Dhaka Univ. J. Biol. Sci. **34**(2): 41-56, 2025 (July) DOI: https://doi.org/10.3329/dujbs.v34i2.83994

# Heavy metal concentrations and their transfer factors in some crops contaminated by industrial wastes and effluents in and around Dhaka

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***Keywords:*** Effluents, Heavy metal contamination, Industrial wastes, Phytotoxic limit, Tolerable range, Toxic limit, Transfer factor, Vegetables and crops

**Abstract**

The present study was undertaken to evaluate the amount and extent of heavy metals contamination in the vegetable crops, rice and grasses grown at different industrial sites in and around Dhaka. In most of the studied crops, Zn and Cu concentrations were found above the phytotoxic limit, while Ni, Pb and Cd contents were found below the phytotoxic limit but above the tolerable range for human consumption. Among the crops, Kalmisak (*Ipomoea aquatica*) was the highest accumulator of Pb and Cd, whereas grass was found the highest accumulator of Cu and Ni. The highest accumulation of Zn was found in Lalsak (*Amaranthus cruentus*), followed by Kalmisak. The transfer factors varied considerably among crops and also within different metals. Among the industries, tube and steel mills as well as battery industries might be responsible for contributing higher levels of heavy metals in soils and plants of these areas.

## Introduction

Environmental contamination by heavy metals is a serious problem throughout the world(1). But, the concentrations of heavy metals in soils are associated with biological and geochemical cycles and are influenced by anthropogenic activities such as industrial activities, waste disposal methods and agricultural practices(2,3). Crops cultivated on the metal contaminated soils accumulate metals quantities excessive enough to cause clinical problems both to animals and human beings consuming these metal rich plants(4). Distribution of heavy metals in plants depends upon the availability and concentrations of heavy metals as well as particular plant species and its populations(5). Food chain contaminated by heavy metals has become a burning issue because of their potential accumulation in bio-system through contaminated water, soil and air. Heavy metal accumulation in soils is a concern in agricultural production due to the adverse effects on food quality, crop growth(6,7) and environmental health.

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Industrial pollution is an area of growing environmental concern in Bangladesh. The country still has a relatively small industry sector (including manufacturing, construction, mining and utilities) contributing to about 20% of the country's GDP[8]. Pollution control issues are relatively recent in Bangladesh. With few exceptions (only 1.75%), the industries are not well equipped with pollution control systems[9]. Islam *et al*.[10] reported that the random disposal of untreated industrial wastes and effluents into the natural system of Bangladesh enriched the water-soil-plant-food system with heavy metals like Fe, Mn, Zn, Cu, Cr, Ni, Pb, Cd and other toxic substances. Similarly, Nuruzzaman[11] and Kashem and Singh[12] reported that tannery, textile, dyeing, battery and sulphuric acid producing industries *etc.* increased the concentration of Cu, Mn, Ni, Pb, Cr, Zn, *etc.* up to toxic levels and somewhere exceeded the toxic limit in the soils and crops near different industrial sites in and around Dhaka.

Transmission of metals from soil to plant tissues is studied using an index called Transfer Factor (TF). It is calculated as a ratio of concentration of a specific metal in plant tissue to the concentration of same metal in soil, both represented in same units[13]. Higher TF values (≥1) indicate higher absorption of metal from soil by the plant and higher suitability of the plant for phytoextraction and phytoremediation. On the contrary, lower values indicate poor response of plants towards metal absorption and the plant can be used for human consumption[13]. Soil to plant transfer of heavy metals is the major path way of human exposure to metal contamination.

So, the present research project was undertaken to evaluate the concentration and/or contamination levels and transfer factor (TF) of heavy metals in some crops collected from nearby different industrial plants in and around Dhaka, Bangladesh.

## Materials and Methods

Thirty three industrial sites from nine industrial clusters around Dhaka and Gazipur city were selected for the collection of soil and crop samples (Table 1).

**Table 1. Industrial clusters, locations, types of industries and collected crop samples**

| Name of the cluster | Location | Type of industries | Collected crop samples |
|---|---|---|---|
| **i. Ashulia** | North-Western part of Dhaka district | Spinning, dyeing and textile industries; chemicals; steel and re-rolling mills; plastic and apparels industries | Kalmisak, grass and spinach |
| **ii. Demra** | Eastern zone of Dhaka city | Re-rolling and corrugated sheet mills; chemical, dyeing and textile industries; polythene and polypacks; tubes and pipes and food and beverage industries mostly | Rice, lalsak and grass |

Table 1. Contd.

| | | | |
|---|---|---|---|
| **iii. Gazipur** | 18 km North from capital city, Dhaka. | Battery factories; dyeing, textile industries and paint factories; chemical industries; tannery industries and steel and re-rolling mills | Kalmisak, grass and lalsak |
| **iv. Hazaribagh** | On the bank of the Buriganga river and within Dhaka city corporation area | Mainly tannery industries | Grass and kalmisak |
| **v. Hotapara** | Northern part of Gazipur Sadar Upazila of Gazipur district | Dyeing and spinning mills; food and beverage industries; apparels | Kalmisak, rice and spinach |
| **vi. Keranigonj** | South bank of the Buriganga river | Battery factories; dyeing and textile industries; chemical industries; steel and re-rolling and corrugated sheet mills; food and beverage industries | Kalmisak, grass and lalsak |
| **vii. Matuail** | Eastern part of Dhaka city | Steel and re-rolling and corrugated sheet mills; chemical industries; food and beverage industries; dyeing and textile industries | Spinach, kalmisak and grass |
| **viii. Savar** | North-Western side of Dhaka city | Mainly textile, dyeing and spinning mills; chemical industries; steel and re-rolling mills; pharmaceuticals; food and beverage industries | Spinach, rice and kalmisak |
| **ix. Shampur** | Southern part of Dhaka city | Metal industries; electroplating, steel and re- rolling mills; dyeing and textile mills; food and beverage etc. | Kalmisak and grass |

Soils and crop samples were collected in the winter season (2009 – 2010) from different industrial clusters within a distance of up to 0.5 km from the factory sites following the sampling methods as described by Radojevic and Bashkin[14] and Imamul and Alam[15]. The sampling sites as geo referenced with GPS (Global positioning system) are shown on the map (Fig. 1). The collected soil samples were air -dried and the large aggregates were gently broken and passed through a 2 mm sieve, the soil thus sieved was mixed thoroughly for a composite sample. A portion of soil was further grounded and passed through 0.5 mm sieve for various chemical analyses. The collected crop samples from contaminated industrial sites were Kalmisak (*Ipomoea aquatica*), spinach (*Spinach oleracea*), Lalsak (*Amaranthus cruentus*), rice (*Oryza sativa*) and grasses. After collection, crop samples were washed with distilled water to remove dust and soil particles and then were air-dried. The samples were oven-dried at 70$^{o}$C for over 48 hours and then crushed in a mortar and later stored in air-tight plastic bottles for chemical analyses.

