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Assessment of Ecological Risk Through Toxic Heavy Metal Contamination in Konabari Terrace Industrial Area of Gazipur, Bangladesh

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The contamination of heavy metal (Cr, Cu, Cd, Pb, and As) in soil of Konabari industrial area of Bangladesh was assessed. Several industries at this study site released effluent into neighboring irrigation canals and lakes, contaminating the land. The study site's polluted soil/land from wastewater irrigation could be a major source of pollution. Cr, Cu, and Pb were the most common contaminants in the research area, in the order Cr>Cu>Pb>As>Cd. According to the geo–accumulation index (Igeo), the study region was classified as uncontaminated to moderately contaminated with As followed by Pb, Cu, Cd, and Cr. The pollution load index (PLI) indicated that the study region was slightly/moderately contaminated, while the contamination factor (CF) showed that contamination was moderate. The study region had a moderate ecological risk based on the potential ecological risk index (RI). According to the findings of this study, the study region was generally moderately contaminated with heavy metals, posing a moderate level of environmental risk.

Key words: Heavy metal, geo–accumulation index, pollution load index, potential ecological risk index

INTRODUCTION

The concentrations of various heavy metals and metalloids are naturally low, ensuring optimal ecological equilibrium. Due to its acute toxicity, heavy metal pollution of agricultural soil has recently become a significant environmental concern in developing countries (Ağca and Özdel, 2014). Heavy metal concentrations in water, soil, and crops are rising as a result of anthropogenic activities such as industrialisation and urbanization (Islam *et al.*, 2017). Heavy metals in agricultural soil come mostly from smelting, mining, textile, dyeing, vehicle emissions, and the application of fertilizers and pesticides (Jiang *et al.*, 2017). Heavy metal deposition in soil frequently leads to ecosystem breakdown and soil/water deterioration because heavy metals are extremely persistent. Toxic metals also infiltrate food systems through contaminated water, soil, and air which contaminating food and posing a significant health risk to humans and animals (He *et al.*, 2015). Major industrial regions in Bangladesh are located in densely inhabited areas, allowing trash to be dumped into the environment without being treated, resulting in substantial pollution (Aktaruzzaman *et al.*, 2014).

The farmland of Gazipur District, Bangladesh, was chosen for this study because it is home to a variety of sectors, including garment, textile, dyeing, ceramics, pharmaceutical, paint, and packing. These enterprises dump a large amount of garbage and effluents into neighboring waterbodies without treatment, while domestic and municipal wastewater from the Konabari suburb region also pollutes the environment with heavy metals. Increasing urbanization and industrialization of study area have negative implication for water quality as well as agricultural practices. In the study site, farmers use the heavy metal contaminated wastewater for irrigation purpose, which is the major cause of heavy metal contamination in soil in the study site. Therefore, the objective of the study was to investigate the ecological risk of study site by using different indices.

MATERIALS AND METHODS

Study area

The research location Konabari, Gazipur is a suburban industrial region about 55 kilometers north of Dhaka. Gazipur district covers 1,806 square kilometers and has a population of 3.4 million people (BBS, 2011). It features a flat lowland landscape with an elevation range of 4 to 24 meters (Shapla *et al.*, 2015). This district is characterized by acid basin clays with nutrient-poor soil, which is lacking in organic matter, phosphate, nitrogen, and lime (UNDP/FAO, 1988). The average annual rainfall is 2,036 mm (Merkel, 2012), with the rainy season lasting from April to October and the dry season lasting from November to March. The average yearly temperature is 25.8°C (Merkel, 2012).

Konabari, where a variety of small–scale companies are located, is the target region (Fig. 1). Textiles, dyes, batteries, metallurgical, ceramics, plastic, garments, agrochemical industries, pharmaceuticals, fabric printing, poultry feed, and fish feed are the most important industries (Ahmed *et al.*, 2018; Ahmed *et al.*, 2019).

