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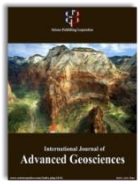

Heavy metal toxicity in agricultural soil due to rapid industrialization in Bangladesh: a review

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Abstract

Heavy metal is a member of loosely defined subset of elements that exhibit metallic properties. It mainly includes the transition metals, some metalloids, lanthanides, and actinides. Heavy metals are ubiquitous in the environment, as a result of both natural and anthropogenic activities. They are stable and cannot be destroyed, and therefore tend to accumulate in the environment. In recent years, there has been a substantial concern over the extent of contamination of the environment with toxic elements. Soil pollution caused by rapid industrial activities has become a worrisome phenomenon due to its impact on soil and environment. Heavy metal pollution in soil arising from industrial discharges significantly poses a great threat to the environment. Heavy metals come to the soil by several ways and the soil becomes toxic which cause serious problem to the environment. In toxic soil, microorganisms cannot persist and there create an imbalance situation in the soil. The main objective of this study was to assess the problem of heavy metal contamination in industrial area soil in Bangladesh with environmental risk assessment.

Keywords: *Heavy Metal, Soil; Environmental Pollution; Industry; Bangladesh.*

1. Introduction

The environment has continued to suffer from pollution due to increased population and industrialization (Goel 2009). The most common environmental pollutants in the world are heavy metals (Papatilippaki et al. 2008). The presence of heavy metals at trace level and essential elements at elevated concentration causes toxic effects if exposed to human population (Fong et al. 2008). The knowledge of heavy metal accumulation in soils, the origin of these metals and their possible interactions with soil properties are a priority in many environmental monitoring (Qishlaqi and Moore 2007). The accumulation of heavy metals in agricultural soils is of increasing concern due to food safety issues and potential health risks as well as its detrimental effects on soil ecosystems (Islam et al. 2016). The concentrations of heavy metals in soils are associated with biological and geochemical cycles. They are influenced by anthropogenic activities, such as transport, waste disposal, industrialization, social and agricultural activities have an effect on environmental pollution and the global ecosystem. These functions lead to a negative effect on human health and on all living organisms. Pollution of the environment with toxic metals has increased suddenly since the onset of the industrial revolution. Soil pollution by heavy metals, such as cadmium, lead, chromium and copper etc. is a problem of concern (Fytianos 2001). Heavy metals in soils have been considered as powerful tracers for monitoring impact of anthropogenic activity such as industrial emission (cement plant, fossil fuel and coal combustion chemical plants), vehicular emission, and atmospheric deposited. These lead to emission of heavy metals into the air and their subsequent deposition into soils (Soriano et al. 2012). Heavy metal is the most dangerous pollutant of anthropogenic environmental pollutants due to their toxicity and persistence in the environment (Koz et al. 2012). The concentrations of heavy metals in soils are associated with biological and geochemical cycles. They are influenced by anthropogenic activities, such as transport, waste disposal, industrialization, social and agricultural activities have an effect on environmental pollution and the global ecosystem. These functions lead to a negative effect on human health and on all living organisms. Pollution of the environment with toxic metals has increased suddenly since the onset of the industrial revolution. Soil pollution by heavy metals, such as cadmium, lead, chromium and copper etc. is a problem of concern (Fytianos 2001). Heavy metals in soils have been considered as powerful tracers for monitoring impact of anthropogenic activity such as industrial emission (cement plant, fossil fuel and coal combustion chemical plants), vehicular emission, and atmospheric deposited. These lead to emission of heavy metals into the air and their subsequent deposition into soils (Soriano et al. 2012, Guo et al. 2012). Heavy metal is the most dangerous pollutant of anthropogenic environmental pollutants due to their toxicity and persistence in the environment (Koz et al. 2012). Soil is dynamic natural resources for the survival of human life and regarded as the key receiver of the relentless pollutants like hazardous elements (Luo et al. 2007, Karim et al. 2014). Soil pollution by heavy metals is a global problem due to its adverse effects on plants, animal and human health. In recent years, trace element contamination in soil and agricultural crops in the vicinity

