



Research Paper

Evaluation of water quality and biodiversity of natural freshwater wetlands discharged by industrial effluent

Accepted 18th March, 2017

ABSTRACT

Natural freshwater ecosystem ensures the supply of several beneficial services, such as freshwater, foods, medicines, clean air, aesthetic values etc., it may be cut off by indiscriminate discharges of industrial effluents. The present study was carried out to evaluate water quality and freshwater biodiversity in polluted and non-polluted wetlands at three Upazilas (administrative unit) in Gazipur district of Bangladesh. Two wetlands, that is, one polluted and another non-polluted were selected from each Upazila. Data were collected through face to face interview of relevant 450 respondents by prior prepared questionnaire. A total of 71 aquatic species were evaluated under four groups: fish and shellfish (50), plants (10), birds (6) and amphibians (5). The existence of maximum aquatic species was drastically affected in polluted wetlands. Twenty fish and shellfish, 3 plants and 1 amphibian species were extinct from all polluted wetlands. Conversely, 39 fish and shellfish, 1 amphibian and 4 plants species were extinct from Mokeshebeel wetland only. Others were observed as threatened (T), endangered (En), and vulnerable (Vu). But majority of the species were visible (V) in non-polluted wetlands. Average 70-80% respondents articulated these results. Water quality severely deteriorated in all polluted wetlands. The minimum and maximum values of dissolved oxygen (DO) were 0.4 and 2.0 mg/L in polluted and 4.2 and 4.9 mg/L in non-polluted wetlands, respectively. Higher values of Cr and Ni were recorded in polluted waters as compared with the standard. Excessively decreased DO was responsible for the destruction of aquatic biodiversity. Proper discharge of measures may helpful to overcome the present problem and conserve aquatic biodiversity.

Key words: Fish and shellfish, Aquatic plants and birds, Amphibians, Endangered, Extinct, Polluted wetlands.

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INTRODUCTION

Biodiversity has become a global agenda now-a-days as it acts as catalyst for maintaining and supporting overall congenial environment and offer enormous economic and aesthetic values. Hence, human beings are dependent on aquatic resources for their foods, medicines, recreational and commercial purposes, such as fishing and tourism. Bangladesh is blessed with rich and extensive inland and marine fisheries resources with a wide variety of indigenous and exotic fish fauna (Khan, 2013). However,

like other developing countries, intensive anthropogenic activities pose an imminent and direct threat on biodiversity in Bangladesh.

In Bangladesh, though agriculture is the backbone of the economy, but presently, the industrial development is playing significant role in strengthening the country's revenue. Among industrial development, the textile is contributing substantial share to it. Accordingly, the district Gazipur (around 50 km north from capital city of

Dhaka) is one of the most thickly industrialized zones in Bangladesh and mainly these are dyeing, knitting, spinning, washing textiles including pharmaceuticals, tannery and other industries. The production of industrial effluents in Gazipur is also higher as compared with others (Hossain et al., 2010). More than 80% industries have not/do not use effluent treatment plant (ETP), therefore, careless and indiscriminate disposal of effluents have been practiced directly to the surrounding natural wetlands, rivers, agricultural fields, irrigation channels, canals etc. (Sultana et al., 2009). Industrial effluent deteriorates not only the quality of water, soil, crop and environment, but also harmful to the human, animal and aquatic lives (Hossain et al., 2010 and 2015). This unplanned disposal of industrial effluent may cause serious negative impacts on aquatic biodiversity and our natural resources. We are assuming such types of negative impacts, but the actual present status is not known to us. Usually the industrial effluent contains different toxic chemicals which are phytotoxic, as well as zootoxic (Alloway, 1995; Modoi et al., 2014) and its disposal is a great problem (Chopra and Pathak, 2012). Disposal of untreated industrial effluent may cause significant alteration of both surface and subsurface water qualities, which might give rise to dwindling aquatic biodiversity such as fisheries, plants, birds, animals and amphibians. The industrial effluent contains specific chemicals which pollute different water bodies and damage mostly aquatic ecosystem (Moeller, 1992; Benard and Wright, 1998; Neermoliet al., 2007). Only proper positive measures, at the right time, may help to sustain friendly aquatic ecosystem and their biodiversity. Industrial effluent is the potential and detrimental source of pollution of aquatic ecosystem and brings an enormous unenthusiastic change to the environment and ecosystem. Phiri et al. (2005) addressed, in their studies, that the continuing discharges of industrial effluent into water bodies may result in severe accumulation of the contaminants that dynamic into food chains, which may affect human health. Effluent of textile dyeing is rich in different inorganic and organic chemical pollutants including heavy metals which are harmful to human beings also (Sultana et al., 2009).

Textile effluent is recognized as the highest ranked pollutants among all industrial sectors considering both its volume and chemical composition (Vanndevivera et al., 1998; Roy et al., 2010), which can easily contaminate the natural resources and harm living beings by its unpleasant chemical characteristics, indiscriminate and non-judicious discharges (Anastasi et al., 2012). Simultaneously, its disposal practices accelerate damage to natural wetlands environment and gradual extinction of aquatic biodiversity, such as disappearing of fishes and other aquatic life, birds, beneficial insects, animals, plants etc. (WHO 2002; Sultana et al., 2009). Accordingly, the nature of damages of water quality, aquatic environment, ecosystem and status of biodiversity are yet to be well noticed in intensive industrial areas of Bangladesh.

Therefore, the present study was carried out to evaluate the present status of freshwater biodiversity and water quality of polluted wetlands by industrial effluent discharges with non-polluted wetlands to provide useful information for relevant readers.

MATERIALS AND METHODS

Experimental site

The study was conducted in Gazipur district of Bangladesh considering six wetlands from three Upazilas (administrative unit of the district), such as Gazipur Sadar, Kaliakair and Sreepur (Two wetlands, that is, one polluted and another non-polluted from each Upazila). The Gazipur district has five Upazilas, but the studied three have intensive industrial development. The selected polluted wetlands were in Jongi, Bangla bazaar and Mokeshbeel; and non-polluted wetlands were in Rajabari, Pajulia and Aloibeel from Sreepur, Gazipursadar and Kaliakair Upazilas, respectively.

Experimental period, procedure and data collection

The present study was conducted from the period of September 2015 to May 2016, mostly in dry seasons. It was carried out by several visits to the polluted and non-polluted wetlands, that is, experimental sites (Figure 1). Moreover, 75 professional and subsistence fishermen (above 30 years of age) living around the targeted wetlands areas were randomly selected from each location. Hence, a total 450 personnel were selected as sample respondents from the selected six wetlands sites. The necessary data on status of aquatic biodiversity in targeted wetlands were collected by face to face interview using pre-tested interview schedule. Moreover, participatory tool such as Focus Group Discussion (FGD) was conducted in each location to list out the aquatic species that were present before the establishment of industries. The interview schedule was prepared to collect the present status of aquatic biodiversity based on scaling as 'Visible' ($V \geq 80\%$) - species that were visible and not considered as remarkable risks; 'Threatened' ($T \leq 79\%$) - species that were likely to become endangered within the foreseeable future; 'Endangered' ($En \leq 30\%$) - species that had become so rare and were in danger of extinction; 'Vulnerable' ($Vu \leq 10\%$) - any species considered to be facing a high risk of extinction; and 'Extinct' ($Ex 0\%$) - no reasonable doubt that the last individual died.

