Original Research Article

TOXICITY ASSESSMENT for AQUATIC ECOSYSTEM, SOIL and CROPS

Abstract: As Tongi is an industrial area, massive amounts of effluents generated by the industries end up in the river and soil of this region. These wastes contain an excessive amount of heavy metals, which is detrimental for both environment and living organisms. 10 water and 10 soil samples were collected from different places of Tongi industrial area, and the concentration of metals like Cadmium (Cd), Chromium (Cr), and Lead (Pb) were determined. In this research, studies were conducted on water and soil by using water quality parameters, geo-chemical index, contamination factor, and pollution load index. This research also investigated the daily metal intake by people consuming the vegetables grown from that contaminated soil. Experimental observations reveal that the water of those areas is extremely polluted with the concentration of Cd (0.0542-0.1728) mgL^{-1}, Pb (0.0421-0.245) mgL^{-1} and Cr (1.0622-2.4357) mgL^{-1}. However, the study also demonstrated that the soil of these areas is severely contaminated with Cd(4.42-100.564)$mgkg^{-1}$, but moderately contaminated with Pb and Cr, and the rate of heavy metal intake is within the World Health Organization (WHO) standard among the consumers of vegetables grown in the local agricultural land. Cadmium concentration is observed to be higher in water and soil compared to the concentration of lead and chromium, which might be due to the high cadmium containing industrial effluent discharge in the river.

Keywords: Heavy metal, Geo-chemical index, Contamination factor, Pollution load index, Daily metal intake

1. Introduction

Tongi is a town of Gazipur, Bangladesh, including a BSCIC industrial area, which produces BDT 1500 crores of industrial products each year. Tongi is one of the most important industrial sectors of Bangladesh. There are several types of industrial units, including aluminum factory, textile and dyeing, pharmaceutical industry, cosmetics industry, machine tools factory, diesel plant, security printing press, ordnance factory, ceramics factory, packaging industry, brickfield, cloth garments, etc (Zakir et al., 2015). Untreated or partially treated effluents from various industries directly thrown into surrounding water bodies and lands are considered as the most significant anthropogenic activity responsible for water and soil pollution by different heavy metals such as Zn, Cu, Cd, Cr, Ni, Mn, and Pb(Tusher et al., 2018).

The Turag River along with Tongi area has been declared as ecologically critical areas (ECA) by the Department of Environment. Study on Turag River water quality has been carried out in different time by Department of Environment (DoE, 2001). Hazardous chemicals from different industries situated near Turag river, which includes both organic and inorganic are released into the river water resulting in different chemical and biochemical interactions in the river system. Thus, it deteriorates the water quality and eventually the pollutants from water tend to move to the soil and also degrades the soil quality as well.

A soil is polluted when it contains an excess concentration of chemical compounds, which is dangerous to human health, plants, and animals. Soil contamination refers to the mixtures of undesirable contaminants or elements into or onto soil, as a result of anthropogenic derived activity like industrial, agricultural or natural processes, and can have harmful effects on quality of both the environment and human health because plants uptake the contaminants as a nutrient by root and accumulate in the leaves, seed, shoot and finally it goes into the food chain which has severe health impacts on human being(Bjelajac et al., 2017).

Soil pollution by heavy metals, e.g., copper, lead, chromium, zinc, nickel, arsenic, etc., is a major problem of concern. Soil contains some natural heavy metals, but also can be polluted from local sources such as different industries, automobile, pharmaceuticals, power plants, iron, steel, and chemical industries; agricultural sources such as fertilizer, phosphates which are used in agricultural lands, contaminated manure and pesticides containing heavy metals; waste incineration, burning of fossil fuels and road traffic(National, 2014).

