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CADMIUM CONTENT IN SOIL AND TOMATO (*LYCOPERSICON ESCULENTUM* MILLER) AROUND INDUSTRIAL AREAS OF BANGLADESH

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Abstract

The levels of cadmium (Cd) in soil and commonly consumed tomato (*Lycopersicon csculentum* Miller) fruits grown around the industrial areas of Dhaka and Narsingdi districts of Bangladesh were quantified and compared the levels with FAO/WHO (2003)safety limits. According to the findings, the order of Cd concentration in soils and tomato fruits was found around the Textile > Pharmaceutical > Tannary industry. The concentration (mg/l) of Cd in soil and tomato ranged from 0.24 to 0.91 and 0.15 to 0.74, respectively. Except Tannery industry levels of Cd in soil and tomato were exceeded the premise limit proposed by joint FAO/WHO. In all sites, the bioconcentration factor (BCF) for this heavy metal in tomatoes was found to be below 1, a sign of low uptake of heavy metals in the tomatoes from the soil. Results suggest that consumption of these tomatoes might cause health risk the consumers.

Introduction

Nowadays soil pollution through heavy metals and associated food safety is a foremost global concern. Heavy metals comprise one group of known harmful substances which are naturally present in soils (Stancic *et al*. 2016) and initiate from the erosion of rocks or volcanic activity. Moreover, anthropogenic manners like mineral processing; chemical, metallurgic, petrochemical, and textile industries; and fuel combustion, among others (Strungaru *et al.* 2018) have augmented heavy metals concentrations. Heavy metals are non-biodegradable, and they can move through food webs to ultimately be consumed by humans, which may result in various health risks due to their acute or chronic toxicity (Aguilar *et al.* 2018).

One of the most important sources of agricultural soil pollution are industrial discharges. Heavy metals like Cd, Zn, and Pb from different sources, more particularly from the industries are responsible for changes in the soil health (Mani *et al.* 2015). Untreated or partially treated industrial discharges may contain significant amount of Cd, Zn and Pb (Islam *et al.* 2012). These pollutants can be injurious for the plants and be also responsible for reducing plants life (Gheorghe and Ion 2012). Cadmium (Cd) is an instance of a heavy metal that is very much toxic for plant growth (Ding *et al*. 2021). In particular, Cd uptake in plants occurs in the roots via essential metal transporters and is partially translocated aboveground (Umer *et al*. 2021). Cadmium in soils not only reduces crop yield and quality but also threatens both animal and human health because this metal can bioaccumulate within a food chain (Haider *et al.* 2021).

According to Khan (2006), around 30,000 industries have been established in Bangladesh, and out of 30,000 industries around 700 are textile, dyeing and glass industries which are situated

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at Dhaka, Gazipur, Narsingdi and Tangail district. It was estimated that around 30 million gallons of untreated discharges are polluting environment daily through mixing with water and soil (Jolly *et al.* 2012).

Vegetables are essential for human nutrition and health, particularly as source of vitamin C, folic acid, minerals, niacin, thiamine, pyridoxine and dietary fiber, their biochemical role and their antioxidative effects (Siegel *et al.* 2014). One of the most essential aspects of food quality assurance is heavy metal contamination of the food items (Wang *et al.* 2005). The presence of heavy metals in vegetables is influenced by many factors, principally by the crop species and its metabolism, and by others such as the soil's initial concentration of contaminants, pH, organic matter availability, and presence of other ions and molecules (Van der Zee *et al.* 2021). Crops that are located close to vehicular traffic and factories also have an increased likelihood of heavy metals presence (Koptsik *et al.* 2021).

Tomato remains to be the most significant vegetable in the whole world all because of increasing dietary and commercial worth, extensive production of tomato as well as exemplary plant to carry out research (Leander D. Melomey *et al.* 2019). It is a significant currency and industrialized crop in several regions of the whole world (Qasim *et al.* 2018). Tomato contributes to a well-proportioned and healthy nutrition. They are rich in vitamins, minerals, important amino acids, dietary fibers and sugars. Tomato comprises abundant vitamin B as well as C, phosphorus and iron. Tomatoes are processed fresh in salads or cooked in pastes, soup and fish or meat dishes.