Sample collection and studied parameters

Water samples were collected and carried in cleaned plastic bottle, and preserved at 4°C in a chiller for



Figure 1: Scenario of polluted (by industrial effluent) and non-polluted wetlands of three upazilas in Gazipur district of Bangladesh.

immediate necessary assessment. The physical and chemical parameters, such as color, odor, temperature, total suspended solids (TSS), total dissolved solids (TDS), pH, dissolved oxygen (DO), chemical oxygen demand (COD), electrical conductivity (EC) and heavy metals of waters (polluted and non-polluted) were assessed to evaluate the existing water quality status. Moreover, the data on aquatic biodiversity such as different group of fishes and shellfish, aquatic plants, birds and animals

(amphibians) were collected through survey and interview of local respondents from the target polluted and non-polluted wetlands sites.

Analytical procedure

Physical parameters of waters, such as color, odor, temperature, TSS and TDS were measured based on the

Table 1: Physico-chemical properties of water in polluted (by discharging industrial effluents) and non-polluted wetlands at different Upazilas of Gazipur district in Bangladesh.

Parameter	Polluted Wetlands			Non-polluted Wetlands			Standard values ¹			
	Jongi, Sreepur	Bangla bazaar, Gazipur sadar	Mokesh beel, Kaliakair	Rajabari Sreepur	Pajulia, Gazipur sadar	Aloi beel, Kalaiakair	BD	EU	Canada	Australia
Color	Black	Black	Black	Slightly turbid	light brown	Clear	-	-	-	
Odor	Pungent	Foul	High pungent	Odorless	Odorless	Fishy	-	-	-	
pH	8.7	10.2	10.5	6.5	6.8	7.2	6-10	6.0-9.0	6.5-9.0	5.0-9.0
Temperature (°C)	36	30.6	32.5	20.5	24	22.8	40°C	-	-	
DO (mg/L)	1.8	2	0.4	4.2	4.4	4.9	5 to saturation	-	5.5	> 5.0
EC (µS/cm)	1573	1488	1190	421	430	115				
Salinity (%)	0.01	0.02	0	0.08	1.6	2.3	≤ 5	-	-	
COD (mg/L)	635	864	623	390	324	355	150			
TSS (mg/L)	464	485	590	10	30	7	150	25		< 40
TDS (mg/L)	802	1745	1634	56	210	214	350			
Lead (Pb), mg/L	Trace	Trace	Trace	Trace	Trace	Trace	0.5	0.001-0.007		<1-7.0
Chromium (Cr), mg/L	0.95	0.58	0.254	0.45	0.41	Trace	0.1	0.02-0.002		-
Cadmium (Cd), mg/L	Trace	Trace	Trace	Trace	Trace	Trace	0.1	0.0002-0.0018		<0.2-1.8
Nickel(Ni), mg/L	0.22	0.41	0.125	0.15	0.13	Trace	1.0	0.025 - 0.15		<100

Note: BD means Bangladesh, ¹(DoE 1991), <http://aquaculture.asia/files/PMNQ%20WQ%20standard%202.pdf> date 18 March 2016

procedures of Standard methods (APHA, 1989). Conversely, the chemical parameters, such as pH was measured by digital pH meter (HI 8424, HANNA), dissolved oxygen (DO) by digital dissolved oxygen meter (HI 8424, HANNA), chemical oxygen demand (COD) based on Standard methods (APHA, 1989), EC by using electrical conductivity meter (DDSJ-308A), and heavy metals, were analyzed based on the procedures of the Standard methods (APHA, 1989), followed by Atomic Absorption Spectrophotometer.

Statistical analysis

Simple statistical tools, such as averages and percentages, and MS Excel program were used to

process the obtained data. Finally, the processed data were presented in tables and figures.

RESULTS

Water quality

Color and odor, the potential physical parameters determine the physical status of water quality, which are important for congenial aquatic environment and ecosystem services for both aquatic and terrestrial lives, and aesthetic values. The observed water color was black and turbid in polluted wetlands and brown to clean in non-polluted wetlands in studied area. Besides, the odor of different waters in polluted wetlands was foul and

highly pungent, whereas odorless to fishy was noticed in non-polluted wetlands (Table 1). Total suspended solids (TSS) denote the suspended impurities present in the water, which are responsible for degradation of aquatic environment. The TSS of the waters of three polluted wetlands was recorded as 464, 485 and 590 mg/L, which was 10, 30, 7 mg/L in non-polluted wetlands in Sreepur, Gazipur sadar and Kaliakair Upazila, respectively (Table 1). The TSS values of waters in three polluted wetlands were significantly higher than the standard. Conversely, the total dissolved solid (TDS) is the measure of total inorganic salts and other dissolved substances in water. The recorded TDS of waters in polluted wetlands were 802, 1745, and 1634 mg/L, which were 56, 210 and 214 mg/L in non-polluted wetlands of Sreepur, Gazipur sadar and

KaliakairUpazilas, respectively (Table 1). The values of the polluted wetlands were quite higher than the standard.

Dissolved oxygen (DO) refers to the level of free, non-compound oxygen present in water or other aqueous solution. It is an important parameter for assessing water quality because it plays life supporting roles in aquatic environment. However, in the present study, the DO of the three different industrial effluent polluted wetlands was recorded as 1.80, 2.0 and 0.4 mg/L, which was 4.20, 4.4 and 4.9 mg/L in three non-polluted wetlands of Sreepur, Gazipursadar and KaliakairUpazilas, respectively (Table 1). The recorded DO values of polluted wetlands waters were much lower than the values of non-polluted wetlands and standard (Table 1).

Chemical oxygen demand (COD) is defined as the amount of a specified oxidant that reacts with the sample under controlled conditions, which is one of the most important parameter to assess the quantity of oxidizing substances/chemicals present in water. Textile industries release a lot of chemical oxygen demanding wastes. The COD of waters in three different polluted wetlands by industrial effluents was recorded as 635, 864 and 623 mg/L, which was 390, 324, 355 mg/L in three non-polluted wetlands of Sreepur, Gazipursadar and KaliakairUpazilas, respectively (Table 1). Increased amount of chromium and nickel was recorded in polluted wetlands as compared with non-polluted, but were much higher than the standard for chromium.

Freshwater biodiversity

Fish and shellfish

A total of 50 fish and shellfish species in the following group were studied in polluted and non-polluted wetlands in three Upazilas of Gazipur district in Bangladesh.

Common carp: Respondent's perception on status of the recorded fish species of common carps were mostly extinct (Ex) and endangered (En) in Jongi and Bangla bazaar wetlands, which were directly and indirectly polluted by indiscriminate discharges of industrial effluent (Table 2a). The obtained record conveyed that the Black rohu (*Labeo calbasu*) and Indian major carp (*Catla catla*) species were severely affected as compared with the others and became extinct in all polluted wetlands. Among the three Upazilas of polluted wetlands, the highest ranked negative impacts on all carp species were observed in Mokeshbeel, where all the carp species have become extinct. However, 80% and above respondents shared the aforesaid opinion. Conversely, abundant common carp species except Black rohu were monitored in wetlands of Rajabari, Pajulia and Aloibeel, which were not polluted by industrial effluent. Thus the recorded results showed that the Black rohu species became affected to some extent ('En' in Rajabari and Pajulia, and 'T' in Aloibeel) even in non-polluted

wetlands, but other species were reported as visible by more than 80% respondents (Table 2a).

Catfish - All catfish species were mostly extinct (Ex) in polluted wetlands at Jongi, Bangla bazaar and Mokeshbeel except Walking catfish (*Heteropneustes fossilis*) and Striped dwarf catfish (*Mystus vittatus*). These two species were reported as endangered and threatened by over 60% of the respondents (Table 2a). But comparatively, superior existence of catfish was observed in non-polluted wetlands except Butter catfish (*Ompok pabda*) and Freshwater shark (*Wallago attu*). These two species were highly affected even in non-polluted wetlands. Above 93% local respondents delivered these reports (Table 2a). It implied that the species Butter catfish and Freshwater shark were the most susceptible to survive at any inconvenience situation which was present in these wetlands.