of industries has attracted global attention owing to its industrial toxicity, abundance and persistence (Sin et al. 2001, Armitage et al. 2007). Soil pollution by heavy metals is a global problem due to its adverse effects on plants, animal and human health. Almost all industrial units are discharging their untreated wastes in the surface drains and spread over agricultural fields. Heavy metals or trace elements are a large group of elements with higher density generally greater than 5 gm/cm3. Large quantities of hazardous trace elements as a group name of heavy metals (Cr, Ni, Cu, As, Cd, Zn, Fe, Hg, Pb etc.) and semimetals (metalloids-As) have been released into soil worldwide due to global rapid population growth and intensive domestic activities, as well as expanding industrial and agricultural productions (Su et al. 2013). Trace metals such as Cr, Ni, As, Cd and Pb have been considered as the most toxic elements in the environment by the US Environment Protection Agency (EPA) (Lei et al. 2010). Industrial wastes are major sources of pollution in all environments and require on- site treatment before discharge into sewage system (Emongor et al. 2005). Soil and environment are under tremendous pressure due to industrial expansion and discharge of effluents. Very few are aware of this discharging, a globally important issue. The third world countries, especially Bangladesh is now in a vulnerable position. Heavy metals are naturally present in soil even though heavy metal contamination comes from local sources: mostly industry (mainly nonferrous industries, but also power plants and iron, steel and chemical industries), agriculture (irrigation with polluted waters, sewage sludge and fertilizer, especially phosphates, contaminated manure and pesticide containing heavy metals), waste incineration, combustion of fossil fuels and road traffic. Long-range transport of atmospheric pollutants adds to the metals in the natural environment. Heavy metals can be found generally at trace levels in soil and vegetation, and living organisms feel the need for micro-elements of these metals. However, these heavy metals have a toxic effect on organisms at high content levels. The industrial hot-spots of Bangladesh are located near the urban and suburban areas and in many cases are surrounded by agricultural fields. The irrigation of industrial, municipal, sewage-sludge effluent and dumping of solid wastes on crop fields due to its high organic matter and nutrient content is a common scenario. As a result the untreated effluents get dispersed throughout the crop field and plants are exposed to a pool of toxic metals without any treatment. Lead, cadmium, arsenic, copper, cadmium, chromium, and nickel are the significant contaminants. Moreover, flooding causes inundation of the cultivated fields with industrial effluents. In rainy season, surface runoff and seepage contribute to the transport of heavy metals over distance along with waste disposals. The extent to which the population of Bangladesh is exposed to food contamination by toxic heavy metals and trace elements is not widely available. Since late 1990s, considerable research has been carried out on arsenic contamination of groundwater and soil and its uptake by rice and vegetable crops (Jahiruddin et al. 2009). Research studies have also reported that that rice and vegetables used in diets might have elevated level of heavy metals (Williams et al. 2006). The Department of Environmental Extension (DoE) identified many polluting industries across the country, which have no treatment facilities for effluents and wastes. These heavily toxic effluents were discharging directly to adjacent soils and rivers (Khan 2008). The existing propensity of industrialization and urbanization diminishes the non-renewable resources and interrupts both the soil and surface water quality through promiscuous disposition of industrial effluents, solid wastes and other toxic wastes, which are the major environmental issues posing threats to the existence of human being (Rahman 2008).

2. Sources and occurrence of heavy metals in the soil

Lead is a widely distributed metal, although lead concentrations are low in environments where there has been little human activity. It is used for a number of industrial, domestic and rural purposes for example, in lead batteries and in leaded petrol (WHO 2000). Arsenic occurs naturally in both organic and inorganic forms in soils. Inorganic arsenic is more toxic than organic arsenic. In the past, arsenic compounds were commonly used in drugs, but the more recent major uses are in pesticides, veterinary drugs and industrial applications. Inorganic arsenic is registered for use in timber preservatives and for control of termites in timber. The main source of as in agricultural fields is as contaminated Shallow Tube Well (STW) water that is used for rice cultivation. There is no registered use of as in food crops or for animal production. Both DSMA (disodium methyl arsenate) and MSMA (monosodium methyl arsenate) are registered as herbicides for use in cotton and sugarcane production. Arsenic contamination of groundwater is a severe problem in the east, south-east and south-west parts of Bangladesh.