The heavy metals can be disseminated from the source point to the soil, ground and underground water; as a result, they can be spread far away and enter into the food chain and can poison the organisms (Idzelis *et al.* 2004). Tusher *et al.* (2017) reported that the concentration of heavy metal status in soil and water varies from place to place and discharge sources. Fruits and leafy vegetables are vulnerable to the heavy metal contamination (Adekunle *et. al.* 2009). The farmers of Bangladesh are using polluted land surrounding industrial areas to produce several kinds of vegetables like tomato, potato and leafy vegetables for the scarcity of cultivable land especially for vegetable cultivation. This fact necessitates for frequent determination of heavy metals in fruits, vegetables and soil to ensure that their levels meet the agreed international standards for the safety of consumers. Thus, the present research was aimed to assess the variation of Cd concentration in soil of different types of industrial area, to find out the influence of distance from source point on concentration of Cd in soil and tomato fruit and to find the effects of Cd concentration on yield of tomato.

Materials and Methods

Top soil (0-15 cm. depths) and fruits of the same species of Tomato (*Lycopersicon esculentum* Miller) were collected from the Tannery (Tan.), Pharmaceutical (Phar.) and Textile (Tex.) industries (I) areas of Savar and Dhamrai upazila under Dhaka district and Narsingdi Sadarupazila under Narsingdi district of Bangladesh. These sites were selected as intensive vegetables grown areas as well as the area are continuously polluted by industrial discharges and agrochemicals. Most of the factories of these areas discharge their effluents to major river directly. The geographical location and climatic information of the study area are presented in Table1.

The soil and tomato samples were collected maintaining 100, 200, 300, 400 and 500 m distance from the selected industries. Five sub-samples of soil and tomato were taken from 2 m × 2 m area of each selected place with 3 replications to prepare composites sample. Each sub-sample was bulked and a representative sample for each location. Altogether, fifteen (5 × 3 = 15) soil and tomato samples were collected from each selected industrial area. A total of forty-five (15 × 3 = 45) soil and tomato samples were collected. Collected soil samples were air-dried for three days at the room temperature and crushed and passed through 2 mm mesh sieve and stored at ambient temperature prior to analysis. Tomato samples were washed with tap water and distilled water in laboratory to remove adsorbed dust and particulate matters and then cut and chopped into small pieces using plastic knife in order to facilitate drying. Subsequently, the samples were air-dried for five days and further dried in hot air oven at 50-60ºC for 24 hrs. to remove moisture and maintain constant mass. The dried samples were grounded into powder using acid washed laboratory mortar and pestle and then sieved using 2 mm mesh size sieve. The sieved samples were finally stored in polyethylene bags and kept in desiccators until digestion and analysis. Cadmium (Cd) from soil and tomato samples were extracted by the method of Jackson (1973) using di-acid digestion mixture (HNO_3:$HClO_4$ = 4:1) and analyzed by Atomic Absorption Spectrophotometer (AAS).

Table 1. Physiographic and climatic information of the selected locations.

Landscape properties	Industrial area		
	Savar	Dhamrai	Narsingdhi sadar
Latitude	$90^0$16'.03"S	$90^0$16'.03"S	$90^0$38'40"S
Longitude	$23^0$49'.05"N	$23^0$49'.05"N	$23^0$59'14"N
Altitude (m above sea level)	8.61	8.61	13.9
Mean annual rainfall (mm)	1990	1990	2050
Mean annual temperature (°C)	25.8	25.8	25.9

Bioconcentration factor (BCF) is a parameter used to describe the transfer of trace elements from soil to tomato fruits. It is calculated as the ratio between the concentration of heavy metals in the vegetables and that in the corresponding soil based on dry weight (Liu *et al.* 2006). BCF = C_{plant} / C_{soil}; Where, C_{plant} and C_{soil} represent the heavy metal concentration in extracts of plants and soils on a dry weight basis.

