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AWARENESS CREATION, KNOWLEDGE DEVELOPMENT AND DISSEMINATION FOR MITIGATING SOIL QUALITY DETERIORATION IN BAKKHALI RIVER, COX'S BAZAR

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ABSTRACT

Ahmad S (2021) Awareness creation, knowledge development and dissemination for mitigating soil quality deterioration in Bakkhali river, Cox's Bazar. *Int. J. Expt. Agric.* 11(1), 14-23.

The coastal zone of Bangladesh faces soil quality deterioration owing to unawareness and lack of knowledge about detrimental effects of anthropogenic activities upon soil. The main objective of the study was to create awareness about soil quality deterioration along the Chattogram coast through developing and disseminating knowledge regarding estuarine soil condition of the Bakkhali River. The Key Informant Interviews (KIIs) and interviews with concerned stakeholders were conducted as qualitative approach. For quantitative research approach, soil samples were collected in 'Composite Soil Sampling' method to measure concentration of five heavy metals, two non-metals, and four physio-chemical parameters of soil. The order of the heavy metal concentration of soil samples were: Fe (3.56 mg/g)> Zn (0.90 mg/g)> Pb (0.33 mg/g)> Cu (0.20 mg/g)> Cd (0.01). Average soil pH was 8.2 indicating alkalinity of soil, average EC was 5.07 mS/cm portraying low soil nutrients, while average temperature was 31.7°C showing an increasing temperature. Exceeding limits of heavy metals and non-metals, along with fluctuation of selected physio-chemical parameters in soil samples prove deterioration of study area terrestrial ecosystem.

Key words: *awareness creation, knowledge development and dissemination, knowledge pool, soil quality deterioration*

INTRODUCTION

The study area, the Bakkhali River and channel estuary comprises one of the biggest fish landing station and industrial zone of Cox's Bazar district, Chattogram. The area has been confronting with declined soil quality owing to unscrupulous anthropogenic interventions. In literatures regarding environmental quality of Bangladesh east coast Ashraful *et al.* (2009), Rashid *et al*. (2015), Raknuzzaman *et al*. (2016), Wang *et al.* (2016), Khan *et al.* (2017), Hasan *et al.* (2019), and Ahmad and Shamim (2019) mentioned about heavy metal contamination in the major rivers along the Bangladesh coastal water mentioning the Bakkhali River estuary as the 'Hotspot' of anthropogenic pollution. The Department of Environment (DoE) in 2014 declared that the Bakkhali River estuary receives around twelve tonnes of municipal wastes daily (Dhaka Tribune, 2014). The researchers also discussed about the adverse impacts of fluctuation in the physio-chemical parameters in water and soil along the east coast of Bangladesh.

Hasan *et al.* (2019) mentioned anthropogenic intervention as the main sources of soil pollution along the Bakkhali River. Wastes generated from the fish landing station, such as the fish wastes, market wastes, and burnt oil from the fishing trawlers are directly dumped into the river water. Ahmad (2018) declared municipal garbage, industrial wastes, effluents from shrimp cultivation area, plantation of exotic and non-native plant species, as well as over exploitation of floral and faunal species for consuming and trading; conflict of multiple as well as unplanned land use, illegal and detrimental land encroachment by the local stakeholders as the anthropogenic causes of soil quality deterioration.

Golam *et al*. (2016) mentioned the Karnaphuli River as the 'Hotspot' of heavy metal pollution owing to anthropogenic activities. Wang *et al.* (2016) declared that, catastrophic events like landslides, cyclones, and heavy rainfall between the years 2007-2008 has changed the volume of pollutants from the point sources and depositional environment in the Karnaphuli River. This led into altered heavy metal and nutrient accumulation in the soil. Khan *et al.* (2017) as well mentioned anthropogenic activity induced toxic pollutants from the point sources of Salimpur union enter into the sediment and water of the Bay of Bengal.

The Soil Resource Development Institute (SRDI) published its report on 'Soil Salinity in Bangladesh' enclosing with a 'Soil Salinity Map' of Bangladesh (2010), where the coastal area was mentioned as the zone of lesser cropping intensity due to certain adverse soil and land condition, such as river bank erosion, flood, water stagnation, acidity, low fertility, climate change induced natural hazards like cyclones and storm surges, untimely rainfall, as well as poor communication and remoteness from urban centers (Ahsan 2010).