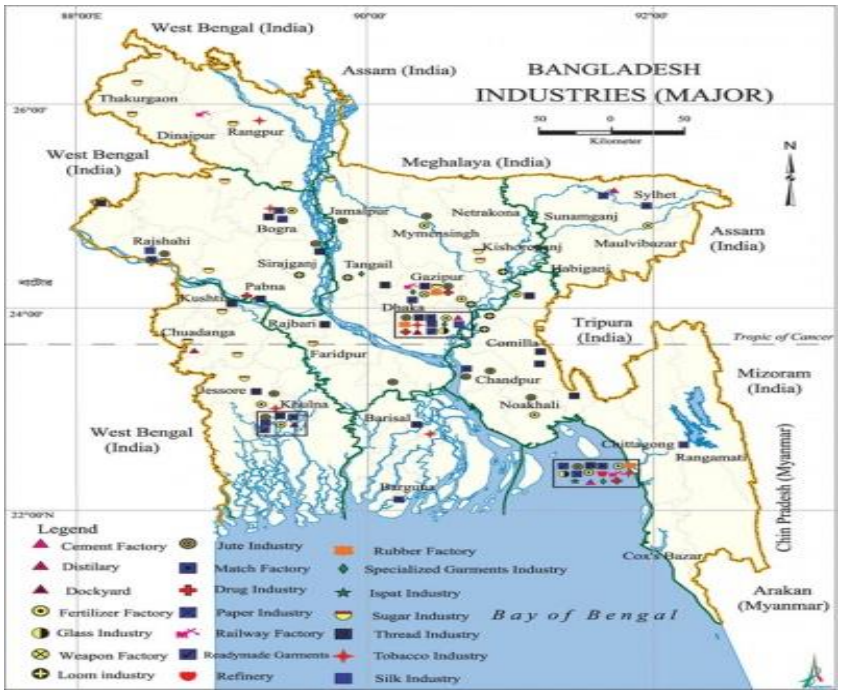

Fig. 1: Industrial Map Showing Major Industries Located in Bangladesh.

In dry and wet season average Pb content of industrially polluted soils of Bangladesh were130.29 and 95.08 mg kg-1, respectively (Mondol et al. 2011). High concentrations of Cu or Pb may be present in sites contaminated by agriculture, mining, industry, or transport (Peter et al. 2009). A study was carried out at Katedan Industrial Development Area (KIDA) of Hyderabad in India to assess the quantitative soil contamination due to heavy metals. They reported that about 300 industries dealing with dying, edible oil production, battery manufacturing, metal plating, chemicals, etc. Most of the industries discharge their untreated effluents either on open land or into ditches. Soil samples showed very high concentrations of Pb, Cr, Ni, Zn, As and Cd throughout the area (Govil et al. 2008). In most rural areas heavy-metal concentrations in soil were similar to their natural background values, but Cd, Cu, Hg, Pb and Zn concentrations were relatively higher in densely populated districts and around industrial facilities. Multivariate analyses (correlation matrix, principal component analysis, and cluster analysis) indicated that Cd, Cu, Hg, Pb and Zn were mainly derived from anthropogenic inputs, and Co, Cr and Mn were controlled by natural source, whereas Ni appeared to be affected by both anthropogenic and natural sources. The result of risk assessment indicated that nearly 48% of the study area suffered from moderate to severe contamination (Gong et al. 2010). It was reported that atmospheric deposition was responsible for 43%-85% of the total As, Cr, Hg, Ni and Pb inputs to agriculture soils in China (Luo et al. 2009). Actually, most of the heavy metal pollutants in air derive from flying ash coursed by highly anthropogenic activities (Liu et al. 2006), such as electric power, mining, metal smelting and chemical plants. The acid rain affected the availability concentrations of heavy metals by decreasing the pH of the soil. The available concentrations of Zn, Cd, Pb increased with the increasing of H+ concentration, whereas the opposite trend was observed for As (Fu et al. 2009).

