ASSESSMENT OF METAL POLLUTION IN THE CROP FIELDS ADJACENT TO INDUSTRIAL AREAS OF KUSHTIA AND JHENIAIDAH DISTRICTS OF BANGLADESH

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DHAKA-1207

JUNE, 2022

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A Thesis
Submitted to the Department of Agricultural chemistry
Sher-e-Bangla Agricultural University, Dhaka
In partial fulfilment of the requirements for the degree of

MASTER OF SCIENCE (MS)

IN

DEPARTMENT OF AGRICULTURAL CHEMISTRY
SEMESTER: JANUARY-JUNE, 2020

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CERTIFICATE

This is to certify that the thesis entitled " **ASSESSMENT OF METAL POLLUTION IN THE CROP FIELDS ADJACENT TO INDUSTRIAL AREAS OF KUSHTIA AND JHENAIDAH DISTRICTS OF BANGLADESH**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN DEPARTMENT OF AGRICULTURAL CHEMISTRY** embodies the result of a piece of *bona fide* research work carried out by **AL ARMUN, Registration No. 15-06676** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma in any other institutes.

I further certify that such help or sources of information, as have been availed during the course of this investigation have duly been acknowledged.

Date: June, 2022
Dhaka, Bangladesh

Professor Dr. Md. Sirajul Islam Khan
Department of Agricultural Chemistry, SAU, Dhaka
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DEDICATED

TO

MY BELOVED

PARENTS

ACKNOWLEDGEMENTS

All praises to the "Almighty Allah" who enable me to complete a piece of research work and prepare this thesis for the degree of Master of Science (M.S.) in Agricultural chemistry.

I feel much pleasure to express my gratefulness, sincere appreciation and heartfelt liability to my venerable research supervisor **Professor Dr. Md. Sirajul Islam Khan,** *Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University (SAU), Dhaka-1207, Bangladesh for his scholastic guidance, support, encouragement, valuable suggestions and constructive criticism throughout the studyperiod.*

I also express my gratitude, gratefulness and thankfulness to reverend co-supervisor, **Dr. Abdul Kaium,** *Associate Professor, Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University (SAU), Dhaka-1207 for his constant inspiration, valuable suggestions, cordial help, heartiest co-operation and supports throughout the study period.*

It is also an enormous pleasure for the author to express his cordial appreciation andthanks to the Chairman and all respected teachers of the Department of Agricultural chemistry, Sher-e-Bangla Agricultural University, for their encouragement and co-operation in various stages towards completion of this research work.

The author deeply acknowledges the profound dedication to his beloved Father, Mother, Sister for their moral support, steadfast encouragement and continuous prayer in all phases of academic pursuit from the beginning to the completion of study successfully.

Finally, the author is deeply indebted to his friends and well-wishers for their kind help, constant inspiration, co-operation and moral support.

The Author

ASSESSMENT OF METAL POLLUTION IN THE CROP FIELD ADJACENT TO INDUSTRIAL AREAS OF KUSHTIA AND JHENAIDAH DISTRICTS OF BANGLADESH

ABSTRACT

In the present study, we investigated the heavy metals pollution in soil, water and crops collected from crop fields near the industrial area of the Kushtia and Jhenaidah districts. In case of water study low concentration of Pb(0.13-0.18 mg/kg) were present in all the studied location but Cd,Cu and Cr concentration were below detectable limits. In case of the soil sample, the mean Cr and Cu concentrations in the soil from the studied location were higher than the permissible limits set by FAO/WHO, indicating that the soil accumulate higher metals near industrial areas. In the case of the rice sample, the mean Pb and Cr concentration in rice grain from all of the studied locations was much higher than the permissible limits set by FAO/WHO, indicating the rice grain accumulate higher Pb and Cr from contaminated field soil. The results also indicate that the contamination factor (CF) values indicating only Cu(falling between 3-6) and Cr(greater than 6) pose significant to severe contamination in field soil, while all metals pose low contamination in water and rice grain samples collected from studied sampling sites(Below 1). The results of the study indicate that the contamination degree (CD) of the water and rice grain samples collected from different industrial areas in the Kushtia and Jhenaidah districts was found to be low(Below 1). However, the field soil samples collected from the same areas exhibited a moderate degree of contamination. A Pollution Load Index (PLI) greater than 1 indicates that the soil samples collected were significantly contaminated with metals.But the PLI values found in the water and rice grain samples were below 1, which means that their contamination levels are low.

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ABBREVIATIONS AND ACRONYMS

Cd	Cadmium
Pb	Lead
Ni	Nickel
Cr	Chromium
SD	Standard deviation
MSW	Municipal solid waste
LFS	Land fill site
Zn	Zinc
Cu	Copper
As	Arsenic
ppm	Parts per million
pH	Potential hydrogen
S	Sulfur
Mn	Manganese
Hg	Mercury
Ha	Hectare
T	Tonne
PLI	Pollution load index
CF	Contamination factor
DEPZ	Dhaka Export Processing Zone
µg	Microgram
Mg	Milligram
Kg	Kilogram
EU	European Union
Co	Cobalt
FAO	Food and Agriculture Organization
WHO	World Health Organization
AAS	Atomic Absorption Spectrophotometer
I Geo	Index of Geo accumulation
HCL	Hydrochloric acid

CHAPTER I

INTRODUCTION

Environmentalists from all around the globe are paying close attention to the environmental pollution caused by heavy metals, particularly in water and agricultural land, which is made worse by human and natural activity. Due to their persistence and possible impact on plants, vegetables, and ultimately human health, heavy metals have a significant potential to contaminate soil and water. The main anthropogenic sources are mining, smelting, electroplating, use of phosphatic, phosphatic and other fertilizers, as well as biosolids in agriculture, sludge dumping, industrial discharge, atmospheric deposition, etc. The main natural sources are weathering of minerals, erosion, and volcanic activity (Fulekar et al., 2009; Sabiha-Javied et al., 2009; Wuana and Okieimen, 2011; Islam et al., 2014). In recent decades, unchecked population increase, rapid urbanization, and large-scale industrialization have all contributed to declining environmental quality and resulting in pollution that is now largely dangerous for the next generation. The most significant problem is heavy metal contamination because of its toxicity and capacity to build up in the biota. One of the main ways that people are exposed to heavy metals is via the food chain (Khan et al., 2008). Vegetable eating is one of the most significant routes for heavy metals that are harmful to human health (Sipter et al., 2008). The phrase "heavy metals" often refers to a set of metals and metalloids whose atomic absorption density is larger than 4 g cm-3, or five times or more, than that of water (Huton and Symon, 1986; Hawkes, 1997). Trace compounds, micronutrients, microelements, minor elements, and trace organic or inorganic are other names for heavy metals.

As a result of growing industrialization and disruption of natural biogeochemical cycles, the issue of heavy metal pollution is becoming worse with time and posing risks to the environment, agriculture, and public health (Fahad and Bano, 2012; Fahad et al., 2015). Lead (Pb), cadmium (Cd), nickel (Ni), zinc (Zn), copper (Cu), iron (Fe), chromium (Cr), and manganese (Mn) are the most prevalent heavy metals (Goyer, 1997; Adrees et al., 2015; Anjum et al., 2016a, b; Shahzad et al., 2018; Bakhat et al., 2017). Even though they are needed in modest amounts, certain of these metals, including Mn, Ni, and Zn, are regarded as essential to plants because of their vital roles in a variety of physiological processes (Goyer, 1997; Kabata-Pendias, 2010). Other metals, such as Cd and Pb, on the other hand, are optional and don't seem to play any major biological roles. These metals build up in increasing proportions and interfere with the plant's regular operation by altering its structural, physiological, and functional makeup (Goyer, 1997; Kabata- Pendias, 2010; Nagajyoti et al., 2010; Afshan et al., 2015; Shahzad et al., 2017).