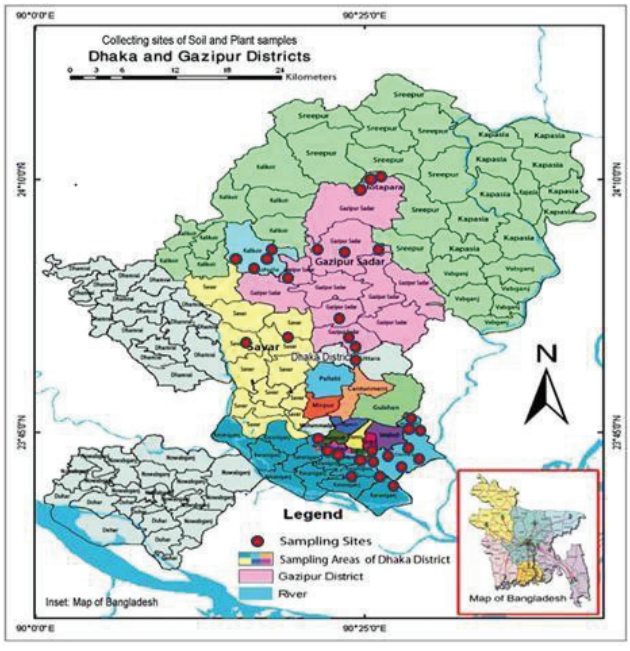


Fig. 1. Sampling sites of Dhaka and Gazipur districts

The total nitrogen of the crop was determined by Micro Kjeldahl's method following $H_2SO_4$ acid digestion as suggested by Jackson[16]. The plant samples were digested with $HNO_3$: $HClO_4$ (5:1) acid mixture for total analyses of P, Na, K, Ca, Mg, Zn, Cu, Ni, Pb and Cd as described by Blum *et al.*[17]. The total phosphorus of the crop samples was determined colorimetrically by using a spectrophotometer (Model: Jenway 6100) after developing the yellow color with vanadomolybdate as described by Jackson[16]. The intensity of the yellow color was measured at 470 nm wavelength.Na and K of the crop plant samples were determined by using flame emission spectrophotometer (model: Jencons PEP 7) at 589 and 769 nm of wavelength, respectively. Calcium and Mg of the crop samples were determined by atomic absorption spectrophotometer (model: VARIAN- 220). Heavy metals such as Zn, Cu, Ni, Pb and Cd of the crop plant samples were determined by atomic absorption spectrophotometer (model: VARIAN- 220). Standard methods were followed for digestion and determination for different parameters of soil samples. All the analyses were done both in the Department of Soil, Water and Environment, University of Dhaka and Centre for Advanced Research of Science (CARS), University of Dhaka. The plant transfer factor (TF) was calculated as follows:

**TF = C $_{plant}$ /C $_{soil}$,** Where $C_{plant}$ and $C_{soil}$ represents the toxic metal concentration in extracts of plants and soils on dry weight basis, respectively.

*Statistical analysis:*

The data were subjected to a one-way analysis of variance (ANOVA) followed by Tukey post-hoc test to evaluate the significant differences ($p < 0.05$) between different crops and heavy metals from various sources. All the statistical analyses were done by using MINITAB-20 (Minitab Inc., State College, PA, USA) statistical software and Microsoft Excel software (Microsoft Corp., USA).

**Results and Discussion**

The results of the soils as contaminated by surrounding wastes and effluents of different industrial clusters under Dhaka and Gazipur districts were already published[18]. In this paper, the results of some nutrient and heavy metal contents and their transfer factors of collected various crops grown in the above mentioned areas are discussed below.

*Plant nutrients and Na content:* The mean values of some nutrient concentration of the collected crop samples from different industrial clusters around Dhaka and Gazipur districts are presented in Table 2.

Results revealed that the major nutrient elements (N, P, K, Ca and Mg) and Na contents in the leafy vegetables (Spinach, Kalmishak and Lalshak), rice crops and grasses under study varied with different industrial sites and types of crops. The highest amount of N was found in Kalmisak at Keranigonj-1 near Momtaz steel mills ltd., whereas the maximum contents of P was obtained in same crop at Matuail-2 near dyeing industries. The lowest amounts of both N and P were also found in Kalmisak at Ashulia-1 near Shariar Fabrics. The highest K content was obtained in Kalmisak at Shampur-1 near Samia steel mills ltd. and the lowest was found in Rice at Savar-2 near Fazlul Haq steel mills ltd. The highest Ca concentration was found in Grass at Keranigonj-2 near dyeing industry and the lowest was obtained in Rice at Demra-1. The maximum amount of Mg was found in Grass at Gazipur-3 and the lowest was found in Kalmisak at Ashulia-1 near Sahriar Fabrics. On the other hand, the maximum Na concentration was found in Kalmisak at Gazipur-5 near Huq battery industry.

So, it was observed that the mineral contents in vegetables and other crops under study varied among different crops and also among different sites. It might be due to the nutrient status and their availability, heavy metals status and their availability to cause toxic effect on nutrient accumulation by different crops at different sites of the sampling areas. The availability of nutrient elements depends on soil pH, organic matter status, presence of different heavy metals and their status in soils and their effect on crops and also other chemical and environmental factors prevailed in those soils.

