DETERMINATION OF HEAVY METALS OF WATER, SOIL AND RICE GRAIN IN THE ADJACENT AREAS OF TANNERY AND TEXTILE MILLS AT SAVAR AND NARAYANGANJ

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CERTIFICATE

This is to certify that the thesis entitled " **DETERMINATION OF HEAVY METALS OF WATER, SOIL AND RICE GRAIN IN THE ADJACENT AREAS OF TANNERY AND TEXTILE MILLS AT SAVAR AND NARAYANGANJ**" 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 **RUHUL AMIN,** Registration No. **15-06544** 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.

June, 2022
Dhaka, Bangladesh

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Dedicated to

MY BELOVED PARENTS

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ABSTRACT

In the present study, we investigated the heavy metals contamination in soil, water and crops in the adjacent areas of the Savar tannery and Narayanganj industrial area. The Pb concentration (0.16–0.32 mg/kg Savar, 0.6– 0.21 mg/kg in Narayanganj) in water from all the studied locations was lower than the permissible limit while Cd concentration (0.10– 0.15 mg/kg in Savar and 0.04 – 0.05 mg/kg in Narayanganj), Cr concentration (3.71 – 8.05 mg/kg in Savar and 1.27 – 1.93 mg/kg in Narayanganj) and the Cu concentration (0.17 – 0.49 mg/kg in Narayanganj) in water from all of the studied locations from Savar tannery and Naryanganj industrial area was higher than the permissible limits except the Cu concentration (0.04 – 0.08 mg/kg) in the sites of the Narayanganj area was lower than the maximum permissible limits. The Pb concentration (16.05–22.85 mg/kg in Savar and 21.95–28.4 mg/kg in Narayanganj) and Cu concentration (36.6 – 62.8 mg/kg in Savar and 25.6– 28.1 mg/kg in Narayanganj) in soil from all of the studied locations was lower than the permissible. On the other hand, the Cd concentration (4.13– 5.95 mg/kg) and Cr concentration (9049.95– 10115.9 mg/kg in Savar) in soil from all of the studied locations from Savar tannery study sites were much higher than the maximum permissible limits. The Cd concentration (0.91 mg/kg – 0.97 mg/kg) and Cr concentration (29.8– 32.05 mg/kg) in soil from the study sites in Narayanganj Industrial was lower than the permissible limits. The Pb concentration (8.42–9.2 mg/kg in Savar and 11.33– 12.88 mg/kg in Narayanganj), Cd (0.51–0.52 mg/kg in Savar and 0.41– 0.43 mg/kg in Narayanganj) and Cr concentration (42 –46 mg/kg in Savar and 37 – 41 mg/kg in Narayanganj) in rice grain from all of the studied locations was much higher than the permissible limits However, the Cu concentration of Savar and Narayanganj 18.8– 19.1 mg/kg and 17.8– 18.7 mg/kg respectively in rice grain from all of the studied locations was lower than the permissible limits (40 mg/kg). The trend of Transfer factor (TF) for heavy metals in studied rice grain samples from all of the studied locations was in order: Cr>Cu>Pb>Cd. In case of the sum of soil pollution index (SPI), the lowest SPI (1.38) in soil was found in the SP washing Ltd. samples and the highest SPI (72.31) was found in the Techplan leather samples. The lowest SPI (0.05) in water samples was found in the IsRA Knitting Ltd samples and the highest SPI (0.18) was found in the A.S Leather Export Ltd. samples. The lowest SPI (110.68) in rice grain was found in Yousuf Leather Co. samples and the highest SPI (153.35) was found in the Waseq textile mills Ltd. smaples. In the case of Metal pollution index, the lowest Metal pollution index (MPI) (24.2 mg/kg) in soil was found in the SP washing Ltd of Narayanganj samples and the highest MPI (42.8 mg/kg) was found in the Fthaf Leather of Savar tannery. The lowest MPI (0.06 mg/kg) in water samples was found in the Waseq textile mills Ltd samples and the highest MPI (0.33 mg/kg) was found in the Aboni leather samples. The lowest MPI (11.13 mg/kg) in rice grain was found in the Tanjin Leather Goods Ltd in and the highest MPI (13 mg/kg) was found in the Yousuf Leather Co. samples. Proper management plan should be taken to control the heavy metal concentration in the studied location of Savar and Narayaganj district.