Heavy metals are accumulated with the environment due to anthropogenic activities(Zhang & Wang, 2020). The metals can enter into surface and groundwater, soil, and crop plants. Heavy metals are not really necessary for plants but are taken up by plants in toxic form very easily. Heavy metals cause serious concerns to human health when crops contaminated with the heavy metals are consumed. The use of wastewater that is contaminated with heavy metals for irrigation over long periods of time increases the heavy metal concentration above the permissible limit(Jolly et al., 2013).

In this research, geo-chemical index is calculated to determine the enrichment of metal concentrations in soil samples above the background level, which was proposed by Muller (1969). Further, to assess the soil contamination, contamination factor and degree have been measured as suggested by Hakanson (1980)(Hakanson, 1980). The Pollution Load Index (PLI) determines the degree to which the soil is associated with heavy metals. It is an important tool to determine the degree of soil pollution(Tomlinson et al., 1980).

Vegetables cultivated on the land near Tongi industrial area take up heavy metals, which cause potential health risks to the consumers. To assess the health risks, it is vital to identify the pollutant sources, the amount of risk agents that come in contact with a human, and the consequences of the health impacts because of the exposure. The primary aims of this analysis is to determine the concentration of heavy metals (Pb, Cd and Cr) present in the water, soil and vegetable samples located in Tongi Industrial area and also to assess the soil quality and daily metal intake of those heavy metals and health condition of local people.

Here we present the data obtained from water and soil quality assessment by using various contamination indexes as well as health impacts due to the consumption of heavy metals. In this article, we offer the first overview on the health conditions of the local people and the effects of river and soil pollution on them.

2. Materials and Methods

Gazipur area has the monsoon climate with moderate rainfall. The dominant soil type of the study area is sandy and clay loam. It has complex mixture of non-calcareous sandy, silty and clayey alluvium (BBS, 2019)

2.1 Study area

Total 10 sampling sites were selected near the Turag river, Tongi during the dry season (1st January, 2021). The specific location of the sampling sites is given in **Table 1, Figure 1.** Locations were determined using mobile GPS. Water and soil samples were collected from the river water and nearby farming land irrigated with the polluted water from Turag river, near the industrial waste discharged point, to a depth of nearly 0-25 cm (USDA 1975). Then samples were preserved in the polythene bag and brought to Environmental Engineering Lab, MIST for testing.

Table 1: Sampling Location for water and soil Sample

SAMPLE NO	LONGITUDE	LATITUDE
1	90◦24'52.1968"E	23◦53'7.7329"N
2	90◦24'52.1046"E	23◦53'8.09524"N
3	90◦24'55.8964"E	23◦53'9.94312"N
4	90◦24'56.0551"E	23◦53'10.0268"N
5	90◦25'0.25032"E	23◦53'10.7032"N
6	90◦25'0.21882"E	23◦53'11.2354"N
7	90◦24'49.8179"E	23◦53'3.95002"N
8	90◦24'50.3373"E	23◦53'4.77107"N
9	90◦24'47.182"E	23◦53'1.86904"N
10	90◦24'46.22"E	23◦53'1.72608"N

Figure 1 Sampling location using GIS

The heavy metals concentrations (Cr, Cd and Pb) for 10 vegetable samples were collected from Bangladesh Agricultural Research Institute (BARI).

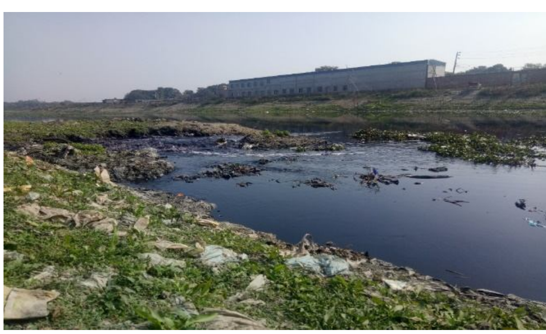


Figure 2 Present condition of Turag river and soil. Photo: Aliching Marma

2.2 The Sampling and Analysis

Heavy metals concentrations (Cd, Cr, Pb) were determined in the laboratory by using standard atomic absorption spectrometry (AAS). Water quality was also determined in the Environment Laboratory, MIST by using standard pocedures.