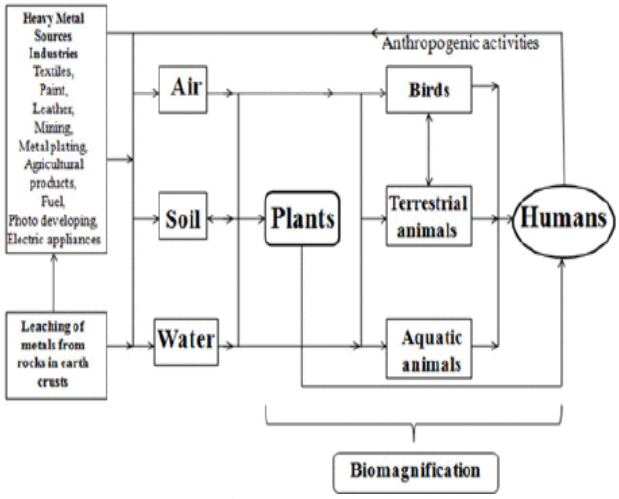

Fig. 2: Source and Fate of Heavy Metals in the Soil and Environment

Inorganic Pb arising from a number of industrial and mining sources occurs in water in the Pb+2 oxidation state. Lead from leaded gasoline used to be a major source of atmospheric and terrestrial Pb. In addition to pollutant sources, Pb bearing limestone and galena contribute Pb to natural waters in some locations. Pollutant Cd in water may arise from industrial discharges and mining wastes. Cd is widely used in metal plating (Manahan 2005). Untreated sewage water irrigation was the major cause of increasing soil and crops metal and short periods of the sewage water irrigation increased individual metals in soils by 2 to 80% and increased metals in crops by 14 to 209% (Qingren et al. 2001). Environmental problems associated with heavy metals in agricultural soils are increasing as a result of reuse of reclaimed sewage water for irrigation disposal of waste water sludge and municipal refusal, application of animal waste and atmospheric fallout (Han and Banin 2001).

3. Heavy metals concentration scenario in Bangladesh soils

An experiment was conducted near industrial areas of Tangail district, Bangladesh. They reported that the concentration of Cr, Ni, Cu, As, Cd and Pb were 10.41, 12.69, 15.66, 12.15, 3.1 and 7.98 mg/kg, respectively (Proshad et al. 2017). An experiment for determining the arsenic status of industrially polluted soils around Dhaka City and reported a higher concentration of arsenic (> 20 µg g-1) in soils particularly near Tannery industry (Nuruzzaman 1998). The as status of five districts of Gangetic floodplains and found that as levels ranged from 2.09 –11.37 mg kg-1. Among the five districts, the soils of the Pabna and Gopalganj districts had relatively lower levels of As compared to Rajbari, Faridpur and Chapai Nawabgonj districts. The highest soil-As concentration of 11.37 mg kg-1 was found in the soil of Rajbari followed by 10.44 mg kg-1 in soil from Faridpur (Islam et al. 2004).

4. Effects of heavy metals on soil and environment

Heavy metal contaminated soil adversely affects the whole ecosystem when these toxic heavy metals migrate into groundwater or are taken up by flora and fauna, which may result in a great threat to ecosystems due to translocation and bioaccumulation. Heavy metals are potentially toxic to crop plants, animals, and human beings when the contaminated soils are used for crop production. Environmental pollution of the biosphere with heavy metals due to intensive agricultural and other anthropogenic activities poses serious problems for secure usage of farming land. Soil is a very important natural resource to man as it is a source of his life on this planet. Without soil, the earth would be as barren as the moon hence lifeless (Misra and Mani 2009). Despite its importance, soil is often contaminated by human activities and this is reflected in the high horizontal and vertical variability brought about by the anthropogenic influence on soil formation and development (Fong et al. 2008). A variety of human activities including municipal waste disposal, industrial emissions, military testing and agricultural practices have left their impacts on soils in the form of elevated and high level of toxicants (Van and Krivolutsky 1996). Materials that find their entry into the soil system persist and accumulate in toxic concentrations becoming sources of pollution in the soil (Misra and Mani 2009). The concentration of heavy metals in soil and their impact on ecosystems can be influenced by many factors such as the parent rock, climate and anthropogenic activities (Jia et al. 2010). Among the pollutants that persist and accumulate in the soils include; inorganic toxic compounds for example fertilizers, organic wastes, organic pesticides and radio cucleides. The soil is thus becoming increasingly polluted with chemicals and other pollutants which can reach the food chain, surface water or groundwater and ultimately be ingested by man (Misra and Mani 2009).

