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EFFECTS OF IRRIGATION WATER ON SOME VEGETABLES AROUND INDUSTRIAL AREAS OF DHAKA

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Abstract

A pot experiment was conducted to investigate the effect of irrigation water collected from different industrial areas on Red amaranth (*Amaranthus tricolor* L.) and tomato (*Solanum lycopersicum* L.). Collected water samples were analyzed for various parameters, which include pH, DO, BOD, COD, P, NH_3-N, K, S, Zn, Cu, Pb and Cd. The results were compared with the irrigation water quality standards by the Department of Environment (DoE) of Bangladesh and many of them were found several-folds higher than the permissible limit. The deterioration trends of the water samples are as follows: Tejgaon canal > Rampura canal > Sitalakhya river. Dry matter of vegetables grown on Tejgaon soil was significantly ($p \leq 0.05$) higher than that of agricultural soil. Both red amaranth and tomato grown in Tejgaon soil accumulate highest concentration of heavy metals followed by Rampura and Sitalakhya soil. The concentrations of zinc (Zn), lead (Pb) and cadmium (Cd) in edible portions of both vegetables were found several times higher than the WHO prescribed permissible limits. The concentration of heavy metals in vegetables were found in the order Zn > Cu > Pb > Cd.

Key words: Heavy metals, irrigation water, vegetables, industrial areas

Introduction

Bangladesh is going through a rapid industrialization and urbanization processes from last decades which promoted socioeconomic development. But beside all positive effects on daily life, they have a deep impact on the environment.

Observation of population growth trends and national industrial development with consequential increase in discharge of waste from factories and mines, it is predicted that the chances of increase of heavy metal contamination levels of soil and their entry into the food chain, is increasing and a cause for alarm (Yargholi *et al.* 2008).

Bangladesh has about 230 small and three large rivers, and a large chunk of the country's 160 million people depend on them for living and for transportation. But experts say many of them are drying up or are choked because of pollution and encroachment. A World Bank study said four major rivers near Dhaka - the Buriganga, Shitalakhya, Turag and Balu - receive 1.5 million cubic meters of waste water every day from 7,000 industrial units in surrounding areas and another 0.5 million cubic meters from other sources. The Department of Environment (DoE) has listed 1,176 factories that cause pollution throughout the country (Ahmed 2009).

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Wastewater irrigation is a wide spread practice around the globe (Mapanda *et al.* 2005). In general, wastewater use provides substantial amount of potentially toxic heavy metals, which are creating problems for agricultural production (Singh *et al.* 2004). Prolonged and continuous use of wastewater for growing vegetables, fodders and other major crops may result in soil build up of heavy metals and salinity that may be phyto-toxic (Qadir and Oster 2004). Inhibition of root growth, shoot development and various metabolic processes in plants have been reported because of higher concentrations of heavy metals in soils which further resulted in chlorosis, damage to root tips, reduced water and nutrient uptake and damage to enzyme system (Sanita and Gabbrielli 1999). Extreme accumulation of heavy metals in agricultural soils through wastewater irrigation may not only result in soil contamination but also lead to elevated heavy metal uptake by crops, threatening food quality and safety (Muchuweti *et al.* 2006).

Soils act as toxic chemical filters may absorb and retain heavy metals from wastewater. However, due to continuous loading of pollutants and changes in pH, the capacity of soils to retain toxic metals is reduced and thus soil may release heavy metals into groundwater or make available for plant uptake (Mapanda *et al*. 2005). Contaminants from industrial, urban and agricultural sources may enter the food chain in addition to the low water quality of an area (Canalid *et al.* 2011).

The daily vegetable consumption by an adult of Bangladesh is 130 g (Islam *et al.* 2005). Vegetables constitute an important part of the human diet since they contain carbohydrates, proteins, as well as vitamins and minerals. In an average Bengali home, the main meal would consist of boiled rice served with some sort of vegetables. Red amaranth (*Amaranthus tricolor* L.) and tomato (*Solanum lycopersicum* L.) are the most common consumed vegetables in Bangladesh which are grown extensively in the country. The agricultural lands near the industrial belts around Dhaka city are used to grow these crops with the waste water coming from various industrial units. However, Khan *et al*. (2008) found that vegetables cultivated on the wastewater irrigated soils may take up polycyclic aromatic hydrocarbons and heavy metals in sufficient quantities to cause health problems for consumers. Information regarding the accumulation of heavy metals in vegetables in industrially polluted areas in Bangladesh is limited. But such information is vital for the production of quality vegetables as well as healthy food stuffs. In this context, the aim of the present study was to see the effect of irrigation water on the growth, and heavy metal concentration of tomato and red amaranth around industrial area of Dhaka.