2.3 Pollution assessment methods

There are several types of industries discharging toxic substances into river water without proper treatment. Tongi area situated in the Bank of Turag River is primarily known and developed as industrial zone according to the Bangladesh Master Plan of 1959. Various categories of industries include metal industries, garments, jute, textile, spinning, pharmaceutical, food manufacturing industry, lot of tanneries, chemical factories etc. are available in Tongi area (RAJUK, 2010, Rahman et al., 2012). Most of the industries discharge their effluents directly or indirectly into the Turag River without any treatment causing pollution of the surface water. Industries by types around Study area, Tongi are:

Table 2 Types of Industries present at study area

Types of Industries	Numbers
Dyeing	10
Paper, pulp, wood	1
Tannery	2
Dairy, Poultry, fishery	5
Chemical	7

Source: Halder S. & Sarkar, 2021

2.3.1 Pollution Concentration analysis

Pollutant concentration was measured for both water and soil to analyze the toxicity level and current status of the study area. (table 3)

Table 3 Concentration of heavy metals for water and soil

Samples	Cd		Cr		Pb	
	Water(mgL^{-1})	Soil($mgkg^{-1}$)	Water(mgL^{-1})	Soil($mgkg^{-1}$)	Water(mgL^{-1})	Soil($mgkg^{-1}$)
1	0.0542	100.564	2.0502	36.97467	0.0421	6.026667
2	0.0754	5.176	1.0622	37.456	0.0852	4.533333

3	0.0857	6.084	1.2791	37.77733	0.0751	6.309333
4	0.104	6.249333	1.4598	40.66933	0.245	5.84
5	0.1172	4.882667	1.5321	42.75733	0.1174	4.04
6	0.1311	4.98	1.8333	44.364	0.219	5.228
7	0.1685	4.424	1.9056	44.364	0.1786	5.376
8	0.1728	5.176	2.1948	46.77333	0.1934	5.036
9	0.1721	4.433333	2.1948	46.61333	0.1523	4.709333
10	0.1623	4.844	2.4357	48.54133	0.1823	4.988
WHO(1996) permissible limit	0.003	0.8	0.05	100	0.01	85

Source: WHO (World Health Organization, 1996)

2.3.2 Water quality standard parameters

Water quality were determined by using the standard water quality parameters suggested by WHO 1996 and ECR 1997 parameters which are given below:

Table 4 Standard water quality parameters

Water quality parameters	Bangladesh standards (mgL^{-1})	WHO guidelines(mgL^{-1})	Methods/ equipments
pH	-	6.5-8.5	pH meter
TDS	1000	-	Multimeter
Salinity	-%0	-	Multimeter
Conductivity	-us/cm	-	Multimeter
Turbidity	10 NTU		Turbidity meter
DO	6	-	Multimeter
BOD	0.2	-	5 days incubation
COD	4	-	Closed reflux method
Nitrate	10	50	UV-VIS
Sulfate	400	-	UV-VIS
Chloride	150-600	-	Titrimetric
Cadmium(Cd)	0.005	0.003	AAS
Chromium(Cr)	0.05	0.05	AAS
Lead (Pb)	0.05	0.01	AAS
Arsenic(As)	0.05	0.01	AAS

Source: WHO (1996), ECR (1997)

2.3.3 Geochemical Index

Geochemical Index (Igeo) is calculated using the following equation:

$$Igeo = log_2\left(\frac{Cn}{1.5Bn}\right) \ldots\ldots\ldots\ldots (1)$$

Where,

Cn = concentration of the enriched metal samples ($mgkg^{-1}$)

Bn = background value of the element ($mgkg^{-1}$)

