributaries, Tanzania (Hellar-Kihampa et al. 2013).

Whereas, the comparison of the mean PCBs concentration in sediments of Post-monsoon with other studies showed that the ∑PCBs concentration of this study was significantly lower than those reported from Makelele, Kalamu, and Nsanga, Congo (Kilunga et al. 2017); River Ravi, Pakistan (Baqar et al. 2017); Liaohe River, China (Lv et al. 2020); CauBay River, Vietnam (Toan and Quy 2015); Sarno River, Italy (Montuori et al. 2014); Soan River, Pakistan (Malik et al. 2014); and River Chenab, Pakistan (Eqani et al. 2012). However, the ∑PCBs concentration was slightly lower or somewhat comparable to those studies recorded from River Thames, England (Lu et al. 2017); Yamuna River, India (Kumar et al. 2013); Songhua River, China (Cui et al. 2016) and Bahlui River, Romania (Neamtu et al. 2009).

326 The total sedimentary PCBs levels reported from developed countries (China, England, France,
327 Italy, and South Africa) were generally a little comparable or higher than the total PCBs levels in
328 the present study. This suggests that eminent industrial activities, and a variety of waste discharges
329 in the environmental compartments of developed countries (Kampire et al. 2017). Whereas, the
330 levels of total PCBs on the river sediments from developing countries (Egypt, Vietnam, Romania,
331 and Mexico) were generally comparable or lower than the total PCBs levels in the present study.
332 The history of PCBs is prevalent and more extensive in developed nations than in developing
333 countries, and the contamination seems to be more profound in developed countries (Mochungong
334 and Zhu 2015).

335 **4. Conclusion**

336 The present study was the first to focus on the levels of PCB organic pollutants in the surficial
337 sediments of the Turag River, Dhaka, Bangladesh. PCB 180 was the most conspicuous one in
338 sediments during both seasons. Considering seasonal variation, the mean concentration of ∑PCBs
339 in pre-monsoon (69.33 ng/g dw) was higher than in post-monsoon (6.42 ng/g dw). Sites 3, 5, and
340 8 in pre-monsoon were subjected to moderate to high adverse biological effects on benthic
341 organisms. Ecological risk assessment reflected high potential ecological risk in pre-monsoon (E_r^i
342 = 277.32) and low potential ecological risk in post-monsoon (E_r^i = 25.69). The sedimentary PCB
343 concentrations of the investigated area were comparable with rivers around the world.

344 The possible sources of PCBs are from dyeing, chemicals, paper mills, domestic industrial and
345 wastewater discharge from factories, (e.g., paper, paint, iron, and textile factories) of industrial
346 clusters. The sources also include landfills, e-wastes, transformers, constructions and demolition
347 wastes, municipal waste open burning, etc. into the Turag River. In the lack of any data on PCBs
348 in the study area, the present study will yield baseline data for subsequent ecological studies in the

future. Again, this study will put stress on the assays of Bangladesh's national implementation plan (NIP) to the exclusion of PCBs as being a party of the Stockholm Convention, 2001.

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Author's Contribution

NJC, MS, and MKU designed and planned the study. NJC collected and analyzed the samples. MAA supported all lab analyses. NJC prepared the draft manuscript. MS and MMR did proof reading.

Declarations

Availability of Data and Materials The authors confirm that the data supporting the findings of this study are available within the article.

Ethics approval and consent to participate Not applicable.

Consent for publication All the authors approved the manuscript for publication.

Competing interests The authors declare that they have no competing interests.