In addition to the aforementioned heavy metals, other metalloids, such as arsenic (As), have also become significant sources of environmental contamination. This is because paddy fields are often irrigated with groundwater from shallow tube wells that are polluted with As (Kalita et al., 2018). Therefore, it has been discovered that the amount of As in rice grains is increasing at worrisome rates, which ultimately poses a danger to food safety and agricultural output in the near future (Rahman and Hasegawa, 2011). Bangladesh has seen the rise of several sectors during the last ten years, particularly the textile and composites industries, which generate enormous volumes of effluents (Saha, 2007). For the augmentation of human nutrition, the use of chemical fertilizers and manures is currently extensively used. The addition of different heavy metals including Cd, Pb, and Zn as impurities in varied proportions by several phosphatic fertilizers and pesticides (Hankens, 1983; Alloway et al., 1988) may persist after fertilizer application and dramatically raise their percentage in the soil. Vegetations become hazardous when there is an excess of heavy metals in the soil, which eventually contaminates the soil.

Almost half of the world's population (more than 3 billion people) consumes rice (Oryza sativa), a cereal crop that is significant from an agroeconomic standpoint (Ghosh et al., 2016). In Bangladesh, rice is the most significant cereal crop, accounting for around 65% of the population's protein consumption and 77% of its calories (Hossain et al., 2015; Mottaleb and Mishra, 2016). In Bangladesh, rice may be farmed virtually all year round. The top five cropping patterns out of 315, which account for more than half of the cultivable area, are rice-based cropping patterns (Biswas et al., 2019). Although it is now decreasing and stands at 7%, rice nevertheless contributes to the GDP (Biswas et al., 2019). It is important to note that since arable land is vulnerable to a variety of biotic and abiotic stressors, there is a significant yield gap between research and farmer production. In addition, Bangladesh's per capita arable land is just 0.04821 hectares, and it is declining at a pace of 0.7% because of the population's continuous increase and the extensive use of land for nonagricultural uses (Biswas et al., 2019).

Most notably, Bangladesh now has a population of around 162.7 million people, and by 2050, it is predicted that there will be 202 million people living there (BBS, 2018; UN, 2015). Therefore, achieving sustained food security poses an additional challenge to growing sufficient rice to feed additional millions of people in the future years (Kabir et al., 2015). Heavy metal pollution may have a catastrophic impact on both agricultural output and environmental pollution. However, there is no such study to understand the heavy metals (Cr, Cd, Pb, and Cu) content in water, soil and rice grain produced near the industry of Jhenaidah and Kushtia districts. Therefore, the following goals were set for the current study:

Objectives of the Research work:

1. To determine the different heavy metals (Cr, Cd, Pb, and Cu) content in water, soil and rice grain collected near the field of different industries of Jhenaidah and Kushtia districts.

2. To assess the environmental pollution to interpret the results of heavy metals contents in water, soil and rice grain samples collected from crop filed near the field of different industries of Jhenaidah and Kushtia district

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CHAPTER II
REVIEW OF LITERATURE

An attempt has been made in this chapter to review the pertinent research information relating to heavy metal contamination in soil, water and rice.

Laboni *et al* (2023) conducted a study to determine the quantity of heavy metals in widely consumed watercress (WC), alligator weed (AW), red amaranth (RA), spinach (SP), cauliflower (CF), and eggplant (EP) cultivated in industrial areas (e.g., Narsingdi district) of Bangladesh to assess the potential health hazards. Atomic absorption spectroscopy (AAS) served to determine the concentrations of lead (Pb), cadmium (Cd), chromium (Cr), and nickel (Ni) in vegetable samples (n = 72). The contents of Pb, Cd, Cr, and Ni were found in most of the analyzed vegetables, whereas 79.17%, 44.44%, and 1.39% of samples exceeded the FAO/WHO maximum allowable concentration (MAC) for Pb, Cd, and Ni, respectively. The estimated daily intake (EDI) of single heavy metal was below the corresponding maximum tolerable daily intake (MTDI). The incremental lifetime cancer risk (ILCR) values of Cd in all samples exceeded the threshold limit (ILCR > 10^{-4}) for both adults and children, indicating lifetime cancer risk due to the consumption of contaminated vegetables.

Kabir *et al* (2022) conducted a study focused on quantifying hazardous heavy metals (As, Cd, Cr, Pb, Ni, and Zn) in soil-rice systems near the Buriganga River in Bangladesh to assess their impact on human health and the environment. The mean concentrations of As, Cd, Cr, Ni, and Zn in soil exceeded FAO/WHO acceptable limits, and the metal pollution index (MPI) indicated that all soil samples collected from the rice fields were severely polluted (MPI>30) than water and rice grain samples. According to the sum of pollution index (SPI) by studied metals, rice grains collected from Kamrangirchor (29.36), Dhakauddan (28.75), and Bosila (18.08) were severely polluted. Mean Bio-concentration factors (BCFs) and Transfer factors (TFgrain/soil) in rice grains were in the following order: Cd (6.034) > Zn (1.752) > Pb (0.697) > Ni (0.666) > Cr (0.135) > As (0.037), and Cd (1.150) > Zn (0.421) > Ni (0.112) > Pb (0.072) > Cr (0.015) > As (0.034) respectively indicating higher accumulation of Cd in rice grain than others toxic heavy metal.

Ali *et al* (2018) conducted a study to assess the levels of toxic metals like arsenic (As), chromium (Cr), cadmium (Cd), and lead (Pb) in water and sediments of the Pasur River in Bangladesh. The ranges of Cr, As, Cd, and Pb in water were 25.76-77.39, 2.76-16.73, 0.42-2.98 and 12.69-42.67 μg/L and in sediments were 20.67-83.70, 3.15-19.97, 0.39-3.17 and 7.34-55.32 mg/kg. The level of studied metals in water samples exceeded the safe limits of drinking water, indicating that water from this river is not safe for drinking and cooking. Certain indices, including pollution load index (PLI) and contamination factor (C^i_f) were used to assess the ecological risk. The PLI indicated progressive deterioration of sediments by the studied metals. Potential ecological risks of metals in sediment indicated low to considerable risk. However, the C^i_f values of Cd ranged from 0.86 to 8.37 revealing that the examined sediments were strongly impacted by Cd. Considering the severity of potential ecological risk (PER) for single metal (E^i_r), the descending order of contaminants was Cd > Pb > As > Cr. According to the results, some treatment schemes must formulate and implement by the researchers and related management organizations to save the Pasur River from metal contamination.

Hasan *et al* (2016) stated in their study that the distribution of heavy metals (Pb, Ni, Fe, Mn, Cd, Cu) in the surface water of Bengal Coast in the southern part of Bangladesh. We also examined the common water quality parameters to discuss the impacts of pollution. It was revealed that the majority of the heavy metals have been introduced into the Bengal marine from the riverine inflows that are also affected by the impact of industrial, ship breaking yards, gas production plants and urban wastes. The concentration of heavy metals was measured using atomic absorption spectroscopy (AAS) instrument. Heavy metal concentrations were found to decrease in a sequence of Fe > Mn > Pb > Cu > Cd > Ni. Results showed that heavy metal concentrations in marine surface water generally exceed the criteria of international marine water quality.

Mottalib *et al* (2016) studied an experiment and found that the PCF values of the investigated heavy metals in the current study for the root of spinach were found Cr 0.06, Cu 0.60 – 0.79, Pb 0.13 – 0.43, Ni 0.15 – 0.27, Cd 0.74 –0.94, As 0.13 –0.34, Sb 0.65 – 0.82 and Fe 0.15 – 0.17. Metal uptake by the root of spinach was in the following order: Cd >Sb > Cu > Pb > As > Ni > Fe > Cr.

Tasrina *et al* (2015) experimented and resulted that the Hg in the sampling station was below the detection limit (<0.03 mg/ kg) and the concentration of Ni, Cu, Cd, Pb, Cr, Co was below the permissible limits recommended by Indian Standard Awashthi and European Union.

Ayenew *et. al* (2014) experimented with Ethiopia on a khat sample and found that the level of Cu in Khat samples varies from 5.44 mg/Kg to 9.05 mg/Kg. The smallest and biggest amounts were found in samples obtained from Addis Ababa and Bahir Dar near the airport respectively.

Napattaorn (2014) found that the highest metal concentrations were found in Soybean. Metal accumulation factors in plants were calculated as 1.2, 0.003, 0.14, 0.080 and 0.001 ppm for Cu, Pb, Zn, Cd and Fe, respectively.