Factor 1.5 is multiplied to minimize the effect of possible variations in the background values, which is attributed to lithologic variations in the soils. Average Shale Value (ASV) is used as the geochemical background value of soil(Turekian et al., 1961). Muller (1981) proposed the descriptive classes for increasing Igeo value(Attia & Ghrefat, 2013) (**Table 5)**

Table 5 *Classification of Geochemical Index*

Class	Value	Soil Contamination Quality
0	Igeo≤0	Uncontaminated
1	0< Igeo <1	Uncontaminated to moderate
2	1< Igeo <2	Moderate
3	2< Igeo <3	Moderate to heavy
4	3< Igeo <4	Heavy
5	4< Igeo <5	Heavy to Extreme
6	Igeo≥5	Extreme

Source: Muller (1981)

2.3.4 Contamination factor

The contamination factor has been measured using the following equation:

$$\boldsymbol{CF} = \left(\frac{\boldsymbol{C}_{\textbf{Heavymeal}}}{\boldsymbol{C}_{\textbf{Background}}}\right) \ldots\ldots\ldots\ldots\ldots \textbf{(2)}$$

Where,

$C_{\text{Heavy metal}}$ = content of metals in the soil ($mgkg^{-1}$)

$C_{\text{Background}}$ = preindustrial concentration of metal ($mgkg^{-1}$)

The background value of heavy metals was calculated using standard concentration by China National Environmental Monitoring Center (CNEMC). The contamination factor is used to estimate the pollution of the environment by single substances. The sum of contamination factors expresses the value of contamination degree by which we can determine the contamination of the environment(Chen et al., 2004). The degree of contamination defines the quality of the environment is given in **Table (6)**

Table 6 *The Degree of Contamination Characterization Range*

Contamination Factor (CF)	Contamination level
CF<1	Low
1≤CF<3	Moderate
3≤CF<6	Considerable
CF≥6	Very high

Source: Hakanson (1980)

2.3.5 Pollution Load Index

The Pollution Load Index (PLI) can be obtained as concentration Factors (CF). The PLI of the study area is calculated by obtaining the n-root from the n- CFs that was obtained for all the metals.

The PLI value of which is greater than 1 is polluted, whereas <1 indicates no pollution(Harikumar et al., 2009). Generally, Pollution Load Index (PLI) was developed by Tomlinson(1980)(Tomlinson et al., 1980), which is as follows:

$$\boldsymbol{PLI = \sqrt[n]{(CF1 * CF2 * CF3 * \ldots\ldots.* CFN)} \ldots\ldots\ldots\ldots.(3)}$$

Where,

CF= Contamination Factor=($C_{Sample}/C_{Background}$)

PLI= Pollution Load Index

2.3.6 Daily Intake of Heavy Metal

Health risk assessment with heavy metals can be evaluated by calculating Daily Metal Intake (DMI) (BBS, 2015).

$$\boldsymbol{DMI = \frac{VIR * C}{BW} \ldots\ldots\ldots\ldots\ldots\ldots (4)}$$

Here,

DMI= Daily metal intake (mg/person/day)

VIR= Vegetable ingestion rate (kg $person^{-1}day^{-1}$)

C= Individual metal concentration in edible parts of vegetable sample ($mgkg^{-1}$)

BW= Bodyweight (Kg)

How much heavy metal is consumed by a person is estimated by DMI. As heavy metal is poisonous to human health, it plays a significant role in determining the health risk.

Tolerable metal intake values for adults are given in **Table 7**

Table 7 *Tolerable Metal Intake Values for Adults*

Hazard	Tolerable daily intake(TDI) $mgkg^{-1}$ of body weight
Cadmium (Cd)	0.02
Lead (Pb)	0.3
Chromium (Cr)	5

Source: World Health Organization (WHO)/FAO, (May 2007)

3. Results and Discussion

The heavy metal concentration of water and soil samples for each sampling site is represented in the **table 3**. From that table, it can be observed that the Turag river water is extremely polluted with the concentration of heavy metals and the concentration of all the three metals are very high than the WHO suggested permissible values.