The soil quality deterioration exerts great impact upon the estuarine biodiversity. For instance, Ansari *et al.* (2004) discussed about effects of heavy metal concentration in marine water, which eventually get accumulated into marine organisms through the marine sediments. While declaring Karnaphuli as one of the most polluted rivers in Bangladesh, Uddin and Jeong (2021) mentioned that, heavy metal concentration in river water and sediment was above US EPA standard. The study also stated that, bioaccumulation of toxic heavy metals in fish, and agricultural crops through polluted water irrigation cause serious health hazards. Ahmad and Shamim (2019) investigated the amount of heavy metal and Calcium Carbonate ($CaCO_3$) concentration in estuarine water and mollusk shells at the point sources of pollution along the Teknaf coast. Rashid *et al.* (2015) also mentioned about escalation of heavy metal concentration in estuarine sediment at the east coast of the Bay of Bengal, which eventually accumulates into sea shells and oysters and causes toxicity.

Hussain *et al*. (2018) emphasized upon establishing marine education and research intertwined with scientific knowledge in Bangladesh. Baten (2018) emphasized upon transfer of knowledge for maritime excellence for an inclusive maritime sustainable development of Bangladesh through a strategic alliance of universities and other stakeholders at national and international arena. The researcher explored that, potentialities of knowledge transfer through strategic alliance become beneficiaries of accessing new opportunities, collaborative technological development, assemble more diverse skills, resources, technological capabilities in accost-effective way, as well as gain inside knowledge. Lloyd (2018) declared ‘Continuing professional development’ (CPD) as the marquee of the professional mariners to be trained as skilled professionals through advanced technology. Nishat (2018) mentioned about the significance of including maritime education in both secondary and higher education, as well as developing public and private maritime professionals at national level.

Ahmad (2020) studied the detrimental consequences of unethical anthropogenic activities upon the terrestrial ecosystem of Teknaf peninsula, the ‘Environmentally Critical area’ (ECA) in Chattogram. The study recommended insertion of moral ethics among local stakeholders through trainings, motivational lectures, demonstrations, and dramas, as well as development of ‘Knowledge Pool’ about adverse effects of unethical activities upon the geo-environment and inclusion of relevant lessons into the text books.

Comprehending the need to mitigate the deteriorating situation of the estuarine ecosystem of Bangladesh, an ‘Integrated Coastal Zone Management Plan’ (ICZMP) was developed by the government of Bangladesh in 1999. The ICZMP was finally institutionalized through the establishment of the Water Resource Planning Organization (WARPO) in 2006 to form a sustainable coastal zone for Bangladesh (WARPO 2006). WARPO (2006) declared lack of awareness and knowledge among local and national stakeholders, as well as weak linkages among the national policy makers and local stakeholders as the causes of partial functionality of the ICZMP in Bangladesh.

The literatures depict insufficiencies in awareness and knowledge about existing state of estuarine environment, which is one major anthropogenic cause of soil quality deterioration due to metal toxicity, and lower nutrient concentration. Hence, the study attempted to find out the causes of soil pollution, reveal the present state of estuarine soil, as well as to create awareness among local and national stakeholders.

The main objective of the study was to create awareness about soil quality deterioration along the Chattogram coast through developing and disseminating knowledge regarding estuarine soil condition of the Bakkhali River. Three specific objectives were - to measure the concentration of five heavy metals, two non-metals, and physio-chemical quality of the soil samples to assess the soil quality deterioration.

MATERIALS AND METHODS

Research Approach

The research was an intermingled one where both Qualitative and Quantitative research approaches were followed.

i) Quantitative Research Approach

The cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), nickel (Ni), lead (Pb), and Zinc (Zn) are the eight most common toxic heavy metals (US EPA 2015). From these, the present study measured concentration of five heavy metals, such as the Cd, Cu, Pb, and Zn in sample soil to measure the toxicity level in soil. Moreover, concentration of Fe was measured as this metal is one of the essential nutrients for biological entities (RCRA Act, 1976, cited in US EPA, 2015). The pH, Temperature, and Electric Conductivity (EC) of soil were also measured to identify the physio-chemical quality of soil along the Bakkhali River and channel estuary.

(ii) Qualitative Research Approach

KIIs were conducted with the Cox’s Bazar City Corporation authority; Deputy Director, Union Team Leader and volunteers of Bakkhali Upazila ‘Cyclone Preparedness Programme’ (CPP); Scientists of Bangladesh Fisheries Research Institute (BFRI), Cox’s Bazar, and the Chief of Operation of Prime Minister’s Rehabilitation Project, Cox’s Bazar in 2018.