Snakehead fish - snakehead fish species were mostly threatened (T), endangered (En) and extinct (Ex) in all polluted wetlands. The Great snakehead (*Channa marulius*) became extinct from all polluted wetlands as reported by 57-60% of the respondents (Table 2a). On the other hand, existence of Snakehead murrel (*Channa striatus*) species was the best among others. Conversely, the performance of the studied fish species in non-polluted Aloibeel in Kaliakair was superior to others as supported by 56-96% of the respondents (Table 2a).

Minnow fish - Minnow fish group was recorded as mostly extinct (Ex), endangered (En) and threatened (T) in polluted wetlands. Among this group, Spotfin swamp barb (*Puntius sophore*) and Barb (*Chela bacaila*) were extinct from all polluted wetlands. Besides, all species were extinct from Mokeshbeel. More than 80% of the respondents shared this message (Table 2b). On the other hand, relatively better existence of this group of fishes was observed in Rajabari, Pajulia and Aloibeel wetlands, which were not discharged by industrial effluent. Besides, Finescale razorbelly minnow (*Salmotoma phulo*) and Molacarp (*Amblypharyngodon mola*) were abundant, that is, visible (V) at all non-polluted wetlands. But some species were observed as threatened, endangered and vulnerable in non-polluted wetlands, as well. Among the member of this group, the present situations of Spotfin swamp barb, Fire-fin barb (*Puntius ticto*) and Barb (*Puntius sarana*) were the worst (Table 2b).

Eel fish - The eel fish species [Striped spiny eel (*Macrognathus pancalus*), Tire-track striped spiny eel (*Macrognathus armatus*) and One-stripe spiny eel (*Macrognathus aculeatus*)] were extinct in polluted wetlands at Bangla bazaar and Mokeshbeel; and endangered in Jongi except Chucia (*Monopterochanna*) which was threatened in Jongi and Bangla bazaar wetlands, but visible in Mokeshbeel (Table 2b). On the contrary, among the non-polluted wetlands all species

Table 2a: Status of fish biodiversity based on respondent's perception in different polluted (by industrial effluents discharges) and non-polluted wetlands at different Upazilas of Gazipur district in Bangladesh (Seventy five respondents were interviewed from each location).

Group	Local name	English name	Scientific name	Polluted Wetlands						Non-polluted Wetlands					
				Jongi, Sreepur		Bangla bazaar, Gazipur sadar		Mokesh beel, Kaliakair		Rajabari, Sreepur		Pajulia, Gazipur sadar		Aloi beel, Kaliakair	
				Status	RP (%)	Status	RP (%)	Status	RP (%)	Status	RP (%)	Status	RP (%)	Status	RP (%)
Common carp	Rui/Ruhu	Indian major carp	<i>Labeo rohita</i>	En	93.33	En	86.67	Ex	82.67	V	86.67	V	82.67	V	96.00
	Kalibaus	Black rohu	<i>Labeo calbasu</i>	Ex	96.00	Ex	90.67	Ex	93.33	En	93.33	En	90.67	T	93.33
	Katol/Catla	Indian major carp	<i>Catla catla</i>	Ex	93.33	Ex	80.00	Ex	87.33	V	96.00	V	80.00	V	93.33
	Mrigal	Indian major carp	<i>Cirrhinus cirrhosus</i>	En	86.67	En	88.00	Ex	86.67	V	89.33	V	86.67	V	86.67
Catfish	Shing	Walking catfish	<i>Heteropneustes fossilis</i>	En	64.00	En	66.67	En	64.00	V	60.00	V	64.00	V	61.33
	Magur	Spotted snakehead	<i>Clarias batrachus</i>	Ex	89.33	Ex	90.67	Ex	86.67	V	86.67	T	86.67	V	85.33
	Pabda	Butter catfish	<i>Ompok pabda</i>	Ex	100.00	Ex	93.33	Ex	96.00	Ex	93.33	En	93.33	En	97.33
	Tengra	Striped dwarf catfish	<i>Mystus vittatus</i>	En	90.67	T	93.33	En	89.33	T	93.33	T	86.67	T	88.00
	Gulsa tengra	Gangetic mystus	<i>Mystus cavasius</i>	Ex	80.00	Ex	86.67	Ex	90.67	Vu	86.67	Vu	90.67	T	80.00
	Aior	Long whisk catfish	<i>Mystus aor</i>	Ex	60.00	Ex	69.33	Ex	73.33	En	66.67	En	73.33	T	60.00
	Bagha aior	Long whiskered catfish	<i>Sperata aor</i>	Ex	96.00	Ex	93.33	Ex	94.67	Vu	93.33	T	96.00	V	96.00
	Boal	Freshwater shark	<i>Wallago attu</i>	Ex	93.33	Ex	90.67	Ex	93.33	Ex	90.67	En	93.33	En	93.33
Snakehead fish	Taki	Spotted Snakehead	<i>Channa punctata</i>	En	53.33	T	61.33	En	60.00	V	60.00	V	66.67	V	56.00
	Shol	Snakehead murrel	<i>Channa striatus</i>	T	84.00	T	80.00	T	72.00	V	80.00	V	73.33	V	84.00
	Gazar	Great snakehead	<i>Channa marulius</i>	Ex	57.33	Ex	58.67	Ex	60.00	En	60.00	T	60.00	T	60.00
	Cheng	Walking snakehead	<i>Channa orientalis</i>	T	96.00	En	89.33	T	80.00	Vu	93.33	T	80.00	V	96.00

Note: RP=Respondents perception, V=Visible (> 80%); T=Threatened ($\leq 79\%$); En= Endangered ($\leq 30\%$); Vu=Vulnerable ($\leq 10\%$); Ex= Extinct (0 %)

were visible at Aloibeel, but three species were threatened and one was visible at Rajabari. Thus threatened and visible species were equal in number at Pajulia. The aforesaid statements were reported by more than 73% of the respondents (Table 2b).

Perch fish - The perch fish species were mostly extinct and vulnerable in Mokeshbeel, but were extinct and endangered in Bangla bazaar. In Jongi, it was extinct, endangered and threatened except Climbing perch (*Anabas testudineus*), which were reported by over 70% of the respondents (Table 2b).

On the other hand, Perch fishes were mostly visible in Aloibeel; visible and threatened in Rajabari and Pajulia freshwater wetlands which were not polluted by industrial discharges. But Gangetic leaf fish (*Nandus nandus*) was threatened in all non-polluted wetlands. Among the non-polluted wetlands, Aloibeel provided the best records of existence of the studied group of fishes reported by average of 80% respondents (Table 2b).

Miscellaneous fish - More than 70% of respondents reported that the miscellaneous group

of fish species were mostly extinct in Mokeshbeel and Jongi polluted wetlands, but both endangered and extinct were observed in Bangla bazaar, contaminated with composite industrial effluent. But Guntea loach (*Lepidocephalichthysguntea*) was vulnerable in Mokeshbeel and Jongi wetlands (Table 2c). The recorded results showed that miscellaneous fish species were severely affected in wetlands polluted by industrial effluent. Conversely, maximum species of miscellaneous fish were visible at Aloibeel and next was at Rajabari, but most of the species were threatened at Pajulia non-polluted

Table 2b. Status of fish biodiversity based on respondent's perception in different polluted (by industrial effluents discharges) and non-polluted wetlands at different Upazilas of Gazipur district in Bangladesh (Seventy five respondents were interviewed from each location).