**Table 2. Mineral nutrients and Na content of some leafy vegetables and other crops collected from different industrial areas in and around Dhaka and Gazipur District**

| Industrial Clusters No. | Sampling Sites No. and the Name of Cluster | Name/Types of Industries | Crop Samples | Mineral Nutrition (%) | | | | | Sodium (Na) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Nitrogen (N) | Phosphorus (P) | Potassium (K) | Calcium (Ca) | Magnesium (Mg) | |
| I. Asuhlia | 1. Ashulia-1 | Sahriar Fabrics (dyeing) | Kalmisak | 1.18 | 0.13 | 1.78 | 0.50 | 0.14 | 0.92 |
| | 2. Ashulia-2 | Horizon Group (dyeing) | Grass | 2.69 | 0.15 | 1.55 | 1.40 | 0.37 | 0.75 |
| | 3. Ashulia- 3 | Aman Spinning Mills Ltd. | Spinach | 2.90 | 0.19 | 1.81 | 1.80 | 0.37 | 0.65 |
| II. Demra | 4. Demra- 1 | Apollo Ispat and C S M Ltd. | Rice | 2.32 | 0.30 | 1.03 | 0.23 | 0.23 | 0.75 |
| | 5. Demra- 2 | Jahir Steel Mills Ltd. | Lalsak | 2.52 | 0.40 | 1.22 | 1.20 | 0.50 | 0.55 |
| | 6. Demra-3 | I ITubes Mills Ltd. | Lalsak | 2.32 | 0.38 | 1.15 | 1.33 | 0.53 | 1.01 |
| | 7. Demra- 4 | Alaksa Steel Mills Ltd. | Grass | 1.90 | 0.30 | 1.45 | 1.67 | 0.41 | 0.65 |
| III. Gazipur | 8. Gazipur-1 | Konabari Industrial Area (dyeing) | Grass | 2.52 | 0.20 | 1.35 | 1.71 | 0.61 | 1.01 |
| | 9. Gazipur- 2 | Appex Tannery, Tongi | Lalsak | 2.99 | 0.08 | 1.16 | 3.50 | 0.95 | 0.79 |
| | 10. Gazipur- 3 | BISIC, Tongi | Grass | 2.74 | 0.19 | 1.41 | 1.28 | 1.09 | 0.97 |
| | 11. Gazipur-4 | Metrocem Ispat Ltd., Tongi | Grass | 2.04 | 0.19 | 1.21 | 2.34 | 0.59 | 0.99 |
| | 12. Gazipur-5 | Haq Battery, Tongi | Kalmisak | 1.97 | 0.26 | 1.44 | 0.54 | 0.17 | 1.02 |
| | 13. Gazipur- 6 | Mail Bazar, N G., Tongi (dyeing) | Kalmisak | 2.43 | 0.21 | 1.03 | 0.82 | 0.39 | 0.91 |
| | 14. Gazipur-7 | Meghna Ghat, Tongi (dyeing) | Kalmisak | 1.85 | 0.38 | 1.67 | 1.12 | 0.52 | 0.90 |
| IV. Hazaribagh | 15. Hazaribag-1 | Hazaribagh Tannery Area | Grass | 2.61 | 0.23 | 1.24 | 0.25 | 0.20 | 0.85 |
| | 16. Hazaribag-2 | Hazaribagh Tannery Area | Kalmisak | 3.26 | 0.19 | 0.85 | 1.00 | 0.48 | 0.49 |
| | 17. Hazaribag-3 | Hazaribagh Tannery Area | Grass | 2.64 | 0.17 | 1.09 | 2.53 | 0.35 | 0.88 |
| | 18. Hazaribag-4 | Hazaribagh Tannery Area | Kalmisak | 2.93 | 0.24 | 1.09 | 2.10 | 0.35 | 0.83 |
| V. Hotapara | 19. Hotapara- 1 | Near Givensee Group (dyeing) | Kalmisak | 2.17 | 0.39 | 1.98 | 0.51 | 0.36 | 0.33 |
| | 20. Hotapara- 2 | Near Givensee Group (dyeing) | Rice | 1.90 | 0.32 | 1.74 | 0.42 | 0.27 | 0.31 |
| | 21. Hotapara-3 | Near Givensee Group (dyeing) | Spinach | 2.50 | 0.29 | 2.38 | 0.61 | 0.31 | 0.23 |
| VI. Keranigonj | 22. Keranigonj-1 | Momtaz Steel Mills Ltd. | Kalmisak | 3.67 | 0.39 | 1.02 | 0.83 | 0.38 | 0.73 |
| | 23. Keranigonj-2 | Dyeing Industry | Grass | 2.28 | 0.17 | 1.04 | 5.79 | 0.72 | 0.79 |
| | 24. Keraniganj-3 | M.V.Corrugations Ltd. | Lal sak | 2.65 | 0.23 | 1.55 | 2.30 | 0.99 | 0.45 |
| VII. Matuail | 25. Matuail-1 | Asmat Ali Steel Mills Ltd. | Spinach | 2.85 | 0.33 | 2.03 | 0.51 | 0.18 | 0.78 |
| | 26. Matuail- 2 | Dyeing Industry | Kalmisak | 2.87 | 0.45 | 2.51 | 0.74 | 0.25 | 0.11 |
| | 27. Matuail-3 | Dastagir Steel Mills Ltd. | Grass | 1.81 | 0.33 | 1.06 | 0.43 | 0.44 | 0.40 |
| VIII. Savar | **28. Savar-1** | Doel Group & Ernlima Yarn (dyeing) | **Spinach** | 2.00 | 0.17 | 1.51 | 1.50 | 0.45 | 0.44 |
| | **29. Savar-2** | Fazlul Haq Steel Mills Ltd. | **Rice** | 2.13 | 0.19 | 0.99 | 1.15 | 0.29 | 0.77 |
| | **30. Savar- 3** | Ofaz Uddin Steel Mills Ltd. | **Kalmisak** | 2.19 | 0.20 | 1.07 | 1.20 | 0.22 | 0.81 |
| IX. Shampur | **31. Shampur-1** | Samia Steel Mills Ltd. | **Kalmisak** | 1.90 | 0.41 | 2.81 | 0.60 | 0.20 | 0.36 |
| | **32. Shampur-2** | Rupashi Dyeing Mills Ltd. | **Grass** | 1.55 | 0.35 | 1.78 | 0.43 | 0.19 | 0.42 |
| | **33. Shampur-3** | Kadamtali Steel Mills Ltd. | **Kalmisak** | 2.10 | 0.30 | 1.99 | 0.47 | 0.34 | 0.78 |

Many researchers found significant difference concerning nutrient utilization efficiency of different crops. Karim *et al*.[19] reported that nutrient utilization efficiency of different plant species differed among genotypes (cultivars) of the same plant species or among different species. Zhang *et al.*[20] reported that the availability of heavy metals and their effect are directly related to the plant itself.

