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Accumulation of Heavy Metals in Associated Irrigated Water, Soil and Production of Tomato around the Export Processing Zone of Bangladesh

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Abstract: Present study assesses the uptake and allotment of heavy metals in irrigated water, soil and tomato (*Lycopersicones culentum*) at the export processing zone of Bangladesh. The elemental distributions of the heavy metals in the plant organs and fruits were determined after the harvesting stage. The uptake and distribution of the three heavy metals Cd, Cr and Pb were found in the several organs of tomato in reducing pattern of green tomato>plant shoot> leaf> ripen tomato> plant root; leaf> ripen tomato> plant shoot> plant root> green tomato and plant shoot> leaf> ripen tomato> plant root> green tomato while Ni has more toxic metal in Plant root but less in ripe tomato. This outline of distribution in the plant organ showed the typical pattern of a prohibited plant with a higher concentration of metals accumulated in the plant parts than in the fruits. The reducing pattern of the bio-concentration factor (BCF) showed that the ability of tomato fruits to accumulate heavy metals was reduced as the level of contamination in plant parts.

Key words: Toxic metals, tomato products, Dhaka export processing zone, irrigated water, contamination.

Introduction

Many elements that arise in low concentration in the Earth's crust are now extracted widely for use. Large quantities of different kinds of elements are discharged into the environment as contaminants regularly by human actions. Pollution of heavy metals in the aquatic environment has attracted worldwide attention owing to its abundance, diligence and environmental toxicity. Both anthropogenic and natural activities are responsible for the abundance of heavy metals in the environment (Barua et al., 2017, 2020). Sediments provide a temporay signal of the aquatic environment condition and act as a key reservoir for metals, though some sediment can also act as a source of contaminants (Mitra et al., 2022). Besides, heavy metal absorption in aquatic environments is a serious concern, due to the toxicity of metal and their accumulation in aquatic habitats. In addition, heavy metals, in contrast to most pollutants, are not biodegradable and they undergo a global ecological cycle in which natural waters are the main pathways. Heavy metals have infected the aquatic environment in the present century because of intense industrialisation and urbanisation (Barua et al., 2017). Heavy metals commenced into the environment through dumping domestic and municipal wastes, industrial effluents, urban runoff, agricultural run-off, atmospheric deposition and mining activities as well as upstream

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runoff are absorbed on the depositions and incorporated into the marine sediments (Joksimović et al., 2021; Perumal et al., 2021). Tomato (*Lycopersicon esculentum* Mill), belongs to the family Solanaceae and is one of the most accepted and suitable vegetables grown in the world. About 500 million tons of tomatoes were produced in the world in 2021. The largest producer, China (50,765,600 tons), accounted for about one-quarter of the global production followed by the United States (20,850,000 tons) and India (15,850,500 tons) (FAO, 2022).

Tomato is the major vegetable crop of these; includes brinjal (egg plant), chilli, lady's finger, potato, bottle gourd, red amaranth, etc. Otherwise, vegetables have been verified to be a significant part of the human diet because they are lacking in the originality of a balanced diet (carbohydrates, proteins, vitamins, minerals and trace constituents (Piscitelli et al., 2020). On the other hand, the liberated and consequent statement of heavy metals in food products like fruits, vegetables, etc. cannot be accentuated. Heavy metals are portable and effortlessly taken up by the plants in the surroundings. Metals gathering in vegetables may pretense a straight hazard to human health (Nyalugwe et al., 2022). Dissimilar materials occur logically in our setting as a result of natural actions. Many diseases are caused by the incapacity of the environment to sustain the mineral requirements of humans, plants and animals or man (Ddamulira et al., 2021*)*.

The water utilised for irrigation is normally attained from urban rivers, and wells and which have frequently been stated to be contaminated by heavy metals that can as well be the foundation of heavy metals build up in farming manufactured goods (Haldar et al., 2022). Investigating the advantages for the crop farmers during the agrochemical situation of town vegetable soils because of their input concentration, year-round vegetative cover, soil and hydrological distinctiveness, and their spatial inconsistency have increased significantly. (Maureira et al., 2022).