Analysis of variance (ANOVA) was used for analyzing data, where the General Linear Models (GLM) of Statistical Analysis Software (SPSS) was used (Sawyer *et al.* 2007). Duncan's Multiple Range Test for values and Least Significant Difference (LSD) at 5% level of confidence were used for separating treatment means. Wherever a significant difference was found the means obtained compared at $p > 0.05$ significant level.

Results and Discussion

Data of physico-chemical parameters of soil samples are summarized in Table 2. Based on the USDA soil classification system, the soil samples were in to sandy loam to loam textural class with varying the percentage sand (55-65, 55-65 and 60-65%), silt (20-30, 20-30 and 60-65%) and clay (25-35, 25-35 and 60-65%), respectively. This indicates that all the soils are suitable for agriculture, as most crops thrive best on loam textured soils (Weil and Brady 2017). The pH value of the analyzed soil samples was found to range from 6.1 to 6.8 showing that the soil in the area covered in this study is neutral in nature. All the top soils are moderately acidic and the subsoil are neutral in reactions. Organic carbon percentage (% OC) of the soil samples was found to be 2.92,2.92 and 1.81% for soil samples under, respectively. Overall, the soils of Savar and Dhamrai are more fertile than soils of Narsingdhi sadar upazila.

Table 2. Physico-chemical properties of the sample collected from selected industrial areas.

Soil properties	Savar	Dhamrai	Narsingdhi sadar
1. Soil texture	Sandy loam (Sand: 55-65%, silt: 20-30% and clay: 25-35%)	Sandy loam (Sand: 55-65%, silt: 20-30% and clay: 25-35%)	Loamy soil (Sand: 60-65%, silt: 45-55% and clay: 60-65%)
2. Soil type	Deep to shallow red brown terrace soil	Deep to shallow red brown terrace soil	Predominantly silt loams to silty clay loams on the ridges and clay in the basins
3. Topsoil/ subsoil	Topsoil moderately acidic but sub soils neutral in reaction	Topsoil moderately acidic but sub soils neutral in reaction	Topsoil moderately acidic but sub soils neutral in reaction
4. Organic matter	2.92%	2.92%	1.85%
5. Soil reaction (pH)	6.8	6.8	6.1

Results of concentrations of Cd in soils of different industrial areas presented in Table 3 showed that Cd contents in soil near to the Tannery industry (Tan.I),Pharmaceutical industry (Phar.I) and Textile industry (Tex.I) ranged from 0.107-0.243, 0.496-0.814 and 0.5887- 0.909 mg/kg, respectively. The highest contents (0.91 mg/kg) were observed in the soil samples collected at 100m far from Tex.I. The lowest level of Cd (0.107mg/kg) was recorded at soils collected from 500m far from Tan.I. Among the sampling locations, the Cd level was highest in the soil around Tex.I followed by Pha.I and lowest in Tan.I. It was also observed that the Cd concentration was decreasing with increasing distance from the industry. The highest concentration (0.24, 0.81 and 0.91 mg/kg) in each location i.e. Tan.I, Phar.I and Tex.I, respectively were recorded in the soil samples collected from100m away from the source point. This might be due to release of effluents from the source points, which is resulting increased heavy metal content of the adjacent soil. The lowest level of Cd (0.11, 0.50 and 0.59 mg/kg) were recorded in soils collected at 500m away from Tan., Phar. and Tex. industry, respectively. Usually, when the distance from the source increases the Cd concentration decreases, which might be due to the industrial discharges are the main pollution source (Al-Khashman 2006). One of the most important sources of metal pollutant in soil are textile industries reported by Deepali and Gangwar, 2010. According to Noor *et al.* (2015), nearly all textile industries of Bangladesh follow conventional methods for manufacturing fabrics, which are responsible for discharging untreated effluents, these untreated effluents contain significant amount of heavy metals. Cadmium can be found in the pharmaceutical industrial area due to different chemicals and medicinal plants used in medicinal industry. That way the effluents can discharge heavy metals into soil (Bulinski *et al.* 2009). The contents of Cd near to 100, 200, 300, and 400m of pharmaceutical and textile industry were higher than the threshold value (0.6 mg/kg). The concentrations of Cd in all the soil samples were below the permissible limit (3.00-6.00 mg/kg) proposed jointly by FAO and WHO (2003).