Rakib *et al* (2014) experimented to assess the heavy metals in Dhaka Metropolitan city and found that the highest content of Pb, Zn, Cr and Cu were found in Hazaribagh and the lowest concentration of Pb, Zn, Cr and Cu was observed in Savar Bazar area in the greater Dhaka City. In addition, the minimum concentration of Pb, Zn, Cr and Cu was found to be 30.02 ppm, 49.91 ppm, 61.24 ppm and 12.21 ppm, respectively. Consecutively, the maximum concentration of Pb, Zn, Cr and Cu has identified 198.16 ppm, 283.21 ppm, 303.89 ppm and 179.80 ppm, respectively

Olafisoye *et al.*, (2013) experimented in South Africa and found that Heavy metals concentrations in vegetables were lower in the wet season when compared to the dry season. Pb showed the highest level of heavy metal concentrations in the roots of the plant.

Naser *et al* (2012) carried out an investigation and found that the concentrations of lead (Pb) and nickel (Ni) in soil and vegetables (bottle gourd and pumpkin) decreased with distance from the road, indicating their relation to traffic and automotive emissions.

Naser *et al* (2012) investigated that, the heavy metal contents at the same distance from the road were found in the following order: Ni>Pb>Cd. Examining the Pb, Cd, and Ni content of roadside soil, it can be concluded that the concentration decreases with increasing distance from the motorway, except Cd.

Rahman *et al* (2012) surveyed for the assessment of heavy metal contamination and found that the average concentration of Fe, As, Mn, Cu, Zn, Cr, Pb, Hg, Ni and Cd in the study area during the dry season was 30,404, 4,073.1, 339, 60, 209, 49.66, 27.6, 486.6, 48.1 and 0.0072 mg/kg, respectively. While the average concentration of Fe, As, Mn, Cu, Zn, Cr, Pb, Hg, Ni and Cd in the wet season was 17,103,2,326.2, 305, 90, 194, 34.2, 23.83, 133.2, 5.5 and 1.04 mg/kg, respectively.

Naser *et al*., (2011) experimented on leafy vegetables in BARI, Gazipur. He found that the Cd and Cr contents in leafy vegetables in this study were detected higher while Pb and Ni were within the permissible limits as per the WHO standard but all the metals were within the maximum allowable level as per PFA, 1954, India.

Shakery *et al* (2010) found that the results of soils texture and the concentrations of selected heavy metals, along with Sc, Fe and Al in the three sampled depths show that soil texture spreads out from a clay end-member to a silty - sandy end member with an average ratio of clay over silt and sand being 1.07 and 3.19, respectively. The highest and lowest average organic carbon (OC) content in A and B are (0.1%) and (0.063%), respectively. Soil pH varies between 7.79 and 8.7.

Fong *et al* (2008) stated in their paper that, heavy metals released from vehicular emission can accumulate in surface soils and their deposition over time can lead to abnormal enrichment, thus causing metal contamination of the surface soils.
Abdullah *et al* (2007) found that mollusc has the potential to be used as a bioindicator for the contamination of Cd and Zn in water and sediment of an estuarine environment, as indicated by its high concentration factors (BCFs) values.

Ayas *et al* (2007) found in their study on heavy metal contamination in Nallihan Bird Paradise (NBP) and its vicinity (Sariyar Dam) of Turkey, their result revealed that P, Cd, Cu and Ni metals are found widespread throughout the study area, but metal concentrations in the water samples are below the detection limits (BDL). Pb, Cd, Cu and Ni contamination were determined in sediments and fish tissues (muscle and liver) and it was seen that they were accumulated and biologically magnified in lish tissues. Metal concentration levels in sediment samples were higher than that of water and fish tissues. The highest amount of metal concentrations in sediment samples among seven stations were determined in Usakbuku (Pb: 0.49 ppm), Sakarya River (Cu: 1.12 ppm) and Sariyar (Ni: 0.77 ppm).

Islam *et al* (2004) studied the As status of five districts of Gangetic floodplains. Among the five districts, the soils of Pabna and Gopalganj districts had relatively lower levels of As compared to Rajbari, Faridpur and Chapai Nawabgonj districts.

Ahmed *et al* (2003) studied the soil sample in the Bhaluka region of Mymensingh. They revealed that heavy metal ranges in soil were As 3.90-25.50 ppm, Cr 80 - 117, Cu 1.20 - 49, Mo 2.00-2.2, Nb 9 - 20, Ni 44 -76 ppm, Pb 12.0-34.0 ppm, Sr 31.0-120.0 ppm, Th 12.0-26 ppm, U 1.60-5.8 ppm, V 134.0-273.0 ppm, Y 33- 54 ppm, Zn 35 -129 ppm and Zr 130.0-370.0 ppm.

Bibi *et al* (2003) found that the detected heavy metal ranges in the soil of different depths were 3.60- 26.20 ppm As, 89.0 - 117 ppm Cr, 8.0 - 48.0 ppm Cu, 19 -24 ppm Pb, 127- 177 ppm Sr, 41 - 143 ppm Zn and 109 - 212 ppm Zr.

Chowdhury (2003) detected that Fe, Mn, Zn, Cu and Pb from soils of various land use practices from BAU farms, Bhaluka (forest land), Boira farmer's field of Mymensingh district, Board Bazar industrial site of Gazipur. He found that total concentrations of Fe, Mn and Pb in surface soils ranged between 2066.80 – 3951.75, 150.5 – 365.71 and 21.48 – 34.00 mg kg-1, respectively.

Diaz–Valverde *et al* (2003) collected soil samples, which were sunshine soil, predominant vegetation, nearby roads, urban centres, and 6 mines in Huelva, Spain. They found that average Pb and cd contents in soil were 2.90 and 0.19 mg kg-1, respectively. There was no such significant variation in heavy metal contents between samples.

Hoque (2003) experimented with the determination of the status of As and other heavy metals and vegetables in five intensively growing areas of Chapai Nawabganj, he investigated that the mean concentration of Pb, Cd, Fe and Mn in soils were 16.2, 0.26, 4030 and 62.72 μg g-1, respectively.

Iannelli *et al* (2002) stated in their paper that heavy metals persist in soil which then reaches down into the groundwater and may induce enhanced antioxidant enzymatic activities in plants or become adsorbed with solid soil particles

Roychowdhury *et al* (2002) experimented on the As affected area of Murshidabad in West Bengal, India. They reported that the mean concentrations of As, Pb, Cd, Cr, Fe, Cu, Ni, Zn, Mn, Se, V, Sb and Hg in the fallow land soils were 5.31, 10.40, 0.37, 33.10, 674, 18.30, 18.80, 44.30, 342, 0.53, 44.60, 0.29, and 0.54, mg kg-1, respectively.

Jahiruddin *et al* (2000) investigated that the soils of Gangetic alluvium contain more As than that of Brahmaputra alluvium and the former soils had more than 20 mg kg-1 As, whereas the later soils had As level below 20 mg kg- 1 which was below maximum acceptable limit for agricultural soils. They also found that the mean concentration (mg kg-1) in calcareous soil were Pb (22.80), Cd (0.25), Sb (0.74), Mo (0.31), Mn (457), Cu (29.20) and Zn (78.50), whereas in non-calcareous soils were Pb (24. 1), Cd (0.15), Sb (0.31), Mo (0.31), Mn (444), Cu (22.4) and Zn (66.4).

Sattar and Blume (2000) experimented on total and available trace metals like Cr, Mn, Co, Zn, Pb, Cu, As, Mo, Ag, Cu, Sn, Sb, Ti, Hg and Ni contents were determined from the representative general soil types of Bangladesh at 0 – 15 depth. A variable available trace metals contents were recorded from the twenty soils and they are Pb (3.6 – 90 mg kg-1), Cd (0.69 – 1.00 mg kg-1), Cr (42 - 74 mg kg-1) and Mn (26 – 716 mg kg-1).

Perez *et al* (1999) studied heavy metal concentrations in water and underneath sediments of a Mexican reservoir. The results showed that mercury, lead, chromium and iron were the main metal contamination problem. In the same study, spatial and temporal distributions of total metal levels had also been identified. No organized pattern was detected for any particular metal concentration.

Adhikari *et al*., (1998) stated in their paper that increasing concentration of trace metals Cd, Pb, Zn, Cu, Mn, and Fe in surface soils irrigated with untreated sewage and industrial effluents.