The health risks will depend on the chemical composition of the waste material and its physical characteristics. Especially tomato is popular for its taste, nutritional status and various uses. The tomato is cultivated all over the country due to its adaptability to a wide range of soil and climate. It ranks third, next to potato and sweet potato, in terms of world vegetable production and tops the list of canned vegetables. During 2011-2012, tomato production in Bangladesh was 255,000 mt. tons and it was 190213 mt. tons in 2009-10. During the year 2021-2022, tomato production in the country reached 320,000 mt. tons which hold about 60% of the total crop production in Bangladesh (Das and Jahan, 2022).

Dhaka Export Processing Zone (DEPZ) is situated on the west-northern side of the Dhaka district of Bangladesh. The water and soil of the area are highly polluted by industrial contaminated heavy metals which come terrified from a number of industries in DEPZ of Dhaka district as like garments factories, plastic material manufacturing industries, dyeing industries, pharmaceuticals industries, chemical industries and different food processing industries which are regularized by without ETP or normal ETP. So easily, nearby industrial areas are contaminated by toxic chemicals. The people of the area cultivate all kinds of vegetables all around the year.

Different literature works in Bangladesh by various researchers found that an accumulation of trace metals from tomatoes grown around industrial sites has revealed high levels of Ni, Pb and Cd in tomatoes. So in the experiment, the authors selected the tomato to evaluate the heavy metal's status in irrigated water, soil and tomato plant parts and fruits for protecting the environment and human health.

Materials and Methods

Dhaka Export Processing Zone (DEPZ) was selected for sample collection (irrigation water, soil and plant materials. The physical and chemical properties of irrigation water and soil were measured following the mentioned procedures. Heavy metal concentration in different samples of irrigation water, soil and tomato (plant root, shoot, leaf, green tomato and ripen tomato) were measured by atomic absorption spectrophotometer (AAS) (Varian Spectra AA55B, Australia).

Physico-Chemical Properties of Irrigation Water

The pH value of water samples was measured with the support of a portable pH meter (Model-WTW pH 522). The electrical conductivity (EC) of the samples was calculated with the help of an EC meter (Model-D.6072 Dreieich, West Germany) total dissolved solids (TDS) of the samples was calculated with the help of a TDS meter (Model-HACH sens IONTM + EC5).

Heavy Metal Concentration in Irrigation Water

Determination of several heavy metals in water samples was done by using an atomic absorption spectrophotometer (AAS) (Varian Spectra AA55B, Australia). Mono component hollow cathode lamp was employed for the determination of each heavy metal of interest. At first, the AAS was calibrated following the manufacturer's commendation. The filtered water sample was run openly for the determination of heavy metal in water samples. A standard curve was ready by plotting the absorbance reading on the Y-axis versus the concentration of each standard solution of metal on the X-axis. Then, the concentration of metal in the water samples of interest was calculated by plotting the AAS reading on the standard line.

Physico-Chemical Properties of Soil

Soil pH was determined by a glass electrode pH meter (WTW pH 522; Germany), electrical conductivity (EC) was measured by a conductivity meter (Model D.6072 Dreieich, West Germany) in 1:5 of soil water suspension. The amount of organic matter in soil samples was calculated by multiplying the content of organic carbon by the Van Bemmelen factor, 1.73. % Organic matter = % OC × 1.73

Heavy Metal Concentration in Sediment

The concentrations of heavy metals in soil samples were determined at the soil science laboratory of the Bangladesh Agricultural Research Institute (BARI), Joydebpur. For the determination of total metal concentration, exactly 1.00 g of powdered soil sample was digested with aquaregia (HNO_3: HCl = 1:3). Then the content was evaporated to dryness and again 5 ml aquaregia was added. This process was repeated 2-3 times for efficient extraction of metals. Then the digest was filtered through a filter paper (Whatman no. 42) and the filtrate volume was made to 25 ml with HNO_3.

The determination of different heavy metals in soil samples was done by using an atomic absorption spectrophotometer (AAS) (Varian Spectra AA55B, Australia). Mono element hollow cathode lamp was employed for the determination of each heavy metal of interest. At first, the AAS was calibrated followed by the manufacturer's recommendation. Then the soil extract was diluted (if required) and/or run directly in AAS for the determination of heavy metal in the sample. A standard curve was prepared by plotting the absorbance reading on the Y-axis versus the concentration of each standard solution of metal on the X-axis. Then, the concentration of metal was calculated in the soil samples of interest by plotting the AAS reading on the standard curve.

