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Quantification of heavy metals concentration and assessment of Ecological health risk in roadside agricultural land of Dhaka-Aricha highway, Bangladesh

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Abstract

The study quantified the heavy metal contamination, their sources and assessed the environmental risk of roadside agricultural land. Forty-five (45) surface soil samples were collected from fifteen (15) sampling points in Dhaka-Aricha highway (Hemayetpur to Uthali) and examined of heavy metals (Pb, Cd, Cu, Zn, Mn, Fe) using the Atomic Absorption Spectrophotometry (AAS) technique. The six heavy metals of the soil samples were measured in the order of Fe>Mn>Pb>Zn>Cu>Cd. The heavy metal cluster analysis (CA) indicated the common origins and accumulation pathways of Zn, Mn, and Fe from vehicular emission in the roadside soils. CA analysis of sampling sites indicates all three clusters have similar characteristics of pollution from road traffic and industrial settings. Moreover, pollution indices are observed by contamination factor (CF) decrease in order of Cd > Pb > Cu > Zn > Mn > Fe. The geo-accumulation index pattern shows the heavy metal concentrations following the order: Pb > Cd > Cu > Zn > Mn > Fe. Pollution load index (PLI) of heavy metals were increased on the order of Fe < Mn < Zn < Pb < Cu < Cd. All the indexes for the metal under investigation were within the range of low to moderately pollute. The environmental health risk level was estimated based on chronic daily intake (CDI), hazard quotient (HQ), and hazard index (HI) for both adults and children. However, the heavy metals hazard index (HI) exceeded the safe level. The outcome may be useful for observing additional increments of substantial, heavy metal focuses in surface soils along highways.

Keywords: *Roadside agricultural land, transportation, emission of vehicles, heavy metal, pollution level, health risk.*

1. Introduction

Dhaka, the fastest-growing megacity globally, has the worst environmental situation. Pollution has gone too far, slowly destroying the ecosystems. High population density and automobile emissions, brickfields are major industrial pollutants that harm the social and ecological system (Chowdhury 2006; Islam 2014). The situation is worse at major points like bus stops. Vehicle emissions harm key highways like Dhaka Aricha, causing industrial pollution and environmental disturbance. Heavy metal poisoning of aquatic habitats has garnered great attention due to its toxicity (Arnason and Fletcher 2003). Heavy metals in environmental compartments like aquatic soils can harm human health through aquatic medium transfer and uptake by living components, therefore entering the food chain (Varol and Sen 2012). Soils are ecologically sensitive components of aquatic ecosystems that act as a reservoir for toxins and help sustain trophic status (Singh et al. 2005 a, b).

Highway plays a major role in building economic development in the country and has resulted in heavy metals pollution in the surrounding (Liu et al. 2006). Road traffic is a major polluter of air, noise, and land (Zechmeister et al. 2005).

The contribution of automobiles and road transport to global pollution emissions is increasing (Viard et al. 2004). Traffic activities can lead to heavy metals in roadside agricultural land and potentially affect public health and the environment. However, sources of heavy metals in roadside soil include fuel tanks, engines, other vehicle components, catalytic converters, tires, brake pads, and road surface materials (Mukta et al. 2020; Atiemo et al. 2011; Ite et al. 2014). Increased traffic movements lead to the deposition of heavy metals in roadside surface soil due to rapid industrialization patterns associated with urbanization (Charlesworth et al. 2011; Wei and Yang 2010). Accumulation of heavy metals in roadside surface soil can effectively cause severe health threats through transportation (Shi et al. 2011).

Heavy metals are accumulated in roadside surface soils due to traffic activities. High metal concentrations in roadside surface soil indicate heavy metal accumulation due to atmospheric deposition and runoff (Xuedong Yan et al. 2013). Heavy metals directly affect public health by entering the body through the soil and dermal contact, breathing, and food chain (Zhang et al. 2012). Ordinarily, high concentrations of heavy metals in soil result in health-related issues influencing mental health, blood pressure, cardiovascular, renal, and regenerative frameworks (Wang et al. 2007). However, plants' uptake of heavy metals and their subsequent accumulation to the

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animal and human body through the food chain create potential threats (Zhang et al. 2012). Moreover, heavy metals are significant sources of soil pollution (Hinojosa et al. 2004). It is important to investigate their effects on soil microorganisms functioning in ecosystems exposed to long-term contamination by heavy metals (Wang et al. 2007).

Dhaka-Aricha highway connects the northwestern and northern regions of Bangladesh with Dhaka. It runs for 75.4 kilometers from Amin Bazar Bridge to Aricha Ghat (Hoque et al. 2007; Yazdi et al. 2015). Traffic load and industrial activity create a pollution hotspot zone surrounding highways emissions from high transportation density diffuse around agricultural land and wetland. The absorption and accumulation of heavy metals in plant tissue depend on temperature, moisture, organic matter, pH, and nutrient availability (Maragkidou et al. 2017). It was found that uptake and accumulation of Cd, Zn, Cr, and Mn in Beta vulgaris (Spinach) were higher during the summer season (Sharma et al. 2007). In contrast, Cu, Ni, and Pb accumulated more during the winter season (Sharma et al. 2007). Heavy metals pollute cultivated soils, posing a risk to the quality and protection of agricultural goods (Barakat et al. 2019). Heavy metals are persistent, which enter the environment from natural and anthropogenic sources and create significant potential risks for humans and the entire ecosystem (Jiang et al. 2017). Presently, soil pollution by heavy metals is an increasing environmental concern due to its potential toxicity and detrimental effects on the environment and public health (Heberer 2002). Pollution of agricultural soils with hazardous metals creates severe environmental health hazards due to the overall metal cycle in nature (Mamat et al. 2016). According to Nabuloa et al. (2006), roadside plants can absorb significant levels of trace metals, posing a serious threat to human health and the environment. Therefore, assessing the human health risks of heavy metals in soils has become a hotspot in environmental research (Eziz et al. 2018).

Monitoring of heavy metal release from anthropogenic sources is usually carried out by the Contamination Factor (CF), Pollution Load Index (PLI), and Index of Geo-accumulation (Igeo) were calculated for showing the severity of pollution level at the Dhaka-Aricha highway. The distribution of the elemental composition of the continental crust has been used by CF (Wedepohl 1995). The pollution load index (PLI) acts as an integrated approach that assesses the soil's quality (Tomlison et al. 1980). The degree of contamination from the trace metals could be assessed by determining the geo-accumulation index (Igeo) proposed by Muller (1969). To estimate environmental health risk using chronic daily intake (CDI), hazard quotient (HQ), and hazard index (HI) for both adults and children (USEPA 2011; Qing et al. 2015). The present study focuses on quantifying heavy metal contamination and assessing the environmental risk of roadside agricultural land of Dhaka-Aricha highway from Hemayetpur to Uthali as a baseline for future heavy metal monitoring in Bangladesh. Major objectives of the present study were (i) to quantify the heavy metal (Pb, Cd, Cu, Zn, Mn, Fe) concentrations in agricultural surface soils along the Dhaka Aricha highway; (ii) to determine potential pollution indices using contamination factor (CF), geo-accumulation index (Igeo), and pollution load index (PLI); and (iii) to estimate environmental health risk using chronic daily intake (CDI), hazard quotient (HQ), and hazard index (HI) for both adults and children. The present study would offer baseline data on heavy metal contamination, sources and environmental health risk of highway agricultural surface soils.