*Heavy metal concentration:* The mean values of the heavy metals such as Zn, Cu, Ni, Pb and Cd concentration and their transfer factors (TF) in different leafy vegetables and crop plants under study collected from different industrially contaminated areas are presented in Table 3.

Results revealed that Zn, Cu, Ni, Pb and Cd concentrations in the leafy vegetables and crops also varied with different industrial sites and types of crops.

From the above results, it was found that the highest Zn concentration was found in Lalsak (1684 mg/kg) at Demra-3 near II Tubes Mills Ltd., followed by Kalmisak (710 mg/kg) at Gazipur-5 near Haq Battery and in the same crop (550 mg/kg) at Gazipur-6 near Mail Bazar, Nisad Gate and the lowest was found in Kalmisak at Ashulia-1 near Shahriar Fabrics. So, except grasses and rice, Zn contents in vegetable crops such as Lalsak, Kalmisak and Spinach were found above the phytotoxic range as described by Sauerbeck[21]. According to Sauerbeck[21], the phytotoxicity limit of Zn, Cu, Ni, Pb and Cd for different crops ranged from 150 - 200, 15 - 20, 20 - 30, 10 - 20 and 5 - 10 mg/kg dry weight, respectively. According to FAO/WHO[22,23], the limit values of heavy metals such as Zn, Cu, Ni, Pb and Cd in vegetable crops are 50 mg/kg, 10 mg/kg, 0.02 - 2.70 mg/kg, 0.30 mg/kg and 0.20 mg/kg, respectively.

The highest Cu concentration was found in Grasses (230 mg/kg) at Demra-4 near Alaksa Steel and Rerolling Mills Ltd. and the lowest was obtained in Kalmisak at Shampur-3 near Kadamtali Steel Mills Ltd. Higher Cu was found in Grass (98 mg/kg) at Shampur-2 near dyeing industry, and in the same crop (77 mg/kg) at Matuail-3 near Dastagir Steel Mills Ltd., in Kalmisak (77 mg/kg) at Shampur-1 near Samia Steel Mills Ltd., in Grass (74 mg/kg) at Gazipur-3 in BISIC area, in Grass (67 mg/kg) at Hazaribagh-3 within tannery area and in Lalsak (61 mg/kg) at Demra-3. All the values of Cu were above the normal concentration and also above the phytotoxic range as described by Sauerbeck[21].

The highest Ni concentration was found in Grass (35.60 mg/kg) at Gazipur-4 near MetrocemIspat Mills Ltd., followed by Lalsak (30.70 mg/kg) at Demra-3 near II Tubes and Pipe Mills Ltd. and the lowest was found at Demra-4 near Alaksa Steel Mills. Higher amounts of Ni were also found in Kalmisak (17.90 mg/kg) at Gazipur-5 near Haq Battery industry, in Grass (16.10 mg/kg) at Hazaribagh-3 within tannery industrial area, in Kalmisak (15.50 mg/kg) at Gazipur-6 near Mail Bazar; Nisad Gate and in Rice (14.69 mg/kg) at Savar-3 near Fazlul Haq Steel Mills Ltd. All the concentration levels were below the phytotoxic limit but above the tolerable range as cited by Sauerbeck[21].

**Table 3. Heavy metal concentrations in soils and crops and their transfer factors (TF) for the collected samples from different industrial clusters in and around Dhaka**