5. Rules and regulations for protection of environmental pollution from industrial pollution

A number of factors led to the framing of pollution oriented laws. The tendency for rapid industrial and economic growth introduced such a technology in Bangladesh that pollution control and establishment of a healthy working environment have become a huge task. The urbanization process added to the load while some heinous-Trans-boundary activities being coupled with dishonest actions within the national frontier are regular contributors to environmental pollution. The Department of Environment (DOE) and other responsible authorities have not yet been successful in checking pollution in the respective sectors they look after despite

the existence of a number of sound laws. This situation entails appropriate enforcement of legal provisions with good policy guidelines through adequate institutional set up. Nevertheless, with the emergence of recent environmental concerns, the conceptual and functional interpretation of the provisions of these laws can give a readily available statutory system and sanction to promote an equitable environmental order. According to Section 2(d) of the Environment Conservation Act 1995, "Environment Means the interrelationship exists between air, water, soil, and physical property and their relationship with human beings, other animals, plants and micro-organisms." Environmental law is a body of law, which is a system of complex and interlocking statutes, common law, treaties, conventions, regulations and policies which seek to protect the environment which may be affected, impacted or endangered by human activities. Some environmental laws regulate the quantity and nature of impacts of human activities: for example, setting allowable levels of pollution or requiring permits for potentially harmful activities. Other environmental laws are preventive in nature and seek to assess the possible impacts before the human activities can occur. The environmental law is the special body of official rules, decisions, and actions concerning environmental quality, natural resources, and ecological sustainability. Governmental steps for pollution control in Bangladesh are given here by.

a) The 'Ministry of Environment and Forest (MOEF)' of Bangladesh is primarily responsible for environmental protection. It was created in 1989. The MOEF has taken some steps to control the environmental pollution of Bangladesh.
b) National Environmental Management Action Plan (NEMAP): The government has taken a project named NEMAP to integrate environment with the development in a policy framework. It provides a guideline for promoting effective management of resources, raising awareness among the people and improvement of environmental degradation.
c) Environmental Acts, Rules and Laws: The government of Bangladesh has modified environmental acts, rules and laws to improve environmental condition. Environment court has already been established to take prompt legal action against environmental pollution. The DOE has been empowered to punish the offenders of environmental rules.
d) Control of Air Pollution: Recently the DOE has taken some measures to carry out surveys on identification and control of polluting industries, protecting habitats, examining the use of compressed natural gas in industries, setting environmental standards and controlling river and automobile pollution on environmental management. It also conducts vehicular emission measurements at Dhaka city.
e) Banning of Polyethylene Bags: Most of the sewage lines of Dhaka city have been blocked by indiscriminate dumping of polyethylene bags over the years. As such, the government has banned the production, marketing and use of polyethylene bags up to 20 microns thick or less from 01 March 2002.
f) Urban Transport Project: A Urban Transport Project has been launched by the Government to improve traffic system, envisage good bus services, improve road networks by constructing over-bridges, fly-overs, underpasses and envisages a positive role for non-motorized transport.
g) Embargo on Import of Items: The government has banned the import of leaded petrol, high sulfur diesel and high sulfur coal. The government has also encouraged to use Compressed Natural Gas (CNG) to the automobiles. Bangladesh Road Transport Authority (BRTA) has restricted the registration on two-stroke three wheelers.
h) Control of Arsenic Pollution: The Government has taken four Strategies to mitigate the arsenic problem. These are as follows: (i). Immediate detection of the arsenic affected patients and ensure their proper treatment. (ii). Identify the arsenic contaminated tube wells, labeled them with red colour for danger ones and green with safe ones. (iii). Detect the reasons for arsenic contamination in soil water and find out the sources of safe drinking water. (iv). Conduct health education campaigns and grow awareness among the people.
i) Knowledge Enrichment Programme: Environmental education program has been incorporated in primary and higher education. Many universities have introduced various curriculum and projects on environmental issue. Government organizations as well as NGOs present meetings and seminars to raise public awareness on the environmental issue.
j) Rural Sanitation Programme: The Bangladesh Government has taken a rural sanitation programme from October 2003 to implement the facilitation, construction and installation of twin pit latrine. It improves rural sanitation coverage and reduces infectious diseases in rural areas.

