Assessment of heavy metal impact on soil and vegetable of hatirjheel lake area and study of the physicochemical parameters of lake water

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ASSESSMENT OF HEAVY METAL IMPACT ON SOIL AND VEGETABLE OF HATIRJHEEL LAKE AREA

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Abstract

Impact of industrial activities of Tejgaon industrial area on the surrounding environment, especially on the water quality of Hatirjheel lake, the soil and vegetables grown beside the lake were evaluated. Average value of pH, EC, DO, TDS, salinity, turbidity, COD and BOD of water samples were found to be 7.66, 761.6 μS/cm, 3.60 mg/L, 380.5 mg/L, 0.032%, 18.13 NTU, 57.75 mg/L, and 37.13 mg/L, respectively. The concentration of heavy metals in the water samples collected from different points of the lake was found to be below detection limit (BDL). Heavy metals such as Pb, Cd, Cr, Zn, Mn and Ni contents in soils, collected from different sites surrounding Hatirjheel lake showed accumulation with 42.43, 10.21, 32.25, 18.21, 23.23 & 137.82 ppm, respectively. Edible parts of three leafy vegetables samples (*Amaranthus gangeticus, Raphanus sativus, Ipomoea aquatic*) were found to contain high amount of heavy metals.

Introduction

About 20-30% of mortality in Bangladesh occurs due to water-borne diseases, *e.g.*, diarrhea, dysentery, gastroenteritis.[1] Rivers, ponds, and lakes are waterways of strategic importance across the world, providing main water resources for domestic, industrial, and agricultural purposes. The expected increase coupled with economic development and changing life-styles over the next 25 years will result in that availability of freshwater resources is predicted to be one of the great issues for humankind to solve in the 21st century.[2] Hatirjheel lake is the important artificial lake of Dhaka Metropolitan city, which is situated in posh area of Dhaka but at the same time slum people are frequently using this lake water for bathing and cooking. This lake was declared an Ecologically Critical Area (ECA) in 2001. This is a semi-aerobic landfill site which facilitates rapid decomposition of waste. The area in and around Hatirjheel has always been Dhaka's most exclusive residential haven mainly because of the pristine lake that used to encircle these neighborhoods. Various kinds of industries established around this lake, such as Jamuna garments, Ha-meem sportswear ltd., Arman group, Padma garments, Sepal group, Nassa mainland, Jita garments, printing industries, pharmaceutical industries, battery industries etc. Different kinds of industrial effluent may be fall in this lake. The physicochemical features and bacterial flora of Dhanmondi lake were investigated earlier.[3,4]

Heavy metals, in contrast to most pollutants, not bio-degradable, they can be concentrated along the food chain, producing their toxic effect at points after far removed from the source of pollution.[5] The most important heavy metals from the point of view of water pollution are Zinc (Zn), Copper (Cu), Lead (Pb), Cadmium (Cd), Mercury (Hg), Nickel (Ni) and Chromium (Cr).[6] These toxic elements may cause physical problems to human beings and animals by entering the food chains.[7] The Hatirjheel lake water is also used for the production of vegetables. Different kinds of leafy vegetables such as *Amaranthus gangeticus* and *Raphanus sativus* are grown around this lake side. Bioaccumulation of heavy metals may occur in the vegetables from the soil and through the food chain might be come to human being.

The present study was undertaken to determine the physicochemical properties water, soil, sediments and leafy vegetables Hatirjheel lake area.

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Experimental

Location of the study area

Hatirjheel lake has been selected as the case study for this research. Soil, sediments, leafy vegetables and water samples were collected from the different places of Hatirjheel lake and Tejgaon industrial area in 2012. Location was confirmed by GPS (***Model***: GPSMAP 76CSx).

Water sample collection

The high-density 500 mL and 100 mL PVC bottles were used for collection and preservation of sample. Each bottle was cleaned thoroughly by rinsing with dilute HNO_3 followed by washing with distilled water.[8] Two 100 mL bottle of samples were collected from each sampling point. One was preserved with toluene for regular water analysis and other was preserved with HNO_3 for the heavy metal analysis.