Marshall (1998) conducted 4 pot and 2 field experiments to evaluate the vegetable uptake of heavy metals from the application of Zn oxysulphate containing 20% Zn, and 4.17 % Cd as Zn sources in red amaranth, sorghum, tomato and cabbage. Zn was applied at the rate of 0, 2, 4 and 6 kg ha -1 in all cases. He resulted that the edible portion take up more of Zn and lesser uptake of Cd and Pb. The highest uptake of Cd was found as 0.02, 0.016, 0.028 and 0.019, and that of Pb were 0.40, 0.25, 2.80 and 2.10 mg/kg in the case of red amaranth, sorghum, tomato and cabbage, respectively.

Sattar (1998) is the pioneer in the determination of the maximum number of heavy metals in the soil environment in Bangladesh like Pb, Al, Ti, Cr, Fe, Co, Ni, Cu, Zn, Cd, Sn, Sb, Ba, Hg, Mo, Ag, Th etc. Recently it was reviewed 30 heavy metals-related articles of Sattar (Ajker Bangladesh, 5 June 2012).
Metz and Wilke (1997) carried out a pot trial experiment on the influence of irrigated sewage affected soil and heavy metal uptake by plants. They reported that contents of Cd, Cu, Pb and Zn increased in crops with increasing soil pollution, but Cd and Zn uptake increased relatively more than that of Cu and Pb. The Cd in leaves ranged from 0.10- 8.20 mg kg- 1, dry matter, respectively.

Zupan *et al* (1997) carried out an experiment in heavy metal-contaminated soil in Slovenia. They found that the highest concentrations of heavy metals (Cd, Pb and Zn) were observed in edible green parts of vegetables (spinach, lettuce) and roots (carrot and radish) whereas in leguminous vegetables (pods and seeds) were very low.

Barman and Lal (1994) experimented in the industrially polluted field in Kalipur, West Bengal. They reported that the Zn, Cu, Cd and Pb concentrations of the soil samples were 309.74 ± 146.47; 41.50 ± 14.52; 6.11 ± 1.65 and 180.43 ± 75.61 μgg-1 soils, respectively.

Thomas *et al* (1992) resulted that the Cd and Pb content in some vegetables (potato, tomato, lettuce and cabbage) food stuffs were in the range of 0.01- 0.22 and 0.01-3.85 μg/g, respectively.

Fritaz and Venter (1988) carried out a pot experiment and grew the vegetables of lettuce, spinach, carrot, radish, bush bean and tomato. They resulted that heavy metal (Pb, Cu, Zn, and Ni) concentrations were generally highest in the leaves and lowest in the roots and fruits. Among the heavy metal, a high Cu level was found in carrots in the root.

Wiersma *et al* (1986) did collection and analysation of the cereals, fruits, fodder crops and vegetables from major growing areas in the Netherlands together with their responding soils. The Cd and Pd levels of cereals were much high to the proposed maximum acceptable concentrations. In lettuce and spinach, relatively high Cd levels occurred, and in fruits such as tomatoes, cucumbers and apples Cd levels were low. The Pb level in curly kale was high. The soils had median values for As, Cd, Pb, and

Hg of 11.0, 0.40, 23 and 0.07 mg kg-1, respectively.

Hibben *et al* (1984) resulted that a mean Pb concentration of 15.20 μg g-1, in some vegetables in Spain and 4.61 μg g-1, 3.80 μg g-1 and 1.24 μg g-1 in some vegetables in the USA, Egypt and the Netherlands, respectively.

Shacklette *et al* (1984) investigated that the mean values for Pb in cited soils of the USA are 17, 19 and 22 mg kg-1, within the range from 10-70, 10-30 and 10-70 mg kg-1, respectively.

Domingo and Kyuma (1983) reported that the mean trace elements status of Cu, Zn, B, Mo, Co, Cr and Ni of paddy soils of Bangladesh were 27.0, 68.0, 68.0, 3.3, 58.0, 133.0, and 22mg kg-1 respectively.

CHAPTER III
MATERIALS AND METHODS

This study was conducted from July 2021 to June 2022 to determine the status of metal pollution in the crop fields near the industrialized areas of the Kushtia and Jhenaidah districts. The fine points of materials and methods for the study are presented in this chapter.

3.1 Study area

Industrialization is a vital part of economic growth and development in many regions, including the Kushtia and Jhenaidah districts of Bangladesh. Industrialization has brought many economic opportunities, increased productivity, and created job opportunities in these districts. However, it has also come with environmental challenges, which have had a significant impact on the surrounding ecosystems. Kushtia and Jhenaidah districts have experienced rapid industrialization in recent decades. The region has a diverse range of industries, including textiles, food processing, pharmaceuticals, and agriculture. These industries have played a significant role in the economic growth and development of the region, contributing to the national economy as well.

The expansion of industries in the region has increased environmental pollution. The major sources of pollution are the discharge of industrial effluent and untreated sewage into the rivers and the deposition of toxic metals in crop fields. Pollution has had a significant impact on the environment and public health. To mitigate the environmental pollution caused by industrialization, there is a need for a comprehensive approach that includes regulations, enforcement, and monitoring.

3.2 Sampling sites

Water, soil and rice samples were collected from the crop fields near the Bulbul Textile (Kumarkhali), BRB Group (Kumargara), of Kushtia district, GK industrial project (Garagonj), and GK industrial project (Katlagari) of Jhenaidah district. Figure 1 shows the sampling location

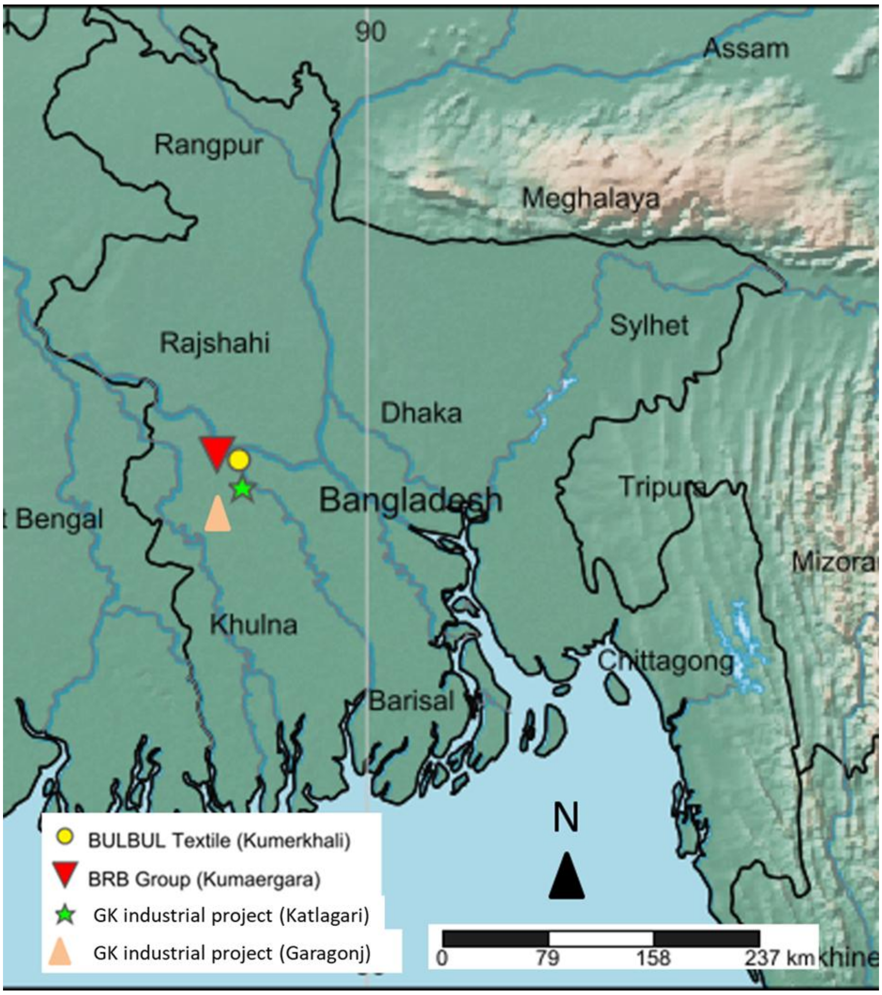

Figure 1. Sample collection site in the present study (created by simple mapper).