2. Materials and method

2.1. Feature of the Study area

The study was conducted along the Dhaka-Aricha highway (54.04 km), which ranges between 23º47′39.58″ N to 23º50′38.15″ N and 90º16′31.26″ E to 89º49′14.31″ E (Fig 1). The study area near Savar, 17 km north of the Dhaka center, runs northward. The study area was selected because it links with Dhaka City with comparatively high traffic density and has industrial influences. This highway carries, on average, 9000 motor vehicles per day. Numerous brickfields surround the study area, and near the Amin Bazar, the landfill area is adjacent to Gabtoli. The Amin Bazar area is the transition point of Dhaka city; the largest bus stand acting as the entry and exit points of the City. In northeastern side there have industrial influences, brickfields influence, and landfill influences. On the other hand, in the southwestern side of the highway, there is no highway, sub-highway link and industries and landfill influences that are connected to the Dhaka-Aricha highway. Thus to get the actual pollution map, we considered the sampling in parallel. The average elevation is 26.5 ft. above sea level. This area is perennially inundated during monsoon months (June to August) and roadside runoff. The geology of this area is the reddish-brown to brownish-red, mottled, sticky, and compact Madhupur Clay Residuum of the Pleistocene age, underlain by Plio-Pleistocene Dupi Tila sandstone formation (Maitra and Akhter 2011).

2.2. Sample collection

The soil samples were collected along the roadside surface soil, situated in the Dhaka-Manikganj district. A total of 45 soil samples were collected from 15 sampling points of the Dhaka-Aricha highway (Hemayetpur to Shibalaya) during the dry season (January to February 2020). The samples were scraped from top to bottom about 0-15 cm from the agricultural land with the help of an auger. The sample was kept separately on paper, and the contents of each paper were mixed thoroughly. The gravels, pebbles, plant roots, leaves, etc., were picked up and removed from the collected samples. Finally, ~1kg of soil sample was collected and placed in sealed polyethylene bags and labelled, including the data collection and sampling location.

2.3. Sample preparation

The collected soil samples were homogeneously mixed up and directly shifted to the Department of Environmental Science and Resource Management laboratory, Mawlana Bhashani Science and Technology University, Tangail-1902, Bangladesh. Unwanted portions like plant roots, stones, or other debris were removed. Then the samples were then air-dried at room temperature, mixed thoroughly, crushed, sieved with a 20-mesh sieve, preserved in polyethylene bags, and labelled the soil sample. Then 10 g of soil sample was dried at 105º C for 72 hours in the oven for subsequent laboratory analyses in the Atomic Energy Commission of Bangladesh.

2.4. Sample analysis

For the quantitative analysis of Pb, Cd, Cu, Zn, Fe, and Mn, at first, 1 g of the soil samples were taken in a 100 ml conical flask and added 10 ml concentrate nitric acid, 5 ml perchloric acid, and then added 2.5 ml hydrofluoric acid. Then the solution was shaken for 30 minutes on a mechanical shaker. After shaking, the solution was heated on a hot plate at 90º C for half an hour. Then the solution was cooled at room temperature, and 5 ml de-ionized water was added to it. Subsequently, the solution was filtered with double filter paper in a 50ml volumetric flask. The filtering solution was 25ml, then added 25ml de-ionized water. Only for Fe and Mn, 12.5ml calcium solution was added after filtering the solution.

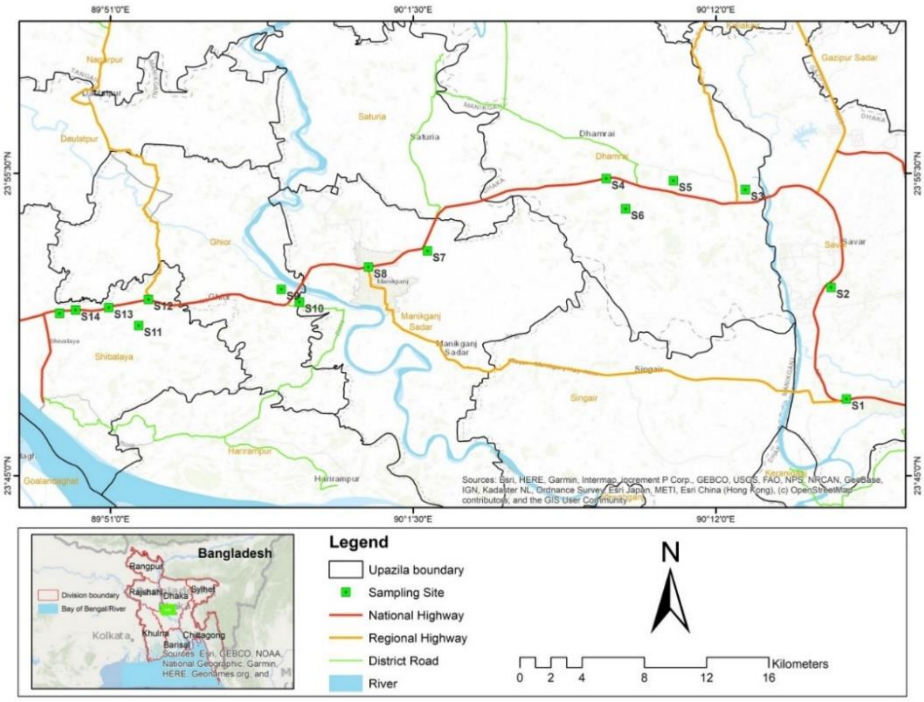

Fig 1. Map showing the sampling locations of the agricultural soils nearly Dhaka-Aricha highway.

2.5 Pollution Indices calculation

A pollution index is a powerful tool for ecological geochemistry assessment. In this study, the Contamination Factor (CF), Pollution Load Index (PLI), and Index of Geo-accumulation (Igeo) were calculated for showing the severity of pollution level at the Dhaka-Aricha highway.

2.5.1. Contamination Factor

The contamination factor (CF) is the ratio obtained by dividing each metal concentration in the soil by the baseline or background value (Hakanson 1980).

$$C_f^i = \frac{C_{heavy\ metal}}{C_{background}}$$

Here, CF is the contamination factor; $C_{heavy\ metal}$ is the concentration of heavy metals; $C_{background}$ is the background concentration of heavy metals and in this study the distribution of the elemental composition of the continental crust has been used (Wedepohl 1995). The contamination factor is classified into four grades for monitoring the pollution of one metal over time. The contamination levels can be classified based on their intensities on a scale ranging from 1 to 6. They were classified as 0 = none, 1 = none to medium, 2 = moderate, 3 = moderately to strong, 4 = strongly polluted, 5 = strong to very strong, and 6 = very strong (Muller 1969).