Sampling point of water

Water samples were collected from twenty different locations which had the latitude and longitude 23º46'26.2" and 90º23'50.2", 23º46'23.2" and 90º24'53.5", 23º46'05.7" and 90º25'23.1",23º46'05.1" and 90º25'22.4", 23º46'14.5"and 90º24'08.4", 23º45'33.6" and 90º24'19.1", 23º46'34.6" and 90º24'21.5", 23º46'35.6" and 90º24'22.6", 23º46'38.2" and 90º24'26.4", 23º46'42.5" and 90º24'30.7", 23º46'14.5" and 90º24'08.4", 23º46'16.3" and 90º24'10.4", 23º46'12.3" and 90º24'06.3", 23º46'10.3" and 90º24'04.4", 23º46'08.4" and 90º24'02.4", 23º46'26.2" and 90º23'50.2", 23º46'22.2" and 90º24'53.5", 23º46'05.7" and 90º25'23.1", 23º46'05.1" and 90º25'22.4", 23º46'14.5" and 90º24'08.4", respectively.

Soil and sediment samples collection

Soil and sediment samples were collected from Tejgaon industrial area-Hatirjheel lake landfill site. The samples were collected by using an auger. After collection, the collected samples were sun dried and pulverized by using an agate pestle mortar and kept in zip tight bags in ambient condition.

Sampling point of soil

Soil samples were collected from five different locations which had the latitude and longitude 23º46'23.2" and 90º24'53.5", 23º46'23.7" and 90º24'53.2", 23º46'23.1" and 90º24'53.6", 23º46'23.4" and 90º25'53.1", 23º46'23.6" and 90º25'53.2", respectively.

Sampling point of sediment

Sediment samples were collected from five different locations which had the latitude and longitude23º46'26.2" and 90º23'50.2", 23º46'23.2" and 90º24'53.5", 23º46'05.7" and 90º25'23.1", 23º46'05.1" and 90º25'22.4", 23º46'14.5" and 90º24'08.4", respectively.

Vegetable samples collection

Vegetable samples were collected by using hand. The samples were separated into portions of soil, root and shoot. Vegetable samples were then rinsed with distilled water, cut into smaller portions and dried to a constant weight in an oven at a temperature of 70^0C. The dried samples were pulverized using an agate pestle mortar and kept in zip tight bags in ambient condition.

Sampling point of leafy vegetables

Leafy vegetables; *Amaranthus gangeticus* (Lal shak)*, Raphanus sativus* (Mula)*, Ipomoea aquatic* (Kolmi shak) were collected from five different locations which had the latitude and longitude 23º46'23.2" and 90º24'53.5", 23º46'23.2" and 90º24'53.6", 23º46'23.4" and 90º25'53.1", 23º46'23.2" and 90º24'53.5", 23º46'23.2" and 90º24'53.6", respectively.

Water sample digestion

For heavy metal analysis water samples were filtered through the Whatman Filter Paper No. 42 and acidified with concentrated HNO_3 to lower the pH <2.0. All these samples were kept in the refrigerator at 4°C for further analysis. The bottles were kept air tight and labeled properly for identification. The water samples were brought to the Soil, Agronomy and Environment Laboratory, Biological Research Division, Bangladesh Council of Scientific and Industrial Research (BCSIR), Dhanmondi, Dhaka-1205 and preserved in refrigerator until analysis. 100 mL of prepared water sample was digested with 5.0 mL of concentrated nitric acid, and placed on a hot plateat 80° C for 3h. On cooling, the digest was filtered into a 100.0 mL volumetric flask and made up to the mark with distilled water.[9]

Soil, sediment and leafy vegetable samples digestion

0.50 g of prepared soil, sediment and leafy vegetable samples were digested with 10.0 mL of concentrated nitric acid, 5.0 mL of perchloric acid (except leafy vegetable samples) and placed on a hot plate for 6h. On cooling, the digest was filtered into a 100.0 mL volumetric flask and made up to the mark with distilled water.[9]

Analysis of physicochemical properties

pH of water was determined by glass electrode using pH meter (***Model:*** Sense Ion, 156; HACH, USA).[10] The electrical conductivity (EC) of irrigation water samples was directly determined in the field by EC meter (Sense Ion, 156; HACH, USA) in μS/cm.[10] Dissolved oxygen (DO) of water samples was determined in the field by DO meter (***Model:*** Mettler- Sense Ion, 156; HACH, USA).[11] Chemical oxygen demand (COD) of water samples was determined by titration process using COD vial, COD reactor for digestion, ferroin solution and 0.125 FAS for titration. BOD Trak apparatus was used to determine BOD.