6. Suggested steps for environmental pollution control

a) The government has taken some steps to improve the pollution control of Bangladesh. But the steps are not adequate. As such, few more steps may also be taken to improve the environmental degradation:
b) Use of Environmental Technologies and Methods: Environmental technologies and methods such as Geographic Information Systems (GIS), remote sensing and environmental impact assessment might be used for integrated policy formulation, decision-making, evaluation and monitoring of the environment.
c) Development of Environmental Database: A comprehensive environmental database may be made and the environmental planners might have the access for environmental upgradation, planning, and management the database is to be updated regularly.
d) Environmental Education and Awareness: Formal and informal methods of education might be adopted through local media, seminars, celebrations, workshops, walks and student competitions to aware the people regarding the process of environmental degradation.
e) Industrial and Solid Waste Management: The government might take appropriate measures to monitor emission limits and Market Based Incentives (MBI) for reducing pollution control. The industries might be given both technical and financial support for introducing mitigation measures, promoting green technologies, using fewer pollution technologies and recycling the waste.
f) Enforcement of Rules and Regulation: Environmental Conservation Rules of 1997, traffic rules and other relevant environmental laws might be enforced further to punish the violation of the emission limits.
g) Urban Transport Management: Government must strengthen vehicle emission standards, complete the emission inventory and conduct an investigation on the emission control measures. Auto-rickshaw must be restricted in Dhaka city. Government must replace old vehicles, two-stroke engine vehicles, improve traffic conditions and promote an equivalent and efficient alternative public transportation services to improve urban transport management.
h) Reduce Sulfur in Diesel: Government must take necessary steps to remove sulfur content from diesel through hydrodesulphurization (HDS) process. The government must also enforce the vehicle manufacturers to install catalytic converters in every vehicle to reduce the vehicular emissions.

7. Conclusions

One of the highlights of this study with respect to heavy metals in soil from the industrial area of Bangladesh was the recurrence of relatively elevated levels. It is of interest to fully resolve the metal contaminations. Globally everyone is potentially vulnerable to the toxic effects of heavy metals. Many toxic heavy metals are ubiqui-

tous in our environment. Metals and their compounds present in the soil fractions vary in the degree of mobility. The bioavailability depends on physical, chemical, biological processes and interaction between them. Various anthropogenic activities without taking any safety measures have caused the problem of heavy metal pollution in the soils which is not going to disappear overnight; on the contrary, it will remain as a legacy of mass industrial and anthropogenic activity for many generations and is likely to escalate further in future. In Bangladesh, heavy metal contamination in soil may cause a serious threat to ecology unless proper strategy will be adopted. The government should have to take effective measures in relation to the proper scientific assessment by the scientists and researchers regarding the monitoring and the impact of industrial activities on metal pollution in Bangladesh.

8. Acknowledgement

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References

[1] Goel P (2009), Water pollution. New Delhi, India: New Age International. pp 1-2.

[2] Papafilippaki A, Kotti M & Stavroulakis G (2008), Seasonal variations in dissolved heavy metals in the Keritis River Chania, Greece. *Global Nest Journal* 3, 320-325.

[3] Fong F, Seng C, Azan A & Tahir M (2008), Possible source and pattern distribution of heavy metals content in urban soil at Kuala Terengganu Town Centre. *The Malaysian Journal of Analytical Sciences* 12, 458-467.

[4] Qishlaqi A & Moore F (2007), Statistical analysis of accumulation and sources of heavy metals occurrence in agricultural soils of Khoshk River Banks, Shiraz, Iran. *American –Eurasian Journal of Agriculture and Environment Science* 2, 565-573.

[5] Islam MS, Ahmed MK & Al-Mamun MH (2016), Apportionment of heavy metals in soil and vegetables and associated health risks assessment. *Stoch Environ Res Risk Assess* 30, 365-377. https://doi.org/10.1007/s00477-015-1126-1.