Materials and Methods

To conduct the present research, the study area for sample collection was chosen from Tejgaon-Rampura canal to Sitalakhya River. The whole area was divided into three small parts, namely Tejgaon Canal, Rampura Canal-Balu River and Sitalakhya River close to Balu River area. The soils were collected at 0 - 15 cm depth from adjacent fields of Tejgaon Canal, Rampura Canal and Sitalakhya River. For agricultural soil, samples were collected from Kayetpara near Rampura which is a few meters away from industrial area. All soils belong to Tejgaon soil series (USDA 1951).

Water samples for irrigation purpose were collected in large plastic drums from the corresponding water bodies of the Tejgaon, Rampura and Sitalakhya areas during the month of December, 2011. The points of water sample collection were selected nearer to the soil sampling sites. Tap water from the Department of Soil, Water and Environment, University of Dhaka was used for irrigation of plants growing on agricultural soil. For laboratory analysis two sets of sample were collected in plastic bottle from each point. One set kept for physicochemical analysis was mixed with 4 - 5 drops of acid and BOD, COD, DO and pH were determined from another set of sample where acid was not used.

The study was conducted with two sets (each set contains 12 pots) of pot experiment of which one set for tomato (*Solanum lycopersicum* L.) and another set for red amaranth (*Amaranthus tricolor* L.). Each set of 12 pots were divided into four subsets, namely Tejgaon (T), Rampura (R), Sitalakhya (S) and Agricultural soil (A). The number of replication was three for each subset. Five kg air-dried soil was taken per pot and required amounts of fertilizers (Urea, MP and TSP) were mixed before planting. Seeds were collected from BADC and were sown in each of the pots on 28th January, 2012. Two tomato and ten red amaranth plants were allowed to grow after one week of germination. During the growing period, pots were irrigated twice a day with collected water. Intercultural operations were done whenever necessary. Red amaranth was harvested by uprooting

Table 1. Physical, chemical and physico-chemical properties of soil.

Properties	Soils			
	Agricultural soil (A)	Tejgaon (T)	Rampura (R)	Sitalakhya (S)
pH	4.40	5.90	4.84	6.24
Moisture content (%)	4.73	7.62	4.96	2.88
Textural class	Silty clay loam	Silt loam	Loam	Silty clay loam
Organic C (%)	1.07	6.28	1.90	0.95
Available N (mg/kg)	673.9	504.2	586.5	308.7
Available P "	8.72	4	6.10	12.17
Available K "	195.65	285.38	36.71	34.15
Total N (%)	0.185	1.07	0.17	0.12
Total P "	0.06	0.19	0.15	0.10
Total K "	0.13	0.23	0.17	0.16
Total S "	0.11	0.13	0.14	0.12

after 30 days of germination. The tomato were collected by picking when it became matured and it was done on regular basis from 70 days of seedling to 110 days. After harvesting, the samples were air dried after washing properly. Again, the samples were oven dried and were ground, sieved and preserved for laboratory analysis.

The soil samples were air-dried at room temperature, then pulverized and sieved through a 2 mm sieve for C analysis. For nutrient and metals analysis, soils were sieved through 0.5 mm sieve. The organic carbon content of the soils was determined by wet oxidation method of Walkley and Black (1934). For total metal analysis, soil samples were wet-digested with aqua regia (HNO_3: HCl = 1 : 3) and various properties were determined following the procedure as described by Huq and Alam (2005) (Table 1). Plant samples were digested with HNO_3 and $HClO_4$ in 5 : 1 ratio. All physico-chemical parameters of collected water and plant samples were determined following standard methods (Jackson 1973). The total metal concentrations were determined by atomic absorption spectrophotometer (AAS). Statistical analysis was performed using the statistical package SPSS 16.0.