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Figures

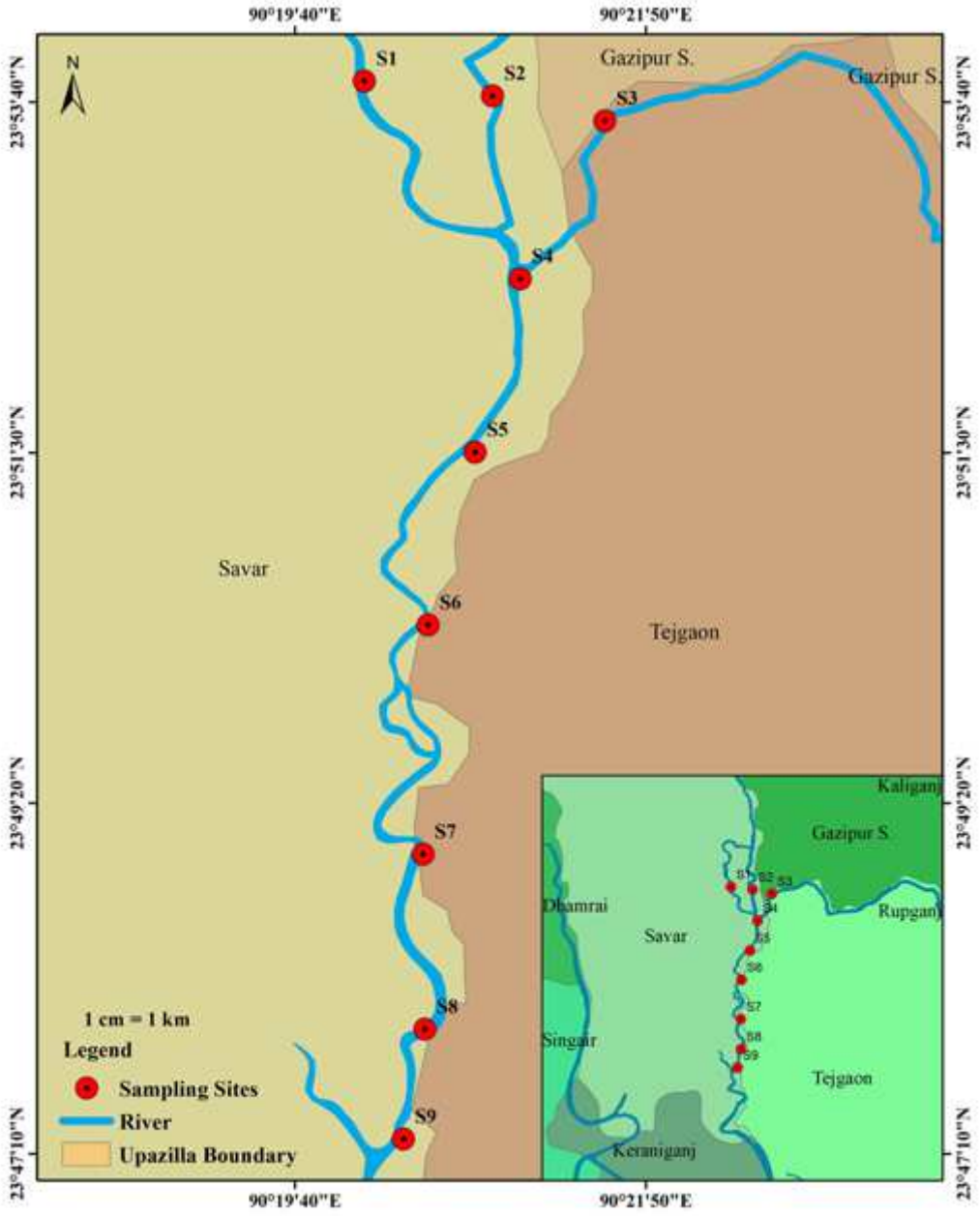

Figure 1

Sampling sites along the Turag River Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