[6] Fytianos KG, Katsianis P, Triantafyllou & Zachariadis G (2001), Accumulation of heavy metals in vegetables grown in an industrial area in relation to soil. *Bulletin of Environmental Contamination and Toxicology* 67, 423-430. https://doi.org/10.1007/s001280141.

[7] Soriano A, Pallarés S, Pardo F, Vicente B, Sanfeliu T & Bech J (2012), Deposition of heavy metals from particulate settleable matter in soils of an industrialised area. *Journal of Geochemical Exploration* 113, 36-44. https://doi.org/10.1016/j.gexplo.2011.03.006.

[8] Koz B, Cevik U & Akbulut S (2012), Heavy metal analysis around Murgul (Artvin) copper mining area of Turkey using moss and soil. *Ecological Indicators* 20, 17-23. https://doi.org/10.1016/j.ecolind.2012.02.002.

[9] Guo G, Wu F, Xie F & Zhang R (2012), Spatial distribution and pollution assessment of heavy metals in urban soils from southwest China. *Journal of Environmental Sciences* 24, 410-418. https://doi.org/10.1016/S1001-0742(11)60762-6.

[10] Luo W, Lu Y, Gisey JP, Wang T, Shi Y, Wang G & Xing Y (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. https://doi.org/10.1007/s10653-007-9115-z.

[11] Karim Z, Qureshi BA, Mumtaz, M & Qureshi S (2014), Heavy metal content in urban soils as an indicator of anthropogenic and natural influences on landscape of Karachi—a multivariate spatio-temporal analysis. *Ecological Indicators* 42, 20-31. https://doi.org/10.1016/j.ecolind.2013.07.020.

[12] Sin SN, Chua H, Lo W & Ng LM (2001), Assessment of heavy metal cations in sediments of Shing Mun River, Hong Kong. *Environ. Int*. 26, 297-301. https://doi.org/10.1016/S0160-4120(01)00003-4.

[13] Armitage PD, Bowes MJ & Vincent HM (2007), Long-term changes in macroinvertebrate communities of a heavy metal polluted stream: the River Nent (Cumbria, UK) after 28 years. *River Res. Appl*. 23, 997-1015. https://doi.org/10.1002/rra.1022.

[14] Su S, Xiao R, Mi X, Xu X, Zhang Z & Wu J (2013), spatial determinants of hazardous chemicals in surface water of Qiantang River, China. *Ecological Indicators* 24, 375-381. https://doi.org/10.1016/j.ecolind.2012.07.015.

[15] Lei M, Zhang Y, Khan S, Qin P & Liao B (2010), Pollution, fractionation and mobility of Pb, Cd, Cu, and Zn in garden and paddy soils from a Pb/Zn mining area. *Environmental Monitoring and Assessment* 168, 215-222. https://doi.org/10.1007/s10661-009-1105-4.

[16] Emongor V, Nkegbe E, Kealotswe B, Koorapetse I, Sankwasa S & Keikanetswe S (2005), Pollution Indicators in Gaborone Industrial Effluent. *Journal of Applied Sciences* 5, 147-150. https://doi.org/10.3923/jas.2005.147.150.

[17] Jahiruddin M, Islam MA, Islam MR & Islam S (2004), Effects of arsenic contamination on rice crop. *Environtropica.* 1, 204-210.

[18] Williams PN, Raab A, Feldmann J & Meharg AA (2007), Market basket survey shows elevated levels of As in south central U.S. processed rice compared to California: consequences for human dietary exposure. *Environmental Science and Technology* 41, 2178-2183. https://doi.org/10.1021/es061489k.

[19] Khan S, Cao Q, Zheng YM, Huang YZ & Zhu YG (2008), Health risk of heavy metals in contaminated soils and food crops irrigated with waste water in Beijing, China. *Environmental Pollution* 152, 686-692. https://doi.org/10.1016/j.envpol.2007.06.056.

[20] Rahman MM, Sultana KR & Hoque MA (2008), Suitability Sites for Urban Solid Waste Disposal Using GIS Approach in Khulna City, Bangladesh. Proc. *Pakistan Acad. Sci.* 45, 11-22.

[21] WHO (2000), WHO Food Additive Series 44.