Results and Discussion

pH of the tap water and Sitalakhya River water were found close to the DoE recommended irrigation water standard value (7.50). On the other hand, pH of water samples from Tejgaon canal and Rampura canal were found slightly below (7.15 and 6.90) from the standard value. Biological oxygen demand (BOD) was several times higher than the DoE recommended (50 mg/l) irrigation standards (Table 2). The maximum threats were in Tejgaon area (520 mg/l) where water directly received the industrial effluents.The high level of BOD in the wastewater also indicated the presence of excessive amount of bacteria in the water, which consumed the dissolved oxygen. Chemical oxygen demand (COD) in water samples from Tejgaon and Rampura canal were 430 and 300 mg/l, respectively which were much higher than the DoE recommended irrigation standards (200 mg/l). The water samples from Sitalakhya River (190 mg/l) were safe in this case. DO is an important water quality parameter for most chemical and biological processes in water bodies and is essential for all aquatic life. As BOD and COD were very much higher in Tejgaon and Rampura canal samples, the dissolved oxygen (DO) was very much lower than the prescribed irrigation water quality standard (6.25 mg/l) by DoE. Sitalakhya River water sample also possesses much lower DO concentrations. This indicates that the water is toxic for aquatic life in that area and it might cause many diseases in crops. Total dissolved solids (TDS) were in safe limits. The concentrations of NH_3-N, P and SO_4^{2-}-S in collected water samples were within the DoE recommended irrigation water quality except the Tejgaon water sample where concentration of P was higher (14.68 mg/l). The maximum concentration of K in irrigation water is 1.2 ppm (Huq and Alam 2005) but the concentration of K was found to be higher in these three areas (12.92, 12.29 and 3.29 mg/l, respectively) and water from Tejgaon canal showed highest concentration (12.92 mg/l).

The concentrations of Zn, Cu and Pb in water were found within the DoE recommended irrigation water quality standards except the concentration of Pb in water sample collected from Tejgaon (0.56 mg/l) canal which was five times higher than the standard value (0.1 mg/l). Very high concentration of Cd was found in the water from Tejgaon canal (0.13 mg/l), Rampura canal (0.17 mg/l) and Sitalakhya River (0.13 mg/l) which exceed the permissible limits (0.05 mg/l) for irrigation water reported by DoE. The prolonged application of this water might result higher accumulation of heavy metals into the soil and plant. The concentration of Zn, Cu, Pb and Cd of tap water (used for agricultural soil) was below the detection limit (Table 2). The trends of heavy metals in the water samples of the study area were Tejgaon canal > Rampura canal > Sitalakhya river. The higher concentrations of different parameters might be due to the deposition of large quantity of industrial effluent in Tejgaon canal and it was decreased towards the Sitalakhya River.

Table 2. Composition of irrigation water collected from various sampling sites (mg/l).

Properties	Tap water	Water collected from industrial area			Irrigation standards (DoE 2008)
		Tejgaon (T)	Rampura (R)	Sitalakhya (S)	
pH	7.20	7.15	6.90	7.30	7.50
BOD	6.25	520	480	110	50
COD	7.49	430	300	190	200
DO	6.62	0.33	0.37	2.69	6.25
TDS	215	1158	1108	781	2100
Ammonia- N	1.12	2.71	2.65	0.53	50
Total P	0.06	14.68	7.20	6.04	8
Total K	0.09	12.92	12.29	3.29	…..
Total S	0.23	7.93	4.84	2.28	22
Total Zn	0.01	0.12	0.15	0.02	5
Total Cu	BDL*	0.01	0.03	0.001	0.50
Total Pb	BDL*	0.56	0.07	BDL*	0.10
Total Cd	BDL*	0.13	0.17	0.13	0.05

* BDL = Below detection limit.