Group	Local name	English name	Scientific name	Polluted Wetlands						Non-polluted Wetlands					
				Jongi, Sreepur		Bangla bazaar, Gazipur sadar		Mokesh beel, Kaliakair		Rajabari, Sreepur		Pajulia, Gazipur sadar		Aloi beel, Kaliakair	
				Status	RP (%)	Status	RP (%)	Status	RP (%)	Status	RP (%)	Status	RP (%)	Status	RP (%)
Minnow fish	Jatputi	Spotfin swamp barb	<i>Puntius sophore</i>	Ex	77.33	Ex	80.00	Ex	86.67	En	80.00	En	80.00	T	80.00
	Titputi	Fire-fin barb	<i>Puntius ticto</i>	T	88.00	En	84.00	Ex	80.00	Vu	82.67	Vu	80.00	Vu	88.00
	Sharputi	Barb	<i>Puntius sarana</i>	Ex	72.00	En	73.33	Ex	70.67	En	73.33	Vu	73.33	En	73.33
	Darkina	Flying Barb	<i>Esomus danricus</i>	En	89.33	Ex	86.67	Ex	84.00	Ex	86.67	Ex	84.00	En	89.33
	Chela	Finescalerazor-belly minnow	<i>Salmostoma phulo</i>	Ex	60.00	En	64.00	Ex	72.00	V	61.33	V	73.33	V	76.00
	Lamba chela	Barb	<i>Chela bacaila</i>	Ex	96.00	Ex	93.33	Ex	90.67	T	93.33	T	90.67	T	96.00
	Mola	Molacarpulet	<i>Amblypharyngodon mola</i>	T	73.33	En	76.00	Ex	80.00	V	66.67	V	80.00	V	74.67
	Kachki	Ganges river sprat	<i>Corica soborna</i>	T	74.67	Ex	77.33	Ex	73.33	T	72.00	V	80.00	T	74.67
Eel fish	Guchi baim	Striped spiny eel	<i>Macrognathus pancalus</i>	En	86.67	Ex	85.33	Ex	86.67	T	80.00	V	86.67	V	85.33
	Boro baim	Tire-track striped spiny eel	<i>Macrognathus armatus</i>	Ex	76.00	Ex	80.00	Ex	86.67	T	80.00	T	86.67	V	76.00
	Tara baim	One -stripe spiny eel	<i>Macrognathus aculeatus</i>	En	98.67	Ex	93.33	Ex	96.00	T	96.00	V	96.00	V	96.00
	Kuchia	Chucia	<i>Monopterosus kuchia</i>	T	74.67	T	93.33	V	82.67	V	73.33	T	82.67	V	74.67
Perch fish	Khalisha	Striped gourami	<i>Colisa fasciatus</i>	T	85.33	En	80.00	Ex	84.00	V	82.67	V	84.00	V	85.33
	Lalkhalisha	Dwraf gourmi	<i>Colisa lalia</i>	Ex	97.33	Ex	90.67	Ex	88.00	T	90.67	T	88.00	V	96.00
	Lalchanda	Indian glassy perchlet	<i>Pseudam bassislala</i>	Ex	74.00	Ex	70.67	Ex	73.33	T	66.67	T	73.33	V	69.33
	Koi	Climbing perch	<i>Anabas testudineus</i>	V	60.00	V	64.00	V	69.33	V	64.00	V	66.67	V	60.00
	Chanda	Elongate Glass Perchlet	<i>Chanda nama</i>	T	96.00	En	90.67	Ex	93.33	V	93.33	V	93.33	V	96.00
	Meni	Gangetic leaf fish	<i>Nandus nandus</i>	En	74.67	En	76.67	Vu	73.33	T	80.00	T	73.33	T	72.00

Note: RP=Respondents perception, V=Visible (> 80%); T=Threatened ($\leq 79\%$); En= Endangered ($\leq 30\%$); Vu=Vulnerable ($\leq 10\%$); Ex= Extinct (0 %)

wetlands (Table 2c), as reported by over 70% of the respondents. Besides the species, Bata (*Labeo bata*), Clown knifefish (*Notopterosus chitala*), Tank goby (*Glossogobius giuris*), queen loach (*Botia dario*) and Guntea loach were threatened even in maximum non-polluted wetlands.

Shellfish - The recorded results on shellfish from polluted and non-polluted wetlands of three Upazilas of Gazipur district are presented in Table 2c. The existence of shellfish species was influenced

by the existing environment of polluted freshwater wetlands by industrial effluent discharges. The observed report showed that Mussel (*Lamellidens* spp.) became extinct from all polluted wetlands of the three Upazilas, such as Jongi in Sreepur, Bangla bazaar in Gazipursadar and Mokeshbeel in Kaliakair. This species might be quite susceptible to industrially contaminated waters, but it was visible, vulnerable and threatened in non-polluted sites. Average 90% respondents delivered such type of comments. On the other hand, the Crab (*Scylla*

serata) showed their existence as threatened in all polluted and non-polluted wetlands except Aloibeel. Relatively, the existence of this species was superior among others. Based on obtained results, the polluted habitats of Jongi and Mokeshbeel offered the worst existence of studied species and non-polluted wetlands, Rajabari and Aloibeel, ensured superior existence to other (Table 2c).

The above results on fish and shellfish suggested that maximum number and percent were extinct from polluted Mokeshbeel wetland. On the other

Table 2c. Status of Miscellaneous fish and Shellfish based on respondent's perception in different polluted (by industrial effluents discharges) and non-polluted wetlands at different Upazilas of Gazipur district in Bangladesh (Seventy five respondents were interviewed from each location).

Group	Local name	English name	Scientific name	Polluted Wetlands						Non-polluted Wetlands					
				Jongi, Sreepur		Bangla bazaar, Gazipur sadar		Mokesh beel, Kaliakair		Rajabari, Sreepur		Pajulia, Gazipur sadar		Aloi beel, Kaliakair	
				Status	RP (%)	Status	RP (%)	Status	RP (%)	Status	RP (%)	Status	RP (%)	Status	RP (%)
Miscellaneous	Foli	Bronze featherback	<i>Notopterus notopterus</i>	Ex	73.33	Ex	69.33	Ex	72.00	V	69.33	V	72.00	V	86.67
	Chital	Clown knifefish	<i>Notopterus chitala</i>	Ex	93.33	Ex	89.33	Ex	73.33	V	86.67	T	73.33	T	96.00
	Tepa/Potka	Green puffer fish	<i>Tetradon fluviatilis</i>	Ex	97.33	Ex	82.67	En	80.00	V	96.00	T	80.00	V	97.33
	Kakila	Freshwater gar fish	<i>Xenentodon cancila</i>	Ex	74.00	En	80.00	Ex	93.33	T	66.67	V	93.33	V	69.33
	Baila	Tank goby	<i>Glossogobius giuris</i>	Ex	84.00	En	88.00	Ex	90.67	V	82.67	T	90.67	T	80.00
	Napit koi	Dwarf chameleon	<i>Badis badis</i>	Ex	74.67	Ex	80.00	En	82.67	V	73.33	T	82.67	V	74.67
	Rani/Bou	Queen/Bengal loach	<i>Botia dario</i>	Ex	98.67	Ex	93.33	Ex	96.00	T	96.00	T	96.00	V	96.00
	Gutum	Guntea loach	<i>Lepidocephala-lichthys guntea</i>	Vu	93.33	En	86.67	Vu	82.67	T	86.67	T	80.00	V	93.33
	Bashpata	Sind Danio	<i>Danio devario</i>	Ex	70.67	Ex	66.67	Ex	69.33	V	66.67	T	69.33	V	70.67
	Bata	Bata	<i>Labeo bata</i>	Ex	89.33	En	86.67	Ex	82.67	T	86.67	T	82.67	T	88.00
	Bacha	River catfish	<i>Eutropiichthys vacha</i>	Ex	88.00	Ex	86.67	Ex	85.33	T	86.67	V	66.67	V	88.00
Shellfish	Beelchingri	River prawn	<i>Macrobrachium daganum</i>	Ex	86.67	T	80.00	Ex	88.00	V	93.33	V	88.00	V	82.67
	Gurachingri	Monsoon river prawn	<i>Macrobrachium lumarre</i>	Ex	77.33	En	80.00	Ex	72.00	T	80.00	En	73.33	T	80.00
	Kakra	Crab	<i>Scylla serata</i>	T	80.00	T	74.67	T	80.00	T	73.33	T	80.00	V	85.33
	Shamuk	Mollask	<i>Pomacea spp.</i>	Ex	86.67	En	82.67	Ex	86.67	V	93.33	T	86.67	V	86.67
	Jhinuk	Mussel	<i>Lamellidens spp.</i>	Ex	93.33	Ex	86.67	Ex	82.67	V	86.67	Vu	82.67	T	96.00