Analysis of heavy metals

Heavy metals (Pb, Cd, Cr, Zn, Mn and Ni) in soil, sediment, leafy vegetables and water samples were determined by the atomic absorption spectroscopy (AAS; Model-Shimadzu AA 7000) by using the software Winlab Changing Technique after digesting the samples.

Results and discussion

The ranges of the physiochemical properties with the average value of the water from Hatirjheel Lake are shown in **Table 1**. The levels of pollution of this lake were determined by comparing the observed values of the various parameters with the water standards value recommended by DoE (Department of Environment), Bangladesh.[12]

pH: The pH of the water samples of Hatirjheel lake was varied from 6.94 to 8.25. The average pH value was found 7.66 (**Table 1**), which is within the permissible limit of DoE standard (6.5-8.5). The pH of Rampura bridge may be due to the discharge of alkaline chemicals.

EC: The EC of the collected water samples ranges from 554.0 μS/cm to 983.00 μS/cm with an average value of 761.6 μS/cm (**Table 1**) which is within the permissible limit of DoE standard (<1000 μS/cm). The highest value was found near the Fortuna industy of batteries and printing may be due to the discharging their chemicals of charge carrying species.

DO: The DO value of the collected water samples ranges from 0.08 mg/L to 7.03 mg/L with the average value of 3.60 mg/L (**Table 1**) which is lower than the standard value recommended by DoE ($\geq$ 6.0). The lowest value was found near Padma garments and this value shows that very deficiency of oxygen may be due to the processes of consume dissolved, suspended, or precipitated organic matter.

TDS: The TDS value of the collected water samples ranges from 277 mg/L to 491 mg/L and average value was found 380.5 mg/L (**Table 1**) which is within the permissible limit of DoE standard ($\leq$500

mg/L). The highest value was found near of Padma garments may be due to the discharging their effluents.

Salinity: The salinity value ranges from 0.02 to 0.05%. The average is 0.032% (**Table 1**).

Turbidity: The turbidity value ranges from 7.4 NTU to 111 NTU. The average is 18.13 NTU(**Table 1**) which was much higher than the DoE standard (10 NTU). The highest value was found near Rampura bridge may be due to the discharging different kinds of waste from near local area.

COD: The COD value of the collected water samples ranges from 0.2514 mg/L to 266.0073 mg/L. The average COD value was found 57.87 mg/L (**Table 1**) in the sampling location. The highest value was found near Aman group of industries may be due to the discharging their organic based substances.

BOD: Biochemical oxygen demand (BOD) value of the collected water samples ranges from 32.39 mg/L to 43.67 mg/L. The average BOD value was found 37.13 mg/L(**Table 1**) in the sampling location. The highest value was found near of Aman group of industries may be due to the discharging their organic based substance.

Table 1. Value of physicochemical parameter

Sampling point	pH	EC (μS/cm)	DO (mg/L)	TDS (mg/L)	Salinity (%)	Turbidity (NTU)	COD (mg/L)	BOD (mg/L)
1	7.14	938	1.38	469	0.04	36.8	12.3541	37.25
2	7.12	833	0.67	416	0.04	23.5	21.6786	35.37
3	7.36	979	0.74	489	0.05	24.9	0.2514	39.73
4	6.94	921	0.68	461	0.04	111	1.1620	39.83
5	7.82	682	7.03	341	0.03	12.3	22.9938	35.99
6	8.25	555	6.90	278	0.02	10.3	21.2234	34.90
7	8.12	561	6.61	280	0.02	12.4	43.1657	37.93
8	8.09	557	6.00	277	0.04	14.2	28.0383	36.37
9	7.37	968	0.35	484	0.04	8.13	163.369	37.83
10	7.42	969	0.08	487	0.02	7.4	65.2416	35.90
11	7.95	573	6.76	285	0.02	10.5	90.6066	34.34
12	7.96	554	6.21	277	0.02	11.5	29.2533	34.38
13	7.98	565	6.53	278	0.02	10.2	52.6293	33.32
14	7.95	558	6.35	280	0.02	8.92	59.8599	32.39
15	7.40	978	0.94	489	0.04	11.7	6.9764	40.64
16	8.03	561	6.65	280	0.02	8.58	62.5095	43.67
17	7.50	983	0.99	491	0.05	8.43	118.213	39.83
18	7.49	977	0.40	488	0.05	14.5	78.8563	37.39
19	7.45	963	0.09	482	0.04	7.44	13.0772	36.30
20	7.99	557	6.82	278	0.02	9.96	266.007	39.37
Average	7.66	761.6	3.60	380.5	0.032	18.13	57.87	37.13

Determination of concentration of heavy metals in collected samples

Pb: The conc. of Pb in sediments collected from different points of lake ranges from 4.27 ppm to 43.59 ppm with an average value 22.55 ppm. The concentrations of Pb in sediments are shown in **Fig. 1**. The highest value was found in sampling point 1 which was the near of Jamuna garments and battery industry. May be these industries used Pb containing raw materials or discharged their waste without proper treatment in the surroundings of this lake.

