



e-ISSN: 2456-6632

This content is available online at AESA

Archives of Agriculture and Environmental Science

Journal homepage: journals.aesacademy.org/index.php/aaes



ORIGINAL RESEARCH ARTICLE



Effects of industrial effluents on growth and heavy metals accumulation in cabbage in Bangladesh

Abu Rashed Md. Maukeeb^{1*} , Md. Kamrul Hasan², Munmun Saha² and Md. Fuad Mondal³

¹Department of Agricultural Chemistry, Khulna Agricultural University, Khulna - 9100, BANGLADESH

²Department of Agricultural Chemistry, Sylhet Agricultural University, Sylhet - 3100, BANGLADESH

³Department of Entomology, Sylhet Agricultural University, Sylhet - 3100, BANGLADESH

*Corresponding author's E-mail: rashedmaukeeb@gmail.com

ARTICLE HISTORY

Received: 22 January 2022

Revised received: 28 February 2022

Accepted: 22 March 2022

Keywords

Accumulation

Cabbage

Growth

Heavy metals

Industrial effluents

ABSTRACT

The purpose of this study was to assess the effects of industrial effluents on cabbage growth and heavy metal accumulation. Untreated effluents were collected from nine dumping sites in Bangladesh's Dhaka, Sylhet, and Chittagong divisions: including Narsingdi, Tongi, Hazaribagh, Alampur, Khadimnagar, Majortilla, Bhatiary, Bayazid bostami, and Sagorika. Pb (2.038 mg l^{-1}), Cd (0.082 mg l^{-1}), Ni (0.237 mg l^{-1}) and Cr (0.172 mg l^{-1}) concentrations found maximum in Hazaribagh effluents, whereas Fe (7.171 mg l^{-1}) and Zn (1.938 mg l^{-1}) were maximum in Khadimnagar. Two pot experiments were carried out in CRD with three replications. Untreated effluents had a significant influence on cabbage germination and growth in the early stages. Seed germination was reduced by 19.78% when Khadimnagar effluents were used instead of control. The seedling mortality rate in Khadimnagar effluents was higher (15.56%), whereas no seedling mortality in the control. Because of the toxicity of heavy metals, shoot length (61.98%) and root length (66.76%), as well as other parameters, were lowered compared to control. The number of leaf plants⁻¹, leaf length, leaf width, fresh weight, and dried weight were all highest in the control, while they were lowest when Khadimnagar effluents used as irrigation. The transfer factor values of several heavy metals (Pb-0.442, Cd-0.400, Ni-0.411, Cr-0.378, Fe-26.317, and Zn-22.951) were maximum when using effluents from Khadimnagar and Hazaribagh. Finally, the overall findings suggest that heavy metals including Pb, Cd, Ni, Cr, Fe, and Zn were significantly contaminated in Khadimnagar and Hazaribagh, with negative effects on cabbage growth and heavy metal accumulation in foodstuffs, potentially posing a health risk.

©2022 Agriculture and Environmental Science Academy

Citation of this article: Maukeeb, A. R. M., Hasan, M. K., Saha, M., & Mondal, M. F. (2022). Effects of industrial effluents on growth and heavy metals accumulation in cabbage in Bangladesh. *Archives of Agriculture and Environmental Science*, 7(1), 42-50, <https://dx.doi.org/10.26832/24566632.2022.070107>

INTRODUCTION

Contaminated locations throughout the world are becoming a greater threat to crop cultivation (Naidu *et al.*, 2015). Industrial pollutants have affected almost all countries, but the extent and severity of pollution vary greatly. Bangladesh is a developing country where massive urbanization, fast industrialization, and advanced agricultural practices have expedited social modernization (Maukeeb *et al.*, 2018). Small industrial units are discharging their untreated effluents into surface drains that extend

across agricultural areas causing significant soil and water pollution. Several research works in recent years have found serious metallic pollution of soil, water, and sediments (Zakir *et al.*, 2012, 2013, 2014; Bakali *et al.*, 2014 and Kohinoor *et al.*, 2014). There has been a gradual increase in industrial effluents in such conditions, and these effluents have been causing serious pollution of nearby water and soils. According to the national pollution profile, Bangladesh today has 30,000 industrial units; 24,000 of which are small and cottage industries, while the remaining 6,000 are large and medium industries

(DOE, 2015). Approximately 300 industries, including textiles, garments, dandy-dyeing, plastics, metal fabrications, leather, tanning, BSCIC, steel mills, release effluents containing Pb, Cd, Cr, Ni, As, Hg, Co, Fe, Zn, and other metals (Ahmed *et al.*, 2011). In most cases, industries discharged their effluents into nearby rivers without treatment. As a result of these industrial discharges, river water has been severely polluted, resulting in a progressive decline in its quality (Khaleel *et al.*, 2013). The global gap between water supply and demand is widening by the day. Because fresh water is in short supply, industrial effluents are employed as an alternative water source for irrigation of crops, mainly in urban areas (Kumar *et al.*, 2013a, 2013b and Vijayaragavan *et al.*, 2011). Untreated effluents are used as a source of plant nutrients as well as irrigation water. As a consequence, crop production was severely hampered as a result of an industrial discharge including metals such as Pb, Cd, Cr, Ni, Cu, Fe, Zn, and other harmful metals being deposited straight over surrounding crop fields. Increased concentrations of industrial effluents in irrigation water can reduce crop germination percentages (Saravanamoorthy, 2007), inhibit seedling growth, and inhibit essential enzyme functions (Nagada *et al.*, 2006 and Yousaf *et al.*, 2010), as well as delay fruiting and low yields (Uaboi-Egbenni *et al.*, 2009). Excessive heavy metal deposition in agricultural soils due to effluents irrigation might lead to soil and food contamination (Muchuweti *et al.*, 2006). Vegetables are an important part of the human diet since they are high in vitamins, minerals, fiber, and antioxidants. When vegetables are grown in contaminated soils, they can accumulate genotoxic compounds, which pose a danger to human health (Mathur *et al.*, 2006). Heavy metals accumulate easily in leafy vegetables' edible portions (Sinha *et al.*, 2007). Crops irrigated with industrial effluents induce diarrhea, mental retardation, and liver and kidney damage when ingested by people (Uzair *et al.*, 2009). According to Naser *et al.*, (2009), there is sporadic information about the accumulation of heavy metals in vegetables cultivated in the country's industrially contaminated water. In Bangladesh, crops and vegetables cultivated in polluted soil or irrigated with untreated industrial effluents are becoming a common scenario. However, consuming heavy metal-contaminated vegetables may be dangerous for health. There seems to be relatively little research on the effects of industrial effluents on vegetable crops such as cabbage in Bangladesh. Therefore, the study was undertaken to evaluate the toxicity of industrial effluents on seed germination, vegetative growth and metal accumulation of cabbage. Variability in the accumulation of heavy metals and the safety issues associated with the consumption of cabbage was also evaluated.