Data Sources

(i) Primary Data Source

The field surveys were conducted from 20th-25th March 2016, 24^{th}-26^{th} March 2017, and 16^{th}-20^{th} March 2018 consecutively. The soil samples were collected from eight source points of pollution along the Bakkhali River and channel estuary during the month of March in two consecutive years 2016 and 2017. The KIIs were conducted to collect the information regarding the management plans and policies proposed and executed by the concerned stakeholders in March, 2018.

(ii) Secondary Data Sources

The secondary data were collected to know about the state, causes and consequences of estuarine soil quality deterioration along the Bakkhali River estuary and channel.

The statistical data were collected from published materials like books, journal articles and reports of concerned authorities and organizations.

Study Area and Sample Areas

The Bakkhali River and channel estuary was selected as the study area after thorough literature review and reconnaissance survey. Total eight extremely polluted point sources of pollution along the study area were selected as the sample areas (Table 1, Figure 1).

Table 1. Absolute Location of the Sample Areas

Sample ID	Sample Area	Latitude	Longitude
Sample 01	No.6 Fishery Ghat, Bakkhali River	21º 27′ 32″ North	91º 58′ 12.7″ East
Sample 02	Nuniarchara Fishery ghat, Bakkhali River	21º 28′ 30.2″ North	91º 58′ 31.9″ East
Sample 03	Khurushkul Project Area, Bakkhali River	21º 30′ 34″ North	91º 02′ 35″ East
Sample 04	Nuniarchara Industrial area, Bakkhali River	21º 27′ 02″ North	91º 58′ 13″ East
Sample 05	Char Para, Bakkhali Channel	21º 27′ 39.8″ North	91º 57′ 17.7″ East
Sample 06	Kutubdia Para, Bakkhali Channel	21º 27′ 51.5″ North	91º 57′ 25.3″ East
Sample 07	Char Para, Bakkhali Channel mouth	21° 27′ 46″ North	91º 57′ 28.3″ East
Sample 08	Kutubdia Para, Bakkhali Channel mouth	21º 28′ 08.5″ North	91º 57′ 23.1″ East

Fig.1. Study Area and Sample Areas, Bakkhali River and Channel Estuary

Sample Collection

The soil samples were collected from a depth of six to eight inches from point sources of pollution by 'Composite Soil Sampling' method. The sources of pollutants and toxic wastes were the industries, fish markets, fish and fisheries processing factories and ice factories, and municipality garbage dumping points of the sample areas (Figure 2-5).

Fig. 2 & 3. Untreated Effluents and garbage being drained continuously from the No.6 Fishery Ghat, Bakkhali River

Fig. 4. Bakkhali River Estuary Municipal Waste Dumping Area, 2016

Fig. 5. Waste water from Khurushkul Bridge construction area has contaminated estuarine soil at Kasturi Ghat area, 2016

Sample Analysis and Data Presentation

The soil samples were dried, grinded, and then digested with Nitric-hydrochloric Acid Digestion method. The digested soil samples were then filtered into clear bottles to measure the concentration of five heavy metals like-Iron (Fe), Zinc (Zn), Lead (Pb), Copper (Cu) and Cadmium (Cd). The Atomic Absorption Spectroscopy (AAS) method was applied to measure the heavy metal concentration. To measure the two non-metal nutrients like-Phosphorous and Sulphur content the soil samples were digested by the HNO_3 digestion method (combination of Nitric-Perchloric acid). The pH Meter, calibrated by pH 7.0 buffer solution (distilled water) was used to measure the physio-chemical parameters of soil like- pH, EC, and Temperature. The samples were processed, measured and analyzed in the Environmental Laboratories of the Department of Geography and Environment; the Department of Soil, Water and Environment; and Centre for Advanced Research in Sciences (CARS), University of Dhaka. The attributed data were presented with Maps, Tables, and different graphic forms.