3.3 Study design

A cross-sectional approach was taken in the present study. It was done all at once or in a short period of time. The research sample was collected between July and December of 2020; it provides an "overview" of the findings. In the Kushtia and Jhenaidah districts, water, soil, and rice samples were selected from four industrialized area

3.4 Chemicals and reagents

The Pb, Cd, Cu, and Cr heavy metal standards (>95%) used in the AAS analysis were purchased from scharlau chemicals (Spain) by way of Bangladesh Scientific and Chemical Company Pvt. Ltd., Dhaka, Bangladesh. Kuri & Company (Pvt.) Limited, Dhaka, Bangladesh, provided analytical grade nitric acid, perchloric acid, distilled water, and hydrogen peroxide.

3.5 Sample preparation

3.5.1 Water sampling

Water samples were collected from crop field canals near four different industries, viz., Bulbul Textile (Kumarkhali), BRB Group (Kumargara),of Kushtia district, GK industrial project (Garagonj), and GK industrial project (Katlagari) from Jhenaidah district (Figure 1). Three 500 ml water samples were taken from each sampling spot. The water samples from the canals in the crop field were collected utilising plastic containers that were acid-washed and labelled, as described by Reza and Singh (2010). The water was tagged with the nearest industry and region where it was obtained. The water samples were kept at 4°C until transported to the laboratory for analysis.

3.5.2 Soil sampling

Soil samples were collected from crop fields near four different industries, viz., Bulbul Textile (Kumarkhali), BRB Group (Kumargara) of Kushtia district, GK industrial project (Garagonj), and GK industrial project (Katlagari) from Jhenaidah district (Figure 1). A stainless-steel sampler collected approximately 0.5 kg of soil at 0-15 cm deep at each sampling location. Three samples were collected from each location and blended in a clean plastic bag to ensure a representative sample. The resulting mixture was then subjected to drying, crushing, and sieving through a 2 mm mesh. The processed sample was then stored in appropriately labelled polythene bags in the sample preparation laboratory for analysis.

3.5.3 Rice grain sampling

Four rice fields were selected in each sampling location near Bulbul Textile (Kumarkhali, Kustia), (BRB group (Kumargara, Kushtia), GK industrial project

(Garagonj, Jhenaidah), and GK industrial project (Katlagari, Jhenaidah)], and three subsamples of rice grain samples were collected from rice fields. The composite samples of whole rice grain were obtained by combining the three sub-samples collected from each sampling site. After sorting and cleaning, the samples underwent a washing procedure with distilled water. Subsequently, the samples were dried, ground, and stored in airtight Ziplock poly bags in the laboratory of the Agricultural Chemistry Department at Sher-e-Bangla Agricultural University in Dhaka, Bangladesh. The heavy metal content in digestion samples was analysed using an Analytica Jena Nov 400P atomic absorption spectrophotometer.

3.6 Sample digestion

3.6.1 Water digestion

The water sample bottles were vigorously shaken by hand. A volume of 100 ml of the sample was measured with a volumetric flask and transferred to a 250 ml conical flask, followed by adding 10 ml of diacid mixture (nitric acid: perchloric acid) in a 2:1 ratio. The solution was gradually heated on a hot plate and subsequently reduced to approximately 20 ml, with precautions to prevent water from boiling. A further 5 ml of diacid mixture of nitic acid: and perchloric acid at a 2:1 ratio was added and slowly heated to dissolve any leftover residue, ensuring complete digestion. The filtrate was put into a 100 ml volumetric flask to cool before filling it to the mark with distilled water .

3.6.2 Soil digestion

According to the ASEAN manual for food analysis, we properly weighed 1 g of homogenized dry soil sample into a 250 mL Erlenmeyer flask. Subsequently, 15 mL of the diacid mixture (HNO3: HClO4 at a 2:1 ratio) was added to the digesting flask and remained undisturbed overnight within the fume hood. The next day, the flask deployed for digestion was heated on a hot plate at a temperature range of 120 to 160 °C until it reached a state of near dryness. The flask was diluted to 100 mL using distilled water after the cooling process. The solution was filtered through Whatman filter papers and transferred to polyethene bottles. Subsequently, the bottles were placed in storage for subsequent examination.

3.6.3 Rice grain digestion

In separate glass digestion tubes, 1 g of dry ground rice samples were predigested with a 15 ml di-acid combination (2:1, HNO3:HClO4). The next day, predigest samples were heated at 180–220°C until near dryness. The procedure led to the complete digestion of plant matter. After digestion, all samples were cooled for 30 minutes, diluted to 100 ml with distilled water, mixed for 10 seconds with a vortex mixer, and filtered through Whatman 42 filter papers. The samples were stored in clearly labelled plastic bottles in a refrigerator (4-7 °C). The heavy metal content in digestion samples was analysed using an Analytic Jena Nov400P atomic absorption spectrophotometer.

3.7 Instrumental analysis

The total copper, chromium, lead, and cadmium content in the water, soil and rice sample digest was determined using an Analytik Jena novA 400P atomic absorption spectrophotometer. Depending on the analysed element, the AAS hollow cathode lamps were used for estimations in different conditions. The heavy metal concentration was quantified in units of parts per million (mg/kg). Table 1 presents a comprehensive overview of the instrumental parameters used in quantifying copper, chromium, lead, and cadmium.

Table 1. Instrumental conditions for determination of Cu, Cr, Pb, and Cd.

Element	**Cu**	**Cr**	**Cd**	**Pb**
Wavelength (nm)	324.8	357.9	228.8	217.0
Slit (nm)	1.2	0.2	1.2	1.2
Lamp	HCL-Cu	HCL-Cr	HCL-Cd	HCL-Pb
Lamp current (mA)	2	4	2	2
Flame	Air-Ac	Air-Ac	Air-Ac	Air-Ac
Air/Ac flow (L/min)	50	100	50	65
Burner Head (mm)	100	100	100	100
Burner height (mm)	6	8	6	6
Read time (seconds)	3	3	3	3

3.8 Quantification of heavy metals

The construction of the standard curve involved plotting the absorbance values on the Y axis against various concentrations of each standard metal solution on the X axis. The estimation of metal concentration in the water, soil and rice samples by using the AAS reading in conjunction with the standard curve. Formula (1) determines the concentration of metal contents based on the Instrumental standard curve.

$$x = (y - b)/m \text{ ………………………………. (1)}$$

Where x is the amount of metals in the sample, y is the instrument's absorbance for metals with known and unknown concentrations, m is the slope from the standard curve relating absorbance versus concentration, and b is the intercept from the standard curve.

The following equation (2) calculates the final concentration of metals in water, soil, and rice samples collected from different crop fields in the Kustia and Jenaidah districts near industrial sites.

$$\text{Metal (mg/kg)} = \frac{C\ x\ V\ x\ D}{W} \text{ …………………………. (2)}$$

Where C is the concentration unit of the sample from the calibration curve, V is the total volume of digest (ml), D is the dilution factor, and W is the weight of the sample (g).

3.9 Quality control of the instrumental analysis

Method linearity and the determination coefficient were used to quality control the instrumental method. The linearity and determination coefficient was determined by generating calibration curves with standard solutions ranging in concentration from 0.0 to 1.0 mg/L. Each analysis was performed three times.

3.10 Assessment of metal pollution

Copper (Cu), lead (Pb), cadmium (Cd), and chromium (Cr) levels were assessed in water, soil, and rice samples collected from fields near factory sites. The Pollution Index is an efficient tool for analysing, interpreting, and disseminating unprocessed environmental data to managers, decision-makers, experts, and the general public. The contamination factor precisely represents the pollution factors found in the study area. The contamination factor (CF) was developed to identify single metal pollution at specific sites. In contrast, Hakanson's (1980) contamination degree (CD), pollution load index (PLI), and potential ecological risk index (PERI) were evaluated as indices for identifying multi-metal pollution.