The pH ranges from 6-9. pH less than 7 are acidic in nature because of industrial effluents discharged in river. pH ranging from 7.1-9 are basic because of anions derived from the dissolution of limestone from industry effluent. (**Table 8**)

Total Dissolved solids were found ranging from 406-759 mg/L. As per ECR, the preferable limit for TDS in water is 1000 mg/L(table 4). The sampling values for TDS are within the standard range. (**table 8**)

The salinity of the samples were found ranging from 0.2 to 0.8 PPT. Fresh river water salinity is less than 0.5 PPT. Sample 1 and sample 6 is very high in salinity concentration which is 0.6 and 0.8 respectively. These samples are high in salinity because of the industrial effluent discharge containing excessive salts. So the river water is unsuitable for drinking and irrigation purposes. Conductivity of the water samples were found ranging from 828 to 1522 μscm^{-1}. Higher amounts of the conductivity indicating higher amounts of impurities.(**table 8**)

If the turbidity of the water is high then it can affect the aquatic lives living in the stream. Turbidity of the water samples were found ranging from 6.83 to 48.31 FTU. ECR standard for Turbidity is 10 JTU(**table 4**). The value of the water sample is huge compared to the standard value. Turbidity is very high in sample 1 because of the sample was collected from the effluent discharge point.(**table 8**)

The value of the samples were found ranging from 0.3 to 1.9 mg/l. As per ECR, the standard value of DO is 6 mgL^{-1}(**table 4**). The amount of oxygen is much less in the sample water. So aquatic lives won't survive in the river.

The values of BOD are within 3.9 mgL^{-1} to 76.5 mgL^{-1}(**table 8**). The standard values of BOD is 0.2 mgL^{-1}(**Table 4**). BOD values of the water sample exceeds the standard value. The higher the BOD value, the more oxygen is depleted in the oxygen. BOD value is very high for the sample 4 and 6 because excess amount of oxygen is depleted in that point.

The values of COD ranges from 52 mgL^{-1} to 121 mgL^{-1}(**table 8**). The standard value of COD is 4 mgL^{-1} (**Table 4**). COD values for water samples are much higher than the standard value suggested by ECR (1997). The COD values are high because of industrial effluent which are discharged in the Turag river.

Nitrate is an important water quality parameters. The values of nitrate are ranging from 60 mgL^{-1} to 75 mgL^{-1}(**table 8**). The standard value for nitrate is 10 mgL^{-1} (**Table 4**). The samples values of nitrate exceed the standard values. The sample water has high nitrate concentrations.

The values of sulfate are ranging from 20 mgL^{-1} to 22 mgL^{-1}(**table 8**). The standard value of sulfate is 400 mgL^{-1} (Table 4). The values of sulfate for water sample are within standard limits.

The values are ranging from 300 mgL^{-1} to 580 mgL^{-1}(**table 8**). The standard value for chloride is 150-600 mgL^{-1} (**Table 4**). The values of chloride for water samples are within standard limits.

From the soil data, the concentration of Cd ranges from 4.42 $mgkg^{-1}$ to 100.56 $mgkg^{-1}$ where the maximum value is 100.56 $mgkg^{-1}$ for sample 1, as sample 1 was collected from the effluent discharged point, and the minimum value is observed to be 4.42 $mgkg^{-1}$ for sample 7. Soil sample concentration for Cd exceeds the standard concentration according to WHO (1996) (**Table 3**). Cd concentration has the detrimental effect on human health(Ametepey et al., 2018).

Cr concentration for the soil samples range from 48.54 to 36.97 $mgkg^{-1}$. The maximum value is 48.54 $mgkg^{-1}$ for sample 10, and the minimum value is 36.97 $mgkg^{-1}$ for soil sample 1. The values for Cr are within standard limits suggested by WHO (1996) (**Table 3**), where the standard value is 100 $mgkg^{-1}$.