Note: RP=Respondents perception, V=Visible (> 80%); T=Threatened (≤ 79%); En= Endangered (≤ 30%); Vu=Vulnerable (≤ 10%); Ex= Extinct (0 %)

hand, the highest number was recorded as visible in non-polluted Aloibeel. However, 39 fish and shellfish species, that is, 78% were extinct from Mokeshbeel, which were 30 in Jongi and 26 in Bangla bazaar. Conversely, in Aloibeel 31 species were visible, that is, 22 and 18 in Rajabari and Pajulia, respectively (Figure 2).

Freshwater animals (Amphibians) species

Amphibian species in the studied area were regarded mostly as endangered (En), followed by threatened (T) and extinct (Ex) in the polluted wetlands of Jongi, Bangla bazaar and Mokeshbeel, contaminated by composite industrial effluent.

Average of 80% respondents expressed such opinion (Table 3). Among the recorded species of animals in the three polluted wetlands, Turtle (*Trachemys scripta*) was extinct and Frog was endangered. On the other hand, the studied group of animal species was mostly visible in all non-polluted wetlands except Turtle and Frog (*Lithobates* spp.) which were threatened. A significant number of respondents shared this statement.

Aquatic (freshwater) birds

The report shown in Table 4 implied that the industrially polluted wetlands environment imposed negative impact on the biodiversity of aquatic birds.

Bird species were mostly endangered and threatened in all polluted wetlands as reported by approximately 85% of respondents (Table 4). Wild Duck (*Anas platyrhynchos*) and Purple Moorhen (*Porphyrio porphyria*) were extinct from Bangla bazaar polluted wetland. On the other hand, Pond Heron (*Ardeola grayii*) existed as threatened at all wetlands, but Kingfisher (*Alcedo atthis*) existed as both threatened and endangered at polluted sites. Conversely, a comparative abundant of all birds species were observed except Wild Duck in Rajabari and Aloibeel as compared with Pajulia, which were non-polluted wetlands as reported by over 84% of the respondents. But the present study observed that Pond Heron was at the stage of threatened at non-polluted wetlands, as well.

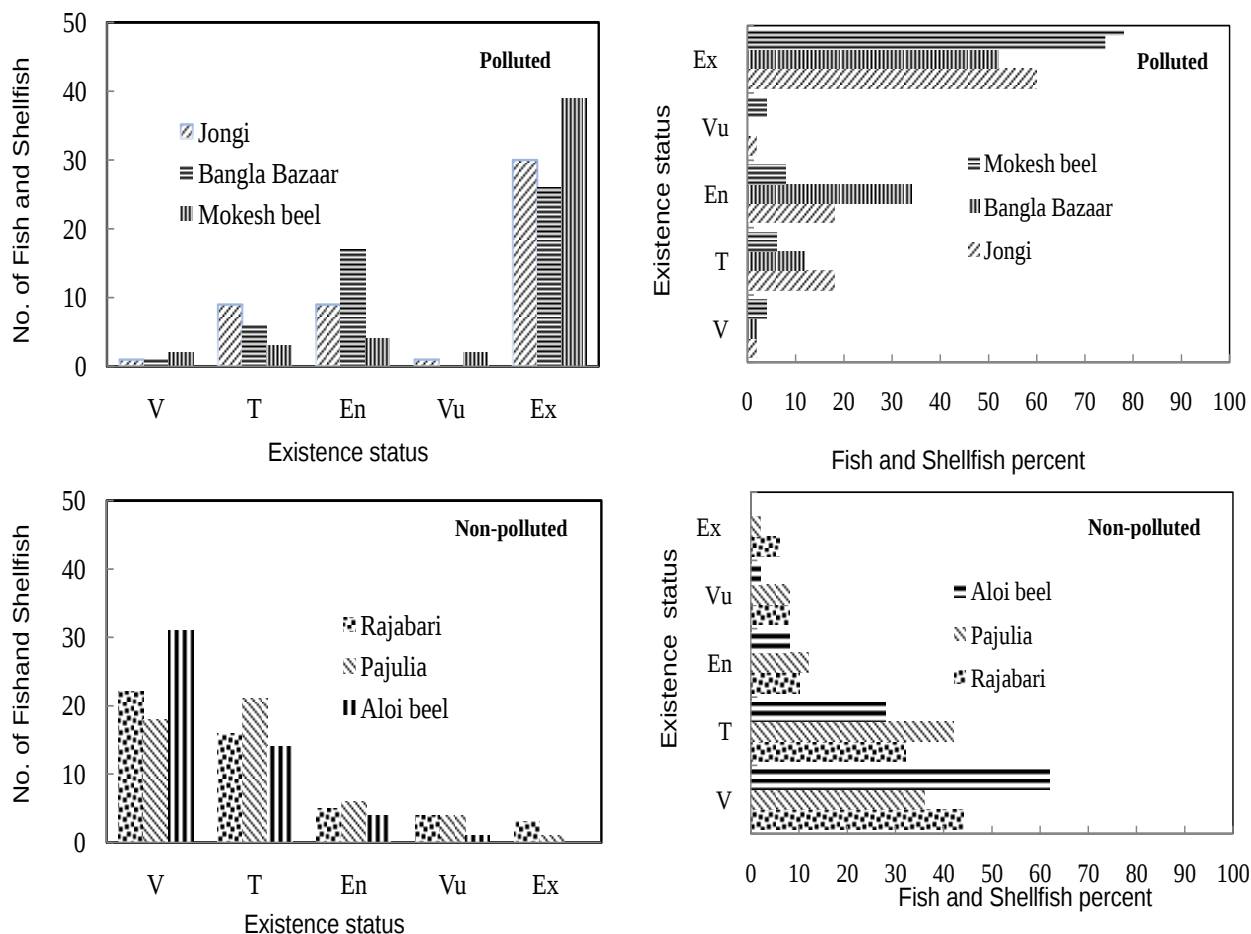


Figure 2. Existence status (V - Visible, T - Threatened, En - Endangered, Vu - Vulnerable & Ex - Extinct) of fish and shellfish species in polluted (Jongi, Bangla Bazaar and Mokeshbeel) and non-polluted (Rajabari, Pajulia and Aloibeel) wetlands in Gazipur district of Bangladesh.

Aquatic (freshwater) plants

The present research shows that most of the aquatic plant species in polluted wetlands are at the stages of endangered, threatened and no more visible. Only common water hyacinth was visible in all wetlands except Mokeshbeel, which was threatened (Table 5). The plant species *Colocasia* (*Colocasia* spp.), Water lotus (*Nelumbo nucifera*) and Water fern (*Azolla pinnata*) were not observed in all polluted wetlands. The record of 'Threatened' was monitored in all polluted wetlands for Water Spinach. Too much horrible situation of aquatic plants was observed in Mokeshbeel, followed by Bangla bazaar and Jongi. On the other hand, abundant aquatic plant species were observed in wetlands in Rajabari, Pajulia and Aloibeel, which were not polluted by industrial effluent. But plant species, Water Lotus and Caltrop (*Trapa natans*), were mostly endangered even in non-polluted wetlands. Based on the present studied species, comparatively Aloibeel was the best habitat, followed by Rajabari and Pajulia. More than 80% of the respondents shared these facts.