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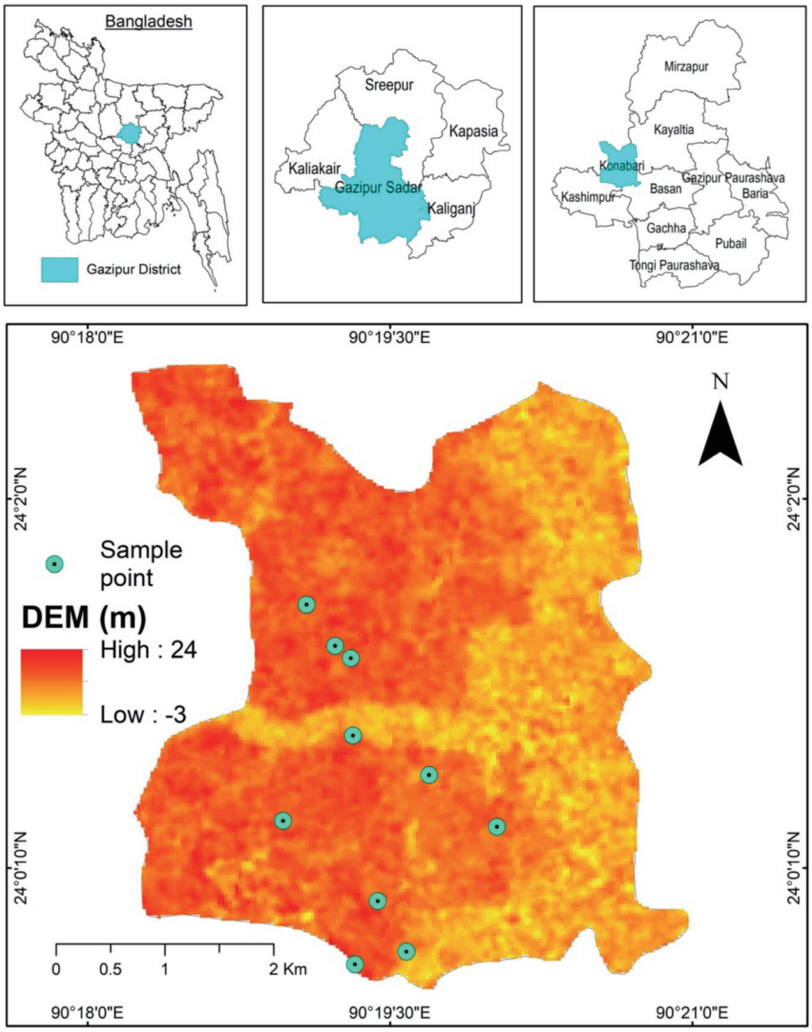

Fig. 1. Sampling locations of the Konabari, Gazipur District, Bangladesh.

Throughout the year, the factories in this area discharge industrial effluent into surrounding irrigation canals.

Soil Sampling and analysis

The soil in the Konabari area of Gazipur District was sampled. Five soil samples were obtained from the surface soil at each sampling site. The soil sampling depth was set at 0–15 cm, based on the root depth and most active zone of maximal root concentration, as well as the most vulnerable zone to erosion and air deposition (Malan *et al.*, 2015; Neagoe *et al.*, 2005). After that, the five soil samples were combined and properly mixed to create a composite soil sample for each sampling station. The soil sample was placed in a Ziploc plastic bag for carrying to the laboratory. Later soil samples are allowed to air dry for at least seven days. The soil samples were crushed to a fine powder and sieved through a 2 mm sieve after air drying. The soil samples were then kept dry in a desiccator in Ziploc plastic bags until they were analyzed. The US EPA 3050B method (USEPA, 1996) was used for the digestion of soil samples. By adding double deionized water to the digested solution, it was volumed to 100 mL, and then filtered with a 4μm paper filter (Whatman 42).