The standard concentration for Pb according to WHO (1996) is 85 $mgkg^{-1}$. The concentrations for Pb for the soil samples range from 6.31 to 4.04 $mgkg^{-1}$. The maximum value is 6.31 $mgkg^{-1}$ for the sample 3 and the minimum value is 4.04 $mgkg^{-1}$ for the sample 5 indicate within the permissible limits set by WHO (1996) (**Table 3)**

3.1 Assessment of soil sample according to Geoaccumulation Index

According to the soil contamination quality, the calculated I_{geo} values for Cd can be considered as heavily contaminated ($4<I_{geo}<5$) and extremely contaminated ($I_{geo}\geq5$) where the value range from 3.29 to 7.80 (**table 9**). For the Cr metal concentration, the values range from -1.48 to -1.87 indicate uncontaminated soil with the toxic metal. Furthermore, the values of I_{geo} for Pb also suggest uncontaminated characteristics of soil. (**Table 9**)

3.2 Assessment of soil sample according to Contamination Factor

From the **table 10**, it can be assumed that the contamination factor varies for different heavy metals. The range of CF for Cd (37.1176-845.076), Cr (1.241-1.629), and Pb (0.164-0.256). CF of Cd for sample 1 is higher as this sample was collected from the effluent discharged point. Moreover, all of the samples for Cd show very high contamination of soil compared to the Cr and Pb. On the contrary, the values for Cr and Pb show moderately, and low contamination of soil, respectively. (**Table 10**)

Table 8 *Characteristics of water samples*

Sample /station No	PH	TDS (mg/L)	Salinity(PPT)	Electrical Conductivity (EC) (µscm^{-1})	Turbidity(FTU)	DO (mgL^{-1})	cl$^-$ (mgL^{-1})	No$_3^-$ (mgL^{-1})	So$_4^{2-}$ (mgL^{-1})	BOD mgL^{-1}	COD mgL^{-1}
1	6.89	619	0.6	1250	48.31	0.6	350	63	20	38.1	87
2	7.14	446	0.4	910	20.87	0.91	330	65	20.1	3.9	62
3	6.76	428	0.4	875	12.89	0.53	300	70	20.3	9.15	52
4	7.09	460	0.5	938	10.35	0.28	400	68	21	68.25	98
5	7.34	453	0.5	924	6.83	1.9	450	60	21	5.7	58
6	8.24	759	0.8	1522	56	0.23	580	75	22	60.6	112
7	7.21	705	0.4	831	12.44	0.89	350	64	20.5	5.1	62
8	7.24	449	0.4	917	18.34	0.43	340	62	21.5	26.1	81
9	6.89	406	0.2	828	20.34	0.55	500	72	20.8	76.5	121
10	7.18	430	0.4	880	22.2	0.28	520	71	20.3	19.65	76
MEAN	7.2±0.1	515.5	0.46	987.5	22.857	0.66	412	67	20.75	31.30	72

Table 9 *Geochemical Index Values with Soil Concentration Classifications*

Heavy metals	ASV	Sample No									
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Cd	0.3	7.80	3.52	3.76	3.79	3.44	3.47	3.29	3.52	3.30	3.43
Cr	90	-1.87	-1.85	-1.84	-1.73	-1.66	-1.61	-1.61	-1.53	-1.53	-1.48
Pb	20	-2.32	-2.73	-2.25	-2.36	-2.89	-2.52	-2.48	-2.57	-2.67	-2.59
Soil Concentration quality	Cd	Extreme	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy
	Cr	Uncontaminated	Uncontaminated	Uncontaminated	Uncontaminated	Uncontaminated	Uncontaminated	Uncontaminated	Uncontaminated	Uncontaminated	Uncontaminated
	Pb	Uncontaminated	Uncontaminated	Uncontaminated	Uncontaminated	Uncontaminated	Uncontaminated	Uncontaminated	Uncontaminated	Uncontaminated	Uncontaminated