3.10.1 Contamination factor (CF)

The contamination factor (CFi) for a single metal is the ratio of that metal's concentration in a biotic or abiotic medium to a regulatory standard, such as that established by the Food and Agricultural Organisation (FAO) or the World Health Organisation (WHO). The computation of the single metal contamination factor (CF) was carried out utilising equation 3, as proposed by Hakanson in 1980 (Hakanson, 1980).

$$CF_i = C_{\text{water or soil or rice plant}} / C_{\text{WHO or FAO}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

The variable C represents the metal concentration in a given water, soil, or rice plant sample. The World Health Organisation (WHO) or the Food and Agriculture Organisation (FAO) established the regulatory limit of heavy metals. The values of the contamination factor (CF) were classified into four overall categories: CF values less than 1 indicating low contamination; CF values between 1 and 3 indicating moderate contamination, CF values between 3 and 6 indicating significant contamination, and CF values greater than 6 indicating severe contamination.

Table 2. Heavy metal limits (allowable limit) in different sources showing references

Source	**Pb**	**Cd**	**Cr**	**Cu**	**References**
Soil	85	1	100	36	FAO/WHO, 2011
Irrigation water	5	0.01	0.1	0.2	(Ayers and Westcot, 1985)
Rice grain	0.1	0.05	2.3	30	FAO/WHO, 2011

3.10.2 Contamination degree (CD)

The calculation of the concentration degree (CD) involves the summation of the contamination factors (CF) linked to the heavy metals quantified at study sites. Equation (4) was used to calculate the level of contamination (CD) at different sites (Islam et al., 2015).

$$CD = \sum CF \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

The contamination degree (CD) values were classified into four broad categories: CF<8 (low degree contamination), 8<CF<16 (moderate degree contamination), 16<CF<32 (significant degree contamination), and CF > 32 (severe degree contamination). The CD is intended to measure the contamination in specific samples from specific sampling sites.

3.10.3 Pollution load index (PLI)

The Pollution Load Index (PLI) is an indicator for assessing the cumulative levels of heavy metals in water, soil and rice plants. This indicator is calculated by calculating the geometric mean of all metal concentrations. The calculation of the pollution load index (PLI) was carried out utilising equation (5) (Varol, 2011).

$$PLI = (CF_1 \times CF_2 \times CF_3 \times \ldots\ldots\times CF_n)^{1/n} \quad \ldots\ldots\ldots\ldots\ldots\ldots \ (5)$$

Where n is the number of parameters, and CF is the contamination factor. This pollution load indicator provides a quick and simple approach to assessing the level of heavy metal pollution. A PLI of more than 1 indicates the presence of metal pollution, whereas a PLI of less than 1 shows no pollution.

3.11 Statistical analysis

The Analytica Jena Aspect LS programme was used to detect, calculate, and statistically analyse the amount of heavy metals in water, soil, and rice plant samples at the 95% significance level. The descriptive statistics were computed using MS Excel 2016 to analyse the quantities of heavy metals

CHAPTER IV

RESULTS AND DISCUSSIONS

In recent decades, the concentrations of heavy metals and metalloids in irrigation water, soil, and food crops have been greatly increasing on farmland due to industrial activities. In the present study, we investigated the heavy metals contamination in soil, water and crops adjacent to industrial areas of the Kushtia and Jhenaidah districts and assess their impact on the environment. The findings of the study are presented here under the following headings.

4.1 Standard curve of the heavy metal standards

The calibration curve of different heavy metals was used to evaluate the method's linearity and determination coefficient. Plotting the absorbance vs the standards' concentrations generated a calibration curve. A new calibration curve was created for each metal for each analytical run. The calibration's good linearity was shown by the calibration curves' range of 0.00 to 1.00 mg/kg. The standards were set or subjected to the same instrumentation conditions on different dates. Cu, Cd, Cr, and Pb had good linearity in Figure 2 with determination coefficients (R2) above 0.998 (Figure 2). These standard calibration curves determined the amount of heavy metals in water, soil, and rice grain samples.

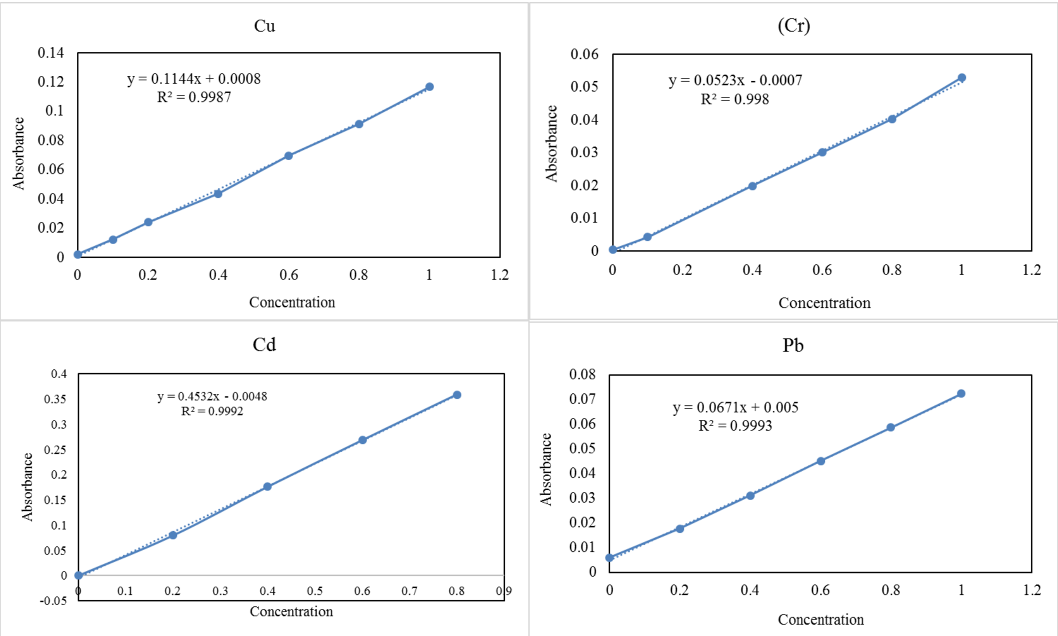

Figure 2. The standard curve of heavy metals shows linearity and determination co-efficient

4.2 Heavy metal concentrations in water, soil, and rice grain samples

4.2.1 Heavy metals concentration in water

We have investigated the lead (Pb), Cadmium (Cd), Chromium (Cr) and Cupper (Cu) concentration on the water in four different locations vi.z., Bulbul Textile (Kumarkhali), BRB group (Kumargara), and GK industrial project (Garagonj, Jhenaidah) and GK industrial project (Katlagari, Jhenaidah) from Jhenaidah district. The mean lead (Pb) concentration in water from four different sampling locations is shown in table 3. In this study, we found the mean Pb concentration in water from the studied location ranged from 0.13 – 0.18 mg/kg. The highest Pb concentration (0.18 mg/kg) was found in water collected from the crop field near the GK industrial project (Katlagari, Jhenaidah) and the lowest (0.13 mg/kg) was found in water collected from the crop field near Bulbul Textile (Kumarkhali, Kushtia). Although the Cd, Cr and Cu in studied water samples were below the detectable limit of the analytical method. The mean Pb concentration in water from all of the studied locations was lower than the FAO/WHO permissible limits (5 mg/kg) (FAO/WHO, 2011).

Table 3. Heavy metals concentration were found in the water of the studied locations.

Water from crop fields near four industrial area	Concentration (mg/kg)			
	Pb	Cd	Cr	Cu
Bulbul Tex. (Kumarkhali, Kushtia)	0.13	BDL	BDL	BDL
BRB Group (Kumargara, Kushtia)	0.16	BDL	BDL	BDL
GK industrial project (Garagonj, Jhenaidah)	0.16	BDL	BDL	BDL
GK industrial project (Katlagari, Jhenaidah)	0.18	BDL	BDL	BDL
MAL (FAO/WHO, 2011)	5	0.01	0.1	0.2

MAL = Maximum allowable limit

4.2.2 Heavy metals concentration in soil

We have investigated the Pb, Cd, Cr and Cu concentration on the soil in four different locations vi.z., Bulbul Textile (Kumarkhali), BRB group (Kumargara), and GK industrial project (Garagonj, Jhenaidah) and GK industrial project (Katlagari, Jhenaidah) from Jhenaidah district. The mean lead (Pb) concentration in soil from four different sampling locations is shown in table 4. In this study, we found the mean Pb concentration in soil from the studied location ranged from 39.27 mg/kg – 83.5 mg/kg. The highest Pb concentration (83.5 mg/kg) was found in soil collected from the crop field near the GK industrial project (Katlagari, Jhenaidah) and the lowest (39.27 mg/kg) was found in soil collected from the crop field near Bulbul Textile (Kumarkhali, Kushtia). We found the mean Cr concentration in soil from the studied location ranged from 588.8 mg/kg – 962.4 mg/kg. The highest Cr concentration (962.4 mg/kg) was found in soil collected from crop fields near the GK industrial project (Garagonj, Jhenaidah) and the lowest (588.8 mg/kg) was found in soil collected from crop fields near the GK industrial project (Katlagari, Jhenaidah). The mean Cu concentration in soil from four different sampling locations was found in soil from the studied location ranging from 101.7 mg/kg – 159.79 mg/kg. The highest Cu concentration (159.79 mg/kg) was found in soil collected from crop field near BRB Group (Kumargara, Kushtia) and the lowest (101.7 mg/kg) was found in soil collected from crop field near the GK industrial project (Katlagari, Jhenaidah). Although the Cd in studied soil samples was below the detectable limit of the analytical method. The mean Pb, Cr and Cu concentration in soil from all of the studied locations was higher than the FAO/WHO permissible limits (FAO/WHO, 2011).