Instrumental analysis

Heavy metal concentrations (Cr, Cu, Cd, Pb, and As) in digested soil solutions were measured using an Atomic Absorption Spectrophotometer (AAS, Perkin Elmer, the PinAAcleTM 900H, USA) at the Department of Agroforestry and Environment, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Bangladesh. The AAS is commonly used in heavy metal analysis because of its reliability, dependability and easy to use tool. By analysing the spectrum (element vaporization and absorption of light in certain frequency) AAS detects the concentration and presence of elements. The use of light wavelength (absorbed by an element) is the technique of AAS. The wavelengths of selected elements in this study are as follows: Cr 357 nm, Cu 324.75 nm, Cd 228.8 nm, Pb 217 nm, and As 193.7 nm. For standard preparation and subsequent dilution of samples the highest purity of Milli–Q, Millipore water (18.2 MΩ/cm; Thermo Scientific, USA) was used. The standard 1000 mg/L stock solution was used for preparing calibration standard solution in a 50 mL volumetric flask.

Table 1. Indices and grades of potential ecological risk of heavy metal contamination (Luo *et al.*, 2007)

Potential ecological risk factor (E^i_r)	Grade of ecological risk	Potential ecological risk index (RI)	Pollution degree
$E^i_r < 40$	Low risk	RI < 65	Low risk
$40 \leq E^i_r < 80$	Moderate risk	65 ≤ RI < 130	Moderate risk
$80 \leq E^i_r < 160$	Considerable risk	130 ≤ RI < 260	Considerable risk
$160 \leq E^i_r < 320$	High risk	RI ≥ 260	Very high risk
$E^i_r \geq 320$	Very high risk		

For the assessment of soil quality in the research area, the following contamination indexes are utilized.

Geo–accumulation index of soil

The geo–accumulation index (Müller, 1981; Ruiz, 2001) is widely used to analyse the contaminated state of soil. The following equation was used to calculate this index.

$$I_{geo}=\log_2 \frac{\text{CM (sample)}}{1.5\times\text{CM (Background)}}$$

Where, $CM_{(Sample)}$ is the measured concentration of heavy metal in soil, $CM_{(Background)}$ is the background value (Kabata–Pendias, 2011) for same element and 1.5 is a multiplying factor.

The classification system of geo–accumulation index includes seven classes (Ruiz, 2001) $I_{geo}\leq 0$ uncontaminated, $0< I_{geo}<1$ uncontaminated to moderately contaminated, $1< I_{geo}<2$ moderately contaminated, $2< I_{geo}<3$ moderately to heavily contaminated, $3< I_{geo}<4$ heavily contaminated, $4< I_{geo}<5$ heavily to extremely contaminated, $5\leq I_{geo}$ extremely contaminated.

Pollution load index of soil (PLI)

To measure soil quality, an integrated approach of heavy metal pollution load indexes (PLI) is calculated for detecting pollution, allowing comparisons of pollution levels between sites and over time. The PLI is the nth root multiplication of the contamination factor of several heavy metals (Islam *et al.*, 2015).

$PLI = (CF_1 \text{ X } CF_2 \text{ X } CF_3 \text{ X} \ldots\ldots \text{X } CFn)^{1/n}$

Where CF in contamination factor or single pollution index

Potential ecological risk index (RI)

On the basis of heavy metal toxicity and environmental reaction, the potential ecological risk index (RI) analyses the degree of heavy metal contamination in soil. The RI is calculated using the calculations below (Guo *et al.*, 2010).

$C^i_f=C^i/C^i_n$

$E^i_r=T^i_r X C^i_f$

$RI=\sum_{i=1}^{n} E^i_r$

Where C^i_f is the contamination factor; C^i is the concentration of heavy metal in the soil; C^i_n is the reference value for the heavy metal (Kabata–Pendias, 2011); E^i_r is the monomial potential ecological risk factor; T^i_r is the heavy metal toxic response factor. The toxic response factors for Cr, Cu, Zn, As, Cd and Pb were 2, 5, 1, 10, 30, and 5, respectively (Guo *et al.*, 2010; Islam *et al.*, 2017). Indices and grades of potential ecological risk of heavy metals are given in Table 1.

Data Analysis

Excel (version 16.5), Numbers (version 11.1), and Origin pro 8 software were used for data calculation, analysis and subsequent graphical presentation. ArcMap 10.3 was used for mapping of study location.