Analysis of Plant Parts and Fruits (Tomato) Samples

The tomato plant parts and fruit samples were collected from Dhaka Exporting Processing Zone (DEPZ). Samples were collected at the stage of harvest by farmers. The growth stage for the tomato sample was more or less the same. The samples of different plant parts and fruits (green, ripen) were put into the individual polythene bag with definite markings and tagging and brought to the central laboratory of BARI. In the laboratory, the collected samples were cut into small pieces and air-dried. The dried samples were then oven dried at 65 °C for 48 hours. The samples were then ground using a grinder machine and stored in plastic containers in the desiccators.

For the determination of total metal concentration, exactly 1.00 g of powdered sample was digested with aquaregia (HNO_3: HCl = 1:3). Then the content was evaporated to dryness and again 5 ml aquaregia was added. This process was repeated 2-3 times for efficient extraction of metals. Then the digest was filtered through a filter paper (Whatman no. 42) and the filtrate volume was made with 25 ml HNO_3. The determination of different heavy metals in prepared subsamples was done by using an atomic absorption spectrophotometer (AAS) (Varian Spectra AA55B, Australia). Mono element hollow cathode lamp was employed for the determination of each heavy metal of interest. At first, the AAS was calibrated followed by the manufacturer's recommendation. Then the soil extract was diluted (if required) and/or run directly in AAS for the determination of heavy metal in the sample. A standard curve was prepared by plotting the absorbance reading on the Y-axis versus the concentration of each standard solution of metal on the X-axis. Then, the concentration of metal was calculated in the soil samples of interest by plotting the AAS reading on the standard curve.

Result and Discussions

Common Properties of Irrigated Water

The studied irrigation water samples were assembled from the experimental area of the Dhaka Export Processing Zone (DEPZ) in the Dhaka district (Table 1). The samples contained different levels of pH value, EC (electrical conductivity) and TDS (total dissolved solid) value. The results were summarised (Table 1) revealing that the average value from three samples was pH, EC and TDS of analysed 7.03**,** 530 μcm^{-1} and 223 mg L^{-1}, respectively. And the level (mg L^{-1}) of heavy metal Cd, Cr, Cu, Fe, Ni, Pb and Zn concentration in irrigation water were 0.01 mg L^{-1}, 0.06 mg L^{-1}, 0.33 mg L^{-1}, 2.89 mg L^{-1}, 0.05 mg L^{-1}, 0.18 mg L^{-1} and 1.05 mg L^{-1}, respectively. It revealed that the amount of heavy metals (Cd, Cr, Fe and Pb) is more than the standard level. So, the level of metals become toxic and hamper the tomato production which has consequences of health hazards for the local people.

Common Properties of Soil Samples

The studied soil samples of the study area were summarised in (Table 2) and also revealed that the value of pH, EC and OM were 7.75, 526 μcm^{-1} and 3.23 (mg kg^{-1}) respectively from the three collected samples. Also, the heavy metal concentration of soil (mg kg^{-1}) of heavy metals in the soil of tomato growing field was analysed regarding Cd, Cr, Cu, Fe, Ni, Pb and Zn (Table 2).

The average value of selected heavy metals in the order of Cd, Cr, Cu, Fe, Ni, Pb and Zn were 1.66 mg kg^{-1}, 4.11 mg kg^{-1}, 15.45 mg kg^{-1}, 69.65 mg kg^{-1}, 4.87 mg kg^{-1}, 5.46 mg $kg^{-1}$and 2.87 mg kg^{-1}, respectively. In the experiment, Cd and Fe are more than the standard level referred by international scientists and organisation. So also its bad impact affects the yield of tomatoes and finally human health.

In the study area, the heavy metals concentration in irrigated water of Cu, Ni and Zn was below than standard level but for Cd, Cr, Fe and Pb were more than the different organisational proposed standard level. On the other hand, in soil Cd and Fe levels were more than standard but Cr, Cu, Pb, Ni and Zn levels were less than different organizational recommended standard scales (Kabata, 2022; WHO, 2020).