| Industrial cluster No. | Sampling sites and type of industries | Crop samples | Heavy Metal Concentrations (mg/kg) and Transfer Factors (TF) on Dry Weight Basis | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Zn | | | Cu | | | Ni | | | Pb | | | Cd | | |
| | | | Soils | Crops | TF | Soils | Crops | TF | Soils | Crops | TF | Soils | Crops | TF | Soils | Crops | TF |
| I. | 1. Ashulia -1 (Sahriar Fabrics) | Kalmisak | 55 | 40 | *0.73* | 201 | 30 | *0.50* | 25 | 6.40 | *0.26* | 38 | 3.85 | *0.10* | 1.80 | 1.78 | *0.99* |
| | 2. Ashulia -2 (Horizon Group) | Grass | 250 | 150 | *0.60* | 121 | 38 | *0.31* | 36 | 6.00 | *0.17* | 51 | 2.23 | *0.04* | 2.70 | 0.90 | *0.33* |
| | 3. Ashulia - 3 (Aman Spinning Mills Ltd.) | Spinach | 300 | 205 | *0.68* | 127 | 35 | *0.28* | 37 | 8.20 | *0.22* | 16 | 2.90 | *0.18* | 3.00 | 1.99 | *0.66* |
| II. | 4. Demra -1 (Apollo Ispat and C S M Ltd.) | Rice | 50 | 45 | *0.90* | 406 | 37 | *0.09* | 32 | 6.50 | *0.20* | 14 | 1.90 | *0.14* | 1.90 | 1.50 | *0.79* |
| | 5. Demra -2 (Jahir Steel Mills Ltd.) | Lalsak | 336 | 400 | *1.19* | 212 | 30 | *0.14* | 15 | 3.50 | *0.23* | 34 | 12.00 | *0.35* | 2.30 | 1.20 | *0.52* |
| | 6. Demra -3 (I ITubes Mills Ltd.) | Lalsak | 2136 | 1684 | *0.79* | 303 | 61 | *0.20* | 139 | 30.70 | *0.22* | 189 | 7.00 | *0.04* | 1.50 | 2.73 | *1.82* |
| | 7. Demra -4 (Alaksa Steel Mills Ltd.) | Grass | 70 | 50 | *0.71* | 790 | 230 | *0.29* | 10 | 1.50 | *0.15* | 30 | 1.80 | *0.06* | 0.50 | 0.30 | *0.60* |
| III. | 8. Gazipur -1 (Konabari Industrial Area) | Grass | 59 | 50 | *0.85* | 251 | 52 | *0.21* | 58 | 3.30 | *0.06* | 10 | 0.67 | *0.07* | 2.40 | 1.95 | *0.81* |
| | 9. Gazipur - 2 (Appex Tannery, Tongi) | Lalsak | 78 | 130 | *1.67* | 55 | 22 | *0.40* | 45 | 10.00 | *0.22* | 33 | 3.50 | *0.11* | 0.90 | 0.50 | *0.6* |
| | 10. Gazipur -3 (BISIC, Tongi) | Grass | 220 | 200 | *0.91* | 390 | 74 | *0.19* | 15 | 8.50 | *0.57* | 57 | 2.91 | *0.05* | 1.50 | 0.99 | *0.66* |
| | 11. Gazipur -4 (Metrocem Ispat Ltd., Tongi) | Grass | 120 | 90 | *0.75* | 300 | 40 | *0.13* | 215 | 35.60 | *0.17* | 15 | 0.95 | *0.06* | 1.50 | 0.99 | *0.66* |
| | 12. Gazipur -5 (Haq Battery, Tongi) | Kalmisak | 736 | 720 | *0.98* | 390 | 27 | *0.07* | 90 | 17.90 | *0.20* | 159 | 2.20 | *0.01* | 0.95 | 0.75 | *0.79* |
| | 13. Gazipur -6 (Mail Bazar, N G., Tongi) | Kalmisak | 500 | 550 | *1.10* | 430 | 28 | *0.06* | 80 | 15.50 | *0.10* | 97 | 1.90 | *0.02* | 3.80 | 3.30 | *0.87* |
| | 14. Gazipur -7 (Meghna Ghat, Tongi-1) | Kalmisak | 140 | 150 | *1.1* | 395 | 31 | *0.08* | 36 | 8.50 | *0.24* | 55 | 2.77 | *0.05* | 2.90 | 1.60 | *0.55* |
| IV. | 15. Hazaribag -1 (Hazaribagh Tannery Area) | Grass | 55 | 50 | *0.91* | 397 | 26 | *0.07* | 75 | 7.70 | *0.10* | 78 | 3.40 | *0.04* | 3.50 | 3.10 | *0.89* |
| | 16. Hazaribag -2 (Hazaribagh Tannery Area) | Kalmisak | 100 | 129 | *1.29* | 255 | 14 | *0.05* | 36 | 5.80 | *0.16* | 45 | 14.00 | *0.3* | 1.70 | 1.58 | *0.93* |
| | 17. Hazaribag -3 (Hazaribagh Tannery Area) | Grass | 58 | 65 | *1.12* | 250 | 67 | *0.27* | 21 | 16.10 | *0.77* | 32 | 4.20 | *0.13* | 4.70 | 1.54 | *0.33* |
| | 18. Hazaribagh -4 (Hazaribagh Tannery Area) | Kalmisak | 496 | 277 | *0.56* | 215 | 26 | *0.12* | 79 | 11.30 | *0.14* | 20 | 3.40 | *0.17* | 2.30 | 3.10 | *1.35* |
| V. | 19. Hotapara -1 (Near Givensee Group) | Kalmi sak | 100 | 121 | *1.21* | 65 | 35 | *0.54* | 42 | 9.00 | *0.21* | 26 | 4.20 | *0.16* | 4.00 | 4.20 | *1.05* |
| | 20. Hotapara -2 (Near Givensee Group) | Rice | 139 | 100 | *0.72* | 71 | 15 | *0.21* | 100 | 6.80 | *0.07* | 36 | 2.70 | *0.08* | 7.00 | 3.70 | *0.53* |
| | 21. Hotapara -3 (Near Givensee Group) | Spinach | 151 | 159 | *1.05* | 87 | 23 | *0.26* | 35 | 11.00 | *0.31* | 32 | 3.90 | *0.12* | 5.00 | 3.90 | *0.78* |
| VI. | 22. Keranigonj -1 (Momtaz Steel Mills Ltd.) | Kalmisak | 182 | 170 | *0.93* | 300 | 26 | *0.09* | 65 | 10.50 | *0.16* | 78 | 2.89 | *0.04* | 1.95 | 2.10 | *1.08* |
| | 23. Keranigonj -2 ( Dyeing Industry ) | Grass | 202 | 190 | *0.94* | 250 | 20 | *0.08* | 50 | 8.60 | *0.17* | 89 | 6.00 | *0.07* | 0.40 | 0.46 | *1.15* |
| | 24. Keranigonj -3 (M.V.Corrugations Ltd.) | Lalsak | 500 | 390 | *0.78* | 100 | 41 | *0.41* | 47 | 5.50 | *0.12* | 109 | 4.00 | *0.04* | 2.00 | 2.44 | *1.22* |
| VII. | 25. Matuail -1 (Asmat Ali Steel Mills Ltd.) | Spinach | 865 | 390 | *0.45* | 467 | 12 | *0.03* | 29 | 4.40 | *0.5* | 106 | 9.00 | *0.08* | 2.40 | 3.70 | *1.54* |
| | 26. Matuail -2 (Dyeing Industry) | Kalmisak | 950 | 481 | *0.51* | 79 | 27 | *0.35* | 18 | 7.70 | *0.43* | 32 | 5.40 | *0.17* | 3.60 | 3.90 | *1.08* |
| | 27. Matuail -3 (Dastagir Steel Mills Ltd.) | Grass | 658 | 200 | *0.30* | 177 | 77 | *0.44* | 47 | 5.11 | *0.11* | 43 | 4.50 | *0.10* | 0.95 | 0.70 | *0.74* |
| VIII. | 28. Savar -1 (Doel Group & Ernlima Yarn) | Spinach | 98 | 71 | *0.72* | 80 | 29 | *0.36* | 55 | 6.40 | *0.12* | 26 | 2.09 | *0.08* | 2.10 | 1.21 | *0.58* |
| | 29. Savar -2 (Fazlul Haq Steel Mills Ltd.) | Rice | 300 | 56 | *0.19* | 200 | 44 | *0.22* | 99 | 14.69 | *0.15* | 20 | 1.67 | *0.08* | 3.30 | 1.90 | *0.58* |
| | 30. Savar - 3(Ofaz Uddin Steel Mills Ltd.) | Kalmisak | 367 | 255 | *0.69* | 85 | 34 | *0.40* | 89 | 9.10 | *0.10* | 22 | 0.89 | *0.04* | 2.00 | 1.90 | *0.95* |
| IX. | 31. Shampur -1(Samia Steel Mills Ltd.) | Kalmisak | 236 | 275 | *1.17* | 250 | 77 | *0.31* | 27 | 14.20 | *0.53* | 290 | 54 | *0.17* | 2.85 | 4.00 | *1.40* |
| | 32. Shampur -2 (Rupashi Dyeing Mills Ltd.) | Grass | 302 | 262 | *0.87* | 384 | 98 | *0.26* | 142 | 14.00 | *0.10* | 180 | 14 | *0.08* | 6.00 | 3.30 | *0.55* |
| | 33. Shampur –3 (Kadamtali Steel Mills Ltd.) | Kalmisak | 365 | 266 | *0.73* | 489 | 11 | *0.02* | 76 | 7.80 | *0.10* | 480 | 21 | *0.04* | 1.90 | 2.50 | *1.32* |