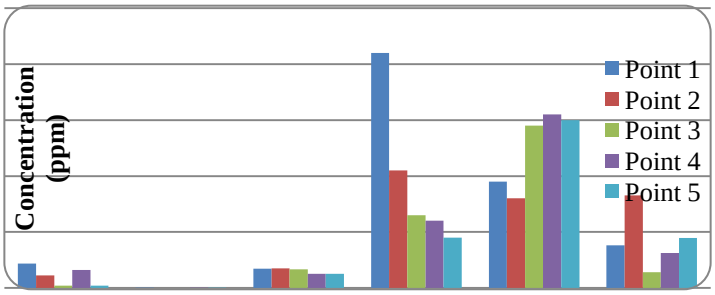

Fig. 1. Heavy metals accumulation trend in sediment

The conc. of Pb in soil and vegetables amples is shown in **Fig. 2**. From the **Fig.2** it is found that the root and shoot of leafy vegetables also contain Pb. The conc. Of Pb in root ranges from 0.92 to 7.89 ppm and in shoot it ranges from 0.06 to 6.13 ppm. Highest accumulation of Pb found in roots and in shoot of *Ipomoea aqutica*. It is found that Pb is entering into food chain through soil-water-vegetables continuum as the edible parts of these vegetables also contains Pb (mean value of Pb is 4.13 ppm) and thus may have the effect on the consumers who consume the edible part of these vegetables.

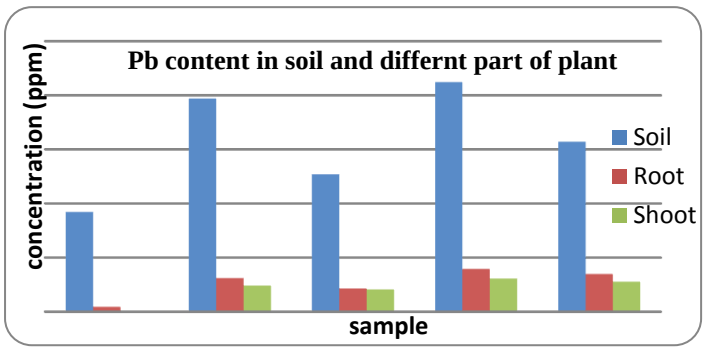

Fig. 2. Pb accumulation trend in soil and vegetables

Cd: The concentrations of Cd in sediments are shown in **Fig. 1**. The conc. of Cd in sediments collected from different points of lake ranges from 0 ppm to 0.198 ppm with an average value of 0.145 ppm. The highest value was found in sampling point 5 which was the near of Aman group of industries may be due to the discharge their effluent here.

The concentration of Cd in soil samples shown in **Fig. 3**. From the Fig. it appears that soil samples collected from different points of Hatirjheel lake contain significant amount of Cd and also the vegetables grown on those soils taken up this heavy metal. Highest accumulation found in root of *Raphanus sativus*.These vegetables also contain Cd (mean value of Cd is 0.77 ppm) and thus may have the effect on the consumers who consume the edible part of these vegetables.