2.5.2. The pollution load index (PLI)

Pollution load index acts as an integrated approach that assesses the quality of the soil. Pollution load index was measured by using the following formula (Tomlison et al. 1980):

$$PLI = \left((CF_1 \times CF_2 \times CF_3 \times \dots \dots \dots \times CF_n)^{1/n}\right)$$

Where CF is the contamination factor for every metal and n is the number of several heavy metals under study. The overall toxicity status of heavy metals in soil may be assessed from the Pollution load index (PLI) calculation.

2.5.3. Index of Geo-accumulation (Igeo)

The degree of contamination from the trace metals could be assessed by determining the geo-accumulation index (Igeo) proposed by Muller (1969). To characterize the level of pollution in the road side soil, geo-accumulation index (Igeo) values were calculated using the equation:

$$Igeo=Log_2 (C_n/1.5B_n)$$

Cn is the measured metal concentration in the soil, and B_n is the geochemical background value of element n in the background sample (Wedepohl 1995). Factor 1.5 is introduced to minimize possible variations in the background values attributed to lithologic variations in the soils (Muller 1969). Muller (1969) proposed the descriptive classes for increasing Igeo levels can be classified based on their intensities on a scale ranging from 1 to 6. They were classified as 0 = none, 1 = unpolluted to moderately polluted, 2 = moderate, 3 = moderately to strong, 4 = strongly polluted, 5 = strong to extreme, and 6 = extreme (Muller 1969).

2.6. Human health risk assessment of heavy metal

2.6.1. Chronic Daily Intake (CDI)

Dermal contact is an important exposure pathway of heavy metals from soils. Chronic daily intake (CDI) via dermal contact is appropriately assessed using site-specific information for the population at risk. The mathematical equation is for assessing heavy metal intake through dermal contact exposure pathway to metals in soils (USEPA 2011; Qing et al. 2015) through the following equation:

$$CDI_{dermal-soil} = \frac{CS \times SA \times AF \times ABS \times IRS \times EF \times ED}{BW \ \times AT} \times CF$$

Where, CDI=chronic daily intake of heavy metals from soil through dermal contact, mg/kg; CS=heavy metal concentration in soil, mg/kg; SA=exposure skin surface area available for contact, 5700 cm^2 for adult and 1600 cm^2 for children (USEPA 2011); AF=soil-to-skin adherence factor, 0.7 mg/cm^2 for adult and 0.2 mg/cm^2 for children (USEPA 2011); ABS=dermal absorption fraction, 0.01 for adult and 0.001 for children (USEPA 2011); IRS= ingestion rate of soil, 100 and 200 mgd for adult and children respectively (USEPA 2011); EF=exposure frequency, 350 days/year (USEPA 2011); ED=exposure duration, 30 years for adult and 6 years for children (USEPA 2011); BW=body weight, 70 kg for adult male, 65 kg for adult female and 15 kg for children; AT=averaging time for non-carcinogens, 365 × ED (USEPA 2011); CF=units conversion factor, 10^{-6} kg/mg (USEPA 2002).

2.6.2. Hazard Quotient (HQ)

HQ for dermal exposure route was calculated using the following equation (Qing et al. 2015):

$$THQ_{dermal-soil} = \frac{CDI}{RFD}$$

Here, RFD for Pb, Cd, Cu, Zn, and Fe is 5.25E-04, 5.00E-04, 1.20E-05, 0.06, and 0.7 mg/kg/day, respectively (USEPA 2002).

2.6.3. Hazard Index (HI)

Assuming additive effect, the hazard index (HI) for dermal exposure route was calculated using the following equation:

$$HI_{dermal-soil} = \sum THQ_n$$

$= \text{THQ element1} + \text{THQ element 2} + \text{.........} + \text{THQ}$ elements n…

3. Results and discussion

3.1. Heavy metal concentration in roadside soil

The heavy metals concentration (mg/kg) in the roadside agricultural soil at Dhaka-Aricha highway is presented in Table 1. The roadside agricultural soil exhibited distinct variations in the levels of heavy metals with concentration ranges of 2.65-81.95, 0.7-3.5, 11.55-21.75, 3.85-56.1, 29.7-120.5, and 122.9-355.1 mg/kg, for Pb, Cd, Cu, Zn, Mn, and Fe, respectively. The Pb, Cd, Cu, Zn, Mn, and Fe concentrations were 19.8, 1.66, 15.91, 27.36, 56.02, and 218.56mg/kg, respectively. Moreover, Pb, Cu, and Cd concentrations were above the corresponding reference value, indicating heavy metal enrichment of roadside agricultural land from transportation activities. However, in this study mean concentration of Pb was 1.2 times higher than the world standard. The concentration of Cd was16.6 times, and the concentration of Cu was 1.1 times higher than the world standard. The spatial distribution of heavy metals was done by ESRI ArcGIS 10, the highest concentration of Pb (81.95 mg/kg), Cd (3.5 mg/kg) and Cu (21 mg/kg) were found at northeaster side at Dhamrai (S3), Dautia (S5) and Borongail (S12) might have attributed from transportation, industrial discharges, roadside vehicular dust, landfill influence, brickfields influences, construction activities etc. are great concern for the sources of heavy metal pollution (Fig 2). On the other hand, there are no other highway, sub highway link and no industrial. Brickfields, and landfill influence at the southwestern part. There is mostly pond, agricultural land, barren land is found alongside of the highway. Therefore, the maximum vehicles are passed through the northeast line and divided into sub-highway.

Table 1. Heavy metal concentrations (mg/kg) in roadside agricultural soil at Dhaka-Aricha highway

Sampling stations	Heavy metals					
	Pb	Cd	Cu	Zn	Mn	Fe
Hemayetpur	21		13.75	24.45	37.4	226.21
Savar	14.5		13.4	56.1	42.75	182.65
Dhamrai	81.95		14.45	41.2	36.95	167.06
Suti para	10.55		11.55	11.05	52.4	222.83
Dautia	55.94	3.5	14.4	26.73	47.65	210.46
Borobaria	15.45	0.8	14.8	37.2	56	212.54
Jaigir	8.2	0.7	19.95	27.15	69.15	252.73
Manikganj	7.55		19.3	32.5	81.85	355.11
Tora Setu	12.2		17.1	19.25	65.65	262.85
Baniajuri	13.5		17.45	23.95	45.55	178.31
Mohadebpur	2.65		18.75	29	61	204.99
Borongail	8.4		21.75	15.9	120.5	312.68
Falsatia	8.55		17.55	18.75	48.1	203.22
Tepra	13.95		12.05	43.4	45.65	164
Uthali	22.4		12.5	3.85	29.7	122.86
World standard	17	0.1	14.3	52	527	30890

3.2. Sources of heavy metals

Pearson's correlation coefficient analysis (CCA) and cluster analysis (CA) were used to identify the sources of heavy metals on roadside soils (Suryawanshi et al. 2016; Jiang et al. 2017; Zglobicki et al. 2018; Jose and Srimuruganandam 2020). The CCA results revealed significant positive correlations between most studied heavy metals (Table 2). We found significant positive correlations (at $p < 0.01$) between Mn and Cu (0.782), Fe and Mn (0.829), and Cu and Fe (0.677), their sources associated with industrial and vehicular emissions (Zakir et al. 2014; Suryawanshi et al. 2016; Jiang et al. 2017; Zhao et al. 2019). On the other hand, Fe showed a significant ($p < 0.05$) positive correlation with Cu (0.68), indicating that the source of Fe is possibly from industrial activities.