Table 4. Heavy metals concentration were found in the soil of all studied locations.

Soil from crop fields near four industrial area	Concentration (mg/kg)			
	Pb	Cd	Cr	Cu
Bulbul Tex. (Kumarkhali, Kushtia)	39.27	BDL	692.4	148
BRB Group (Kumargara, Kushtia)	59.79	BDL	716.6	159.79
GK industrial project (Garagonj, Jhenaidah)	75.81	BDL	962.4	104.2
GK industrial project (Katlagari, Jhenaidah)	83.5	BDL	588.8	101.7
MAL (FAO/WHO, 2011)	85	0.8	100	36

MAL = Maximum allowable limit

4.2.3 Heavy metals concentration in rice grain

We have investigated the Pb, Cd, Cr and Cu concentration on the rice grain collected in four different locations vi.z., Bulbul Textile (Kumarkhali), BRB group (Kumargara), and GK industrial project (Garagonj, Jhenaidah) and GK industrial project (Katlagari, Jhenaidah) from Jhenaidah district. The mean lead (Pb) concentration in rice grain from four different sampling locations is shown in table 4. In this study, we found the mean Pb concentration in rice grain from the studied location ranged from 3.29 – 8.18 mg/kg. The highest Pb concentration (8.18 mg/kg) was found in rice grain collected from crop fields near the BRB Group (Kumargara, Kushtia) and the lowest (3.29 mg/kg) was found in rice grain collected from crop fields near the GK industrial project (Garagonj, Jhenaidah). The mean Cr concentration in rice grain from four different sampling locations is shown in table 4. We found the mean Cr concentration in rice grain from the studied location ranged from 1.3 – 3.92 mg/kg. The highest Cr concentration (3.92 mg/kg) was found in rice grain collected from the crop field near Bulbul Tex. (Kumarkhali, Kushtia) and the lowest (1.3 mg/kg) was found in soil collected from the crop field near the GK industrial project (Katlagari, Jhenaidah). The mean Cu concentration in rice grain from four different sampling locations was found in rice grain from the studied location ranging from 2.21 – 159.79 mg/kg. The highest Cu concentration (6.12 mg/kg) was found in rice grain collected from crop field near BRB Group (Kumargara, Kushtia) and the lowest (2.21 mg/kg) was found in soil collected from crop field near the GK industrial project (Katlagari, Jhenaidah). Although the Cd in studied rice grain samples was below the detectable limit of the analytical method. The mean Pb, and Cr concentration in rice from all of the studied locations was higher than the FAO/WHO permissible limits, while the Cd and Cu concentrations were lower than the FAO/WHO permissible limits (FAO/WHO, 2011).

Table 5. Heavy metals concentration in rice grain collected from the studied locations.

Rice grain collected from crop fields near four industrial area	Concentration (mg/kg)			
	Pb	Cd	Cr	Cu
Bulbul Tex. (Kumarkhali, Kushtia)	5.92	BDL	3.92	5.82
BRB Group (Kumargara, Kushtia)	8.18	BDL	3.57	6.12
GK industrial project (Garagonj, Jhenaidah)	3.29	BDL	2.82	3.86
GK industrial project (Katlagari, Jhenaidah)	6.99	BDL	1.3	2.21
MAL (FAO/WHO, 2011)	0.2	0.4	1	20

MAL = Maximum allowable limit

4.3 Environmental pollution by heavy metals

4.3.1 Contamination factor (CF)

The calculation of the single metal contamination factor (CF) involves determining the proportion of a specific metal present in a biotic or abiotic medium relative to the established regulatory threshold established by authoritative bodies such as the Food and Agricultural Organisation (FAO) and the World Health Organisation (WHO). The assessment of pollution caused by individual heavy metals in water, soil, and rice grain samples is important, and the contamination factor (CF) for a single metal plays a significant role in this assessment. According to Hakanson's (1980) classification, a CF value less than 1 signifies low levels of contamination, while a CF value ranging from 1 to 3 indicates moderate pollution. A CF value between 3 and 6 indicates significant pollution. However, a CF value greater than 6 implies severe pollution. The status of CF=1 as a critical state renders the involved samples significant for environmental monitoring. The study reveals that the soil in the crop field near the industrial areas of Kushtia and Jhenaidah districts has been significantly contaminated by Cu, with a contamination factor falling between 3 and 6. On the other hand, the soil has been severely contaminated by Cr, with a contamination factor greater than 6. The CF<1 values for Pb and Cd suggest that the level of contamination in the soil of crop fields located adjacent to industrial areas in the Kushtia and Jhenaidah districts is low, as shown in Table 6

Table 6.Contamination factor CF in soil of all studied location

Area	Pb	Cu	Cr	Cd
BULBUL Tex. (Kumarkhali, Kushtia)	0.46	4.111	6.924	BDL
BRB Group (Kumargara, Kushtia)	0.703	4.438	7.166	BDL
GK industrial project (Garagonj, Jhenidah)	O.891	2.894	9.624	BDL
GK industrial project (Katlagari, Jhenidah)	0.982	2.825	5.988	BDL

BDL=Below detectable limit

The results also indicate that the contamination factor (CF) values for Cu, Cr, Cd, and Pb in both water and rice grain samples were below 1, indicating low levels of contamination. The soil of crop fields located around industrial areas in Kushtia and Jhenaidah districts had moderate to severe Cu and Cr contamination, ranging from moderate to severe.

Table 7.Contamination factor CF in water of all studied location

Area	Pb	Cu	Cr	Cd
BULBUL Tex. (Kumarkhali, Kushtia)	0.027	BDL	BDL	BDL
BRB Group (Kumargara, Kushtia)	0.03	BDL	BDL	BDL
GK industrial project (Garagonj, Jhenidah)	O.03	BDL	BDL	BDL
GK industrial project (Katlagari, Jhenidah)	0.04	BDL	BDL	BDL

BDL=Below detectable limit

Table 8.Contamination factor CF in rice grain of all studied location

Area	Pb	Cu	Cr	Cd
BULBUL Tex. (Kumarkhali, Kushtia)	0.069	0.161	0.039	BDL
BRB Group (Kumargara, Kushtia)	0.096	0.17	0.035	BDL
GK industrial project (Garagonj, Jhenidah)	O.04	0.107	0.028	BDL
GK industrial project (Katlagari, Jhenidah)	0.08	0.061	0.013	BDL

BDL=Below detectable limit

4.3.2 Contamination degree (CD)

The Contamination Degree (CD) is determined by calculating the sum of the Contamination Factors (CF) of heavy metals that have been measured at the specified locations. The objective of the Contamination Degree (CD) is to evaluate the comprehensive degree of contamination of particular samples at a specified sampling location. The CD values showed significant variation among the soil samples collected from the field and in the water and rice grain samples obtained from the area under study (Figure 4). The results indicate that the soil samples collected from different industrial regions in the Kushtia and Jhenaidah districts showed a moderate level of contamination, whereas the water and rice grain samples showed a low level of contamination, as shown in Figure 4. The study revealed that the field soil collected from the GK industrial project area in Garagonj, Jhenaidah exhibited the highest level of contamination, whereas the field soil collected from the vicinity of the GK industrial project in Katlagari, Jhenaidah showed the lowest level of contamination. The contamination degree results showed that all field soil samples collected near different industrial areas in the Kushtia and Jhenaidah districts had a moderate degree of contamination, but all water and rice grain samples had a low degree of contamination.