RESULTS AND DISCUSSION

Heavy metals are naturally occurring soil elements whose concentration varies depending on the parent materials (Barbieri, 2016). Heavy metal concentration in soil has increased in the studied area as a result of anthropogenic activities such as industrial waste dumping. Soil health suffers as a result of these activities. Cr (66.25 μg/g) was found to have the greatest mean heavy metal concentration in the research location, followed by Cu (48.09 μg/g), Pb (40.65 μg/g), and As (8.91 μg/g) (Table 2). Cd (0.52 μg/g) had the lowest mean heavy metal concentration. Cr, Cu, and Pb had the highest standard error, indicating that these heavy elements were not evenly distributed throughout the study site. The amount of heavy metals found in the soil at the study site was within the Ministry of Environment Finland's permitted level. Only As concentration exceded that permissible limit but very close. Variations in heavy metal concentrations in soil could be related to changes in irrigation water distribution from the point of discharge to the surrounding areas (Ahmed and Goni, 2010). Agricultural soil in Bangladesh is frequently contaminated by repetitive use of wastewater from various industries and other anthropogenic sources, as is the case in the Konabari research region. Overall, the concentrations of heavy metals in soil were in the following order: Cr>Cu>Pb>As>Cd.

The only assessment of heavy metals in the upper layer of soil cannot provide overall indicators regarding the state of soil contaminations because it does not distinguish between natural background value and anthropogenic enrichment (Barbieri, 2016). Many researchers utilize certain indices to assess soil pollution (Islam *et al.*, 2017; Islam *et al.*, 2015; Aktaruzzaman *et al.*, 2014).

Table 2. Heavy metal concentration in soil (μg/g) of Konabari industrial area, Gazipur (n =10)

Heavy metal	Mean	S. E.	Maximum	Minimum	Permissible Limit [a]
Cr	66.25	2.72	76.58	50.30	100
Cu	48.09	1.55	54.54	40.44	100
Cd	0.52	0.01	0.62	0.48	1
Pb	40.65	1.46	48.18	33.93	60
As	8.91	0.55	12.24	6.58	5

[a] Ministry of Environment Finland (2007)

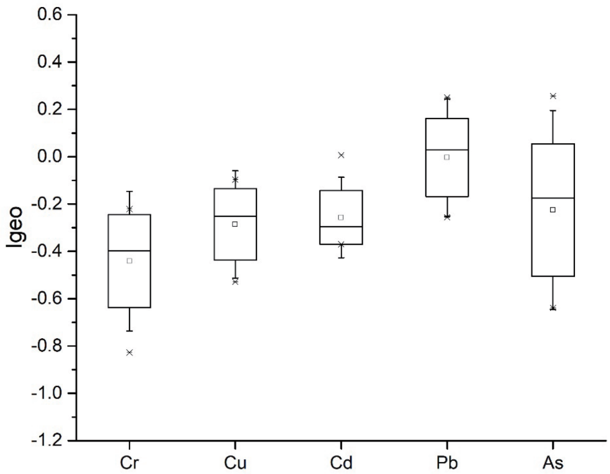

Fig. 2. Geo–accumulation index (Igeo) value of heavy metals in the study area.

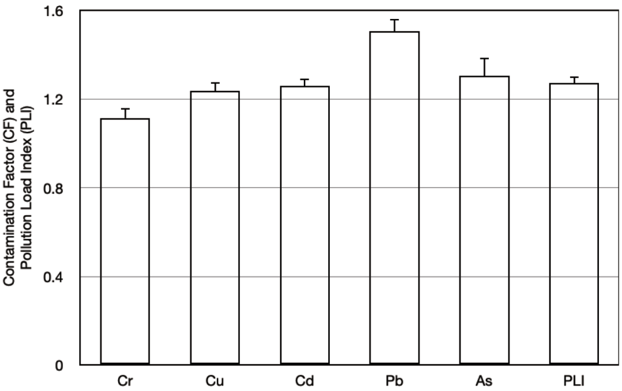

Fig. 3. Contamination factor (CF) and Pollution load index (PLI) values of heavy metals in the study area.