The CA among the heavy metals results is presented in figures 3 and 4, where both of the heavy metals and sampling sites are grouped into three major clusters. However, cluster 1 was formed with Pb, Cu. In contrast, cluster 2 was formed with Zn, Mn, and cluster 3 was formed with Fe, indicating their common origins and accumulation pathways from vehicular emission in the roadside soils of the study area.

On the other hand, while considering CA analysis among sampling sites, cluster 1 was constructed with eleven sampling sites (1, 2, 4, 5, 6, 7, 9, 10, 11, 13, and 14), the cluster 2 was formed with two sampling sites (3 and 15), and the cluster 3 was developed with two sampling sites (8 and 12) (Fig 4). The cluster analysis of sampling sites, cluster 1, cluster 2, and cluster 3, indicating the similar characteristic features of pollution, might be related to the road traffic activities and industrial settings.

Table 2. Pearson correlation coefficients (r) of heavy metals from roadside soils of Dhaka-Aricha highway

Heavy Metals	Pb	Cu	Zn	Mn	Fe
Pb	1				
Cu	-0.339	1			
Zn	0.216	-0.138	1		
Mn	-0.394	0.782**	-0.154	1	
Fe	-0.346	0.677**	-0.091	0.829**	1

**. Correlation is significant at the 0.01 level (2-tailed).

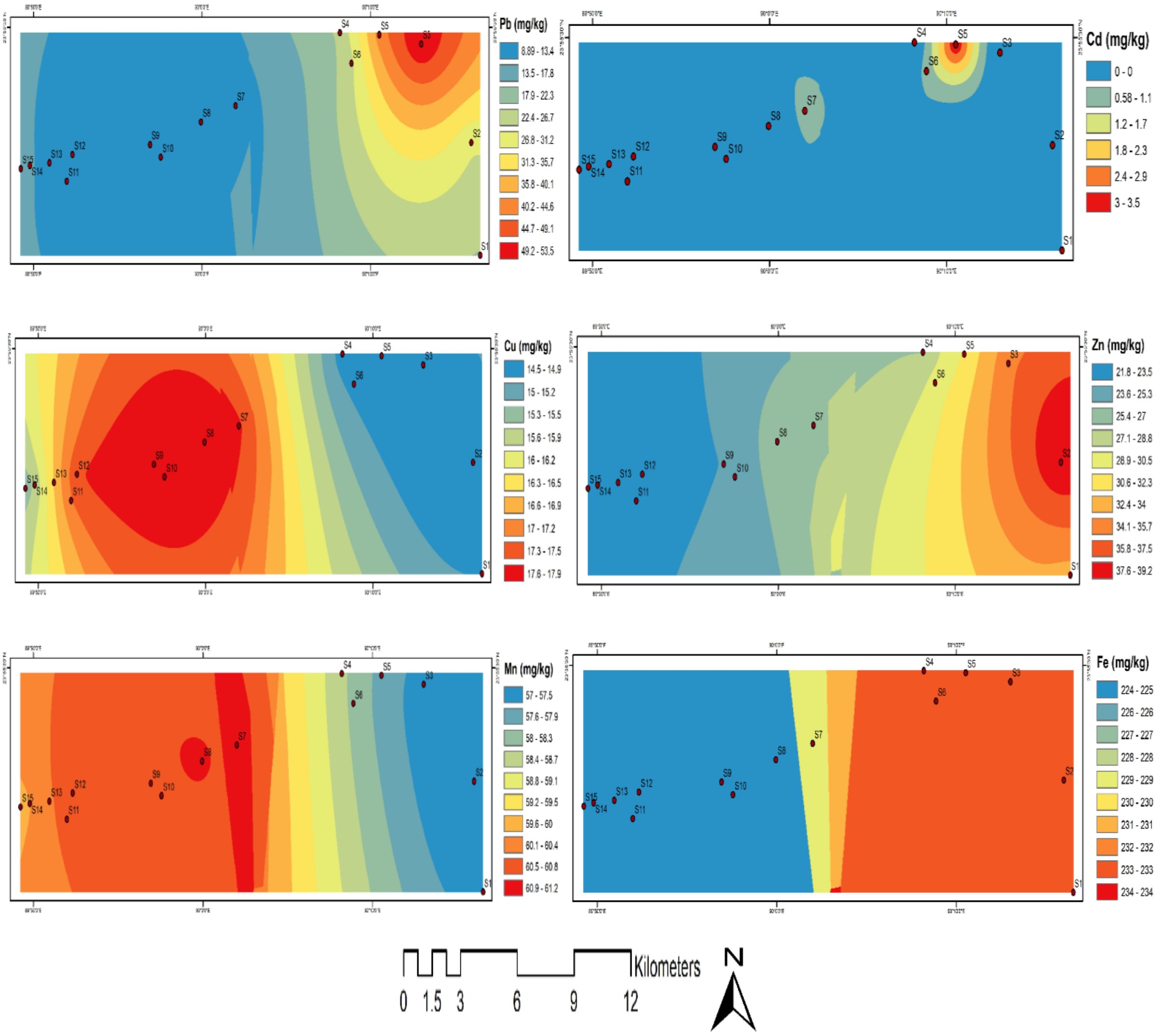

Fig 2. Spatial distribution of heavy metals on roadside soil of Dhaka-Aricha highway.