[22] Mondol MN, Chamon AS, Faiz B, Rahman MH & Elahi SF (2011), Fractionation, characterization and speciation of lead in the industrially polluted soils of Tejgaon Area of Bangladesh and lead pollution of associated plants and water. *Bangladesh Journal of Scientific and Industrial Research* 46, 277-290. https://doi.org/10.3329/bjsir.v46i3.9032.

[23] Peter MK, Blamey F.P.C, Colin JA & Neal WM (2009), Trace metal phytotoxicity in Solution culture: a review. *Journal of Experimental Botany* 6, 1-10.

[24] Govil PK, Sorlie JE, Murthy NN, Sujata D, Redd, G.L.N, Rudolph L, Krishna AK & Mohan, KR (2008), Soil contamination of heavy metals in the Katedan Industrial Development area, Hyderabad, India. *National Geophysical Research Institute* 140, 313-323. https://doi.org/10.1007/s10661-007-9869-x.

[25] Gong M, Wu L.X.Y, Bi LM, Ren L, Wang ZD, Ma Z.Y & Li ZG (2010), Assessing heavy metal contamination and sources by GIS-based approach and multivariate analysis of urban-rural top soils in Wuhan, central China. *Environmental Geochemistry and Health* 32, 59-72. https://doi.org/10.1007/s10653-009-9265-2.

[26] Luo L, Ma Y, Zhang S, Wei D & Zhu YG (2009), Inventory of trace element inputs to agricultural soils in China. *Journal of Environmental Management* 90, 2524-2530. https://doi.org/10.1016/j.jenvman.2009.01.011.

[27] Liu XM, Wu JJ & Xu JM (2006), characterizing the risk assessment of heavy metals and sampling uncertainty analysis in paddy field by geostatistics and GIS. *Environmental Pollution* 141, 257-264. https://doi.org/10.1016/j.envpol.2005.08.048.

[28] [28] Fu TH, Ni DH, Xu FJ, Zhang YS & Lin XY (2009), Effect of stimulated acid rain on the bioavailability of heavy metals from the vegetable soil amended with swine manure. *Acta Agriculturae Zhejiangensis* 21, 593-598.

[29] Manahan SE (2005), Environmental Chemistry. 8th ed., CRC Press LLC, 2000 N.W. Corporate Blvd. Boca Raton, Florida 33431.

[30] Qingren W, Dong Y, Wi Y, Liu X & Wang D (2001), Instances of soil and crop heavy metal contamination in China. *Soil and Sediment Contamination* 10, 497-510. https://doi.org/10.1080/20015891109392.

[31] Han FX & Banin A (2001), Fractional loading isotherm of heavy metals in an arid-zone soil. *Communications in Soil Science and Plant Analysis* 32, 2691-2708. https://doi.org/10.1081/CSS-120000955.

[32] Proshad R, Ahmed S, Rahman M & Kumar T (2017), Apportionment of Hazardous Elements in Agricultural Soils Around the Vicinity of Brick Kiln in Bangladesh. *J. Environ. Anal. Toxicol.* 7, 2. doi: 10.4172/2161-0525.1000439. https://doi.org/10.4172/2161-0525.1000439.

[33] Nuruzzaman M, Islam A, Ullah SM, Rashid MH & Gerzabek MH (1998), Contamination of soil environment by the tannery industries. *Bangladesh Journal of Soil Science* 25, 1-10.

[34] Islam MS & Tanaka M (2004), Impacts of pollution on coastal and marine ecosystems including coastal and marine fisheries and approach for management: A review and synthesis. *Marine Pollution Bulletin* 48, 624-649. https://doi.org/10.1016/j.marpolbul.2003.12.004.

[35] Misra S & Mani D (2009), Soil pollution. New Delhi, India: S. B Nangia APH Publishing Corporation. pp 29-59.
[36] Van N & Krivolutsky (1996), Bioindicator systems for soil pollution. Dordrecht, Netherlands: Kluwer Academic Publishers. pp 1-8.
[37] Jia L, Yonghua L & Yang L (2010), Heavy metals in soil and crops of an intensively farmed area: Case study in Yucheng City, Shandong province, China. *International Journal of Environmental Research and Public Health* 7, 395-412. https://doi.org/10.3390/ijerph7020395.