The geo–accumulation index (Igeo), contamination factor (CF), pollution load index (PLI), and potential ecological risk index (RI) are four typical indices for grading soil contamination.

Fig. 2. shows the computed Igeo for soil heavy metals and their contamination intensity. Cr (–0.44), Cu (–0.29), Cd (–0.26), and As (–0.23) all had zero class Igeo values, suggesting that the soil was uncontaminated by these heavy metals. As (0.26) had the highest positive Igeo value, with positive values in the range of 0 < Igeo < 1, suggesting uncontaminated to moderately contaminated soil by As. Similarly, the maximum positive Igeo value of Pb (0.10) representing uncontaminated to moderately contaminated soil by Pb.

Among the other heavy metals in the research site, the Igeo values for As were found to be the highest, followed by Pb, which could be due to higher concentrations in soil, particularly for As, and lower levels in the background samples. Furthermore, positive Igeo values suggested that the research area had been contaminated by anthropogenic sources of As and Pb, particularly from industrial discharge.

The contamination factor (CF) was calculated to determine contamination status in the soil of study site. The highest mean contamination factor was observed for Pb (1.51) followed by As (1.31), Cd (1.26), Cu (1.24) (Fig. 3). On the other hand, the lowest CF value was found in Cr (1.11). The contamination factor was found more than one for all heavy metals in the study site. According to Håkanson, 1980 the contamination factor between 1 to 3 indicated the moderate level of soil contamination. The soil of the study site perfectly matched the moderate level of contamination in contamination factor.

The pollution load index (PLI) was used to determine the overall toxicity and quality of the soil samples. Fig. 3. shows the computed pollution load index (PLI) values for heavy metals in soils, which ranged from 1.10 to 1.42. The higher PLI (1.42, which is greater than one) value confirmed that the soils in the study area were mildly contaminated and/or polluted. The mean pollution load index (1.27) also suggested that the study site was slightly contaminated and/or polluted. The PLI provide a thoughtful awareness about the quality of the overall environment to the residents of any area (Islam *el al.*, 2015). Furthermore, it provides crucial evidence to decision makers on the status of pollution or contamination (Suresh *et al.*, 2012). From this PLI results people/ policymakers should aware about continuous discharge of heavy metals from companies in the research area for future remediation actions.

The degree of heavy metal contamination was evaluated based on their toxicity and environmental response to produce an ecological risk index (RI). The potential ecological risk factor (E^i_r) and risk index (RI) for the study area were depicted in Fig. 4. Individual heavy metals' potential ecological risk factor (E^i_r) showed significant variance, indicating that heavy metals are eco-

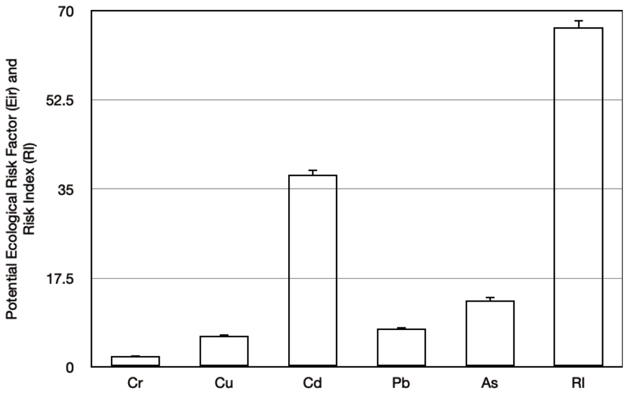

Fig. 4. Potential ecological risk factor (E^i_r) and risk index (RI) values of heavy metals in the study area.

logically hazardous. Cr, Cu, As, and Pb E^i_r values were significantly lower than 40 (minimum grade of ecological risk), indicating that soils in the research area pose a minimal potential ecological risk. In some locations of Konabari area, the E^i_r values of Cd were somewhat greater than the minimal grade. However, the Konabari area's mean potential ecological risk index (RI) was slightly higher i.e., 66.76, suggesting moderate risk.