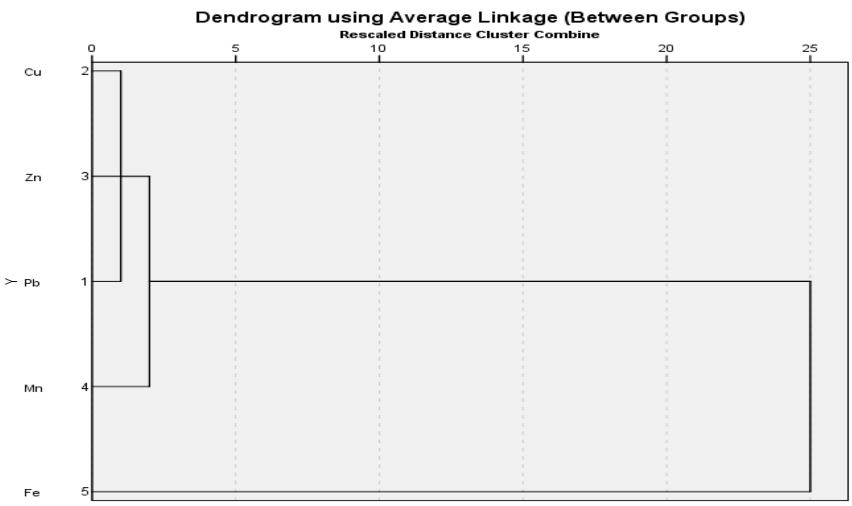

Fig 3. Cluster analysis of heavy metal on roadside soils from the study area

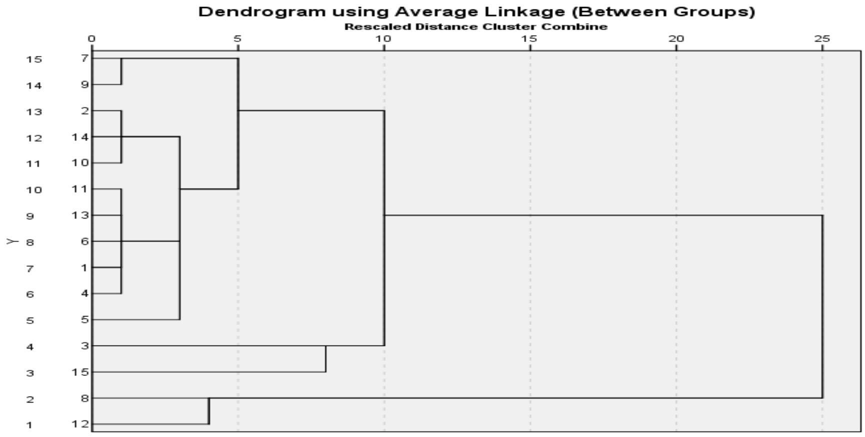

Fig 4. Cluster analysis of sampling points on roadside soils from the study area.

3.3. Pollution indices

In the present study, Contamination Factor (CF), Pollution Load Index (PLI), Index of Geo-accumulation (Igeo) have been used to assess the heavy metal contamination level in the soil samples from the roadside agricultural land of the Dhaka-Aricha highway.

3.3.1. Contamination Factor

The CF for Pb, Cd, Cu, Zn, Mn and Fe were 1.16±1.24, 16.67±15.88, 1.1±0.22, 0.53±0.25, 0.11±0.04 and 0.007±0.002, respectively, and average concentrations were determined as 1.16, 16.67, 1.1, 0.53, 0.11 and 0.007, respectively (Table 3). According to the CF classification (Hakanson 1980), the average calculated value of the index was classed as low pollution to very strong pollution. Pb and Cd were classed as very strongly polluted, especially in Dautia, Dhamrai, Borobaria and Jaigir sampling stations. Cd and Pb's highest CF was found in Dautia and Dhamrai, where transportation, excessive crowded, frequent squalors, roadside vendors, market, residential, construction activities, and dustbin are a great concern for the sources of heavy metal pollution. Based on the pollution index, the order of the level of heavy metal in soil samples was arranged as follows: Cd>Pb>Cu>Zn>Mn>Fe. Eziz et al. (2018) reported that the contamination factor of Pb and Cu were 4.97 and 2.74 in agricultural soils of Yanqi Basin, China which was higher than the present study. Ahmed et al. (2019) reported that the contamination factor of Fe was 2.1 at Amin Bazar, which also higher than the current study.

Table 3. Contamination factor of heavy metals in roadside soil of Dhaka-Aricha highway.

Sampling Points	Contamination Factor (CF)					
	Pb	**Cd**	**Cu**	**Zn**	**Mn**	**Fe**
Hemayetpur	1.23		0.96	0.47	0.07	0.007
Savar	0.85		0.93	1.07	0.08	0.005
Dhamrai	**4.82**		1.01	0.79	0.07	0.005
Suti para	0.62		0.80	0.21	0.09	0.007
Dautia	**3.29**	35	1.00	0.51	0.09	0.006
Borobaria	0.90	8	1.03	0.71	0.10	0.006
Jaigir	0.48	7	1.39	0.52	0.13	0.008
Manikganj	0.44		1.34	0.62	0.15	0.011
Tora Setu	0.71		1.19	0.37	0.12	0.008
Baniajuri	0.79		1.22	0.46	0.08	0.005
Mohadebpur	0.15		1.31	0.55	0.11	0.006
Borongail	0.49		1.52	0.30	0.22	0.010
Falsatia	0.50		1.22	0.36	0.09	0.006
Tepra	0.82		0.84	0.83	0.08	0.005
Uthali	1.31		0.87	0.07	0.05	0.003

3.3.2. Pollution load index (PLI)

In this study, PLI values ranged from 0.00000378 to 3.55, which is classed as high-level pollution (Table 4) based on the related classification. The pollution load index for Pb, Cd, Cu, Zn, Mn, and Fe were 0.6, 3.5, 1.2, 0.1, 0.003, and 0.000004 found in the roadside agricultural soil. Cd's highest PLI was found, which deteriorates the sampling site quality. The calculated PLI values were in the following order Fe>Mn>Zn>Pd>Cu>Cd, which is classed as low to a high level of pollution. Bastami et al. (2014) reported that the Cd was the highest pollution load index, indicating a very high pollution level and Cu, Zn, Mn, and Fe.

3.3.3. Index of geo-accumulation ($_{Igeo}$)

In the present study, the geo-accumulation index was used to evaluate contamination levels of heavy metals in roadside soil samples. The results of Igeo are demonstrated in Table 4. The mean values of Igeo for Pb, Cd, Cu, Zn, Mn, and Fe in roadside soil samples were 2.1, 3.3, 0.2, 0.1, 0.02, 0.001, respectively. According to Muller (1969) and concerning the results presented, Igeo values for Pb, Cd, Cu, Zn, Mn, and Fe were determined as unpolluted to extremely polluting. In terms of the Muller classification, the pattern of average heavy metal concentrations in the roadside soil was ranked in the following order: Cd>Pb>Cu>Zn>Fe>Mn. Results show that concentrations of Cd and Pb were higher among the studied elements. However, the maximum geo-accumulation (Igeo) values for Cd (7.4) and Pb (7.02) were found in Dautia, suggesting that this sampling site is extremely contaminated with heavy metals, especially Cd and Pb, as a result of high traffic and industrial activity along the Dhaka-Aricha highway.

3.4. Health risk assessment

3.4.1. Chronic Daily Intake (CDI)

The calculated CDI value for an adult of each metal was computed, and the results are presented in Table 5. CDI analysis for adult and children for heavy metals were found within the safe limit. Eziz et al. (2018) reported that their values are less than 1in the agricultural soils of Yanqi Basin, Silk Road Economic Belt, China.