DISCUSSION

Water quality

Pure water does not possess any kind of color; however, the color of water may provide evidence that there is some form of contamination. It would be difficult for aquatic life to thrive in colored water wetlands which could lead to the long term impairment of the ecosystem. The higher value of total dissolved solid (TDS) of effluent is not desirable because a high content of dissolved solids elevates the density of water, influences osmoregulation of freshwater organisms, reduces solubility of gases (such as oxygen) and utility of water for drinking, irrigation and industrial usages (Uddin et al., 2014). In the present study, pollution of natural water bodies was mostly caused by textile effluents which imposed water quality parameters beyond the permissible limits (Noreen et al., 2017). A maximum TDS value of 400 mg/L is permissible for diverse fish production (Chhatwal, 1998; Meade, 1998). A similar observation was reported by Singh et al. (2010) for wastewater of Raniganj industrial area in India. Conversely, dissolve oxygen (DO) is another potential

Table 3. Status of freshwater animal species (amphibians) based on respondent's perception in different polluted and non-polluted wetlands at different upazilas of Gazipur district in Bangladesh (Seventy five respondents were interviewed from each location).

Local name	English name	Scientific name	Polluted Wetlands						Non-Polluted Wetlands					
			Jongi, Sreepur		Bangla bazaar, Gazipur sadar		Mokesh beel, Kaliakair		Rajabari, Sreepur		Pajulia, Gazipur sadar		Aloi beel, Kaliakair	
			Status	RP (%)	Status	RP (%)	Status	RP (%)	Status	RP (%)	Status	RP (%)	Status	RP (%)
Bang	Frog	<i>Lithobates</i> spp.	En	80.00	En	82.67	En	73.33	T	66.67	T	70.67	V	69.33
Jock	Leech	<i>Hirudu medicinalis</i>	En	86.67	T	93.33	T	86.67	V	60.00	V	60.00	V	60.00
Guisap	Monitor lizard	<i>Varanus bengalensis</i>	T	82.67	En	82.67	En	82.67	V	80.00	V	80.00	V	86.67
Shap	Snake	<i>Serpentes</i>	En	73.33	T	73.33	Vu	76.67	V	86.67	V	85.33	V	86.67
Kocchop	Turtle	<i>Trachemys scripta</i>	Ex	93.33	Ex	93.33	Ex	93.33	T	73.33	T	73.33	T	66.67

Note: RP=Respondents perception, V=Visible (> 80%); T=Threatened (≤ 79%); En= Endangered (≤ 30%); Vu=Vulnerable (≤ 10%); Ex= Extinct (0 %).

Table 4. Status of bird species based on respondent's perception in different polluted and non-polluted wetlands at different Upazilas of Gazipur district in Bangladesh (Seventy five respondents were interviewed from each location).

Local name	English name	Scientific name	Polluted Wetlands						Non-Polluted Wetlands					
			Jongi, Sreepur		Bangla bazaar, Gazipur sadar		Mokesh beel, Kaliakair		Rajabari, Sreepur		Pajulia, Gazipur sadar		Aloi beel, Kaliakair	
			Status	RP (%)	Status	RP (%)	Status	RP (%)	Status	RP (%)	Status	RP (%)	Status	RP (%)
Bali hash	Wild Duck	<i>Anas platyrhynchos</i>	En	70.67	Ex	86.67	En	82.67	V	66.67	V	82.67	V	69.33
Konch Bak	Pond Heron	<i>Ardeola grayii</i>	T	98.67	T	93.33	T	89.33	T	96.00	T	89.33	T	96.00
Gangchil	Black Headed Gull	<i>Larus ridibundus</i>	En	89.33	En	88.00	En	82.67	V	86.67	V	82.67	V	86.67
Machh-ranga	Kingfisher	<i>Alcedo atthis</i>	T	86.67	T	82.67	En	89.33	V	84.00	V	89.33	V	86.67
Pankouri	Little Cormorant	<i>Phalacrocorax niger</i>	En	93.33	En	93.33	En	96.00	V	90.67	T	96.00	V	96.00
Kalim Bird	Purple Moorhen	<i>Porphyrio porphyria</i>	En	96.00	Ex	93.33	En	90.67	V	93.33	T	90.67	V	90.67

Note: RP=Respondents perception, V=Visible (> 80%); T=Threatened (≤ 79%); En= Endangered (≤ 30%); Vu=Vulnerable (≤ 10%); Ex= Extinct (0 %).

parameter of water, as ≥ 5.0 mg/L was suggested for fisheries, recreational and irrigational water bodies (EQS, 1997). While the dissolved oxygen levels in water drop below 4.0 mg/L, then aquatic life are put under stress in vital respiratory activities. The recorded DO values in the studied polluted wetland's waters were 2 mg/L and lower, which was

lethal for aquatic life (Table 1). The reduced DO situation enhances to dominate anaerobic organisms, which create uninhabitable aquatic environment for gill-breathing organisms (Yusuff and Sonibare, 2004). Conversely, hydrogen sulphide is formed at deficient aquatic environment in presence of organic materials and sulphate (WHO,

2000). The optimum level of oxygen present in water is a positive sign of the healthy body of water, but absence/reduced of oxygen is an indication of severe pollution. The standard range of DO for fish culture at saturation is 5 ppm (Meade 1998) and more than 5.0 ppm (Chowdhury et al., 2007), the DO levels below 1 ppm will not support fish (Rahaman

Table 5: Status of aquatic (freshwater) plant species based on respondent's perception in different polluted and non-polluted wetlands at different Upazilas of Gazipur district in Bangladesh (Seventy five respondents were interviewed from each location)

Local name	English name	Scientific name	Polluted Wetlands						Non-Polluted Wetlands					
			Jongi, Sreepur		Bangla bazaar, Gazipur sadar		Mokesh beel, Kaliakair		Rajabari, Sreepur		Pajulia, Gazipur sadar		Aloi beel, Kaliakair	
			Status	RP (%)	Status	RP (%)	Status	RP (%)	Status	RP (%)	Status	RP (%)	Status	RP (%)
Kachuripana	Common Water Hyacinth	<i>Eichhornia crassipes</i>	V	93.33	V	90.67	T	93.33	V	86.67	V	93.33	V	86.67
Topapana	Water Cabbage/ Water Lettuce	<i>Pistia stratiotes</i>	T	73.33	En	80.00	Ex	85.33	En	80.00	T	85.33	T	74.67
Shapla	Water Lily	<i>Nymphaea</i>	En	89.33	En	86.67	En	82.67	V	86.67	V	82.67	V	84.00
Kachu	Colocasia	<i>Colocasia spp.</i>	Ex	74.67	Ex	80.00	Ex	72.00	V	73.33	V	72.00	V	73.33
Helencha	Marsh herb	<i>Enhydra fluctuens</i>	En	64.00	Ex	66.67	En	69.33	V	66.67	V	69.33	V	66.67
Kalmi	Water Spinach	<i>Ipomoea aquatica</i>	T	66.67	T	73.33	T	74.67	V	73.33	V	74.67	V	69.33
Poddo	Water Lotus	<i>Nelumbo nucifera</i>	Ex	96.00	Ex	93.33	Ex	88.00	En	90.67	En	88.00	T	93.33
Paniphal	Caltrop	<i>Trapa natans</i>	Ex	86.67	En	80.00	T	80.00	En	82.67	Vu	80.00	Vu	82.67
Azolla	Water/mosquito fern	<i>Azolla pinnata</i>	Ex	53.33	Ex	61.33	Ex	60.00	T	60.00	T	64.00	T	56.00
Duckweed	Common duckweed	<i>Lemna minor</i>	En	86.67	En	86.67	En	88.00	V	80.00	V	85.33	V	84.00