The concentrations of Cd in tomato fruits grown around the Tannery, Pharmaceutical and Textile industries were found to differ significantly (Table 3). Cadmium (Cd) contents in tomato samples exhibited decreased trend in the order of Textile (0.25- 0.74 mg/kg) > Pharmaceutical (0.19 - 0.68 mg/kg) > Tannery industry (0.02 - 0.15 mg/kg). The concentrations of Cd in tomato were found to be at maximum close to the Tex.I followed by Phar.I and lowest at Tan.I. In all the sites, the highest concentration of Cd in tomato (0.74, 0.68 and 0.15 mg/kg, respectively) were observed in the samples collected at 100m distance from the source point. Similarly, the lowest value of Cd (0.02, 0.19 and 0.25 mg/kg, respectively) were found in tomato collected from 500 m away from source point. The concentration of Cd in tomatoes (0.74, 0.68 and 0.15 mg/kg) from 100,200,300, and 400 m far of Phar.I and Tex.I were above the proposed level (0.20 mg/kg) jointly by FAO and WHO (2003). But, Cd in tomatoes around the Tan.I was below the FAO and WHO (2003) standard. Mingorance *et al.* (2007) and Khan *et al.* (2008) reported the deposition of heavy metals in soil, crops and vegetables grown in the vicinity of industrial areas. Jolly *et al.* (2013) observed that heavy metals can be readily adsorbed by vegetable roots, and can be accumulated in the edible parts of vegetables at high levels, regardless of their concentration in the soil. Naser *et al.* (2012) also found that Cd level of the road side plants are negatively correlated with the distance from road.

Table 3.Cadmium concentration (mg/kg) in soil of selected industrial areas.

Name of the industry	Distance from the industry				
	100m	200m	300m	400m	500m
Tannery industry (Tan.I)	0.24c	0.21c	0.18c	0.18c	0.11c
Pharmaceutical industry (Phar.I)	0.81b	0.80b	0.72b	0.65ab	0.50b
Textile industry (Tex.I)	0.91a	0.86a	0.79a	0.68a	0.59a
CV (%)	11.73	7.13	9.24	6.38	17.10

Table 4.Cadmium concentration (mg/kg) in tomato of selected industrial areas.

Name of the industry	Distance from the industry				
	100m	200m	300m	400m	500m
Tannery industry (Tan.I)	0.15c	0.12b	0.08c	0.06c	0.03c
Pharmaceutical industry (Phar.I)	0.68ab	0.59ab	0.47ab	0.29b	0.19b
Textile industry (Tex.I)	0.74a	0.61a	0.53a	0.35a	0.25a
CV (%)	8.38	3.22	12.13	13.10	15.00

Effects of Cd concentration on the weight (kg/plant) of tomato fruit at different industrial area are illustrated in Table 5. The weight of tomato collected around the different industrial areas were significantly ($p < 0.05$) different from each other. In general, the weight of tomato had increased with increased distance from the industries. Irrespective of distance, the highest weight of tomato was found around the Tan.I, whereas the lowest weight was observed at Tex.I area. This shows a direct relation between the concentration of Cd and weight of fruits, where higher concentration of Cd resulted lower weight of fruit. The higher concentration of Cd in soil inhibits percentage of germination, survival percentage, plant height, root length, early flowering, more pollen viability, total chlorophyll content hence, fruit weight and girth decreased due to increasing concentrations of Cd. Cadmium (Cd)was reported to affect various aspects of metabolism in different plant systems (Shah and Dubey 1997). At low concentrations, Cd acts as a photophosphorylation inhibitor in spinach chloroplasts (Tukendorf 1993). Ding *et al.* (2021) reported that Cadmium (Cd) is an instance of a heavy metal that is very much toxic for plant growth. Therefore, as the physiological process is hampered by Cd concentration, reduced fruit weight was observed from the study.