The maximum Pb content was found in Kalmisak (54 mg/kg) at Shampur-1 near Samia Steel Mills Ltd., followed by Kalmisak (21 mg/kg) at Shampur-3 near Kadamtali Steel and Rerolling Mills and the lowest was found at Gazipur-1 at Konabari industrial area. Somewhat higher amount of Pb was also found in Kalmisak (14 mg/kg) at Hazaribagh-2 near tannery industry, in Grass (14 mg/kg) at Shampur-2 near dyeing industry and in Lalsak (12 mg/kg) at Demra-2 near Jahir Steel and Rerolling Mills Ltd. Pb concentration in the crops collected from Shampur industrial area was found above or within the phytotoxic limit as described by Sauerbeck[21]. But in other locations, Pb contents were found more or less below the phytotoxic limit but above tolerable range as described by Sauerbeck[21].

The highest Cd concentration was found in Kalmisak (4.20 mg/kg) at Hotapara-1 near dyeing industry followed by Kalmisak (4 mg/kg) at Shampur-1 near Samia Steel Mills Ltd., Spinach (3.90 mg/kg) at Hotapara-3 near Givensee Groups and Kalmisak (3.90 mg/kg) at Matuail-2 near dyeing industry and the lowest was found in Grass at Demra-4 near Alaksa Steel Mills Ltd. (Table 3). Higher Cd contents were also found in Rice (3.70 mg/kg) at Hotapara-2 near Givensee Groups, in Spinach (3.70 mg/kg) at Matuail-1 near metal industry, in Grass (3.30 mg/kg) at Shampur-2 near dyeing industry. But, Cd contents in the collected crops samples were found below the phytotoxic limit but above tolerable range as described by Sauerbeck[21].

So, a wide variation in the concentration of Zn, Cu, Ni, Pb and Cd was found in different vegetables and crop plants and in most cases exceeded the phytotoxic limits except Ni. This might be due to higher metal concentrations in the soils at different locations of the sampling sites. Alegria *et at*.[24] reported that the anthropogenic activities such as agriculture, industry and urban life increased the Pb, Cd and Ni contents of soils and waters and, therefore, had an effect on the metal contents of vegetables. Naser *et al*.[25] reported that the heavy metal content by plants can be affected by several factors including metal concentrations in soils, soil pH, cation exchange capacity, organic matter content, types and varieties of plants, and plant age. In addition, heavy metal availability can also be directly affected by plant itself[20]. Grunhage and Jager[26] found that the Cd, Pb, Zn and Cu concentration of shoot of *Allium porrum* increased with increasing heavy metal contamination of soil and no visible symptoms of heavy metal toxicity were recognized. And, the antagonistic effect of Pb, Cd, Zn and Cu uptake by plant was attributed to yield depression.

Again, it was evident from the Figures 2a-c, Lalsak and Kalmisak were the higher Zn contaminated crops and the maximum sources of Zn in soils near different industrial areas were steel and rerolling mills. Similarly, higher levels of Cu concentrations were found in grasses near different steel and rerolling, dyeing and tannery industries. Grass and Kalmisak were considered as the most Ni hyper-accumulating crops as they accumulated higher levels of Ni from the soils near different steel and re-rolling mills of the sampling sites. At different locations in and around Dhaka, Pb contents in Kalmisak were found higher near different steel and rerolling, tannery and dyeing mills.