Heavy Metal Concentration in Tomato Products

The collected different samples of tomato fruits or plant parts from the study area contained different heavy metals at different concentrations (Table 3). The average value of selected heavy metals viz. Cd, Cr, Cu, Fe, Ni,

Table 1: Common properties and heavy metal concentration of irrigation water samples

Sample	*Common properties of irrigated water*			*Heavy metal concentrations in irrigated water samples (mg L^{-1})*						
	pH	*EC (µ cm^{-1})*	*TDS (mg L^{-1})*	*Cd*	*Cr*	*Cu*	*Fe*	*Ni*	*Pb*	*Zn*
Water Sample	7.03	530	223	0.01	0.06	0.33	2.89	0.05	0.18	1.05
DoE(1997), Standard	6.5-8.5	350.00	1000.00	0.005	0.05	NA	0.30-1.00	0.10	0.05	5.00
WHO (1993), Guideline	NA	NA	NA	0.003	0.05	NA	NA	0.02	0.01	3.00
USEPA(2008) Guideline	NA	NA	NA	0.005	0.1	NA	0.30	NA	NA	5.00

Table 2: Common (physical and chemical) properties of soils and heavy metal concentration in sediments

Sample	*Common properties of Sediment*			*Heavy metal concentrations in Sediments (mg L^{-1})*						
	pH	*EC (µ cm^{-1})*	*OM (mg kg^{-1})*	*Cd*	*Cr*	*Cu*	*Fe*	*Ni*	*Pb*	*Zn*
Soil Sample	7.03	530	223	0.01	0.06	0.33	2.89	0.05	0.18	1.05
Standard level of heavy metals level in sediments by Kabata and Pendis (2019)	NA	NA	NA	NA	NA	100.00	NA	NA	NA	NA
Standard level of heavy metals level in sediments by WHO (2020),	NA	NA	NA	6.00	25.00	NA	NA	20.00	NA	123.00
Standard level of heavy metals level in sediments by USEPA (2020)	NA	NA	NA	0.60	25.00	NA	30.00	16.00	30.00	110.00
Standard level of heavy metals level in sediments by CCME (2020),	NA	NA	NA	0.06	37.00	NA	NA	NA	NA	123.00

Pb and Zn were 0.05 mg kg^{-1}, 0.74 mg kg^{-1}, 12.51 mg kg^{-1}, 45.81 mg kg^{-1}, 1.65 mg kg^{-1}, 0.17 mg kg^{-1} and 15.84 mg kg^{-1} which were ranged from 0.02-0.09 mg kg^{-1}, 0.26-0.75 mg kg^{-1}, 11.36-13.32 mg kg^{-1}, 21.12-74.15 mg kg^{-1}, 1.43-2.72 mg kg^{-1}, 0.11-0.23 mg kg^{-1} and 12.16-21.44 mg kg^{-1}, respectively.

The finding of the study revealed that the highest value of Cr (0.75 mg kg^{-1}) and Zn (21.44 mg kg^{-1}) was found in leaf, Cu (13.32 mg kg^{-1}) and Fe (74.15 mg kg^{-1}) was found in ripen tomato; Cd (0.09 mg kg^{-1}) was found in green tomato; Ni (2.72 mg kg^{-1}) was found in plant root and Pb (0.23) was found in shoots. Considering the present status of selected heavy metals (Cd, Cr, Pd and Zn) in tomato fruits or plant parts collected from the study area were lower than standard level but in Cu, Fe and Ni were larger than the maximum permissible level institutions standard range (WHO, 2020; FAO, 2021). So it is stated that the heavy metal limit of all tomato fruits from selected areas of Bangladesh is not harmful to health.

The finding of Table 3 shows the overall variation of Cd, Cr, Cu, Fe, Ni, Pb and Zn in green tomato. Many scientists agree with our observation that the total amounts of heavy metals in soils are not suitable for estimating the solubility and mobility and consequently the toxicity of heavy metals (Abollino et al., 2018; Pueyo et al., 2020; Nunes et al., 2022). The overall concentration of each metal significantly varied in ripened tomatoes. The accumulation of Cd, Cr and Pb in green tomatoes was found higher than in WHO and FAO. But Cu, Fe and Ni concentration in green tomatoes is higher than all referred limitations and Zn status is higher than FAO.