MATERIALS AND METHODS

Collection and analyses of industrial effluents

Effluents were collected from 9 (nine) common dumping-off zones of different industrial sites in Bangladesh's Dhaka, Sylhet, and Chittagong divisions, namely Narsingdi, Tongi, Hazaribagh, Alampur, Khadimnagar, Majortilla, Bhatiary, Bayazid bostami,

and Sagorika. At the discharge points of industry, samples from nine sites were collected in 30L plastic containers. The samples were collected according to the American Public Health Association's guidelines (APHA, 2017). All of the samples had subsamples obtained for laboratory analysis. Pb, Cd, Ni, Cr, Fe, and Zn concentrations in effluents were determined using an atomic absorption spectrophotometer (AAS; iCE 3300, Thermo Fisher Scientific, USA). All the analytical techniques established by the American Public Health Association (APHA, 2017).

Experiment 1: Seedling test of cabbage

Experimental design and preparation of petri dish: The experiment was performed at Sylhet Agricultural University in Sylhet-3100, Bangladesh, using a completely randomized design (CRD) with three replications. There were a total of ten (10) treatments, comprising nine (9) industrial effluents and a control group (Hoagland solution). The Hoagland solution is a hydroponic nutrient solution that contains all of the nutrients required for plant growth and is suitable for a wide range of plant species (Hoagland and Arnon, 1950). The germination test of cabbage (Atlas 70) was conducted in a Petri dish using the paper towel method, as prescribed by ISTA guidelines (Hoagland and Arnon, 1950), under optimal conditions. According to the treatments, 30 sterilized glass Petri dishes with a size of 125 mm x 15 mm were used and lined with wet filter paper. Seeds of cabbage were collected from the Bangladesh Agricultural Research Institute, Gazipur, Bangladesh and sterilized by soaking in a 0.1% HgCl₂ solution for 5 minutes and then washed with running tap water followed by deionized water. Then, 40 (forty) seeds were placed in each petri dish, taking up as little space as possible. Following the placement of the seed, the petri dish was watered with treatments at regular intervals.

Seedling test parameter: The seedling test parameters including seed germination (%), seedling mortality (%), shoot length (cm), and root length (cm) were recorded.

The equation used to calculate germination percentage (%) of seed was;

$$\text{Germination percentage (\%)} = \frac{\text{Number of germinated seeds}}{\text{Total number of seeds}} \times 100$$

The equation used to calculate the mortality percentage (%) of seedlings was;

$$\text{Mortality percentage (\%)} = \frac{\text{Number of dead seedlings}}{\text{Total number of seedlings}} \times 100$$

Experiment 2: Growth test of cabbage

Pot experiment: This experiment was also designed in a completely randomized design (CRD) with three replications at Sylhet Agricultural University, Sylhet-3100, Bangladesh. The same treatments as in Experiment 1 were used. A total of 30 plastic pots sized 80 mm x 110 mm were collected. A sample of sand for cabbage cultivation was collected from a nearby river. The sand was then rinsed several times with distilled water to

remove any remaining ionic components. Sand was then air-dried and sieved through a 2 mm mesh sieve before being stored in a clean plastic bag. After that, all of the plastic pots were filled with 0.5 kg of prepared sand and arranged to ensure adequate spacing. Cabbage seedlings were transferred into the prepared pot while they were fifteen days old and healthy. According to the treatment, effluents were applied to each pot. The cabbage was irrigated until it was ready to be sampled.

Growth parameter observed: The number of leaves, leaf length and width, as well as the fresh and dry weight of a shoot from a 40-day-old cabbage plant from each treatment, was all measured.

Analysis of metals in cabbage: Cabbage samples from each treatment were collected and brought to the laboratory. For chemical analysis, the obtained plant samples were properly cleaned with tap water and rinsed with a 0.1 M HCL solution, followed by several rinses with distilled water. The samples were oven-dried at 70 °C after initial air drying to remove all moisture content. The dried plant samples were ground and stored separately in polythene zipper bags using a mechanical grinder. Then, 0.5g of dried cabbage sample was digested with Di-Acid mixture ($\text{HNO}_3:\text{HClO}_4=2:1$) till visible fumes were generated (Tandon, 1995). After cooling, the samples were filtered using Whatman filter paper no. 1. The final volume was made to 50 ml using double distilled water. Then the different heavy metal content in samples was determined using an atomic absorption spectrophotometer (iCE 3300, Thermo Fisher Scientific, USA) using the reagent blank. Thermo Fisher Scientific provided standard solutions (1000 mg/l) of many metals, including Pb, Cd, Ni, Cr, Fe, and Zn. The standard curve was prepared using various concentrations that were made from standard solution.

Transfer factor (TF): Transfer factor (TF) was calculated to understand the extent of risk and associated hazards due to effluent irrigation and consequent heavy metal accumulation in the edible portion of the test crop (Cui et al., 2004).

TF= concentration of metal in edible part/concentration of metal in soil

Statistical analyses

The statistical analyses of the seedling test and growth data were performed using the computer package program R software (Version 3.4.3). There was no statistical analysis for metals found in effluent samples and absorbed by the plant.