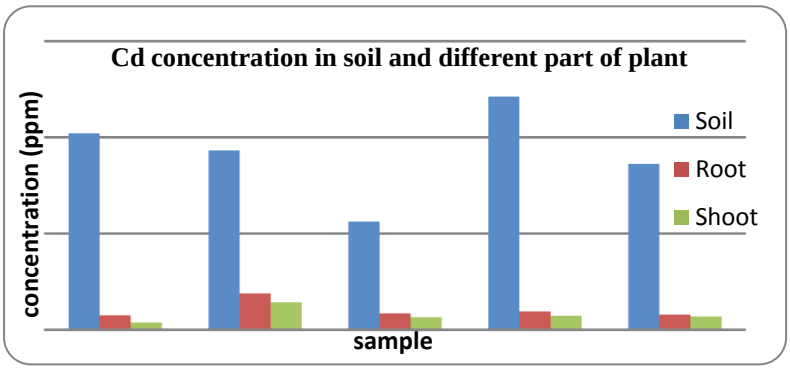

Fig. 3. Cd accumulation trend in soil and vegetables

Cr: The concentrations of Cr in sediments are shown in **Fig 1**. The conc. of Cr in sediments collected from different points of lake ranges from 25.20 ppm to 35.06 ppm with an average value of 30.39 ppm. The highest value was found in sampling point 2 which was the joint place of Hatirjheel and Gulshan lake may be due to the various kinds of industrial effluent discharge here.

The concentration of Cr in soil samples are shown in **Fig. 4**. The conc. of Cr in root ranges from 11.32 to 19.32 ppm and in shoot it ranges from 6.91 to 20.12 ppm. From the **Fig. 4** it is found that soil samples collected from different points of Hatirjheel lake contain significant amount of Cr and also the vegetables grown on those soils taken up this heavy metal. Highest accumulation found in shoot of *Raphanus sativus*.These vegetables also contain Cr (mean value of Cr is 10.97 ppm).

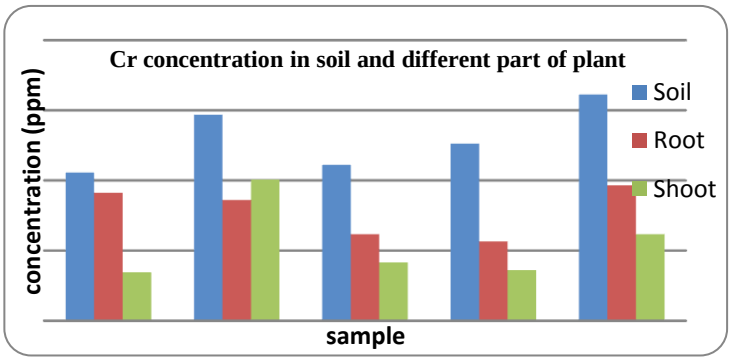

Fig. 4. Cr accumulation trend in soil and vegetables

Zn: The conc. of Zn in sediments collected from different points of lake ranges from 90 to 420 ppm with an average value of 194 ppm (**Fig. 1**). The highest value was found in sampling point 1 which was the near of Jamuna garments may be due to the discharging their effluent at this point.

The concentration of Zn in soil samples are shown in **Fig. 5**. The conc. of Zn in root ranges from 6.32 to 9.23 ppm and in shoot it ranges from 3.21 to 8.21 ppm. From the Fig. it is found that soil samples collected from different points of Hatirjheel lake contain significant amount of Zn and also the vegetables grown on those soils taken up this heavy metal. Highest accumulation found in root of *Raphanus sativus*.

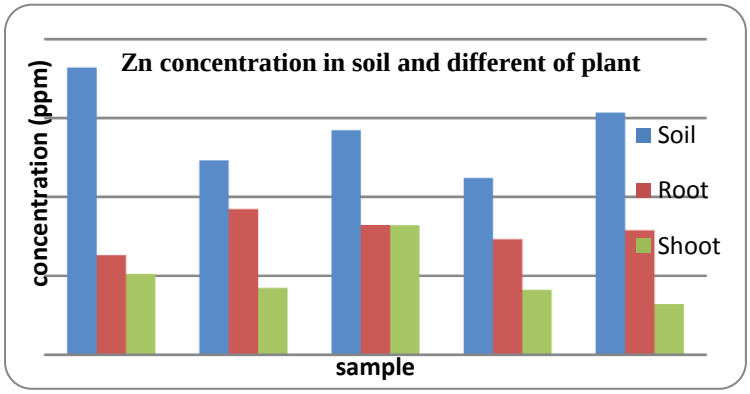

Fig. 5. Zn accumulation trend in soil and vegetables

Mn: The conc. of Mn in sediments collected from different points of lake ranges from 160 to 310 ppm with an average value of 250 ppm (**Fig. 1**). The highest value was found in sampling point 4 which was the near of Rampura bridge may be due to the discharging different kinds of industrial effluent at this point.