Limitations

1) The management authority of the shrimp hatcheries and fish processing factories were not available for KIIs, 2) The local stakeholders and tourists were unaware and ignorant about adverse impacts of land pollution upon terrestrial ecosystem of the study area,

RESULTS AND DISCUSSION

Cd Concentration in Soil

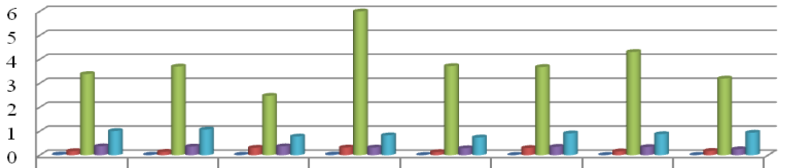
The Cd concentration ranged from 0.01 to 0.03 mg/g in the sample areas with an average (n=8) concentration of 0.02 mg/g (Table 2, Fig. 6). The highest concentration (0.03 mg/g) was found at S 01 and S 04, while the lowest concentration (0.01 mg/g) was found in majority sample areas like S 05, S 06, S 07, and S 08. The S 02 and S 03 had 0.02 mg/g concentration of Cd. The third highest concentration was found with the Zn (0.90 mg/g). Anthropogenic sources of Cd were the Cd-bearing materials and fossil fuels, fertilizers, and municipal wastes and sludge discharge residues from electroplating of motor parts, and batteries (Eisler 1985). Eisler 1985 also mentioned that, proximity to industrial and urbanized areas and point sources of Cd contained wastes consequences into decreased growth, depressed respiration, and shortened life-span of plants and animals. Hence, accelerating amount of untreated industrial waste disposal might increase Cd concentration in soil of the Bakkhali River and channel estuary ensuing into degradation of its terrestrial ecosystem.

Table 2. Heavy Metal Concentration in Soil of the Bakkhali River and Channel Estuary

Sample ID	**Cd-content**	**World Standard of Cd**	**Cu-content**	**World Standard of Cu**	**Fe-content**	**World Standard of Fe**	**Pb-content**	**World Standard of Pb**	**Zn-content**	**World Standard of Zn**
Soil Sample	mg/g	mg/g	mg/g	mg/g	mg/g	mg/g	mg/g	mg/g	mg/g	mg/g
Sample 01	0.03	0.11	0.17	0.9	3.39	3.4	0.37	0.03	1.01	5.0
Sample 02	0.02	0.11	0.14	0.9	3.70	3.4	0.36	0.03	1.07	5.0
Sample 03	0.02	0.11	0.31	0.9	2.48	3.4	0.37	0.03	0.78	5.0
Sample 04	0.03	0.11	0.32	0.9	6.00	3.4	0.32	0.03	0.83	5.0
Sample 05	0.01	0.11	0.13	0.9	3.72	3.4	0.29	0.03	0.74	5.0
Sample 06	0.01	0.11	0.30	0.9	3.68	3.4	0.35	0.03	0.91	5.0
Sample 07	0.01	0.11	0.16	0.9	4.31	3.4	0.34	0.03	0.88	5.0
Sample 08	0.01	0.11	0.18	0.9	3.20	3.4	0.25	0.03	0.94	5.0
Average=	0.02		0.21		3.81		0.33		0.90	

Cu Concentration in Soil

The Cu concentration ranged from 0.13 mg/g to 0.32 mg/g with an average (n=08) value of 0.21 mg/g, which was quite below the world average (0.9 mg/g) (Table 2, Fig. 6).



	Sample 01(No.6 Fishery Ghat, Bakkhali River)	Sample 02 (Nuniarchara Fishery Ghat, Bakkhali River)	Sample 03 (Khurushkul, Bakkhali River)	Sample 04 (Nuniarchara I/A, Bakkhali River)	Sample 05 (Char Para, Bakkhali Channel)	Sample 06 (Kutubdia Para, Bakkhali Channel)	Sample 07 (Char Para, Bakkhali Channel mouth)	Sample 08 (Kutubdia Para, Bakkhali Channel mouth)
Cd-content (mg/g)	0.03	0.02	0.02	0.03	0.01	0.01	0.01	0.01
Cu-content (mg/g)	0.17	0.14	0.31	0.32	0.13	0.3	0.16	0.18
Fe-content (mg/g)	3.39	3.7	2.48	6	3.72	3.68	4.31	3.2
Pb-content (mg/g)	0.37	0.36	0.37	0.32	0.29	0.35	0.34	0.25
Zn-content (mg)	1.01	1.07	0.78	0.83	0.74	0.91	0.88	0.94

Fig. 6. Heavy Metal Concentration in Soil samples of the Bakkhali River and Channel Estuary, Cox's Bazar

The highest concentration was found at S 04 (0.32 mg/g) followed closely by that of S 03 (0.31 mg/g). The lowest concentration was found at S 05 (0.13 mg/g). The garbage from Cox's Bazar municipality and two major fish markets, toxic effluents from more than fifty dried fish processing factories, fish cold storages and ice and salt factories, use of copper containing marine anti-fouling paints for the water vehicles constantly pollute the soil along the bank. Moreover, a narrow channel stretched along the village Uttar Kutubdia Para was observed to drain household wastes into the channel. Though the Cu is an essential heavy metal for biological functions, increasing anthropogenic interferences might raise the amount of Cu in the study area estuary. High concentration of Cu turns the heavy metals toxic and affects the metabolic process of marine organisms (Leal *et al.* 2018).