Keywords: Heavy metals, metal pollution, the sum of pollution index.

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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
Cfi	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
IGeo	Geo accumulation Index
HCL	Hydrochloric Acid

CHAPTER I
INTRODUCTION

Heavy metal contamination in soil, water, and plants is one of the most serious problems in the globe, particularly in Bangladesh. Soil pollution is far more likely to result from it. The issues of the impact of the metal that are being brought about by large-scale industrialization and growing urbanization have become a severe concern for the next generation. One of the major problems is heavy metal pollution since these substances may build in the biota and are hazardous. Over three-fourths of the cities in Asia, Africa, and South America regularly use industrial or municipal wastewater irrigation as an example (Gupta et al., 2008). High amounts of Ni, Pb, and Cd have been found in vegetables after investigations on the buildup of heavy metals from vegetables cultivated close to industrial facilities (Gupta et al., 2022). Metals that exhibit toxicity and a harmful impact at low concentrations and are particularly dense are referred to as "heavy metals" (Lenntech Water Treatment and Air Purification 2004).

The phrase "heavy metals," which refers to a set of metals and metalloids with atomic absorption densities larger than 4 g/cm3 or five times or more, greater than water, is typically used collectively (Huton and Symon, 2005; Hawkes, 1997). In general, heavy metals are referred to as trace inorganic elements, microelements, micronutrients, and minor elements. There are currently 38 elements classified as heavy metals, but most industries emit more than thirteen of these substances (Rizwana, 2016). Examples of these substances include copper (Co), iron (Fe), mercury (Hg), molybdenum (Mo), cadmium (Cd), chromium (Cr), cobalt (Co), nickel (Ni), lead (Pb), arsenic (As), tin (Sn), and zinc (Zn). In addition, it should be noted that most heavy metals have little impact on human health. Nevertheless, it has not been demonstrated that lead (Pb), arsenic (As), mercury (Hg), or cadmium (Cd) are necessary for either plants or animals. Due to their capacity to attach to both organic and inorganic colloids, heavy metals are a topic to arise. Pesticides, fossil fuels, fertilizers, manure, municipal wastes, industrial discharge, sewage-sludge, mining wastes, animal wastes, polluted water, etc. are a few examples of the causes of heavy metal pollution in both soil and water (Arora et al., 2008). These released materials ultimately sink into the earth.

According to research by Kabata-Pendias and Pendias (1992), soil serves as the final destination or sink for all trace and elemental elements. The residence period for Cd in soil was predicted to be between 75 and 380 years, whereas the residence time for more highly bound elements like As, Cu, Ni, Pb, and Zn was predicted to be between 1500 and 3000 years

(Butt, 2005). There has been evidence recently in the vicinity of the Dhaka metropolis that vegetable farming is outpacing cereal cultivation in terms of population growth. As there is a severe dearth of clean water throughout the rabi season and for the majority of the year, extensive use of waste water in crops is more typical in these areas. As a result, there may be several opportunities for heavy meats to enter the human food chain.

Wastes are one of the subjects that get the most attention these days. One of the things referred to as the most urgent issues is industrial waste. Industrial wastes are the primary source of effluence in all ecosystems, necessitating on-site treatment prior to placement in sewage systems (Imongor et al., 2005). The discharge of effluents from quickly growing enterprises is putting great pressure on the environment of land and water. In Bangladesh, industrialization is accelerating quickly, which is causing an incremental rise in industrial trash. These goods pollute the environment by contaminating the land, the air, and the water.

It is seriously threatened by an agricultural nation like Bangladesh, which has a mass pollution rate of more than 1077 (BBS, UNICEF 2019). textile, sugar, fertilizer, and pharmaceutical products. Bangladesh's one of the primary industries are leather. Regrettably, these industries' raw materials and production processes are harming the environment. Bangladesh is a third-world developing nation that is in a precarious position. Bangladesh has over 30,000 industrial units, of which roughly 24,000 were small and cottage industries (Nuruzzaman 2012). Since 1981, production has climbed by 46%. Also, during the past ten to fifteen years, a group of items related to tanning, industrial chemicals, medicines, and clothing has seen an increase of 200 to 4000 percent (DoE, 2008). There are around 1200 enterprises that pollute heavily and lack waste treatment facilities (DoE, 2008).