RESULTS AND DISCUSSION

The concentration of heavy metals in effluents

The heavy metal concentrations in industrial effluents used for irrigation were analyzed, and the results are shown in Table 1 of nine samples. The highest concentration of Pb (2.038 mg l^{-1}) was found in Hazaribagh effluents, while the lowest value (0.001 mg l^{-1}) was detected in Majortilla industrial effluents. Pb concentrations in effluents used for irrigation were determined to be within the acceptable limits (5.0 mg l^{-1}) in the sampling area, as recommended by Ayers and Westcot (1985). According to Ayers and Westcot (1985), the maximum acceptable concentration of Cd in irrigation water is 0.01 mg l^{-1} . Considering this value as standard, among the samples, Hazaribagh industrial effluents (0.082 mg l^{-1}) exceeded the limit, which might not be safe for long-term irrigation. The maximum Ni (0.237 mg l^{-1}) and Cr (0.172 mg l^{-1}) concentrations were found in Hazaribagh industrial effluents, which exceeded the acceptable limit in all samples, while the minimum concentrations were found in Majortilla (0.035 mg l^{-1}) and Narsingdi (0.01 mg l^{-1}). Ni and Cr concentrations in irrigation water to be 0.20 mg l^{-1} and 0.10 mg l^{-1} , respectively Ayers and Westcot (1985). Industrial effluents from Khadimnagar exhibited the highest concentrations of Fe (7.171 mg l^{-1}) and Zn (1.938 mg l^{-1}). On the contrary, a minimum concentration of Fe (0.249 mg l^{-1}) and Zn (0.052 mg l^{-1}) was found in Hazaribagh and Bhatiary industrial effluents. Among the nine locations, it was found that the Fe concentration in Khadimnagar industrial effluents exceeded the maximum recommendation limit (5.0 mg l^{-1}) and the Zn concentration in all sampling areas was below the permissible limits (2.0 mg l^{-1}) recommended by Ayers and Westcot (1985).

Table 1. Mean concentration of heavy metals in different industrial effluents (mg l^{-1}).

Location	Pb	Cd	Ni	Cr	Fe	Zn
Narsingdi	0.907±0.01	0.005±0.0	0.112±0.02	0.010±0.06	0.773±0.05	0.704±0.05
Tongi	0.041±0.01	0.009±0.0	0.042±0.01	0.011±0.04	0.282±0.04	0.801±0.02
Hazaribagh	2.038±0.03	0.082±0.001	0.237±0.03	0.172±0.06	0.249±0.04	0.863±0.04
Alampur	0.031±0.02	0.004±0.0	0.043±0.0	0.011±0.02	3.517±0.09	0.599±0.02
Khadimnagar	0.244±0.02	0.002±0.0	0.141±0.001	0.011±0.02	7.171±0.21	1.938±0.05
Majortilla	0.001±0.0	0.003±0.0	0.035±0.05	0.013±0.02	2.905±0.08	0.202±0.01
Bhatiary	0.010±0.0	0.003±0.0	0.100±0.04	0.012±0.01	1.515±0.03	0.052±0.01
Bayazid bostami	0.535±0.01	0.001±0.0	0.045±0.06	0.014±0.01	0.986±0.02	1.005±0.05
Sagorika	0.042±0.001	0.016±0.001	0.205±0.05	0.012±0.03	0.986±0.03	0.122±0.06

Table 2. Effects of different industrial effluents on seed germination in cabbage.

Treatment	Seed germination (%)				
	1DAS	2DAS	3DAS	4DAS	5DAS
Narsingdi	46.85c	85.56c	86.67d	86.67c	86.67c
Tongi	57.77b	90.00b	90.56bc	90.56ab	90.56ab
Hazaribagh	58.89b	81.56c	82.78e	82.78d	82.78d
Alampur	45.00c	89.44b	89.11ab	90.78ab	90.91b
Khadimnagar	0.00 d	2.78d	55.56f	74.44e	74.44e
Majortilla	57.77b	90.56ab	90.56 bc	90.56ab	90.56ab
Bhatiary	60.56b	90.00b	91.11ab	91.11ab	91.11ab
Bayazid bostami	49.44c	90.00b	90.56bc	90.56ab	90.56ab
Sagorika	61.11b	88.89b	88.89c	88.89bc	88.89bc
Control	72.78a	92.22a	92.78a	92.78a	92.78 a
CV%	5.11	1.44	1.38	1.73	1.68

In a column, figure(s) followed by the same letter(s) do not differ significantly at 1% level of significance, CV = Coefficient of variation.

Experiment 1: Germination of seeds

Table 2 shows how industrial effluents affected the germination percentage of cabbage at various DAS. Maximum seed germination of cabbage (72.78, 92.22, 92.78, and 92.78%, respectively) was observed in control and minimum seed germination (0.00, 2.78, 55.56, 74.44, and 74.44%, respectively) was found when Hazaribagh industrial effluents were used as irrigation water in all observations 1, 2, 3, 4, and 5 DAS. The seed germination performance was good in almost all of the treatments. However, the rate of germination differs among industrial effluents. When compared to the control treatment, Khadimnagar effluents reduced germination by 19.77%, followed by Hazaribagh effluents (10.78%). Different authors have reported the negative effects of heavy metals on seed germination (Li et al., 2005 and Datta et al., 2011), as well as the effects of heavy metals on seed germination as a reduction in water uptake and transport (Becerril et al., 1989). The presence of heavy metals such as Pb, Ni, Cr, Fe, Cd, Cu, and Zn at high concentrations in irrigation water has been found to reduce seed germination in vegetable crops (Jadoon et al., 2013). Seed germination is inhibited and crop germination percentage is reduced when high amounts of Fe (Rasafi et al., 2016) and Pb (Shafiq et al., 2008) are present in wastewater.