The maximum potential ecological risk index (RI) was 71.64, indicating that ecological risk was also moderate. The mean value of E^i_r indicates low potential ecological risk. But mean value of RI representing the moderate risk. According to Islam *et al.* (2017), RI denotes the sensitivity of various biological communities to various toxic compounds and shows potential ecological risk initiated by heavy metals. Cd had the highest E^i_r values in the research area, indicating that it contributes significantly to the environment and could come from manmade sources, particularly industrial activity (Luo *et al.*, 2012). Overall, the range of RI is 63.64 to 71.64, signifying low to moderate ecological risk too.

CONCLUSIONS

Considering geo–accumulation index (Igeo) the study area was uncontaminated to moderately contaminated especially by As and Pb. The contamination factor (CF) and the pollution load index (PLI) both suggested the moderate level of contamination. The potential ecological risk index (RI) indicated that the heavy metals in soil samples posed moderate risk to the surrounding environment of the study area.

AUTHOR CONTRIBUTIONS

Minhaz Ahmed contributed to the study conception, design, material and sample preparation, and analysis. The first draft of the manuscript was written by Minhaz Ahmed. Md. Abiar Rahman designed and supervised the research work. Muhammad Ziaul Hoque helped in mapping of the study site and subsequent revisions. Md. Shamim Hossain helped in the data analysis and preparation of manuscript. Masaru Matsumoto critically reviewed the manuscript with valuable suggestions and comments. All authors read and approved the final manuscript.

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REFERENCES

Ağca, N. and E. Özdel 2014 Assessment of spatial distribution and possible sources of heavy metals in the soils of Sariseki-Dörtyol District in Hatay Province (Turkey). *Environ. Earth. Sci.*, **71**: 1033–1047. doi: 10.1007/s12665-013-2507-8

Ahmad, J. U. and M. A. Goni 2010 Heavy metal contamination in water, soil, and vegetables of the industrial areas in Dhaka, Bangladesh. *Environ. Monit. Assess.*, **166**: 347–357. doi: 10.1007/s10661-009-1006-6

Ahmed, M., Matsumoto, M. and K. Kurosawa 2018 Heavy Metal Contamination of Irrigation Water, Soil, and Vegetables in a Multi–industry District of Bangladesh. *Int. J. Environ. Res.*, **12**: 531–542. doi: 10.1007/s41742-018-0113-z

Ahmed, M., Matsumoto, M., Ozaki, A. and N. V. Thinh 2019 Heavy Metal Contamination of Irrigation Water, Soil, and Vegetables and the Difference between Dry and Wet Seasons Near a Multi–Industry Zone. *Water*, **11**: 583. doi: 10.3390/w11030583

Aktaruzzaman, M., Chowdhury, M. A. Z., Fardous, Z., Alam, M. K., Hossain, M. S. and A. N. M. Fakhruddin 2014 Ecological risk posed by heavy metals contamination of ship breaking yards in Bangladesh. *Int. J. Environ. Res.*, **8**: 469–478

Barbieri, M 2016 The Importance of Enrichment Factor (EF) and Geoaccumulation Index (Igeo) to Evaluate the Soil Contamination. *J. Geol. Geophys.*, **5**: 1–4. doi: 10.4172/2381-8719.1000237

BBS 2011 *District Statistics Gazipur*. Bangladesh Bureau of Statistics, Statistics and Informatics Division, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka

Guo, W., Liu, X., Liu. Z. and G. Li 2010 Pollution and potential ecological risk evaluation of heavy metals in the sediments around Dongjiang Harbor, Tianjin. *Procedia. Environ. Sci.*, **2**: 729–736. doi: 10.1016/j.proenv.2010.10.084

Håkanson, L 1980 An ecological risk index for aquatic pollution control: a sedimentological approach. *Water. Res*,, **14**: 975–1001

He, Z., Shentu, J., Yang, X., Baligar, V. C., Zhang, T. and P. J. Stoffella 2015 Heavy Metal Contamination of Soils: Sources, Indicators, and Assessment. *J. Environ. Indic.*, **9**: 17–18