Fe Concentration in Soil

The concentrations of Fe in soil samples ranged from 2.48 mg/g to 4.31mg/g, while the average (n=8) Fe concentration was 3.5 mg/g. Among total eight point sources, five point sources (S 02, S 04, S 05, S 06 and S 07) showed higher concentration of Fe than that of the world standard average (3.4 mg/g). The rest three source points (S 01, S 03, and S 08) showed lower concentration of Fe than that of the world standard average (Table 2, Fig. 6). The highest concentration of Fe (6.0 mg/g) was found at Nuniarchara Industrial area (S 04). The second highest concentration of Fe (4.31 mg/g) was found at Charpara, Bakkhali channel area (S 07). The third highest Fe concentration was 3.72 mg/g, found at Char Para dried fish processing area (S 05). The other two sample areas with higher Fe content are the Nuniarchara fishery ghat area (S 02) along Bakkhali River and the Kutubdia Para village (S 06) along Bakkhali channel. The average Fe concentration was the highest among five selected heavy metals (3.56 mg/g). The high concentration of Fe in soil samples were owing to increasing socio-economic activities, such as ice factories, use of motorized fishing trawlers and speed boats, construction of 'Fishing Community Rehabilitation Project' and Khurushkul Bridge. The average Fe concentration in soil (3.56 mg/g) of the study area exceeded the limit of world average (3.4 mg/g). Both deficiencies and/ or excess Fe concentration might disrupt photosynthesis of phytoplankton that forms the base of marine food base (Boyd *et al.* 2007).

Pb Concentration in Soil

The concentration of Pb varied from 0.25 mg/g to 0.37 mg/g with an average (n=8) value of 0.33 mg/g, which was about 11 times more than the world average (0.03 mg/g). The highest concentration (0.37 mg/g) was found at two source points of Bakkhali River (S 01 and S 03), while the second highest concentration (0.36 mg/g) was found at Nuniarchara fishery ghat, Bakkhali River (S 02). The lowest concentration of Pb (0.25 mg/L) was found at Kutubdia Para, Bakkhali channel mouth (S 08). The Pb (0.33 mg/g) showed the second highest average concentration among the selected heavy metals. The average concentration of Pb (0.33 mg/g) among the sample areas of the present study was 10 times more than that of the world standard (0.03 mg/g) (Table 2, Fig. 6). The Pb is a non-essential heavy metal which is considered as a major industrial effluent added from Pb smelting factories, automobile industries, ship breaking industries, leaded petrol, fuel combustion, and solid waste combustion (Arbabi *et al.* 2015).

Zn Concentration in Soil

The concentration of Zn in soil varied from 0.74 mg/g to 1.07 mg/g with an average (n=8) of 0.9 mg/g in the study area, which was very insignificant in comparison to world average (5.0 mg/g) (Table 2, Fig. 6). The highest Zn concentration (1.07 mg/g) was found at Nuniarchar fishery ghat (S 02), while the second highest concentration (1.01 mg/g) was found at No.6 fishery ghat area (S 01). Though Zn is an essential heavy metal for most aquatic organisms, increased anthropogenic interventions like accelerating rate of unscrupulous dumping of effluents from industries, tourist areas and households along the study area might increase the Zn concentration in near future. Though little amount of zinc is needed in environment, lower or excess concentration of zinc in soil hampers natural growth of plants (Greipsson 1995). The average heavy metal concentration in soil samples of the river depicted highest concentration of Fe (3.56 mg/g) followed by Zink (0.90 mg/g) and Pb (0.33 mg/g). According to the DoE, more than six tonnes of household garbage from the Cox's Bazar municipality was deposited at the ghat area daily (Dhaka Tribune, 2014), which turned the soil and water filthy black, toxic and highly polluted. The Kasturi ghat area was observed to be highly contaminated by garbage and wastes from the municipality. Toxic and polluted black water was seen to flow through the Kasturi ghat area to fall in the Bakkhali River water. In 2018, soil lifting vehicle was seen to excavate highly contaminated soil from garbage sites and dump them at Kasturi ghat area to fill the Khurushkul bridge site.