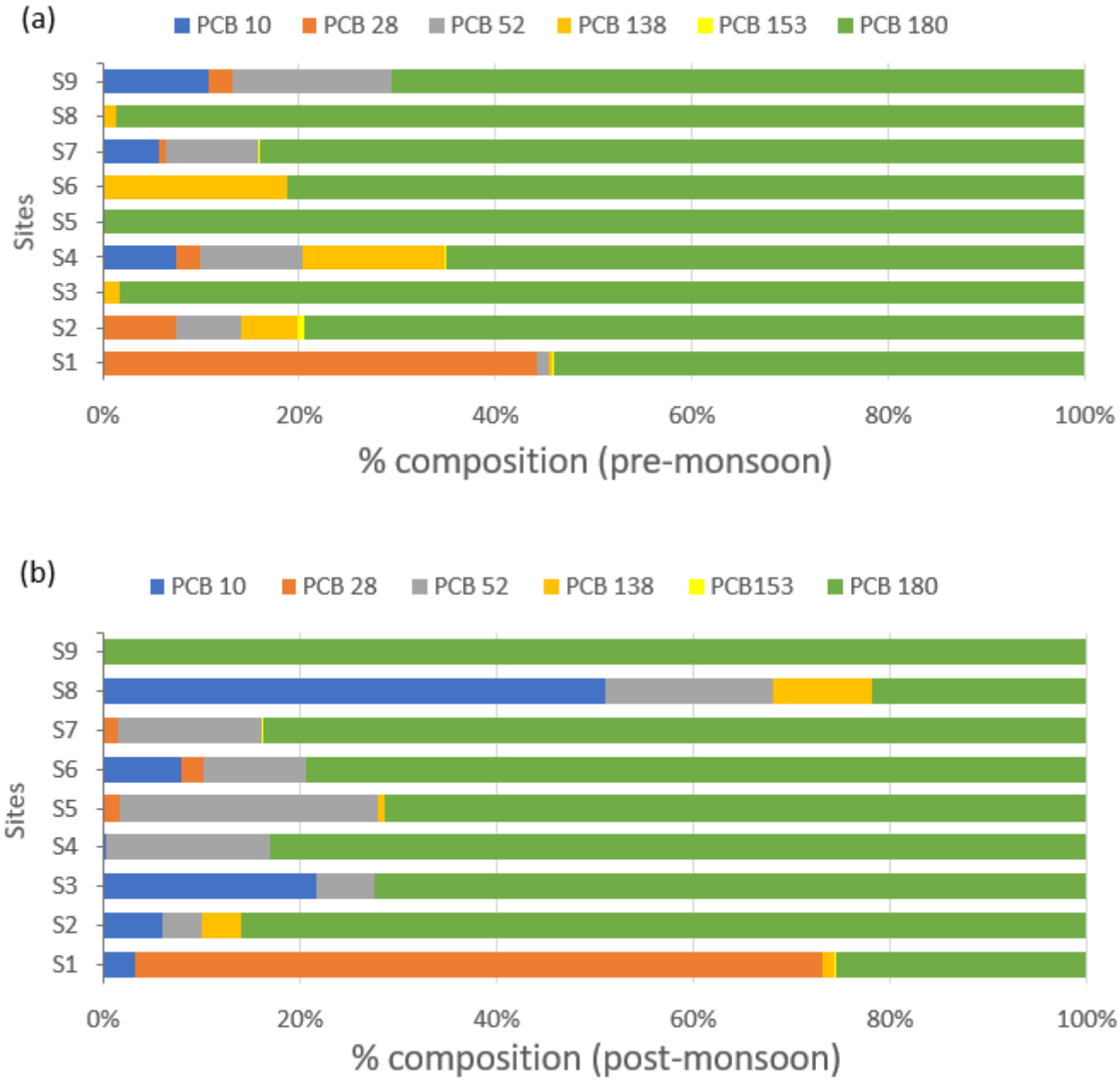

Figure 2

Composition (%) of six PCB congeners in sediment samples of (a) pre-monsoon and (b) post-monsoon