Note: RP=Respondents perception, V=Visible (> 80%); T=Threatened ($\leq 79\%$); En= Endangered ($\leq 30\%$); Vu=Vulnerable ($\leq 10\%$); Ex= Extinct (0 %).

et al.,2012). In the present study, the recorded DO values in non-polluted wetlands were closer to the standard values, which were congenial for sustaining fisheries and other aquatic life. Chemical oxygen demand (COD) is another parameter with influence on the quality of water. The higher level of COD enhances the depletion of oxygen level in water, that is, deoxygenation which is hazardous of aquatic life (Chakraborty et al., 2013). Metals are essential but all metals are toxic at higher concentrations due to cause of oxidative stress by formation of free radicals (Ghosh and Singh, 2005).

Freshwater biodiversity

Fish and shellfish

Wetland biodiversity of Bangladesh is quite rich and its present status is at an extreme risk by the

increasing different environmental threats (Alam, 2014). The results of this study on fish and shellfish showed that maximum number and percent of species were extinct from polluted wetlands and the highest number was in Mokeshbeel, followed by Jongi and Bangla bazaar wetlands (Figure 2). The extent of existence status of the studied species had close relationship with the deterioration level of water quality parameters as shown in Table 1. The water quality of Mokeshbeel was worst than the others. The dissolved oxygen (DO) is the vital life sustaining factor, and a minimum of 5.0 mg/L is required for sound respiratory activities of aquatic life. But in Mokeshbeel, 0.4 mg/L was recorded, which was too lethal for fish and shellfish species. For congenial growth and development, every aquatic organism needs the suitable range of water quality parameters and therefore, every one of it have minimum and maximum limit. Accordingly, ADB (1994) reported that the suitable pH value for

fishing water should be 6.5-8.5. In another report, Meade (1998) mentioned that the desirable values of pH and DO are 6.5-8.0 and 5 mg/L to saturation, respectively for the maximum aquatic organisms. Almost similar recommendations were made by EU, Canada and Australia (Table 1). Both DO and temperature of all polluted wetlands were out of these limits except pH of the water of Jongi wetland. The DO of all wetlands was too low; perhaps it was the main reason for not supporting the existence of freshwater organisms. Therefore, maximum fish and shellfish species became extinct from those ecosystems, followed by endangered (En), threatened (T) and vulnerable (Vu).

Besides, in the discharges of hazardous substance into water by several industries, the different pollutants may be toxic at low concentration, carcinogenic, mutagenic and bioaccumulative. Similarly some are toxic at high concentration, such as different trace elements that are needed in trace

amount. These toxic environments might appeared lethal to habitat and life of aquatic biodiversity. Moreover, some of these chemicals may be ingested and/or absorbed by aquatic organisms, which might be the potential reasons for failure of reproductive system and development. Therefore, the toxic environment of all polluted wetlands is induced to extinct maximum fish and shellfish species in the studied areas. Alternatively, it was observed that Climbing perch (*Anabas testudineus*) was visible to all polluted wetlands even at low level of DO (that is, < 5.0 mg/L), this is because Climbing perch is a stress tolerant species, which has special respiratory organ called accessory air breathing organ. Therefore, low DO in polluted wetlands did not impact such problem to its existence.

Furthermore, the existence scenario of the studied fish and shellfish species in non-polluted wetlands was satisfactory because the water quality was much better as compared with the polluted wetlands. Moreover, the existence of plant biodiversity was quite remarkable, which ensured sufficient feed for other biodiversities. Among the three non-polluted wetlands, the most suitable level of pH and DO was present in Aloibeel's water as compared with others (Table 1). Perhaps these factors are enhanced to conserve the highest visible number of fish and shellfish species in Aloibeel. Moreover, the recorded statistics showed that a remarkable number of species were threatened, followed by endangered, vulnerable and extinct in non-polluted wetlands. These may be attributed to the over harvesting of fish and shellfish including some unknown factors, as well as the substandard DO of the waters of the wetlands. The application of excessive fertilizers and pesticides in intensive crop cultivation near to the wetlands might be washed out into the water and induced toxicity. Thus this is another potential cause of decline of fish biodiversity in the wetlands. Over exploitation is one the important category that pose threats to global freshwater biodiversity (Dudgeon et al., 2006). None of the species was extinct from Aloibeel, but 3 from Rajabari and 1 from Pajulia were extinct even in non-polluted wetlands (Tables 2a and b, and Figure 2). The immunity of all species against any stress is not same; therefore, some of the individual was recorded more susceptible to exist in the present studied wetlands. Besides, among the non-polluted wetlands, the lowest DO value was recorded in Rajabari, which resulted in the extinction of Butter catfish (*Ompok pabda*), Freshwater shark (*Wallago attu*), and two member of Catfish and Flying Barb (*Esomus danricus*) of Minnow fish.

Freshwater animals (amphibians)

In the present study, five aquatic animals (amphibians) were studied and regarded as endangered, threatened, vulnerable and extinct at all polluted wetlands, and none was visible. But almost all of those species were visible in

non-polluted wetlands. An average 80% of the respondents made such type of comments. However, it is clearly implied that similar pattern of results (such as in fish and shellfish) were monitored. Therefore, similar explanations could be drawn against the present status of the animals in polluted and non-polluted wetlands as explained above. Perhaps, the foods they were taking from polluted wetlands were toxic and as such, enhanced their present status due to the continuous discharges of effluent. Toxicities of the discharged industrial effluent enhance the damage of tissues of mollusks and restrict growth and number of population (Bhattacharya et al., 2016). But Turtle (*Trachemys scripta*) became extinct in all polluted wetlands and threatened in non-polluted habitats. Also, the status of Frog (*Lithobates* spp.) was both endangered and threatened in all wetlands except Aloibeel, in which it was visible. Perhaps both species were too susceptible to exist in habitats polluted with industrial effluent.

Aquatic (freshwater) birds

Aquatic birds were affected in similar trend like others in polluted habitats, but were mainly visible in non-polluted wetlands. Generally, the birds hunt different fish species mainly as their foods. Though the fish and shellfish species in polluted wetlands were drastically affected and decreased in number, therefore the birds of those habitats received insufficient and toxic/contaminated fish and shellfish as their food, which resulted in its existence as threatened (T), endangered (En) and extinct (Ex). Conversely, the existence scenario of the studied birds in all non-polluted wetlands was reverse and almost all species were visible (V) except Pond Heron (*Ardeola grayii*). It was extinct in all wetlands including non-polluted. The can be attributed to the illegal hunting of this bird by local people.

Aquatic (Freshwater) plants

Similar to other aquatic biodiversities, maximum member of aquatic plant species were under a risk of surviving in polluted wetlands. Three plant species were extinct already in polluted sites, but two of them [Water lotus (*Nelumbo nucifera*) and Water fern (*Azolla pinnata*)] were threatened and endangered in non-polluted wetlands. This two species have economic values and as such, might be exploited by local people in non-polluted wetlands, thereby pushing its existence under threats. Poor water quality and insufficient DO of polluted wetlands induced the present threats to aquatic plants. Only common water hyacinth (*Eichhornia crassipes*) was monitored in all wetlands except Mokeshebeel, which was badly polluted by industrial discharges. Water hyacinth has pseudobulb, modified petiole containing innumerable air-chambers, perhaps the stored oxygen supports the normal

physiological activities of the plants to survive even in polluted wetlands. The non-polluted wetlands provided good habitats for the studied plants due to the fact that its water quality is superior as compared with polluted wetlands.