Non-Metals or Nutrients in Soil

The amount of Phosphorous (P) and Sulphur (S) in soil samples was below 03 PPT during study. Both P and S are essential nutrients for all living things. Though the P mined from phosphate rocks is the major source of commercial agricultural fertilizer (Cho 2013), the anthropogenic sources are municipal wastes, drainage from agricultural land, excreta from livestock, and diffused urban drainage (Kroiss *et al.* 2011 and Holtan *et al*. 1988). Lower concentration of P in soil might lead to reduced crop yield (Douglas and Philip, 2002), decreased plant growth, death (Provin and Pitt), and distortion of plant morphology (Atkinson and Davison, 1973). On the other hand, excess P in water increase algal growth ensuing into eutrophication in water bodies, decreased number of fish and desirable plants (USGS). The S is one of the major nutrients for the living beings. Mostly originated from the natural source like S containing minerals in parent materials, this nutrient enters into the food chain through microbial activities in soil, from plants and animal residues, and from external sources (Prasad and Yashbir, 2016). Deficiency of S in soil hinder growth, quality and amount of plant and crop yield (Prasad and Yashbir, 2016), while excess S in soil decrease the pH in soil and lead to low pH induced problems (Agronomi Library).

The present study found the No.6 fishery ghat, Kasturi ghat and Nuniarchara fishery ghat as the point sources of pollution. Huge amount of municipal wastes, toxic effluents from dried fish processing factories, fish cold storage, shrimp hatcheries, salt and ice factories, and other industries; burnt oil and waste disposal from daily commuting passenger and fishing boats are constantly disposed off at these points, ensuing into degradation of estuarine soil condition. Nevertheless, least awareness and knowledge about the anthropogenic causes of soil quality degradation was found among the stakeholders during the present study survey.

Physio-Chemical Quality of Soil samples

The physio-chemical quality of soil samples was measured with the HI 9813-5 and 9813-6 Portable machine at the Environmental laboratory of the department of Geography and Environment, University of Dhaka. The three parameters taken to measure the physio-chemical quality of the soil samples were: i) pH, ii) Electric Conductivity (EC), and iii) Temperature.

i) pH of Soil

The standard range of pH in soil is 6.5 -7.5 (USDA 1998), while the pH value of the present study sample areas varied from pH 5.1 to 8.4. Table 3 shows that, the lowest content of soil pH was 5.1 at Kutubdia Para (S 08) and the highest content was 7.4 at Nuniarchara industrial area (S 04), which is categorized as 'Slightly Alkaline'. The soil samples of the Char Para and Kutubdia Para channel estuary and Char Para river mouth (S 05, S 06, S 07) was categorized as 'Neutral soil' (pH 6.9-7.3). The soil pH of other three sample areas, such as No.6 fishery ghat, Nuniarchara fishery ghat, and Khurushkul project area (S 01, S 02, and S 03) were 'Moderately Alkaline' (pH 8.2-8.4). Nevertheless, the average pH value was 7.2 (n=8), which was at the last edge of 'Neutral Soil' range in the pH scale (USDA 1998).

Table 3. pH of Soil

Sample areas	pH	EC *(mS/cm)	Temperature (°C)
Sample 01 (No.6 Fishery Ghat, Bakkhali River)	8.4	2.31	24.3
Sample 02 (Nuniarchara Fishery Ghat)	8.2	6.42	23.5
Sample 03 (Khurushkul Project area)	8.3	6.00	23.2
Sample 04 (Nuniarchara I/A, Bakkhali River)	7.4	6.37	24.2
Sample 05 (Char Para, Bakkhali Channel)	7.3	3.98	22.5
Sample 06 (Kutubdia, Bakkhali Channel)	6.9	4.26	22.6
Sample 07 (Char Para, Bakkhali Channel)	6.9	5.80	23.1
Sample 08 (Kutubdia Para, Bakkhali Channel)	5.1	5.35	22.1
Average	7.2	4.6	23.2