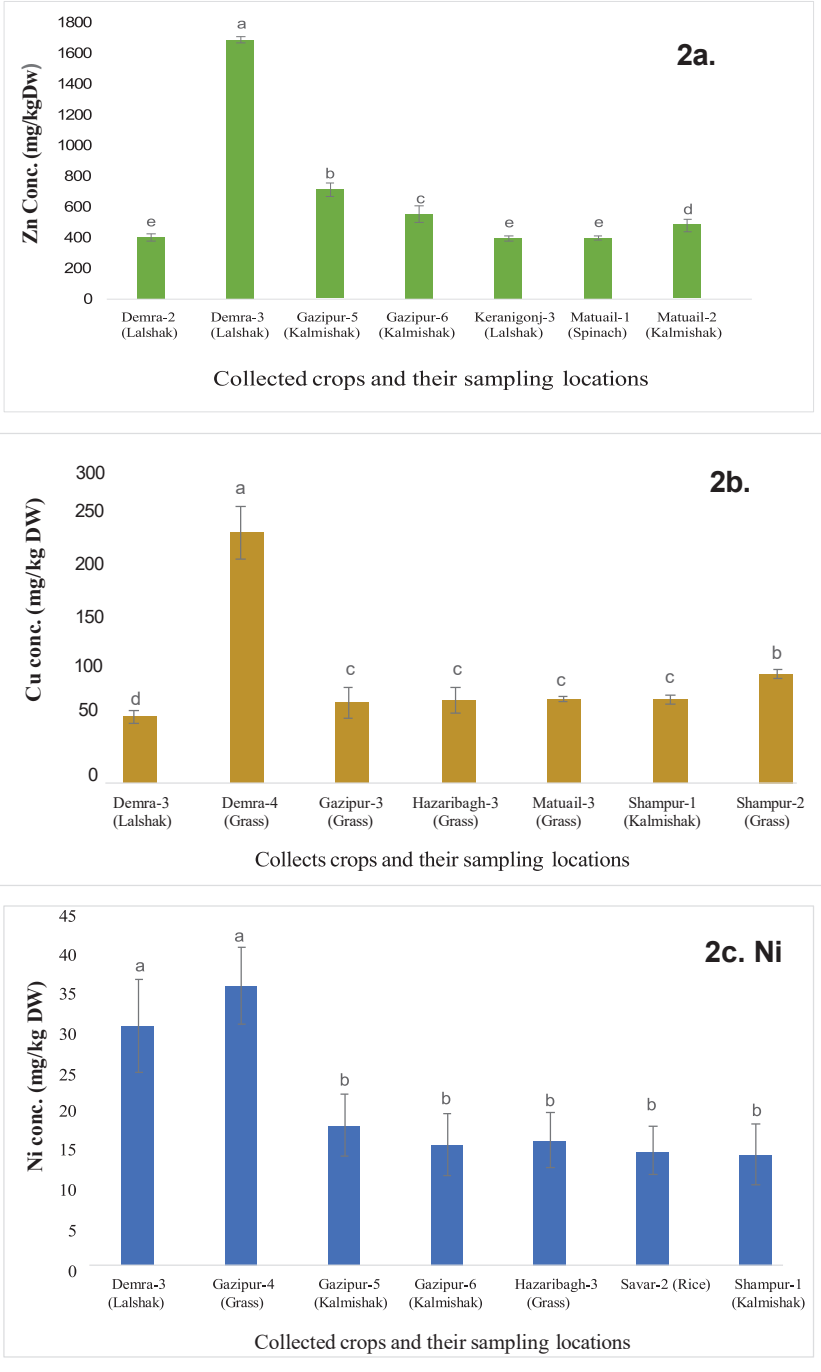


Fig. 2. a-c. Higher levels of heavy metal contamination in some collected crops at different industrial sites under investigation. Different lowercase letters indicate significant differ ences among the treatments by Tukey's post-hoc test ($p \leq 0.05$).

But, Cd concentrations in Kalmisak near most of the dyeing industrial plants were found alarmingly higher than other types of industries (Fig. 2d-e).

Many researchers[27,28] observed that Indian spinach had a tendency to take up large amount of Pb grown on by roadsides and industrial sites. Several studies also showed that the uptake of the metals by vegetable plants increased with increasing concentration of heavy metals in soil[27]. Conversely, some species of grasses are Pb tolerant, some has been found to contain high levels of Pb in soil[29]. Similarly, Rotikittkhun *et al*.[30] identified some species of grasses that could tolerate high Pb concentrations in soils and showed a very good growth performance. Tyksinski *et al*.[31] found excessive concentration of Pb, Cd and Cu in leafy vegetables, root vegetables and other vegetable crops grown on contaminated soils. Dowdy and Larsen[32] also reported that vegetables and plants grown in heavy metal contaminated soils had higher concentration of heavy metals than those grown in uncontaminated soils. Kashem and Singh[12] reported that the concentration of the selected heavy metals (Zn, Cu, Ni, Pb, Cd) were higher in vegetable samples of tannery areas and the content of Pb in grass samples exceeded the toxic limit. Naser *et al*.[25] investigated some vegetables from industrially polluted soils around Dhaka and found that Pb, Cd, and Ni concentrations in the studied vegetables were higher than those in vegetables from other countries. Nuruzzaman[11] found excessive concentrations of several heavy metals in the plants adjacent to pharmaceuticals, battery industry (Tongi) and tannery factories (Hazaribagh) around Dhaka.

Transfer factors: The transfer factors of Zn, Cu, Ni, Pb and Cd varied significantly among the crops. It might be due to the different crop species, types of metals and metal concentrations in different soils etc. Sauerbeck[21] also reported that the transfer co-efficient of different metals were varied widely among the crops. The assimilability of heavy metals by plants depends on many factors such as the contents of the elements in soil, interactions between and the ability of the plant itself to absorb selectively certain metals[33]. According to Horak[34], the transfer factors of Zn, Cu, Ni, Pb and Cd in plants ranges from 0.5 – 2.0, 0.06 – 0.5, 0.01 – 0.2, 0.003 – 0.05 and 0.5 – 2.0, respectively. Hossain et al.[35] studied on the transfer of Cd from soil to the vegetable crops and found that the transfer factor of Cd in roots of vegetables decreased in the order: Lettuce > Spinach> Data sak> Lal sak, in shoots the order of Cd concentration was: Data sak > Spinach > Lettuce > Lal sak and the transfer factor varies from 2.03 to 6.785 in roots and 0.166 to 0.525 in shoots.