Islam, M. S., Ahmed, M. K., Habibullah–Al–Mamun, M. and S. M. A. Islam 2017 Sources and Ecological Risk of Heavy Metals in Soils of Different Land Uses in Bangladesh. *Pedosphere*. doi: 10.1016/S1002-0160(17)60394-1

Islam, M. S., Ahmed, M. K., Raknuzzaman, M., Habibullah–Al–Mamun, M. and M. K. Islam 2015 Heavy metal pollution in surface water and sediment: A preliminary assessment of an urban river in a developing country. *Ecol. Indic.*, **48**: 282–291. doi: 10.1016/j.ecolind.2014.08.016

Jiang, X., Xiong, Z., Liu, H., Liu, G. and W. Liu 2017 Distribution, source identification, and ecological risk assessment of heavy metals in wetland soils of a river–reservoir system. *Environ. Sci. Pollut. Res.*, **24**: 436–444. doi: 10.1007/s11356-016-7775-x

Kabata–Pendias, A 2011 *Soils and soil processes*. In: Trace elements in soils and plants, Fourth Edi. CRC Pess, Taylor and Francis Group, LLC, New York, pp 37–63

Luo, W., Lu, Y., Giesy, J. P., Wang, T., Shi, Y., Wang, G. and Y. Xing 2007 Effects of land use on concentrations of metals in surface soils and ecological risk around Guanting Reservoir, China.

Environ. Geochem. Health., **29**: 459–471. doi: 10.1007/s10653-007-9115-z

Luo, X.S., Yu, S., Zhu, Y.G. and X.D. Li 2012 Trace metal contamination in urban soils of China. *Sci. Total. Environ*., **421**–**422**: 17–30. doi: 10.1016/j.scitotenv.2011.04.020

Malan, M., Müller, F., Cyster, L., Raitt, L. and J. Aalbers 2015 Heavy metals in the irrigation water, soils and vegetables in the Philippi horticultural area in the Western Cape Province of South Africa. *Environ. Monit. Assess*., **187**: 1–8. doi: 10.1007/s10661-014-4085-y

Merkel, A. 2012 Climate data.org. https://en.climate-data.org/asia/bangladesh/dhaka-division/gazipur-969817/#climate-graph. (Accessed on 11 June 2021)

Ministry of the Environment Finland 2007 *Threshold and guideline values for harmful substances in soil*. In Government Decree on the Assessment of Soil Contamination and Remediation Needs (214/2007, March 1, 2007); Ministry of the Environment Finland: Helsinki, Finland.

Müller, G 1981 Die Schwermetallbelastung der sedimente des Neckars und seiner Nebenflusse: eine Bestandsaufnahme. *Chem. Zeitung*., **105**: 157–164

Neagoe, A., Ebenå, G. and E. Carlsson 2005 The effect of soil amendments on plant performance in an area affected by acid mine drainage. *Chemie. Der. Erde*., **65**: 115–129. doi: 10.1016/j.chemer.2005.06.009

Ruiz, F 2001 Trace metals in estuarine sediments from the southwestern Spanish coast. *Mar. Pollut. Bull*., **42**: 482–490. doi: 10.1016/S0025-326X(00)00192-2

Shapla, T., Park, J., Hongo, C. and H. Kuze 2015 Agricultural Land Cover Change in Gazipur, Bangladesh, in Relation to Local Economy Studied Using Landsat Images. *Adv. Remote. Sens*., **4**: 214–223

Suresh, G., Sutharsan, P., Ramasamy, V. and R. Venkatachalapathy 2012 Assessment of spatial distribution and potential ecological risk of the heavy metals in relation to granulometric contents of Veeranam lake sediments, India. *Ecotoxicol. Environ. Saf*., **84**: 117–124. doi: 10.1016/j.ecoenv.2012.06.027

UNDP/FAO 1988 *Agro–ecological regions of Bangladesh*. In: Technical report–2, (BDG/81/035) FAO. Rome, Italy, p 570

USEPA 1996 *Method 3050B: Acid digestion of sediments, sludges, and soils, Revision 2*. In: Office of solid waste and emergency response, United States Environmental Protection Agency 3050B. Washington D. C., pp 01–07