The concentration of Mn in soil samples are shown in **Fig. 6**. The conc. of Mn in root ranges from 5.25 to 18.21 ppm and in shoot it ranges from 4.25 to 14.32 ppm. From the Fig. it is found that soil samples

collected from different points of Hatirjheel lake contain significant amount of Mn and also the vegetables grown on those soils taken up this heavy metal. Highest accumulation found in root of *Raphanus sativus*. It is found that these vegetables also contain Mn (mean value of Mn is 9.65 ppm).

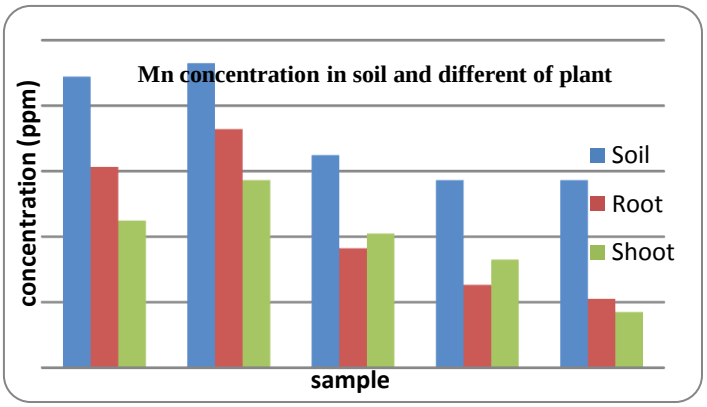

Fig. 6. Mn accumulation trend in soil and vegetables

Ni: The conc. of Ni in sediments collected from different points of lake ranges from 27.97 ppm to 165.23 ppm with an average value 89.14 ppm (**Fig. 1**). The highest value was found in sampling point 2 which was the near of Fortuna printing and battery industries may be due to the discharging different kinds of industrial effluent at this point.

The concentration of Ni in soil samples are shown in **Fig. 7**. The conc. of Ni in root ranges from 70.13 to 150.52 ppm and in shoot it ranges from 60.52 to 124.00 ppm. From the Fig.12 it appears that soil samples collected from different points of Hatirjheel lake contain significant amount of Ni and also the vegetables grown on those soils taken up this heavy metal. Highest accumulation found in root of *Amaranthus gangeticus*. From this result it is found that Ni is entering into food chain through soil-water-vegetables continuum as the edible parts of these vegetables also contain Ni (mean value of Ni is 83.17 ppm).

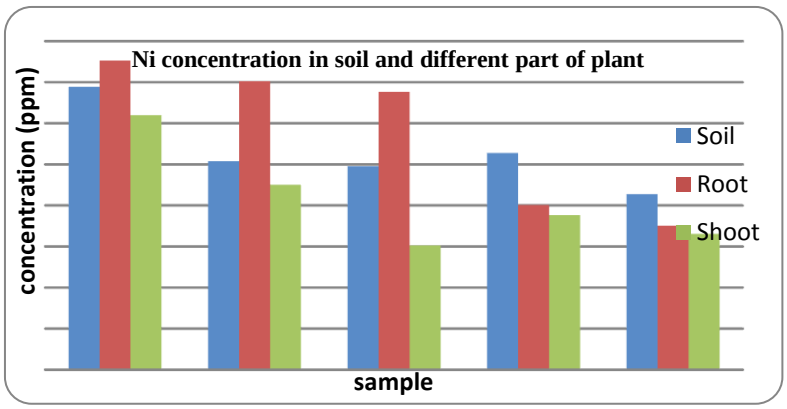

Fig. 7: Ni accumulation trend in soil and vegetables

It is found that the highest values of heavy metals in soil samples were found in the sample collected from near of joint place of Hatirjheel and Gulshan lake where there is a common outlet of different outlets coming from Tejgaon and Gulshan area.

Conclusion

The result suggests that many physicochemical parameters (like pH, DO, BOD etc.) in many sampling points exceeds the standard value set for waste discharged quality standards. The another part of this study was to assess the contents of different heavy metals in soil, sediment and their corresponding uptake by leafy vegetables and thus quantify the amount of heavy metals in food chain. From the result, there is a strong indication of the deposition of heavy metals in the sediments. Heavy metal contents in soils collected from different sites surrounding Hatiejheel lake, shows that there is significant accumulation of heavy metals like Ni, Pb, Cr, Mn, Zn and Cd in soils according to decreasing order. It is found that both part of vegetable samples like root and shoot contain high level of heavy metals.

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