Table 4. The geo-accumulation index and pollution load index of heavy metals on roadside soil at the Dhaka-Aricha highway.

Sampling points	Geoaccumulation index of heavy metal					
	Pb	Cd	Cu	Zn	Mn	Fe
Hemayetpur	0.24788		0.19295	0.09435	0.01424	0.00147
Savar	5.29975		0.18804	0.21649	0.01628	0.00119
Dhamrai	1.40096		0.20277	0.15899	0.01407	0.00109
Suti para	0.68227		0.16208	0.04264	0.01995	0.00145
Dautia	7.42842	7.02333	0.20207	0.10315	0.01814	0.00137
Borobaria	0.18844	1.60533	0.20768	0.14355	0.02132	0.00138
Jaigir	3.94259	1.40467	0.27995	0.10477	0.02633	0.00164
Manikganj	0.1735		0.27083	0.12542	0.03117	0.00231
Tora Setu	6.37081		0.23996	0.07429	0.025	0.00171
Baniajuri	0.19199		0.24487	0.09242	0.01734	0.00116
Mohadebpur	1.25057		0.26311	0.11191	0.02323	0.00133
Borongail	0.60856		0.30521	0.06136	0.04588	0.00203
Falsatia	1.2729		0.24627	0.07236	0.01832	0.00132
Tepra	0.99292		0.16909	0.16748	0.01738	0.00107
Uthali	2.04394		0.17541	0.01486	0.01131	0.0008
PLI	0.60266	3.5465	1.249552	0.136552	0.003125	0.00000378

Table 5. Chronic daily intake of heavy metals from roadside soil for adults and children of the study area.

Sampling points	Chronic Daily Intake of heavy metals for adult					
	Pb	**Cd**	**Cu**	**Zn**	**Mn**	**Fe**
Hemayetpur	1.15E-03		7.38E-04	1.34E-03	2.04E-03	1.24E-02
Savar	7.93E-04		7.32E-04	3.07E-03	2.34E-03	9.98E-03
Dhamrai	4.48E-03		7.90E-04	2.25E-03	2.02E-03	9.13E-03
Suti para	5.77E-04		6.31E-04	6.04E-04	2.86E-03	1.22E-02
Dautia	3.06E-03	1.91E-04	7.87E-04	1.46E-03	2.60E-03	1.15E-02
Borobaria	8.44E-04	4.37E-05	8.09E-04	2.03E-03	3.06E-03	1.16E-02
Jaigir	4.48E-04	3.83E-05	1.09E-03	1.48E-03	3.78E-03	1.38E-02
Manikganj	4.13E-04		1.06E-03	1.78E-03	4.47E-03	1.94E-02
Tora Setu	6.67E-04		9.35E-04	1.05E-03	3.59E-03	1.44E-02
Baniajuri	7.38E-04		9.54E-04	1.31E-03	2.49E-03	9.75E-03
Mohadebpur	1.45E-04		1.03E-03	1.59E-03	3.33E-03	1.12E-02
Borongail	4.59E-04		1.19E-03	8.69E-04	6.59E-03	1.71E-02
Falsatia	4.67E-04		9.59E-04	1.02E-03	2.63E-03	1.11E-02
Tepra	7.62E-04		6.59E-04	2.37E-03	2.50E-03	8.96E-03
Uthali	1.22E-03		6.83E-04	2.10E-04	1.62E-03	6.72E-03
	Chronic Daily Intake of heavy metals for children					
Hemayetpur	8.59E-05		5.52E-05	1.00E-04	1.53E-04	9.24E-04
Savar	5.93E-05		5.48E-05	2.30E-04	1.75E-04	7.46E-04
Dhamrai	3.35E-04		5.91E-05	1.69E-04	1.51E-04	6.83E-04
Suti para	4.32E-05		4.73E-05	4.52E-05	2.14E-04	9.11E-04
Dautia	2.29E-04	1.43E-05	5.89E-05	1.09E-04	1.95E-04	8.60E-04
Borobaria	6.32E-05	3.27E-06	6.06E-05	1.52E-04	2.29E-04	8.69E-04
Jaigir	3.35E-05	2.86E-06	8.16E-05	1.11E-04	2.83E-04	1.03E-03
Manikganj	3.09E-05		7.90E-05	1.33E-04	3.35E-04	1.45E-03
Tora Setu	4.99E-05		7.00E-05	7.88E-05	2.69E-04	1.07E-03
Baniajuri	5.52E-05		7.14E-05	9.80E-05	1.86E-04	7.29E-04
Mohadebpur	1.08E-05		7.67E-05	1.19E-04	2.50E-04	8.38E-04
Borongail	3.44E-05		8.90E-05	6.51E-05	4.93E-04	1.28E-03
Falsatia	3.50E-05		7.18E-05	7.67E-05	1.97E-04	8.30E-04
Tepra	5.71E-05		4.93E-05	1.78E-04	1.87E-04	6.70E-04
Uthali	9.16E-05		5.11E-05	1.58E-05	1.22E-04	5.02E-04

3.4.2. Hazard Quotient (HQ)

The calculated HQ value for an adult of each metal was computed, and the results are presented in Table 6. The HQ analysis of lead (8.53E+00) showed the highest value at Dhamrai. Furthermore, the highest HQ value for Mn (3.58E+00) was identified at Borongail. Both results indicate that roadside soil from Dhamrai and Brongail is strongly hazardous for adults. Eziz et al. (2018) reported that their values are less than 1 in agricultural soils of Yanqi Basin, Silk Road Economic Belt, China, which indicated that unpolluted to moderately pollute. However, calculated HQ values for children of each metal within the safe limit indicate no potential non-carcinogenic health risk of heavy metals for children from roadside agricultural soils of the study area.

Table 6. Hazard Quotient (HQ) of heavy metals on roadside soil for adult and children at Dhaka Aricha highway.