* mS/cm= mili Siemens/centimeter

The average amount of pH (pH 8.2) in soil samples was alarmingly higher than the neutral level (7.5) (Table 3). The reason of such high availability of pH in soil is the constant discharge of effluents from the source points like the fishery ghat, fish processing factories, dried fish processing farms, ice factories, pollutants from the industrial area, and the Fishing Community Rehabilitation project. Fondriest (2014) mentioned that, human induced pollution and toxicity in all physical biomes of the earth increase the amount of pH in ecosystem leading to significant changes in the biodiversity. Soil pH can affect the plant growth as bacteria which change as well as release nitrogen from organic matters and other fertilizers operate best in the pH range 5.5 to 7.0 considered as 'Neutral' (Ward 2015). Hence, Neutral Soil pH is most the most suitable level of pH for plants and crops. In highly alkaline soil (pH above 7.0) the nutrient P and other micronutrients become less available, while pH below 5.0 in soil causes heavy metal toxicity to plant growth, as well as calcium deficiency. Moreover, alkaline soil (pH above 7.0) might cause deficiency of heavy metal nutrients such as Cu and Zn (Ward 2015).

ii) Electrical Conductivity (EC) of Soil

The average EC in soil samples was 4.6 mS/Cm, ranging from 2.3-6.4 mS/Cm (Table 3). The highest EC (6.42 mS/Cm) was found at Nuniarchara Fishery ghat (S 02), followed by the EC 6.0 at Nuniarchara industrial area (S 03 and S 04); while the lowest EC (2.31 mS/Cm) was found at No. 6 Fishery Ghat area (S 01). Soil EC is a measure of soil salinity and indicates soil condition. Soil EC affects crop yields, plant nutrient availability, and helps the microorganisms to emit greenhouse gases. On the other hand, soil EC is affected by municipal wastes, cropping, irrigation, land use, application of fertilizer, manure, and compost (USDA). Fourie (2019) mentioned that the optimal soil EC should range between 110-117 mS/cm. The average soil EC (5.07 mS/Cm) in the study area indicates lower level of soil EC (Table 3), which might have reduced plant growth in the dry seasons (Ahsan 2010).

iii) Temperature in Soil

The soil temperature at the sample areas ranged between 22.1°C-24.3°C during the survey, with an average of 23.4°C, showing an increasing pattern in comparison to the average temperature of 22°C, prevailing at the east and south coast of Bangladesh (Banglapedia 2015a,b) (Table 3). The average temperature ranged between 23.2°C in soil samples. Fondriest (2014) mentioned that, for every 1°C increase in temperature, EC can increase up to 2 to 4 percent, which consequences imbalance in the terrestrial ecosystem leading to biodiversity change and /or loss. Hence, the high amount of EC might be the consequence of increased temperature at the sample area (Table 3).

CONCLUSION

The order of the heavy metal concentration in soil samples were: Fe (3.56 mg/g)> Zn (0.90 mg/g)> Pb (0.33 mg/g)> Cu (0.20 mg/g)> Cd (0.01). Average soil pH was 8.2 indicating alkalinity of soil, average EC was 5.07 mS/cm portraying low soil nutrients, while average temperature was 31.7°C showing an increasing temperature. The No.6 fishery ghat, Kasturi ghat and Nuniarchara fishery ghat were the point sources of pollution. Hence, the study explored the causes of soil pollution; reveal the present state of estuarine soil, as well as to create awareness among local and national stakeholders. Awareness creation through development and dissemination of coastal environment relevant knowledge for mitigating estuarine soil quality deterioration is expected to show the ways for developing and/ or restructuring a fully-functional Integrated Coastal Zone Management Plan (ICZMP) for Bangladesh.

RECOMMENDATIONS

The study recommends minimization of municipal garbage disposal, and toxic industrial effluents from the point sources of pollution by implementing advanced 'Waste Treatment Plant' and close regular monitoring in the study area. Nevertheless, besides the application of modern waste treatment mechanisms, strong emphasis has to be given upon development and dissemination of awareness and knowledge about the state and causes of estuarine soil quality deterioration, as well as the ways to mitigate the anthropogenic activity induced soil deterioration along the Bakkhali River and channel estuary. Further, the study emphasizes the need to ensure implementing environmental laws and monitoring their full-functionality; conducting regular trainings, demonstrations and dramas; motivational lectures, as well as incorporation of lessons about consequences of unethical anthropogenic activities upon the coastal environment into text books at all levels of education.

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CONFLICT OF INTEREST

The author declares no conflict of interests.

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