Table 5. Weight (kg/plant) of tomato fruit of Cd affected soil from different industrial areas.

Name of the industry	Distance from the industry				
	100 m	200 m	300 m	400 m	500 m
Tannery industry (Tan.I)	0.93a	1.07a	1.05a	1.15a	1.24a
Pharmaceutical industry (Phar.I.)	0.51b	0.54b	0.58b	0.72b	0.85b
Textile industry (Tex.I.)	0.46c	0.48bc	0.57b	0.62c	0.74c
CV (%)	13.04	11.88	1.63	13.19	12.29

The experimental results revealed that the bioconcentration factor (BCF) of the Cd differed significantly ($p < 0.05$). The BCF of Cd from soil to tomatoes was increased in the order of Tan.I < Tex.I< Phar.I. This is an apparent sign that the BCF of Cd in tomato sample grown at Phar.I was higher compared to that of other industries. Results of this study also revealed that tomato grown near the Tex.I accumulates Cd to larger extent compared with Phar. and Tan. industries. Conversely, Cd was observed to accumulate in tomato samples very comparably with BCF values of 0.61, 0.8410 and 0.81grown around Tan.I, Phar.I and Tex.I, respectively (Table 6). Even though the BCF values obtained in this study are all < 1. Khan *et al.* (2009) reported that higher BCF imitate comparatively poor retention in soils or greater efficiency of vegetables to absorbs metals. Low transfer factor reflects the strong absorption of metals to the soil colloids. Transfer and accumulation rates of the heavy metals to plants vary depending upon certain factors together with types of plant species, amount and types of heavy metals, physicochemical characteristics of the soil itself (Naser *et al.* 2012, Sharma *et al.* 2018).

Table 6. Bioconcentration factor (BCF) of Cd for Tomato.

Name of the industry	Distance from the industry				
	100m	200m	300m	400m	500m
Tannery industry (Tan.I)	0.625c	0.571c	0.444c	0.328	0.209
Pharmaceutical industry (Phar.I.)	0.840a	0.738a	0.653a	0.446	0.380
Textile industry (Tex.I.)	0.813b	0.709b	0.671b	0.515	0.424
CV (%)	2.02	3.45	2.68	13.39	10.37

The experiment results revealed that the the concentration of Cd in soils and tomatoes samples exhibited decreased trend in the order of Textile >Pharmaceutical> Tannery industrial area. Cadmium (Cd) concentration in soil and tomato fruits decreased with increased distance from the industries indicating that industrial effluents are playing a vital role for adding Cd in the soil and growing crops which is ultimately enter into food chain. Therefore, regulation should be forced to establish effluent treatment plant (ETP) in every industry to treat their effluent before discharge in open place for keeping soil and crops grown industrial areas Cd free. Results also indicate that the concentration of Cd in tomatoes around Pharmaceutical industry and Textile industry were above the proposed level jointly by FAO and WHO, but around the Tannery industry below the FAO and WHO standard. The BCF of Cd in tomatoes was found to be lower than 1,representing balance proportion of Cd between the soil and the vegetables. Overall results suggest that vegetables growing soil around the industrial area containing higher amount of metals that could be transferred into edible parts of the plant then human body, so studied area need to be monitored regularly to avoid health risk of human being due to exposure of toxic level.

References

Adekunle IM, Olorundare O and Nwange C 2009. Assessments of lead levels and daily intakes from green leafy vegetables of southwest Nigeria. Nutr. Food Sci.**39**: 413-422.