CONCLUSIONS

Based on the present study, it was concluded that indiscriminate discharges of industrial effluent severely degraded the wetland habitats and water quality, which induced negative impacts on the existence of freshwater biodiversity. A total of 24 species (20 fish and shellfish, 3 plants and 1 amphibian) were extinct from each polluted wetland, but the number of extinct species was highest in Mokeshbeel. The status of aquatic biodiversity in polluted wetlands was under extreme risk due to toxic industrial effluent. Conversely, none noticeable environmental risk was monitored for aquatic species in non-polluted wetlands. Enhanced threats on aquatic biodiversity were proportionally related to the increased level of pollution by industrial discharges. The industrial development in Bangladesh and indiscriminate discharge of effluent appeared as a significant threat on wetland (freshwater) biodiversity.

ACKNOWLEDGEMENTS

The authors would like to express their sincere gratitude to the Research Management Centre (RMC) of Bangabandhu Sheikh MujiburRahman Agricultural University, Gazipur, Bangladesh for providing the grant [Code no. SL-25A(21), 33006366] to conduct the presented research. We also sincerely appreciation the respondents in respective areas for their necessary cooperation to conduct the present research project.

REFERENCES

- ADB Asian Development Bank (1994). Training Manual for Environmental Monitoring. USA: Engineering Science Inc. 2-16.
- Alam MZ (2014). Status of Biodiversity at Wetland Ecosystem of MohangonjUpazila in Netragona District. Adv. Ecol. 2014:1-8.
- Alloway BJ (1995). Heavy Metals in Soils. 2nd Ed Blackie, Glasgow.
- Anastasi A, Spina F, Romagnolo A, Tigrini V, Prigione V, Varese GC (2012). Integrated fungal biomass and activated sludge treatment for textile wastewaters bioremediation. Bioresour. Technol. 123:106-111.
- APHA (1989). Standard methods for the examination of water and wastewater. (14th Eds.), American Public Health Association, Washington. 1193.
- Benard J, Wright TW (1998). Environmental Science. (The Way the World Work) (6thEds.), Prentice Hall, New Jersey.
- Bhattacharya P, Swarnakar S, Mukhopadhyay A, Ghosh S (2016). Exposure of composite tannery effluent on snail, *Pilaglobosa*: A comparative assessment of toxic impacts of the untreated and membrane treated effluents. Ecotoxicol. Environ. Safety. 126:45-55.
- Chakraborty C, Huq MM, Ahmed S, Tabassum T, Miah MR (2013). Analysis of the causes and impacts of water pollution of Buriganga river: A critical study. Inter. J. Sci. Technol. Res. 2(9):245-252.
- Chhatwal GR (1998). Encyclopedia of Environmental Biology. Anmol. Pub. Pvt. Ltd., New Delhi, India. 2:287-301.
- Chopra AK, Pathak C (2012). Bioaccumulation and translocation efficiency heavy metals in vegetables grown on long-term wastewater irrigated soil near Bindalriver, Dehadun. Agric. Res. 1(2):157-164.
- Chowdhury AMS, Rahman MA, Rahman MM, Mohiuddin ASM, Zaman MB (2007). Nature and the extent of industrial pollution in river water around Dhaka city. Bangladesh J. Environ. Sci. 13(1):46-49.
- Dudgeon D, Arthington AH, Gessner MO, Kawabata ZI, Knowler DJ, Leveque C, Naiman RJ, Prieur-Richard AH, Soto D, Stiassny MLJ, Sullivan AA (2006). Freshwater biodiversity: importance, threats, status and conservation challenges. Biol. Rev. 81:163-182.
- EQS Environmental Quality Standard (1997). Bangladesh Gazette, Registered nr. DA-1, Ministry of Environment, Government of Bangladesh.
- Ghosh M, Singh SP (2005). Review on phytoremediation of heavy metals and utilization of its byproducts: Appl. Ecol. Res. 3(1):1-18.
- Hossain MA, Rahman GKMM, Rahman MM, Molla AH, Rahman MM, Uddin MK (2015). Impact of industrial effluents on growth and yield of rice (*Oryza sativa* L.) in silty clay loam soil. J. Environ. Sci. 30:231-240.
- Hossain MA, Uddin MK, Molla AH, Afrad MSI, Rahman MM, Rahman GKMM (2010). Impact of industrial effluents discharges on degradation of natural resources and threat to food security. The Agriculturists 8(2):80-87.
- Khan S (2013). Fish biodiversity and livelihood status of fishing community of the Tistariver, Bangladesh. Glob. Vet. 10(4):417-423.
- Meade JW (1998). Aquaculture Management. CBS Publishers & Distributors, New Delhi, India. 9.
- Modoi OC, Roba C, Török Z, Ozunu A (2014). Environmental risks due to heavy metal pollution of water resulted from mining wastes in new Romania. Environ. Eng. Manage. J. 13(9):2325-2336.
- Moeller DW (1992). Toxic chemicals, In: Environmental Health, USA. 2.
- Neermoli S, Rahman SH, Tareq SM (2007). Report on Environmental Damage Assessment due to Industries around KarnoparaKhal, Savar, Dhaka, prepared by Department of Environmental Science, Jahangirnagar University (JU), Savar, Dhaka.
- Noreen M, Shahid M, Iqbal M, Nisar J, Abbas M (2017). Measurement of cytotoxicity and heavy metal load in drains water receiving textile effluents and drinking water in vicinity of drains. Measurement 109:88-99.
- Phiri O, Mumba P, Moyo BHZ, Kadewa W (2005). Assessment of the impact of industrial effluents on water quality of receiving rivers in urban areas of Malawi. Int. J. Environ. Sci. Technol. 2(3):237-244.
- Rahman AKML, Islam M, Hossain MZ, Ahsan MA (2012). Study of the seasonal variations in Turag river water quality parameters. African J. Pure Appl. Chem. 6(10): 144-148.
- Roy R, Fakhruddin AMN, Khatun R, Islam MS (2010). Reduction of COD and pH of textile industrial effluents by aquatic macrophytes and algae. J. Bangladesh Aca. Sci. 34(1):9-14.
- Singh AK, Mahato MK, Neogi B, Singh KK (2010). Quality assessment of mine water in the Raniganj coalfield area, India. Mine Water Environ. 29:248-262.
- Sultana MS, Islam MS, Saha R, Al-Mansur MA (2009). Impact of the effluents of textile dyeing industries on the surface water quality inside DND embankment, Narayanganj. Bangladesh J. Sci. Ind. Res. 44(1):65-80.
- Uddin MN, Alam MS, Mobin MN, Miah MA (2014). An Assessment of the River Water Quality Parameters: A case of Jamuna River. J. Environ. Sci. Natural Resour. 7(1):249 – 256.
- Vandevivera PC, Bianchi R, Verstraete W (1998). Treatment and reuse of wastewater from the textile wet-processing industry: Review of emerging technologies. J. Chem. Technol. Biotechnol. 72:289-302.
- WHO (2000). WHO Air Quality Guidelines, 2nd Edition, World Health Organization, Europe Regional Office, Copenhagen.
- WHO (2002). Water Pollutants: Biological Agents, Dissolved Chemicals, Non-dissolved Chemicals, Sediments, Heats, WHO CEHA, Amman, Jordan.
- Yusuff RO, Sonibare JA (2004). Characterization of textile industries' effluents in Kaduna, Nigeria and pollution implications. Global Nest: the Int. J. 6(3):212-221.