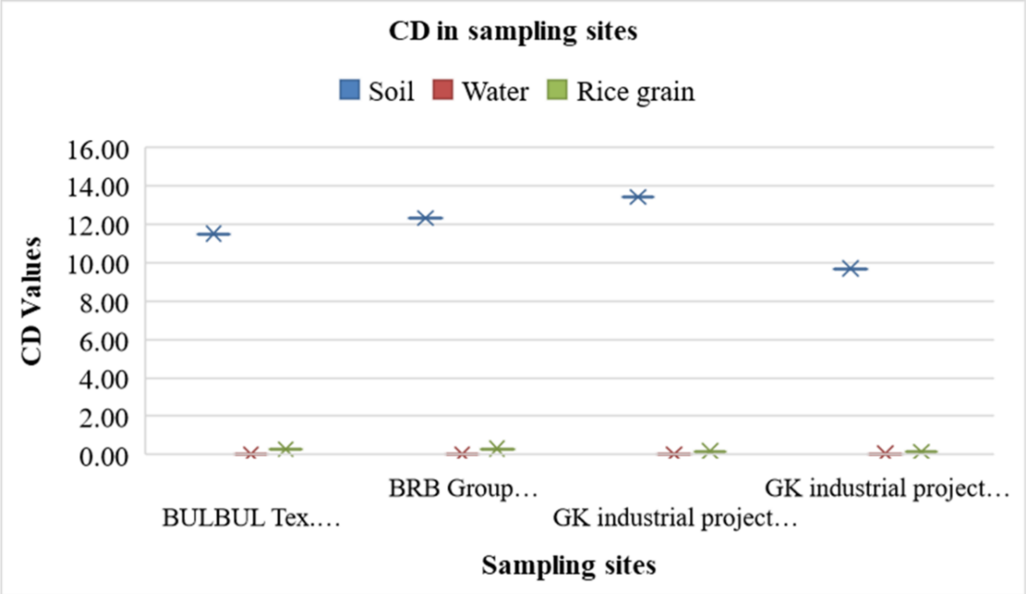

Figure 4. Contamination degree (CD) of heavy metals in water, soil and rice grain collected from different industrial areas in the Kushtia and Jhenaidah districts.

4.3.3 Pollution load index (PLI)

The Pollution Load Index (PLI) is an indicator used to measure the cumulative heavy metal amounts present in water, soil, and rice grain samples within a specified location. The method mentioned earlier has been performed by computing the geometric mean of the concentrations of all metals. The overall toxicity of the sample was evaluated by the PLI, which resulted from the combined effects of four toxic metals. PLI values varied significantly between soil and other samples collected from the research area (Figure 5). According to Figure 5, all of the collected soil samples were contaminated with metals (PLI greater than 1). On the other hand, the PLI values found in all water and rice grain samples were below 1, suggesting the absence of metal contamination in the aforementioned samples.

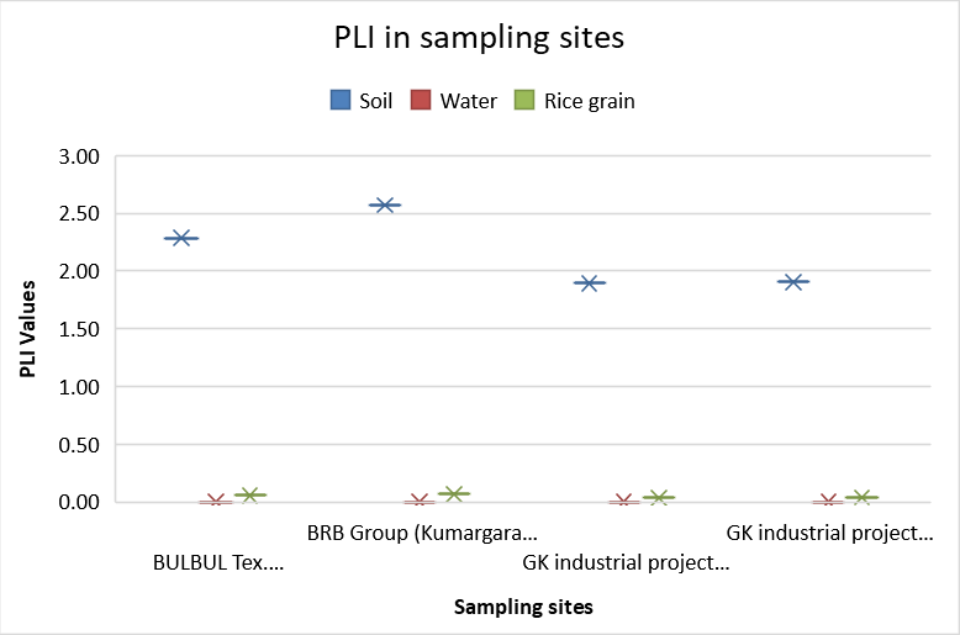

Figure 5. The pollution load index (PLI) of heavy metals in water, soil and rice grain collected from different industrial areas in the Kushtia and Jhenaidah districts.

CHAPTER V

SUMMARY AND CONCLUSION

In recent decades, the concentrations of heavy metals and metalloids in irrigation water, soil, and rice grain have been greatly increasing on farmland due to industrial activities. In the present study, we investigated the heavy metals contamination in soil, water and rice grain in the adjacent areas of the Kushtia and Jhenaidah districts and assess their environmental pollution. Water, soil and rice grain sample were collected from four different crop fields near the Bulbul Textile (Kumarkhali), BRB group (Kumargara), of Kushtia and GK industrial project (Garagonj, Jhenaidah) and GK industrial project (Katlagari, Jhenaidah) from Jhenaidah district. Rice grain.

In the case of the water study, the mean Pb,Cd,Cu and Cr concentration in water from all of the studied locations was lower than the FAO/WHO permissible limits (5 mg/kg) (Ayers and Westcot, 1985). This result indicates that the user of water as irrigation from all the studied locations would not contaminate the crop fields' soil and vegetation. In the case of soil samples, the mean Cu and Cr concentrations in soil in all of the studied locations were higher than the FAO/WHO permissible limits (FAO/WHO, 2011). This result indicates that soil accumulated higher levels of Cu and Cr and can contaminate the crops grown in that's field. In the case of the rice grain sample, the mean Pb and Cr concentration in rice grain from the studied locations were higher than the FAO/WHO permissible limits (FAO/WHO, 2011). These results indicate the rice grain form all of the studied locations accumulated higher levels of Pb and Cr from contaminated crop filed soil and water. Moreover, the cadmium level was below our analytical method detection level. In the present study, an assessment of environmental pollution was conducted through the calculation of the contamination factor (CF), contamination degree (CD), and pollution load index (PLI) based on the quantification of heavy metal concentrations in water, soil, and rice grain samples collected from the selected sampling locations. For contamination factor (CF), the soil in the crop field near the industrial areas of Kushtia and Jhenaidah districts has been significantly contaminated by Cu (3<CF<6), while the soil has been severely contaminated by Cr, with a contamination factor greater than 6. The results also indicate that the contamination factor (CF) values for Cu, Cr, Cd, and Pb in both water and rice grain samples were below 1, indicating low levels of contamination in crop fields near industrial areas of the Kushtia and Jhenaidah districts. Furthermore, the findings relate to the contamination degree (CD) indicate that while the water and rice grain samples obtained from different industrial areas in the Kushtia and Jhenaidah districts showed low levels of contamination, the field soil samples collected from the same industrial regions in these districts showed a moderate degree of contamination. The Pollution Load Index (PLI) was used as an indicator for quantifying the cumulative heavy metal levels in water, soil, and rice grain samples collected from specific sites nearby to the industrial regions of the Kushtia and Jhenaidah districts. The results indicate that the soil samples collected were contaminated with metals, as showed by a PLI greater than 1. However, the PLI values observed in the water and rice grain samples were below 1, indicating the absence of metal contamination.

CHAPTER VI

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