Aguilar M, Mondaca P, Ginocchio R, Vidal K, Sauvé S, Neaman A 2018. Comparison of exposure to trace elements through vegetable consumption between a mining area and an agricultural area in central Chile, Environ. Sci. Pollut. Res. **25**: 19114-19121.

Al-Khashman OA and Shawabkeh RA 2006. Metals distribution in soils around the cement factory in southern Jordan. Environ. Poll.**140**(3): 387-394.

Bulinski R, Bloniarz J and Libelt J 2009. Presence of some Trace Elements in Polish Food Products. Australian J. Soil Res.**15**: 59-68.

Deepali KK and Gangwar K 2010. Metals concentration in textile and tannery effluents, associated soils and ground water. New York Sci. J.**3**(4): 82-89.

Ding X, Zhao Z, Xing Z, Li S, Li X, Liu Y 2021. Comparison of Models for Spatial Distribution and Prediction of Cadmium in Subtropical Forest Soils, Guangdong, China. Land, **10**: 906-911.

FAO/WHO 2003. Codex Alimentarius International Food Standards CODEX STAN-179. Codex Alimentarius commission, WHO/FAO.

Gheorghe IF and Ion B 2012. The effects of air pollutants on vegetation and the role of vegetation in reducing atmospheric pollution. In: Impact of air pollution on health, economy, environment and agricultural sources. ISBN: 978-953-307-528-0.

Haider FU, Liqun C, Coulter JA, Cheema SA, Wu J, Zhang R, Farooq M 2021. Cadmium toxicity in plants: Impacts and remediation strategies. Ecotoxicol. Environ. Saf.**10**: 211-219.

Idzelis RL, Budreika A and Vaiskunaite R 2004. Dirvozemio tarsos sunkiaisiais metals Kairiu karinio poligono teritorijoje tyrimai ir vertinimas. J. Environ. Eng. Landscape Manag.**12**(2): 42-48.

Islam MS, Tusher TR Mustafa M and Mamun SA 2012. Investigation of soil quality and heavy metal concentrations from a waste dumping site of Konabari industrial area at Gazipur in Bangladesh. IOSR J. Environ. Sci. Toxicol. Food Tech.**2**(1): 01-07.

Jackson ML 1973. Soil Chemical Analysis. Prentice-Hall, New Delhi, India. pp.15.

Jolly YN, Islam A and Akbar S 2013. Transfer of metals from soil to vegetables and possible health risk assessment. Springer Plus. **2**: 385-91.

Jolly YN, Islam A and Mustafa AI 2012. Impact of dyeing industry effluent on soil and crop. Universal J. Environ. Res. Tech.**2(6)**: 560-568.

Khan HR 2006. Assessment of SPWAC (Soil-Plant-Water-Air-Continuum) quality within and around Dhaka City. Report submitted to the director of the centre for Advanced Studies and Research in Biotechnological sciences, University of Dhaka, Bangladesh.

Khan S, Cao Q, Zheng YM, Huang YZ and Zhu YG 2008. Health risks of heavy metals in contaminated soils and food crops irrigated with wastewater in Beijing, China. Environ. Poll. **152**: 686-692.

Khan S, Farooq R, Shahbaz S, Khan MA and Sadique M 2009. Health risk assessment of heavy metals for population via consumption of vegetables. World App. Sci. J.**6**(12): 1602-1606.

Koptsik GN, Koptsik SV, Smirnova IE, Sinichkina MA 2021. Effect of Soil Degradation and Remediation in Technogenic Barrens on the Uptake of Nutrients and Heavy Metals by Plants in the Kola Subarctic. Eurasian Soil Sci. **54**: 1252-1264.

Leander D. Melomey, Agyemang Danquah, Samuel K. Offei, Kwadwo Ofori, Eric Danquah and Michael Osei 2019. Review on Tomato (*Solanum lycopersicum* L.) Improvement Programmes in Ghana. http://dx.doi.org/10.5772/intechopen.75843.