Sampling points	Hazard Quotient of heavy metals for adult					
	Pb	Cd	Cu	Zn	Mn	Fe
Hemayetpur	1.34E-03		6.15E-02	2.23E-02	1.11E+00	1.77E-02
Savar	1.51E+00		6.10E-02	5.11E-02	1.27E+00	1.43E-02
Dhamrai	8.53E+00		6.58E-02	3.75E-02	1.10E+00	1.30E-02
Suti para	1.10E+00		5.26E-02	1.01E-02	1.56E+00	1.74E-02
Dautia	5.82E+00	3.83E-01	6.56E-02	2.44E-02	1.42E+00	1.64E-02
Borobaria	1.61E+00	8.75E-02	6.74E-02	3.39E-02	1.66E+00	1.66E-02
Jaigir	8.54E-01	7.65E-02	9.09E-02	2.47E-02	2.05E+00	1.97E-02
Manikganj	7.86E-01		8.79E-02	2.96E-02	2.43E+00	2.77E-02
Tora Setu	1.27E+00		7.79E-02	1.75E-02	1.95E+00	2.05E-02
Baniajuri	1.41E+00		7.95E-02	2.18E-02	1.35E+00	1.39E-02
Mohadebpur	2.76E-01		8.54E-02	2.64E-02	1.81E+00	1.60E-02
Borongail	8.75E-01		9.91E-02	1.45E-02	3.58E+00	2.44E-02
Falsatia	8.90E-01		7.99E-02	1.71E-02	1.43E+00	1.59E-02
Tepra	1.45E+00		5.49E-02	3.95E-02	1.36E+00	1.28E-02
Uthali	2.33E+00		5.69E-02	3.51E-03	8.82E-01	9.59E-03
HI	2.87E+01	5.47E-01	1.09E+00	3.74E-01	2.50E+01	2.56E-01
	Hazard Quotient of heavy metals for children					
Hemayetpur	1.64E-01		4.60E-03	1.67E-03	8.32E-02	1.32E-03
Savar	1.13E-01		4.57E-03	3.83E-03	9.51E-02	1.07E-03
Dhamrai	6.39E-01		4.93E-03	2.81E-03	8.22E-02	9.75E-04
Suti para	8.22E-02		3.94E-03	7.53E-04	1.17E-01	1.30E-03
Dautia	4.36E-01	2.86E-02	4.91E-03	1.82E-03	1.06E-01	1.23E-03
Borobaria	1.20E-01	6.55E-03	5.05E-03	2.54E-03	1.25E-01	1.24E-03
Jaigir	6.39E-02	5.73E-03	6.80E-03	1.85E-03	1.54E-01	1.48E-03
Manikganj	5.88E-02		6.58E-03	2.22E-03	1.82E-01	2.07E-03
Tora Setu	9.51E-02		5.83E-03	1.31E-03	1.46E-01	1.53E-03
Baniajuri	1.05E-01		5.95E-03	1.63E-03	1.01E-01	1.04E-03
Mohadebpur	2.07E-02		6.39E-03	1.98E-03	1.36E-01	1.20E-03
Borongail	6.55E-02		7.42E-03	1.08E-03	2.68E-01	1.83E-03
Falsatia	6.66E-02		5.98E-03	1.28E-03	1.07E-01	1.19E-03
Tepra	1.09E-01		4.11E-03	2.96E-03	1.02E-01	9.57E-04
Uthali	1.75E-01		4.26E-03	2.63E-04	6.60E-02	7.17E-04
HI	2.31E+00	4.09E-02	8.13E-02	2.80E-02	1.87E+00	1.91E-02

3.4.3. Hazard Index (HI)

The calculated HI values for adults from each metal are presented in Table 6. As shown in Table 6, HI values of Pb (2.87E+01), Mn (2.50E+01), and Cu (1.09E+00) for adults were higher than the safety limit, which indicates the adverse non-carcinogenic health risk of heavy metals for adults. Moreover, HI values of Cd, Zn, and Fe were within the safety limit. Besides, HI values of Pb (2.31E+00) and Mn (1.87E+00) for children were higher than the safety limits, indicating Pb and Mn might have non-carcinogenic health hazards to the children of the study area.

4. Conclusion

This present work was carried out to assess the surface soil condition of the Hemayetpur to Uthali region. CA, CF, PLI, and Igeo showed the contamination state and their anthropogenic sources. Cd and Pb demonstrate great loading, and Cu, Mn and Fe appearance low pollution load in CF, PLI and Igeo. During the study, we found significant positive correlations (at $p < 0.01$) between Mn and Cu (0.78), Fe and Mn (0.83), and Cu and Fe (0.68), indicating their sources associated with industrial and vehicular emissions. On the other hand, Fe showed a significant ($p < 0.05$) positive correlation with Cu (0.68), confirming that the source of Fe is transportation activities. The cluster analysis of sampling sites might be related to road traffic activities and industrial settings. Hazard Quotient (HQ) analysis of Pb and Mn showed the highest value at Dhamrai, and Borongail indicates strongly hazardous for adults. Hazard Index (HI) analysis of studied heavy metals Pb and Mn were higher than the safety limits, might have a non-carcinogenic health hazard towards the children of the study area. The current study shows that the soils are polluted with certain harmful heavy metals. Subsequently, there is a desperate need to decrease/direct the anthropogenic sources of contamination in the review region.

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References
Ahmed F, Khan TA, Fakhruddin AN, Rahman MM, Mazumdar RM, Ahmed S, Imam MT, Kabir M, Abdullah AT (2019) Estimation and exposure concentration of trihalomethanes (THMs) and its human carcinogenic risk in supplied pipeline water of Dhaka City, Bangladesh. *Environmental Science and Pollution Research* 26:16316-16330.

Arnason JG, Fletcher BA (2003) A 40+ year record of Cd, Hg, Pb, U deposition in soils of Patroon Reservoir, Albany County, NY, USA. *Environ Pollution* 123:383–391.

Atiemo MS, Ofosu GF, Kuranchie-Mensah H, Tutu AO, Palm ND, Blankson SA (2011) Contamination assessment of heavy metals in road dust from selected roads in Accra, Ghana. *Research Journal of Environmental and Earth Sciences* 3:473-480.

Barakat A, Ennaji W, Krimissa S, Bouzaid M (2019) Heavy metal contamination and ecological-health risk evaluation in peri-urban wastewater-irrigated soils of Beni-Mellal city (Morocco). *International journal of environmental health research* 30:372-387.

Bastami KD, Bagheri H, Kheirabadi V, Zaferani GG, Teymori MB, Hamzehpoor A, Soltani F, Haghparast S, Harami SR, Ghorghani NF, Ganji S (2014) Distribution and ecological risk assessment of heavy metals in surface sediments along southeast coast of the Caspian Sea. *Marine pollution bulletin* 81:262-267.

Charlesworth S, De Miguel E, Ordóñez A (2011) A review of the distribution of particulate trace elements in urban terrestrial environments and its application to considerations of risk. *Environmental geochemistry and health* 33:103-123.

Chowdhury MHI (2006) Urban diversity changes under globalization. A management perspective on beneficial urban development with a special reference to Dhaka megacity. Paper submitted to T.U., Berlin, Germany earth’s crust. *Bull Geol Soc Am* 72:175–192.

Eziz M, Mohammad A, Mamut A, Hini G (2018) A human health risk assessment of heavy metals in agricultural soils of Yanqi Basin, Silk Road Economic Belt, China. *Human and Ecological Risk Assessment* 24:1352-1366.

Hakanson L (1980) An ecological risk index for aquatic pollution control. A sedimentological approach. *Water research*, 14,75-1001.

Heberer T (2002) Occurrence, fate, and removal of pharmaceutical residues in the aquatic environment: A review of recent research data. *Toxicol Lett* 131:5–17.

Hinojosa MB, Carreira JA, García-Ruíz R, Dick RP (2004) Soil moisture pre-treatment effects on enzyme activities as indicators of heavy metal-contaminated and reclaimed soils. *Soil Biology and* Biochemistry 36:1559-1568.