Table 10 Contamination Factor of Heavy Metals

Heavy metal(mgkg^{-1})	Background Value(mgkg^{-1})	Sample No									
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Cd	0.119	845.076	43.496	51.126	52.515	41.031	41.849	37.176	43.496	37.255	40.706
Cr	29.8	1.241	1.257	1.268	1.365	1.435	1.489	1.489	1.570	1.564	1.629
Pb	24.6	0.245	0.184	0.256	0.237	0.164	0.213	0.219	0.205	0.191	0.203
CF	Cd	Very high	Very high	Very high	Very high	Very high	Very high	Very high	Very high	Very high	Very high
	Cr	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
	Pb	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low

3.3 Assessment of soil according to Pollution Load Index

Based on the contamination factor and using equation 3, the pollution load index for the three heavy metals was calculated, which has been presented in table **10**.

Table 11 *Pollution Load Index of heavy metals*

Sample No	Cd	Cr	Pb
1	6.3790	0.2450	1.2408
2	2.1599	0.1843	1.2569
3	2.5520	0.2565	1.2677
4	2.5720	0.2374	1.3647
5	2.1300	0.1642	1.4348
6	2.3656	0.2125	1.4887
7	2.2953	0.2185	1.4887
8	2.4087	0.2047	1.5696
9	2.2343	0.1914	1.5642
10	2.3779	0.2028	1.6289
Maximum	6.3790	0.2565	1.6289
Minimum	2.1300	0.1642	1.2408

PLI for Cd and Pb are higher than 1, which indicates the high pollution potential of soil with heavy metals. However, the PLI for the concentration of Cr less than 1 indicates a relatively lower pollution risk.

3.4 Quality Assessment of Vegetable samples

The concentrations for heavy metals are given in table 10 for 10 different crops, which were collected from BARI (2019), Gazipur.

The concentrations of Cd for vegetable samples range from 2.13 to 2.81 mgkg^{-1}. The allowable limit for Cd in plants is 0.02 mgkg^{-1}. So, the sample values are much higher than the standard limits suggested by WHO (1996) (**table 12**). Furthermore, the concentrations of Cr range from 2.98 to 9.37 mgkg^{-1} exceeding standard values (**table 12).** However, the concentrations of Pb are within standard values, and it is lower than 2 mgkg^{-1} by recommended value (**table 12**).

Table 12 *The concentration of heavy metals in vegetables*

Sample No	Cr(mgkg^{-1})	Pb (mgkg^{-1})	Cd (mgkg^{-1})
Red amaranth	6.79	0.893	2.81
Spinach	7.32	0.723	2.39
Cabbage	4.39	0.516	2.47
Cauliflower	9.37	0.612	2.38
Tomato	3.78	0.312	2.32
Chili	2.98	0.298	2.17
Bottlegourd	3.68	0.587	2.61
Potato	3.63	0.592	2.68
Onion	4.38	0.397	2.13
Amaranth	6.42	0.431	2.15
WHO(1996) permissible limit	1.3	2	0.02

3.5 Daily Intake of Heavy Metal

The daily metal intake of the vegetable sample was determined using equation 4 and has been represented in table 13. Vegetable ingestion rate (VIR) was calculated from Bangladesh Bureau of Statistics (2014). Assumed Body weight for man is 70 kg and for woman is 55 kg.