Seedling mortality

The effects of industrial effluents on cabbage seedling mortality at 9, 12, and 15 DAS varied significantly among treatments, as shown in table 3. For all treatments, there were no effects of industrial effluents on cabbage seedling mortality at 3 and 5 DAS. Khadimnagar industrial effluents exhibited the highest seedling mortality (0.42, 11.67, and 15.56 %) at 9, 12, and 15 DAS, followed by Hazaribagh industrial effluents at 12 and 15 DAS (3.89 and 6.81 %). On the contrary, for all observations, the control had zero seedling mortality. The seedling mortality rate in Khadimnagar industrial effluents is increasing day by day, followed by Hazaribagh that might showing heavy metal toxicity of Pb, Ni, Fe, and etc. At high concentrations, Fe might be lethal. An excess amount of Fe is harmful to live cells, which can act

catalytically via the Fenton reaction and catalyze the conversion of hydrogen peroxide into harmful free radicals that can cause damage to various cellular structures and also, they can eventually kill the cell (Crichton et al., 2002). Toxic heavy metal accumulation in plant living cells causes a range of deficiencies, including reduction in cell activity, stunted photosynthetic activity, and sometimes even plant death (Shafiq et al., 2008).

Shoot and root length

Figure 1 show the results of shoot and root length of cabbage seedlings at 15 DAS under various industrial effluents. When compared to control, effluents had an adverse effect on cabbage shoot and root growth. In comparison to the other treatments, the control treatment showed higher shoot and root length. Cabbage shoot length was observed to be a maximum (8.76 cm) in control and a minimum (3.53 cm) in Khadimnagar industrial effluents. In contrast, the control had the longest root length (3.91 cm) and the shortest (1.30 cm) due to the use of Khadimnagar industrial effluents as irrigation water in cabbage. Using Khadimnagar effluents, shoot and root length were reduced by 61.98% and 66.76%, respectively, as compared to the control treatment. The adverse effects of heavy metal toxicity in industrial effluents may be responsible for the reduction in shoot and root length. Heavy metals may inhibit root and shoot development by interfering with cell division. Pb and Cd were more harmful to the development of the shoots and roots. According to Juwarkar and Shende (1986), Pb inhibits root and stem elongation in *Allium species* and *Raphanus sativas*. Plants experience higher oxidative damage under Fe stress conditions, and as Fe content increases, shoot and root length will decline (Verma and Pandey, 2017). Because roots are the first part of the plant to come into contact with the growing medium, they are particularly vulnerable to metal poisoning. Reduced mitotic cells in the meristematic zone of the root might just be the cause of root length reduction in heavy metal poisoning (Shafiq et al., 2008).

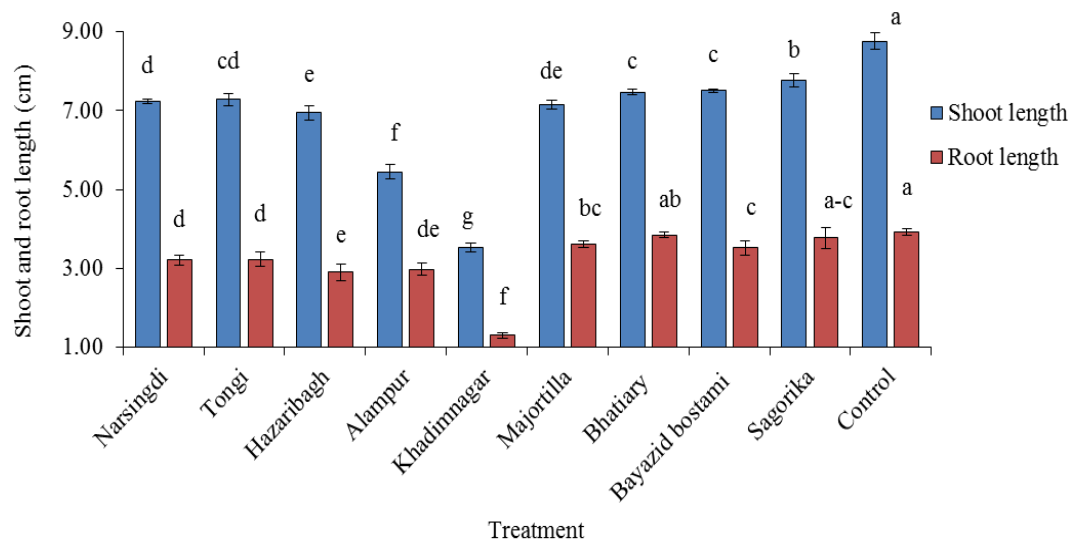


Figure 1. Effects of industrial effluents on the shoot and root length in cabbage.

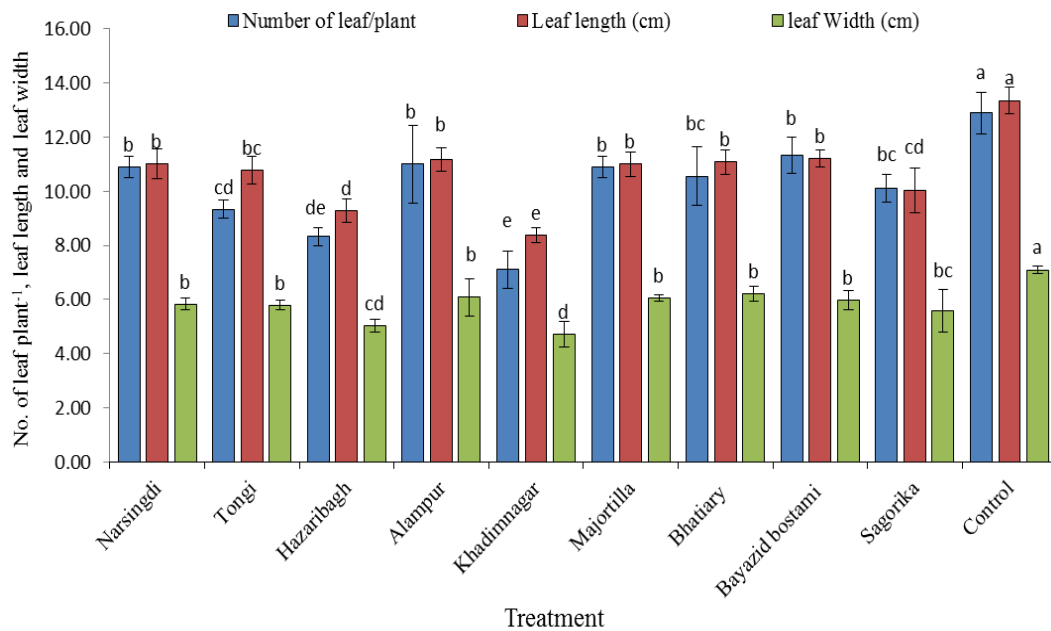


Figure 2. Effects of industrial effluents on number of leaves, leaf length, and leaf width in cabbage.