Liu W, Li X, Li HHSr and Wang YW 2006. Heavy metal accumulation of edible vegetables cultivated in agricultural soil in the Suburb of Zhengzhou City, People's Republic of China. Bulletin of Environmental. Cont.Toxicol.**76**: 163-170.

Mani D, Kumar Cand Patel NK 2015. Integrated microbiochemical approach for phytoremediation of cadmium and zinc contaminated soils. *Ecotox. Environ. Safe.* **111**: 86-95.

Mingorance MD, Valdes B and Olivia Rossini S 2007. Strategies of heavy metal uptake by plants growing under industrial emissions. Environ. Int.**33**(4): 514-520.

Naser HM, Sultana S, Gomes R and Noor S 2012. Heavy metal pollution of soil and vegetable grown near roadside at Gazipur. Bangladesh J.Agril. Resources.**37**(1): 9-17.

Noor S, Muslim MNZ and Rohasliney H 2015. Determination of heavy metal contamination from batik factory effluents to the surrounding area. Int. J. Chemical, Environ. Biol. Sci. **3**(1): 7-9.

Qasim M, Farooq W and Akhtar W 2018. Preliminary report on the survey of tomato growers in Sindh, Punjab and Balochistan.

Sawyer W and Beebe A 2007. Chemistry Experiment for Instrumental Methods. Wiley, New York. pp. 43-51.

Shah K and Dubey RS 1997. Effect of cadmium on proline accumulation and ribonuclease activity in rice seedlings: role of proline as a possible enzyme protectant. Biologia Plantarum, **40**: 121-130.

Sharma S, Nagpal AK and Kaur I 2018. Heavy metal contamination in soil, food crops and associated health risks for residents of Ropar wetland, Punjab, India and its environments. Food Chem. **255**:15-22.

Siegel KR, Ali MK, Srinivasiahm A, Nugent RA and Narayan KMV 2014. Do we produce enough fruits and vegetables to meet global health need?.PLoS One.**9**:104059.

Stancic Z, Vujevic D, Gomaz A, Bogdan S, Vincek D 2016. Detection of heavy metals in common vegetables at Varaždin City Market, Croatia, Arhiv Za Higijenu Rada i Toksikologiju, **67**: 340-350

Strungaru SA, Robea MA, Plavan G, Todirascuciornea E, Ciobica A and Nicoara M 2018. Acute exposure to methylmercury chloride induces fast changes in swimming performance, cognitive processes and oxidative stress of zebrafish (*Danio rerio*) as reference model for fish community. J. Trace Elem. Med. Biol. **47**: 115-123.

Tukendorf A 1993. Rola kompleksów metaloproteinowych w tolerancji roślin wyższych na toksyczne stężenia metali cieżkich. Rozprawa habilitacyjna XXXIX, Wydawnictwo UMCS, Lublin.

Tusher TR, Piash AS, Latif MA, Kabir MH and Rana MM 2017. Soil Quality and Heavy Metal Concentrations in Agricultural Lands around Dyeing, Glass and Textile Industries in Tangail District of Bangladesh.J. Environ. Sci. Natural Resources.**10**(2):109-116.

Umer S, Hussain M, Arfan M, Rasul F2021. Spatiotemporal variations of metals in urban roadside soils and ornamental plant species of Faisalabad Metropolitan, Pakistan. Int. J. Environ. Sci. Technol. **6**: 1-8.

Van der Zee L, Remigio AC, Casey LW, Purwadi I, Yamjabok J, van der Ent,, A, Kootstra G, Aarts MGM 2021. Quantification of spatial metal accumulation patterns in Noccaea caerulescens by X-ray fluorescence image processing for genetic studies. Plant Methods, **17**: 2-16.

Wang XL, Sato T, Xing BS, Tao S 2005. Health risks of heavy metals to the general public in Tianjin, China via consumption of vegetables and fish. Sci Total Environ. **35**0: 28-37.

Weil RR and Brady NC 2017. *The Nature and Properties of Soils. 15th edition*. Pearson Education, Inc., Boston, MA.

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