The data from Table 3 reveal that the irrigation of water has a great significance on amaranth and tomato. The production of red amaranth (dry matter basis) was highest in Tejgaon and lowest in Rampura. On the other hand, the production of tomato (dry matter basis) was higher in Sitalakhya soil compared to agricultural soil but Tejgaon and Rampura soil produced lower amount of tomato compared to agricultural soil. The N concentrations for both vegetables were higher in comparison to the vegetables grown on agricultural soil. In red amaranth P concentrations at vegetables grown in Rampura and Sitalakhya soils were close to the agricultural soil except in vegetables grown in Tejgaon soil which was found lower than the agricultural soil. But the P concentration in tomato was higher in Rampura and lower in the agricultural soil. The trend of concentration of K was found as agricultural soil > Sitalakhya > Rampura > Tejgaon in red amaranth and Tejgaon > Rampura > agricultural soil > Sitalakhya in tomato.

Several-folds higher concentrations of all the heavy metals were observed in vegetables irrigated with water collected from industrial area as compared to vegetables irrigated with tap water (Figs 1 and 2). The use of contaminated irrigation water increased the concentration of heavy metals in the vegetables. In both cases of red amaranth and tomato, the concentration of Zn was found to be highest in Tejgaon as 416.38 and 232.73 mg/kg, respectively and lowest amount was found in the agricultural soil as 40.96 and 17.19 mg/kg, respectively. The concentration of Zn in amaranth and tomato grown on the soils of industrial area were significantly differ but ($p \leq 0.05$) from plants grown on agricultural soil. The values of Zn concentration for both red amaranth and tomato exceeded permissible level in vegetables which is 100 mg/kg (WHO 2001). The concentrations of Cu in both vegetables were found to be below the safe limit which is 73 mg/kg (WHO 2001). The vegetables irrigated with water from industrial area showed higher accumulation of Cu than the vegetables grown on agricultural soil. The concentration of Cu in amaranth grown on the soils of industrial area varied significantly ($p \leq 0.05$) from the plants grown on agricultural soil and in case of tomato the Cu concentration in agricultural soil varied significantly ($p \leq 0.05$) with Tejgaon soil only.

Table 3. Effect of irrigation on the growth and nutritional status red amaranth and tomato (%).

Soil	Red amaranth				Tomato			
	Dry-wt. (gm/100 plants)	N	P	K	Dry-wt. (gm /2 plants)	N	P	K
Agricultural soil (A)	22.15	1.90	0.46	8.48	2.11	1.71	0.63	5.91
Tejgaon (T)	32.95	2.60	0.37	6.65	1.26	1.79	0.75	7.04
Rampura (R)	18.35	2.19	0.43	6.96	1.17	1.90	0.82	6.37
Sitalakhya (S)	23.30	2.07	0.48	8.26	3.97	2.01	0.72	5.88
$LSD_{0.05}$	9.79	0.23	0.06	NS	2.40	0.12	0.10	0.67

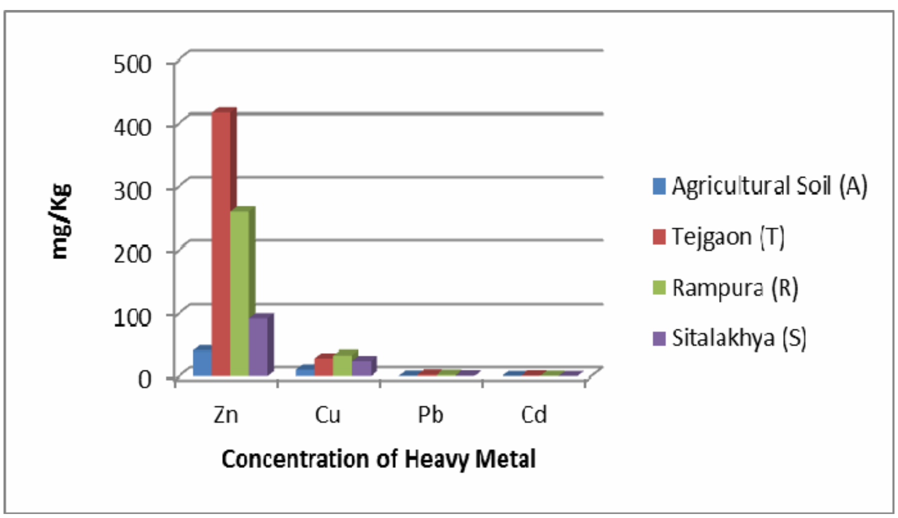

Fig 1. Effect of irrigation on the concentration of heavy metals in red amaranth.