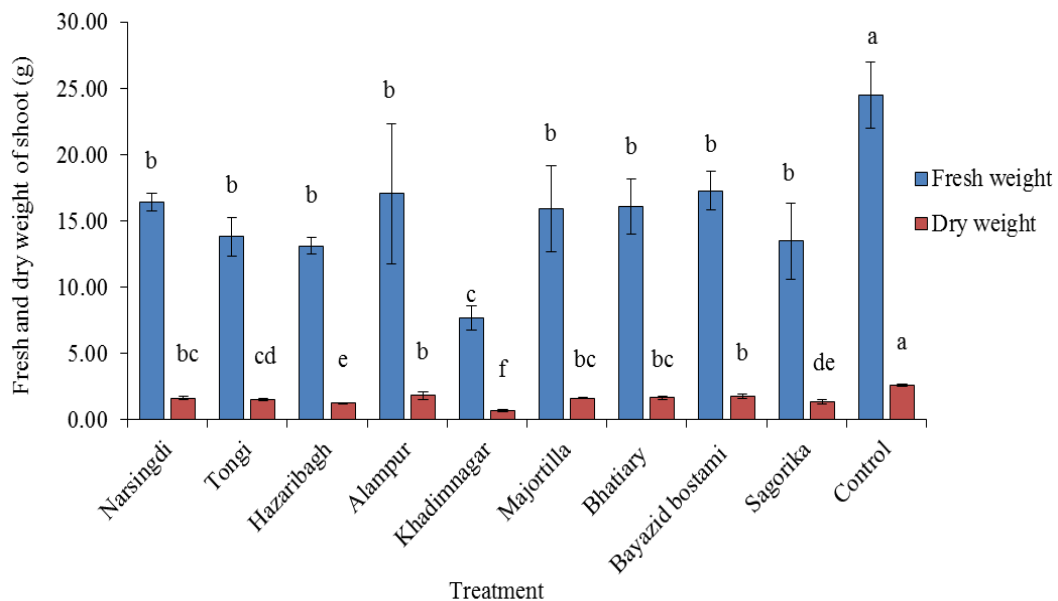


Figure 3. Effects of industrial effluents on shoot fresh and dry weight in cabbage.

Table 3. Effects of different industrial effluents on seedling mortality in cabbage.

Treatment	Seedling mortality (%)				
	3DAS	6DAS	9DAS	12DAS	15DAS
Narsingdi	0.00	0.00	0.00b	1.67c-e	2.78c
Tongi	0.00	0.00	0.00b	2.78bc	3.33c
Hazaribagh	0.00	0.00	0.00b	3.89b	6.11b
Alampur	0.00	0.00	0.00 b	1.11d-f	2.78c
Khadimnagar	0.00	0.00	0.42a	11.67a	15.56a
Majortilla	0.00	0.00	0.00b	2.22cd	3.33c
Bhatiary	0.00	0.00	0.00b	1.11d-f	2.78c
Bayazid bostami	0.00	0.00	0.00b	0.56ef	2.78c
Sagorika	0.00	0.00	0.00b	2.78bc	4.44bc
Control	0.00	0.00	0.00b	0.00f	0.00d
CV%	0.00	0.00	52.81	28.95	23.41

In a column, figure(s) followed by the same letter(s) do not differ significantly at 1% level of significance, CV = Coefficient of variation.

Table 4. Concentrations (mg/kg) of heavy metals uptake by cabbage shoot irrigated by industrial effluents.

Treatment	Pb	Cd	Ni	Cr	Fe	Zn
Narsingdi	0.054	0.001	0.041	0.001	15.32	7.34
Tongi	0.002	0.001	0.008	0.001	6.41	8.21
Hazaribagh	0.901	0.011	0.054	0.065	4.54	11.02
Alampur	0.011	ND	0.008	0.001	80.11	9.04
Khadimnagar	0.091	0.002	0.058	0.002	188.72	44.48
Majortilla	ND	ND	0.006	0.002	65.01	3.88
Bhatiary	ND	0.001	0.033	0.001	28.35	1.06
Bayazid bostami	0.023	ND	0.003	0.002	22.22	10.74
Sagorika	0.010	ND	0.014	0.001	19.22	8.86
Control	ND	ND	ND	ND	32.44	1.86

ND=Not detected

Table 5. Transfer factor of heavy metals from different effluents to cabbage.

Location	Pb	Cd	Ni	Cr	Fe	Zn
Narsingdi	0.060	0.200	0.366	0.100	19.819	10.426
Tongi	0.049	0.111	0.190	0.091	22.730	10.250
Hazaribagh	0.442	0.134	0.228	0.378	18.233	12.769
Alampur	0.355	ND	0.186	0.091	22.778	15.092
Khadimnagar	0.373	0.400	0.411	0.182	26.317	22.951
Majortilla	ND	ND	0.171	0.154	22.379	19.208
Bhatiary	ND	0.333	0.330	0.083	18.713	20.385
Bayazid bostami	0.043	ND	0.067	0.143	22.535	10.687
Sagorika	0.238	ND	0.068	0.083	19.493	15.246

ND=Not detected

Experiment 2: Number of leaf plant⁻¹, leaf length, and leaf width

Results of the number of leaves, leaf length, and leaf width of cabbage at 40 DAS under different industrial effluents are given in figure 2. When compared to the other treatments, all observations were found to be better in the control condition. The number of leaf plant⁻¹ (12.89), leaf length (13.36 cm), and leaf width (7.10 cm) of cabbage were highest in control, and the lowest value was found in Khadimnagar industrial effluents (Number of leaf plant⁻¹ 7.11, leaf length 8.38 cm, and leaf width 4.72 cm). In comparison to the control treatment, the number of leaf plant⁻¹, leaf length, and leaf width decreased by 44.85, 37.28, and 33.52%, respectively, when Khadimnagar effluents were used,

followed by Hazaribagh effluents. This suggests that increasing effluent content in irrigation water inhibits cabbage growth and development. Crop performance has been reduced as a result of excessive concentrations of different metals of industrial effluent from a variety of types and sources. Increased levels of Pb concentration in soil affect leaf growth (Kevresan et al., 2001) and prevent leaf expansion of *Raphanus sativus* (Juwarkar and Shende, 1986). Research results from Khaleel et al. (2013) revealed that tannery effluents caused a reduction in the growth of sunflower along with other parameters. An increase in Zn contamination in the growth media resulted in a significant reduction in leaf area (Chaves et al., 2011).