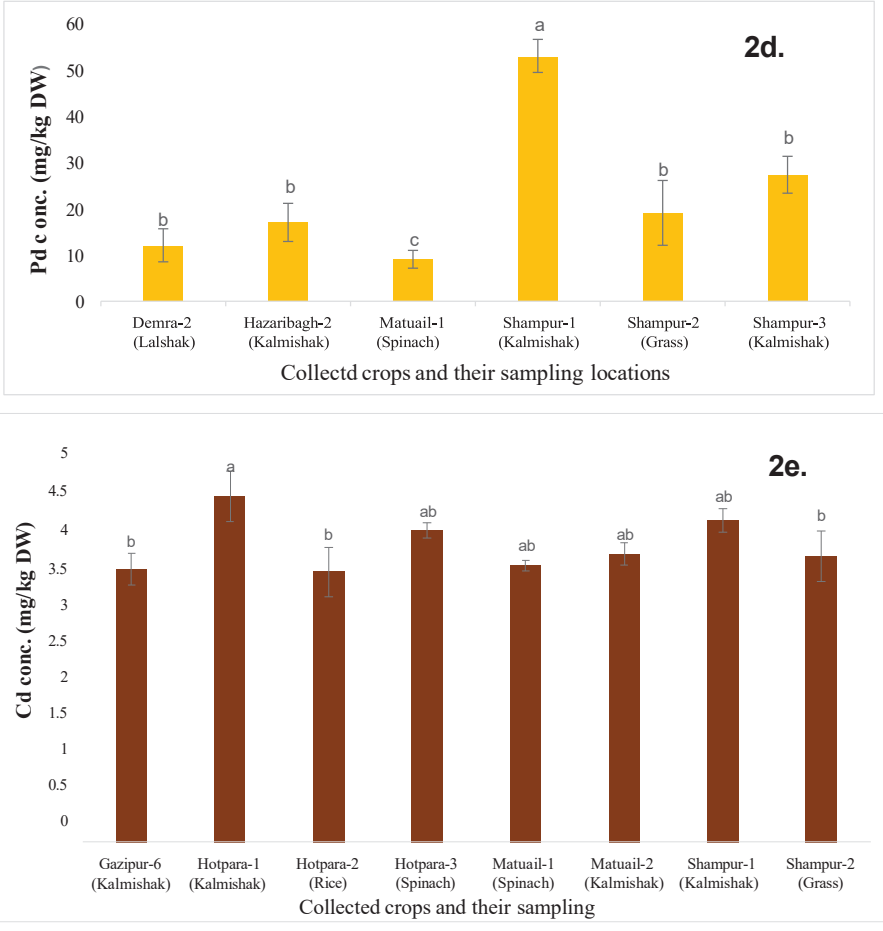


Fig. 2. d-e. Higher levels of heavy metal contamination in some collected crops at different industrial sites under investigation. Different lowercase letters indicate significant differences among the treatments by Tukey's post-hoc test ($p < 0.05$).

*Principal component analysis (PCA):* The principal component (PC) analysis was carried out by applying varimax rotation on the dataset of heavy metals to identify the possible sources of the heavy metals in the different crop and sampling locations.

Figure 3 shows the Biplot of Principal Component 1 and Principal Component 2 for the heavy metals in different crops and sampling locations. PCI has an eigenvalue of 1.6503 and explains 33% of the data variance and is highly loaded with Zn (0.588), Ni (0.521). An interesting result in comparing the PCA findings is the similarity in the PCA weight of concentrations as a significant pair between such as Cu vs Zn and Cd vs Pd. The Cu concentration showed high positive loading with Zn in PC1 while Cd concentration exhibited high positive loading with Pd in PC5.

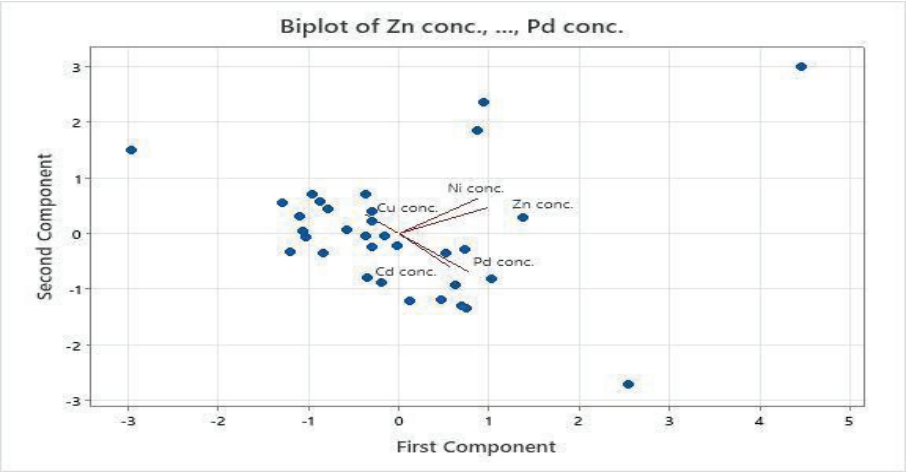


Fig. 3. Biplot of principal component 1 and principal component 2 for heavy metals based on the pearson correlation matrix component plot of principal component analysis.

Road traffic and many industrial sectors have a big influence on heavy metal contamination in the environment. Another significant source of such materials is industrial and municipal sewage Zwolak *et al*.[36]. It inferred that similar pathway of heavy metals were contributing to heavy metal pollution. The obtained results indicated that PCA can assist as an important means to identify the major pathways contributing heavy metal pollution in different locations.

Heavy metals' slow entry into agricultural soils as a result of urban and industrial activity is the root cause of this worry. Lead (Pb), zinc (Zn), nickel (Ni), copper (Cu), and cadmium (Cd) are the metals that have been receiving the most attention. Among these, high amounts of Cu, Ni, and Zn are phytotoxic, inhibiting plant growth. Additionally, some livestock are poisoned by Cu. Only Cd can easily enter the food chain through plant absorption, while both Pb and Cd are pollutants of the food chain Notten *et al*.[37].

## Conclusion

Metal concentration in plants depends upon the relative level of exposure of plants to the contaminated soil as well as the deposition of toxic elements in the soils. Through random disposal of untreated industrial wastes and effluents from different industrial plants in and around Dhaka, vegetables and other crops near different industrial plants had been polluted by several heavy metals such as Zn, Cu, Ni, Pb and Cd. In most studied crops, the concentration as well as contamination levels of these heavy metals near different industrially polluted sites in and around Dhaka were found above the tolerable limits which poses a risk to human health. It was also evident that steel and rerolling mills contributed maximum contamination of Zn, Cu, Ni and Pb. And, dyeing industries were considered as major Cd source in different sampling sites. On the other hand, Lalsak

(*Amaranthus cruentus*) and Kalmisak (*Ipomoea aquatica*) were found as higher metal accumulators. The soil to plant transfer factor (TF) of various metals of most common vegetables and other crops varied among different locations and plant species.

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*(Manuscript Received on 24 December, 2024; Accepted on 29 June, 2025)*