Hoque MS, Moniruzzaman SM, Mahmud SS (2007) Effectiveness of black spot treatments along Dhaka-Aricha highway. *Journal of Civil Engineering* 35:93-104.

Islam MS (2014) Metropolitan government. An option for sustainable development of Dhaka Megacity. *Environ Urban ASIA* 51:35–48.

Ite AE, Udousoro II, Ibok UJ (2014) Distribution of some atmospheric heavy metals in lichen and moss samples collected from Eket and Ibeno Local Government Areas of Akwa Ibom State, Nigeria. *American journal of Environmental protection* 2:22-31

Jiang Y, Chao S, Liu J, Yang Y, Chen Y, Zhang A, Cao H (2017) Source apportionment and health risk assessment of heavy metals in soil for a township in Jiangsu Province, China. *Chemosphere* 68:1658-1668.

Jose J, Srimuruganandam B (2020) Investigation of road dust characteristics and its associated health risks from an urban environment. *Environmental geochemistry and health* 6:1-22

Liu J, Cui B, Dong S, Zhu J, Yao W (2006) Study on the effect of highway construction on photosynthetic rate of roadsides plant in longitudinal Range-Gorge Region. *Chinese Sci Bull* 51(Supp):59–68

Maitra MK, Akhter SH (2011) Neotectonics in Madhupur tract its surroundings floodplains. *Dhaka Univ J Earth Environ Science* 12:83-89.

Mamat Z, Haximu S, yong Zhang Z, Aji R (2016) An ecological risk assessment of heavy metal contamination in the surface sediments of Bosten Lake, northwest China. *Environmental science and pollution* research 23:7255-7265.

Maragkidou A, Arar S, Al-Hunaiti A, Ma Y, Harrad S, Jaghbeir O, Faouri D, Hämeri K, Hussein T (2017) Occupational health risk assessment and exposure to floor dust PAHs inside an educational building. *Science of the total environment* 579:1050-1056.

Mukta T, Hoque M, Sarker M, Hossain MN, Biswas G (2020) Seasonal variations of gaseous air pollutants (SO2, NO2, O3, CO) and particulates (PM2.5, PM10) in Gazipur: an industrial city in Bangladesh. *Advances in Environmental Technology*, 6(4), 195-209.

Muller G (1969) Index of geoaccumulation in soils of the Rhine River. *Geojournal* 2:108-118.

Nabuloa G, Oryem-Origa H, Diamond M (2006) Assessment of lead, cadmium, and zinc contamination of roadside soils, surface films, and vegetables in Kampala City, Uganda. *Environmental Research* 101:42–52.

Qing X, Yutong Z, Shenggao L (2015) Assessment of heavy metal pollution and human health risk in urban soils of steel industrial city (Anshan), Liaoning, Northeast China. *Ecotoxicology and environmental safety* 120:377-385.

Sharma RK, Agrawal M, Marshall F (2007) Heavy metal contamination of soil and vegetables in suburban areas of Varanasi, India. *Ecotoxicology and environmental* safety 66:258-266.

Shi G, Chen Z, Bi C, Wang L, Teng J, Li Y, Xu S (2011) A comparative study of health risk of potentially toxic metals in urban and suburban road dust in the most populated city of China. *Atmospheric environment* 45:764-771.

Singh KP, Malik A, Sinha S, Singh VK, Murthy RC (2005a) Estimation of source of heavy metal contamination in soils of Gomti River India using principal component analysis. *Water Air Soil Pollution* 166:321–341.

Singh KP, Malik AD, Mohan S, Sinha S, Vinod KS (2005b) Chemometric data analysis of pollutants in wastewater—a case study. *Analytica Chimica Acta* 5321:15–25.

Suryawanshi PV, Rajaram BS, Bhanarkar AD, Rao CC (2016) Determining heavy metal contamination of road dust in Delhi, India. *Atmósfera* 29:221-234.

USEPA (2002) Supplemental Guidance for Developing Soil Screening Levels for SUPERFUND SITES. U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, DC, USA.

USEPA (2011) Reactive nitrogen in the United States: an analysis of inputs, flows, consequences, and management options. US Environmental Protection Agency, Washington, DC.

Varol M, Sen B (2012) Assessment of nutrient heavy metal contamination in surface water soils of the upper Tigris River, Turkey. *Catena* 92:1–10.

Viard B, Pihan F, Promeyrat S, Pihan JC (2004) Integrated assessment of heavy metal (Pb, Zn, Cd) highway pollution: bioaccumulation in soil, Graminaceae and land snails. *Chemosphere* 55:1349–1359

Wang Y, Shi J, Wang H, Lin Q, Chen X, Chen Y (2007) The influence of soil heavy metals pollution on soil microbial biomass, enzyme activity, and community composition near a copper smelter. *Ecotoxicology and environmental safety* 67:75-81.

Wedepohl KH (1995) The composition of the continental crust. *Geochimica et cosmochimica Acta* 59:1217-1232.

Wei B, Yang L (2010) A review of heavy metal contaminations in urban soils, urban road dust, and agricultural soils from China. *Microchemical Journal* 94:99-107.

Yan X, Gao D, Zhang F, Zeng C, Xiang W, Zhang M (2013) Relationship between heavy metal concentrations in roadside topsoil and distance to road edge based on field observations in the Quinghai-Tibet plateau, Chaina. *International journal of environmental research and public health* 10(3):762-765.

Yazdi A, Ziaaldini S, Dabiri R (2015) Investigation on the Geochemical Distribution of REE and Heavy Metals in Western Part of Jalal-Abad Iron Ore Deposit, Zarand, SE of Iran, *Open journal of ecology* 5 (09): 460-476.

Zakir HM, Sultana N, Akter M (2014) Heavy metal contamination in roadside soils and grasses: A case study from Dhaka city, Bangladesh. *Journal of Chemical, Biological and Physical Sciences* 4:1661.

Zechmeister HG, Hohenwallner D, Hanus-Illnar A (2005) Estimation of element deposition derived from road traffic sources by using mosses. *Environ Pollution* 138:238–249.

Zglobicki W, Telecka M, Skupiński S, Pasierbińska A, Kozieł M (2018) Assessment of heavy metal contamination levels of street dust in the city of Lublin, E Poland. *Environmental earth sciences* 77:1-11.

Zhang F, Yan X, Zeng C, Zhang M, Shrestha S, Devkota LP, Yao T. (2012) Influence of traffic activity on heavy metal concentrations of roadside farmland soil in mountainous areas. *International journal of environmental research and public health* 9:1715-1731.

Zhao L, Hu G, Yan Y, Yu R, Cui J, Wang X, Yan Y (2019) Source apportionment of heavy metals in urban road dust in a continental city of eastern China: Using Pb and Sr isotopes combined with multivariate statistical analysis. *Atmospheric environment* 201:201-211.