Fresh and dry weight of shoot

The results of the fresh and dry weight of cabbage shoots at 40 days by applying industrial effluents were found to be significantly different from one treatment to another, as shown in figure 3. In the control condition, the maximum fresh weight (24.56g) and dry weight (2.61g) were obtained. In contrast, Khadimnagar industrial effluents had the lowest fresh weight (7.71g) and dry weight (0.68g), followed by Hazaribagh effluents. In comparison to the control, fresh and dry weight were reduced to 68.61% and 73.95% when Khadimnagar effluents were used for irrigation, followed by Hazaribagh. Heavy metals in untreated effluents from textile, clothing, dandy-dyeing, leather, tanning, and other industries have a negative impact on crop vegetative growth, fresh and dry matter production. According to Jadoon *et al.*, (2013), applying untreated textile effluents to crops decreases root and shoot biomass. In green gram seedlings, excessive Fe concentrations resulted in a considerable decrease in fresh and dry matter yield (Verma and Pandey, 2017); similar results were also observed by Nenova (2006). Pd and Cd may be the most harmful metals responsible for the significant loss in shoot and root dry weight. This suggestion is supported in the case of Pd and Cd (Shafiq *et al.*, 2008), as well as Fe, by Olaleye *et al.*, (2001).

The concentration of heavy metals in cabbage

The effects of different industrial effluents on heavy metal uptake in cabbage are presented in Tables 4. The use of Hazaribagh industrial effluents as irrigation water resulted in the highest uptake of Pb, Cd, and Cr (0.901, 0.011, and 0.065 mg/kg, respectively) in cabbage, followed by Khadimnagar industrial effluents (Pb 0.091, Cd 0.002, and Cr 0.002 mg/kg, respectively). Khadimnagar industrial effluents exhibited the maximum uptake of Ni (0.058 mg/kg), Fe (188.72 mg/kg), and Zn (44.48 mg/kg), followed by Alampur (Fe 80.11 mg/kg), and Majortilla (Fe 65.01 mg/kg). Heavy metal concentrations in shoots of cabbage pots watered with effluents were generally greater than in control water-grown cabbage. In terms of effluent concentrations, the heavy metal content in cabbage was Hazaribagh > Khadimnagar > control (no effluent). The findings revealed a higher concentration of metals in industrial effluents, resulting in a significant accumulation of metals in cabbage. The prolonged irrigation of vegetables with industrial effluents enhanced heavy metal deposition, resulting in contamination of food crops. Arora *et al.*, (2008) discovered that radish, spinach, turnip, brinjal, cauliflower, and carrot cultivated under wastewater irrigation absorbed higher concentrations of heavy metals than those grown under clean water irrigation. According to Yousaf *et al.*, (2010) in higher plants, roots are the first organs to come into contact with toxic metal concentrations, and root tips are the primary source of harm, resulting in delayed root development, lower water uptake, stunting growth, and ultimately yield reduction.

Transfer factor (TF) from effluents to cabbage

To determine the extent of the risk of heavy metal accumulation in the edible portion of cabbage, the transfer factor (TF) was

determined. The TF values of Pb, Cd, Ni, Cr, Fe, and Zn for various effluents varied greatly (Table 5). The TF value for Pd in nine effluents ranged from 0.043 to 0.442. Cd TF ranged from 0.111 to 0.400, Ni from 0.067 to 0.411, Cr from 0.083 to 0.378, Fe from 18.233 to 26.317, and Zn from 10.250 to 22.951. In Hazaribagh, the TF values of Pb (0.442) and Cr (0.378) were the highest among the nine effluents. In Khadimnagar, however, the TF values of Cd (0.400), Ni (0.411), Fe (26.317), and Zn (22.951) were the highest. Pb (0.043) and Ni (0.067) had the lowest TF values in Bayazid bostami, Tongi had Cd (0.111) and Zn (10.250), Sagorika had Cr (0.083), and Hazaribagh had Fe (18.233). The Transfer Factor is a measure that describes the transfer of metals from effluents to plant bodies, which is one of the most important aspects of human metal exposure through the food chain. Variation in transfer factor of heavy metals among different industrial effluents may be attributed to differences in the concentration of metal in the effluents and differences in element uptake by different vegetables (Zheng *et al.*, 2007). Metal mobility from soil to plants is influenced by various environmental and human factors, as well as the physical and chemical properties of the soil and vegetable species (Zurera *et al.*, 1987). The transfer factor value of different heavy metals was found to be higher in Khadimnagar and Hazaribagh effluents during cabbage growth among these nine effluents. As a result, cabbage grown in that location may accumulate heavy metals in its edible portions, posing a risk to human health.

Conclusion

Heavy metal toxicity is a considerable concern to the world's agricultural systems, and it is intensified by industrial pollution. It has limited metabolic functions and has an adverse effect on plant growth, particularly in the early stages. The purpose of this study was to see how cabbage performed in nine different industrial effluents. According to the findings of the study, high concentrations of metals such as Pb, Cd, Ni, and Fe were found in Khadimnagar and Hazaribagh industrial effluents, which had negative effects on seed germination, seedling mortality, shoot and root length, as well as growth characteristics of cabbage. Fresh and dried biomass was reduced by 68.61% and 76.95%, respectively, when untreated effluent was used in cabbage. Due to irrigation with Khadimnagar and Hazaribagh effluents, accumulation and transfer factor value of different heavy metals are increased at the early stage of cabbage growth. Long-term untreated effluents irrigation led to the accumulation of heavy metals in soil and consequently into the cabbage, which may result in economic loss of cabbage production as well as human health risks if cabbage cultivated in the region is consumed.

Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

ACKNOWLEDGMENT

This research work was financially supported by Sylhet Agricultural University Research System (SAURES), Bangladesh.

Open Access: This is an open access article distributed under the terms of the Creative Commons Attribution NonCommercial 4.0 International License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author(s) or sources are credited.

REFERENCES

- Ahmed, G., Miah, M. A., Anawar, H. M., Chowdhury, D. A., & Ahmad, J. U. (2011). Influence of multi-industrial activities on trace metal contamination: an approach towards surface water body in the vicinity of Dhaka Export Processing Zone (DEPZ). *Environmental Monitoring Assessment*, 2(1), 1-10.
- APHA (American Public Health Association). (2017). Standard methods for the examination of water and wastewater. 23rd Edition, AWWA and WEF, Washington, USA. pp. 1-175.
- Arora, M., Bala, K., Rani, S., Rani, A., Kaur, B., & Mittal, N. (2008). Heavy metal accumulation in vegetables irrigated with different water sources. *Food Chemistry*, 111(4), 811-815.
- Ayers, R. S., & Westcot, D. W. (1985). Water quality for agriculture. FAO irrigation and drainage paper, 29, 8-96.
- Bakali, B., Mia, M. Y., & Zakir, H. M. (2014). Water quality evaluation of tongi area in bangladesh: an impact of industrialization. *Journal of Chemical, Biological and Physical Sciences*, 4(2), 1735-1752.
- Becerril, J., Iez-Murua, C.G.I., Munoz-Rueda, A., & De Felipe, M. R. (1989). Changes induced by cadmium and lead in gas exchange and water relations of clover and lucerne. *Plant Physiology and Biochemistry*, 27(6), 913-918.
- Chaves, L. H. G., Estrela, M. A., & Souza, R. S. (2011). Effect on plant growth and heavy metal accumulation by sunflower. *Journal of Phytology*, 3(12), 04-09.
- Crichton, R. R., Wilmet, S., Legssyer, R., & Ward, R. J. (2002). Molecular and cellular mechanisms of iron homeostasis and toxicity in mammalian cells. *Journal of Inorganic Biochemistry*, 91(1), 9-18.
- Cui, Y. J., Zhu, Y.G., Zhai, R. H., Chen, D. Y., Huang, Y.Z., Qiu, Y., & Ling, J.Z. (2004). Transfer of metals from soil to vegetables in an area near a smelter in Nanjing, China. *Environment International*, 30(6), 785-791.
- Datta, J.K., Bandhyopadhyay, A., Banerjee, A., & Mondal N. K. (2011). Phytotoxic effect of chromium on the germination, seedling growth of some wheat (*Triticum aestivum* L.) cultivars under laboratory condition. *International Journal of Agricultural Technology*, 7(2), 395-402.
- DOE (Department of Environment). (2015). Bangladesh: State of the Environment. Ministry of Environment and Forestry. Publication, UNEP, pp. 1-74.
- Hoagland, D. R. and Arnon, D. I. (1950). California Agricultural Experiment Station Circular, 347, 1-32.
- Jadoon, I. B. K., Shafaqat, A., Qurratulain, B. K. J., Shako, M. B., Bharwana, S. A., & Farooq, M. A. (2013). Effects of irrigation with wastewater from different industries on vegetables grown in vicinity of Faisalabad, Pakistan. *International Research Journal of Plant Science*, 4(6), 144-148.
- Juwarkar, A. S., & Shende, G. B. (1986). Interaction of Cd-Pb effect on growth yield and content of Cd, Pb in barley. *Indian Journal of Environmental Health*, 28, 235-243.
- Kevesan, S., Petrovic, N., Popovic, M., & Kandrac, J. (2001). Nitrogen and protein metabolism in young pea plants as affected by different concentrations of nickel, cadmium, lead, and molybdenum. *Journal of Plant Nutrition*, 24(10), 1633-1644.
- Khaleel, R. I., Ismail, N., & Ibrahim, M. H. (2013). The impact of waste water treatments on seed germination and biochemical parameter of *Abelmoschus esculentus* L. *Procedia-Social and Behavioral Sciences*, 91, 453-460, <https://doi.org/10.1016/j.sbspro.2013.08.443>
- Kohinoor B. K. M., Mohiuddin, H. M., Zakir, M., Rahman, M., & Hasan, M. N. (2014). Heavy Metal Pollution and Major Nutrient Elements Assessment in the Soils of Bogra City in Bangladesh. *Canadian Chemical Transactions*, 2(3), 316-326.
- Kumar, N., Baudhdh, K., Kumar, S., Dwivedi, N., Singh, D.P., & Barman, S.C. (2013a). Accumulation of metals in weed species grown on the soil contaminated with industrial waste and their phytoremediation potential. *Ecological Engineering*, 61, 491-495, <https://doi.org/10.1016/J.ecoleng.2013.10.004>
- Kumar, N., Baudhdh, K., Kumar, S., Dwivedi, N., Singh, D.P., & Barman, S.C. (2013b). Extractability and phytotoxicity of heavy metals present in petrochemical industry sludge. *Clean Technology Environmental Policy*, 15(6), 1033-1039, <https://doi.org/10.1007/s10098-012-0559-1>
- Li, W., Khan, M.A., Yamaguchi, S., & Kamiya Y. (2005). Effects of heavy metals on seed germination and early seedling growth of *Arabidopsis thaliana*. *Plant Growth Regulation*, 46(1), 45-50, <https://doi.org/10.1007/s10725-005-6324-2>.
- Mathur N., Bhatnagar P., & Verma H. (2006). Genotoxicity of vegetables irrigated by industrial wastewater. *Journal of Environmental Sciences*, 18(5), 964-968. [https://doi.org/10.1016/S1001-0742\(06\)60022-3](https://doi.org/10.1016/S1001-0742(06)60022-3)