Table 13 *Daily Metal Intake*

Plant Name	VIR Kg/person/day	DMI					
		Cd (mgday^{-1}person^{-1})		Cr (mgday^{-1}person^{-1})		Pb(mgday^{-1}person^{-1})	
		Man	Woman	Man	Woman	Man	Woman
Red amaranth	0.0363	0.001	0.002	0.004	0.004	0.000	0.001
Spinach	0.0363	0.001	0.002	0.004	0.005	0.000	0.000
Cabbage	0.155	0.005	0.007	0.010	0.012	0.001	0.001
Cauliflower	0.155	0.005	0.007	0.021	0.026	0.001	0.002
Tomato	0.1186	0.004	0.005	0.006	0.008	0.001	0.001
Chili	0.0098	0.000	0.000	0.000	0.001	0.000	0.000
Bottlegourd	0.155	0.006	0.007	0.008	0.010	0.001	0.002
Potato	0.0667	0.003	0.003	0.003	0.004	0.001	0.001
Onion	0.0278	0.001	0.001	0.002	0.002	0.000	0.000
Amaranth	0.0363	0.001	0.001	0.003	0.004	0.000	0.000

The values of DMI indicate potential health concerns for the local people and the consumers. Tolerable daily intake for both Man and Woman is 0.02, 5 and 0.3 mgkg^{-1} body weight for Cd, Cr, and Pb, respectively suggested by WHO (2007) (**Table 7**). According to **table 13**, Cadmium (Cd) intake concentration in the vegetables are within the range of WHO/FAO limit ranging from 0.000-0.006 $mgkg^{-1}$ for males and 0.000-0.007 $mgkg^{-1}$ for females. Chromium (Cr) ingestion rate concentration in vegetables ranges from 0.000-0.021 $mgkg^{-1}$ for males and 0.001-0.026 $mgkg^{-1}$ are presented in **table 13** and less than recommended by WHO/FAO (2007)(**Table 7**). At last, Lead (Pb) intake rate is 0.000-0.001 $mgkg^{-1}$, 0.000-0.002 $mgkg^{-1}$ for men and women, respectively, and the ingestion rate is also within the permissible limit (**Table 7**).

Conclusion

In this paper, the pollution potential of heavy metals in water and soil has been described, and the daily metal intake of vegetables grown in that area has been assessed. From the observed physicochemical properties and calculated value of Water Quality Index, it can be concluded that the Turag river water is extremely polluted due to discharge of industrial effluents containing heavy metals. Not only the river water in Turag is gradually becoming destructive but also it affects through soil, agricultural land and mostly to the living habitants.

From the calculated data we found, the order of heavy metals is Cd>Cr>Pb respectively which indicates Cd have highest concentration among these three heavy metals.

The calculation of $I_{geo,}$ CF, and PLI of soil samples indicates the ecological risk and health risks of Tongi industrial area. From the experimental data of the geochemical index, it shows extremely contaminated soil for cadmium. Moreover, the contamination factor is very high for cadmium which indicates that the soil is highly contaminated by cadmium concentration. The high concentration of cadmium concentration might be due to the industrial effluents containing the acute amount of the cadmium discharging to the river. However, lower values for chromium, and lead in soil indicate moderately and low contamination of soil, respectively.

From the calculation, PLI (pollution load index) is higher than 1 for all of the soil sample which indicates that the soil around Turag river is highly polluted with the heavy metal concentration with cadmium and lead. The highest value for PLI was found to be 6.397 for cadmium, which exceeded the standard value.

Consequently, this pollution with heavy metals will affect the people. Lead and cadmium has carcinogenic effect on human health associated with kidney and bone damage. Though, daily metal intake is within the permissible ingestion rate, excessive consumption of these metals can cause adverse health impacts. Women are the most vulnerable to soil pollution, and men are also susceptible to potential pollution risks(Ametepey et al., 2018). A further detailed study with more heavy metals is recommended on aquatic ecosystems, soil, and residents of the study area in order to evaluate the total pollution scenario.

This study suggests that as per our observation, the effluents from the industries discharged directly to the Turag river without any proper treatment. Definite measures should be taken against it to minimize the overall pollution scenario. Also heavy metals such as As, Mg, Cu, Fe, Ni, Hg, K etc. are needed to be measured to complete the total assessment scenario.

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