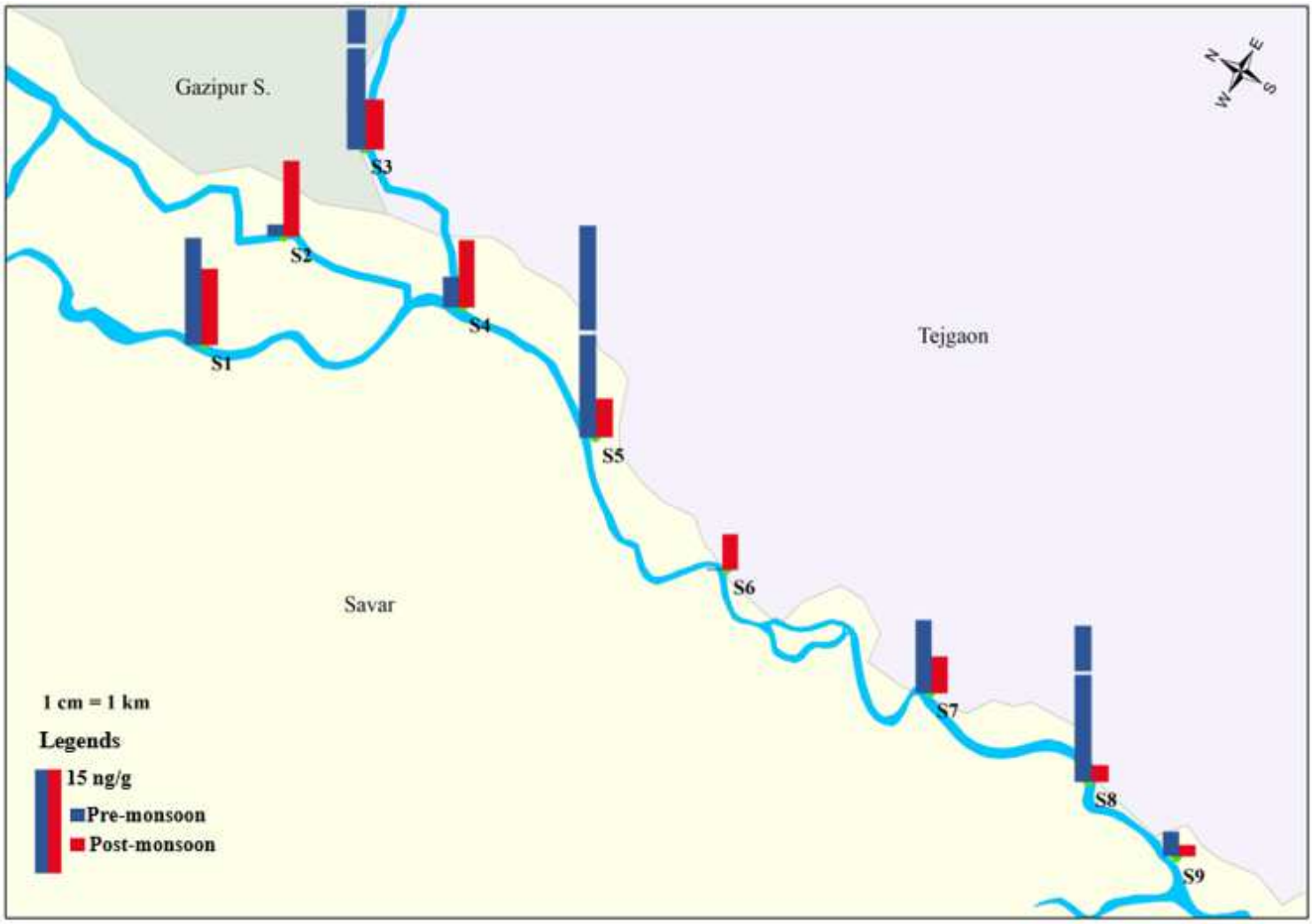

Figure 3

Distribution of total PCBs in surface sediment along the Turag River collected in post-monsoon and pre-monsoon Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.