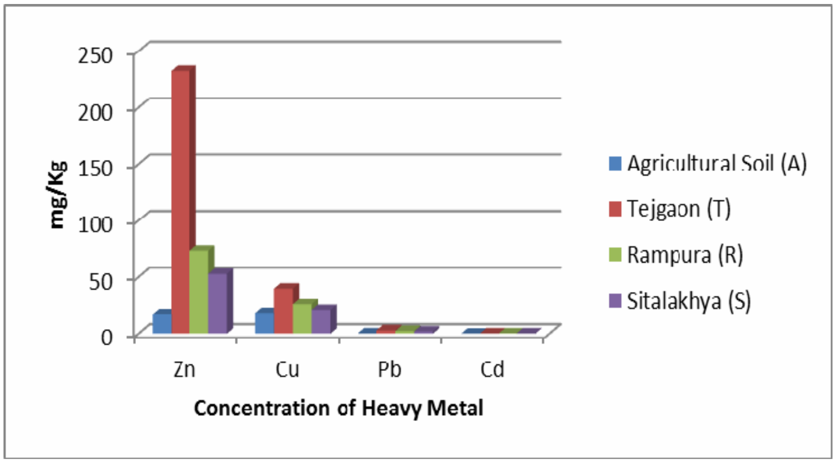

Fig. 2. Effect of irrigation on the concentration of heavy metals in tomato.

In both cases, the concentration of Pb was higher in Tejgaon soil (2.52 mg/kg in red amaranth and 2.84 mg/kg in tomato) and lowest in agricultural soil. The values of Pb concentration for both vegetables exceeded the permissible limit which is 0.3 mg/kg (WHO 2001). The concentration of Pb in tomato grown on agricultural soil varied significantly ($p \leq 0.05$) with the soils of industrial area. Accumulation of Cd was highest in red amaranth grown on Tejgaon soil (1.03 mg/kg) and in tomato grown on Rampura soil (0.22 mg/kg), respectively. In both cases, Cd was not found in vegetables grown on agricultural soil. The permissible level of Cd in vegetables is 0.1 mg/kg (WHO 2001). The concentration of Cd in red amaranth and tomato grown on the agricultural soil varied significantly ($p \leq 0.05$) from soils of industrial area.

Cd and Pb are nonessential metals causing adverse health effects even at very low concentrations (Ikeda *et al.* 2000). The Cd concentration of vegetables in this study was in agreement with the findings of Naser *et al.* (2009). Variations in the heavy metal concentrations between the test vegetables reflect the differences in uptake capabilities and their further translocation to the edible portion of the plants. The concentration of Zn and Cd in amaranth was higher than tomato. Cu and Pb concentration, were same in both vegetables. The concentration of heavy metals in vegetables grown on soils were in the order Tejgaon > Rampura > Sitalakhya > Agricultural soil except Cu in red amaranth and Cd in tomato grown on Rampura soil were higher. The results revealed that leafy vegetables accumulate higher concentration of heavy metals than fruit vegetables. The higher uptake of heavy metals in leafy vegetables may be due to higher transpiration rate to maintain the growth and moisture content of these plants (Tani and Barrington 2005). The higher concentration of Zn, Cu, Pb and Cd from the experiment indicates that the plants grown in industrial area accumulate more heavy metals. Several studies have indicated that vegetables grown in heavy metal contaminated soil and irrigated with industrially wastewater have higher concentration of heavy metals than those grown in uncontaminated soil (Kashem and Singh 1999, Bigdeli and Seilsepour 2008).

Conclusion

From the study it is revealed that both red amaranth and tomato grown on Tejgaon soil accumulate more heavy metals followed by Rampura and Sitalakhya soil. The concentration of Zn, Pb and Cd of both the vegetables were several-folds higher than that of WHO recommended permissible limits. It could be concluded that the use of contaminated water as irrigation purpose increased heavy metal concentration to the vegetables which might pose potential health risks in the long-term consumption.

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