In addition, Table 3 shows the overall variation of Cd, Cr, Cu, Fe, Ni, Pb and Zn in ripened tomatoes. The overall concentration of each metal significantly varied in ripened tomatoes. The accumulation of Cu, Fe and Ni is found in higher and Ca, Zn, Cd is found in lower concentration in ripened tomatoes according to the permissible level of WHO and FAO. According to Gomes et al. (2017), plants have a variety of methods to counteract the harmful effects of heavy metals on plants. One of the primary tactics is limiting their uptake from the soil by using organic substances generated and released from complicated metals in the base. Plants may become activated if a dangerous heavy metal gets into the root. various strategies for tolerance, including metal compartmentalisation in various intracellular structures, or the formation and accumulation of several substances worked to prevent metal complexation, preventing their transfer from a plant's root to another area. choosing a strategy in particular relies on the environmental factors and genetic makeup of the plant. The outcomes of this research focussed on the presence

Table 3: Concentration of heavy metal (mg kg^{-1}) in BARI tomato-5 at DEPZ in Dhaka

Specimen	*Concentration of heavy metal in BARI tomato-5 in the study area*						
	Cd	*Cr*	*Cu*	*Fe*	*Ni*	*Pb*	*Zn*
Plant root	0.02	0.32	12.13	34.22	2.72	0.12	15.86
Plant Shoot	0.08	0.62	11.36	45.10	1.43	0.23	16.76
Leaf	0.04	0.75	13.31	21.12	1.73	0.21	21.44
Green Tomato	0.09	0.26	12.42	54.45	1.11	0.11	12.16
Ripen Tomato	0.03	0.73	13.32	74.15	0.25	0.16	12.98
Range	0.02-0.09	0.26-0.75	11.36-13.32	21.12-74.15	0.25-2.72	0.11-0.23	12.16-21.44
Mean	0.05	0.54	12.51	45.81	1.45	0.17	15.84
Max.	0.09	0.75	13.32	74.15	2.72	0.23	21.44
Min.	0.02	0.26	11.36	21.12	1.43	0.11	12.16
Guideline of Optimum level for range of heavy metals in fruits and vegetable by WHO (2022)	0.06	NA	0.1	NA	NA	0.1	15.00
Guideline of Optimum range of heavy metals in fruits and vegetable heavy metals by FAO (2015)	0.01	NA	0.20	5.00	0.20	5.00	2.00

of heavy metals in soils and their buildup in the plant providing considerable support for the aforementioned theories.

Conclusions and Recommendations

As a result of repeated use of fertilisers and pesticides in the cultivation of food crops, heavy metal contamination of the soils increases, having detrimental impacts on human health. Consuming food crops grown on these soils can improve one's health. In order to reach this goal, legislation in some industrialised nations has set tolerance limitations on heavy-metal additions to soils (fertilisers and biosolids). As a result, it is necessary to eliminate heavy metal contamination in greenhouse soils. Unfortunately, Bangladesh lacks any relevant legislative regulations. Only the maximum permitted levels of dangerous heavy metals in agricultural soils were set by law in our nation. Such soil can be regarded as heavy metal-polluted and unusable for agriculture if any of the concentrations of the aforementioned heavy metals in it are higher than the limit value.

The study was performed in the Dhaka Export Processing Zone (DEPZ) of Bangladesh to monitor the heavy metal standing in irrigation water, soil and tomato plant parts and fruits. Sample collection was replicated thrice. Selected heavy metals such as Cd, Cr, Cu, Fe, Ni, Pb and Zn were determined from sample analysis. Allowing for the permitted status of heavy metals in irrigation water, soil and tomato plant parts and fruits suggested by several international organization guidelines. It is confirmed that in the investigational areas of Dhaka Export Processing Zone (DEPZ) in Dhaka district, the heavy metals pollution in irrigation water, soil and tomato plant parts and fruits were sometimes below than permissible stage and otherwise more. Considering the plant concentration factor or transfer factor of the metals, it can be suggested that vegetables like tomatoes and cabbage grown in the contaminated soils of the study areas should not be used as food or even feed. It is of prime importance to the researchers for protecting the soil health from industrial pollution by taking different pragmatic actions for healthy vegetable production

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