- Maukeeb, A. R. M., Mondal, M. F., Saha, M., & Hasan, M. K. (2018). Effects of industrial effluents on seed germination and growth of radish. *Journal of Sylhet Agricultural University*, 5(1), 51-59.
- Muchuweti, M., Birkett, J. W., Chinyanga, E., Zvauya, R., Scrimshaw, M. D. and Lester, J. N. (2006). Heavy metal contents of vegetables irrigated with mixture of wastewater and sewage sludge in Zimbabwe: implications for human health. *Agroforestry Ecosystem & Environment*, 112(1), 41-48, <https://doi.org/10.1016/j.agee.2005.04.028>
- Nagada, G.K., Diwan, A.M., & Ghole, V.S. (2006). Seed germination bioassays to assess toxicity of molasses fermentation based bulk drug industry effluent. *Electronic Journal of Environmental, Agriculture and Food Chemistry*, 5(6), 1598-1603.
- Naidu, R., Wong, M.H., & Nathanail, P. (2015). Bioavailability-the underlying basis for risk- based land management. *Environmental Science and Pollution Research International*, 22, 8775-8778, <https://doi.org/10.1007/s11356-015-4295-z>
- Naser, H. M., Shil, N. C., Mahmud, N. U., Rashid, M. H., & Hossain, K. M. (2009). Lead, cadmium and nickel contents of vegetables grown in industrially polluted and non-polluted areas of Bangladesh. *Bangladesh Journal of Agricultural Research*, 34(4), 545-554.
- Nenova, V. (2006). Effect of iron supply on growth and photosystem II efficiency of pea plants. *General and Applied Plant Physiology*, Special issue; 81-90.
- Olaleye, A. O., Tabi, F. O., Ogunkunle, A. O., Singh, B. N., & Sahrawat, K. L. (2001). Effect of toxic iron concentrations on the growth of lowland Rice. *Journal of Plant Nutrition*, 24(3), 441-457.
- Rasafi, T., Nouri, M., Bouda, S., & Haddioui A. (2016). The effect of Cd, Zn and Fe on seed germination and early seedling growth of wheat and bean. *Ekologia (Bratislava)*, 35 (3), 213-223.
- Saravanamoorthy, M., & Ranjitha-Kumari, B. D. (2007). Effects of textile wastewater on morphophysiology and yield of two varieties of peanut (*Arachis hypogaea* L.). *Journal of Agricultural Technology*, 3(2), 335-343.
- Shafiq, M. Zafar, I.M., & Athar, M. (2008). Effect of lead and cadmium on germination and seedling growth of *Leucaena leucocephala*. *Journal of Applied Sciences and Environmental Management*, 12(2), 61-66.
- Sinha, S., Gupta, A. K., & Bhatt, K. (2007). Uptake and translocation of metals in fenugreek grown on soil amended with tannery sludge: Involvement of antioxidants. *Ecotoxicology and Environmental Safety*, 67(2), 267-277.
- Tandon, H. L. S. (1995). Methods of Analysis of Soils, Plants, Waters and Fertilizers. Fertilizer Development and Consultation Organization, New Delhi, India. pp. 87-92.
- Uaboi-Egbenni, P. O., Okolie, P. N., Adejuyitan, O. E., Sobande, A. O., & Akinyemi, O. (2009). Effects of industrial effluents on the growth and anatomical structure of *Abelmoschus esculentus* (Okra). *African Journal of Biotechnology*, 8 (14), 3251-3260.
- Uzair, M., Ahmad, M., & Nazim, K. (2009). Effects of industrial waste on seed bank and growth of wild plants in Dhabeji area, Karachi, Pakistan. *Pakistan Journal of Botany*, 41(4), 1659-1665.
- Verma, L., & Pandey, N. (2017). The Effect of Iron Toxicity on Seed Germination and Early Seedling Growth of Green Gram (*Vigna radiata* L. Wilczek). *International Journal of Science and Research*, 6(8), 1427-1430.
- Vijayaragavan, M., Prabhakar, C., Sureshkumar, J., Natarajan, A., Vijayarangan, P., & Sharavanan, S. (2011). Soil irrigation effect of sugar mill effluent on changes of growth and biochemical contents of *Raphanus sativus* L. *Current Botany*, 2(7), 9-13.
- Yousaf, I., Ali, S.M., & Yasmin, A. (2010). Germination and early growth response of glycine max. varieties in textile and paper industry effluents. *Pakistan Journal of Botany*, 42(6), 3857-3863.
- Zakir, H.M., Hasan, M.N., Quadir, Q., Sharmin, F. S., & Ahmed, I. (2013). Cadmium and lead pollution in sediments of midstream of the river Karatoa in Bangladesh. *International Journal of Engineering Sciences*, 2(2), 34-42.

- Zakir, H.M., Rahman, M.M., Rahman, A., Ahmed, I., & Hossain, M.A. (2012). Heavy metals and major ionic pollution assessment in waters of midstream of the river Karatoa in Bangladesh. *Journal of Environmental Science and Natural Resources*, 5(2), 149-160.
- Zakir, H. M., Sultana, N., & Akter, M. (2014). Heavy Metal Contamination in Roadside Soils and Grasses: A Case Study from Dhaka City, Bangladesh. *Journal of Chemical, Biological and Physical Sciences*, 4(2), 1661-1673.
- Zheng, N., Wang, Q., Zhang, X., Zheng, D., Zhang, Z., & Zngang, S. (2007). Population health risk due to dietary intake of heavy metals in the industrial area of Huludao City, China. *Science of the Total Environment*, 387(1-3), 96-104. <https://doi.org/10.1016/j.scitotenv.2007.07.044>
- Zurera, G., Estrada, B., Rincon, F., & Pozo, R. (1987.) Lead and cadmium contamination levels in edible vegetables. *Bulletin of Environmental Contamination and Toxicology*, 38(5), 805-812, <https://doi.org/10.1007/B F01616705>