These industries' effluents are discharged either to the ground or to rivers (Khan, 2003). As the world's environment pollutes quickly, so are the causes. That is now a significant concern. A few instances, such as weak logistical assistance, fast industrialization, inadequate waste treatment, inequality monitoring, and unplanned urbanization, significantly changed the situation. the harm to health and welfare posed by these industrial pollutants has made the environment unfriendly in recent years (The Daily Star, 2016). Throughout much of the globe, the quantity of different pollutants in the air, water, and soil has significantly grown. Industrial and urban sewage that is discharged finds its own way to water bodies and the soil surface through surface run-off and rivers. Water features including lagoons, ponds, and lakes are attracting pollutants and growing more susceptible as a result. The wastewater contributes significantly to the soil's accumulation of heavy metals. When plants quickly absorb the effluents, all of these factors are posing serious health risks. The primary consumers of the crops that are absorbing the metals from these effluents are humans and livestock. Heavy metal poisoning of soil and water is becoming a major worry for the entire planet. So, Plants need metals like Mn, Zn, Fe, Cu, and Mo, yet other metals, such as Cd, Hg, Pb, and As, appear to be poisonous to plants and animals, while Ni, Cr, and Sr are toxic to mammals (Hayes and Green, 2008).

Bangladesh's two main resources are said to be soil and water. In places where factories are growing in fungal - birth, quick and uncontrolled urbanization is leading to a larger degree of soil and water pollution. Both number and quality must be considered while evaluating the resources. Soil and water quality evaluation becomes a serious problem when agricultural cultivation is involved. In industrial effluents and waste disposal, heavy metals as Cu, Cr, As, Cd, Fe, Hg, Mn, Ni, Pb, and Zn are abundant (Arora et al., 2008). This progressive buildup of metals puts plants, animals, and human health at risk by increasing their toxicity (Rizwana, 2016).

In Bangladesh, the majority of industrial effluents are used to irrigate crops. It includes certain beneficial nutrients, but it also has some other plant-harmful elements. Particularly they are lowering regular exercise. Quick uptake of heavy metals in plants is to blame for the efficiency reduction in nutrient absorption (Rahman and Hasegawa, 2011). Heavy metals have the ability to sink into the soil, which aids in accumulation at a faster rate or long-term ascent of some other criminal. Moreover, industrial solid waste, municipal pollutants, fertilizers, sewage sledges, etc. can contaminate agricultural land. The overall concentration of heavy metals in living tissue is typically minimal, and it must be kept within a range that allows for optimal biological function. Avoiding the use of this water and applying manure, which can boost the overall absorption capacity of plant nutrients, are the only means or the simplest ways to improve production and crop quality (Rizwana, 2016). Bangladesh has a small land area and is densely inhabited. In the meantime, 60 to 80 percent of people are directly and indirectly dependent on agriculture. Bangladesh has to provide for this enormous population using this constrained of resources. Consequently, even a little decrease in output might result in a significant shift in the national index. Also, the country's health support is insufficient. Bangladesh must thus proceed cautiously. A significant shift in the National index is being aided by a little increase in health risks. It is desirable to increase agricultural yield, and doing so can be done by using the land we now have intensively. The unplanned and enlarged industries cause severe harm to agricultural fields and water bodies. The majority of these industrial pollutants are claimed to be released in low-lying regions as a result of industrial operations, which reduce agricultural yield, food quality, and soil quality. It's time to assess these industrial wastes' toxicity levels and fertilizer potential.

Important industrial areas in Savar Upazila include Ashulia, Savar, Aminbazar, and Dhamsona. In these parts of Saver, which are bordered by the rivers Turag and Buriganga, as well as by the river Dhawleshari, there are businesses in the textile, pharmaceutical, tannery, dyeing, food, and beverage industries. Additionally, there are vast tracts of agricultural land here that are intensively farmed using polluted water as irrigation.

On the other hand, the Narayanganj district has several industrial areas. Those locations have textile, steel, cement, and dyeing businesses. These regions contain a sizable quantity of agricultural acres that are also irrigated with very contaminated water. The impact of waste, which resulted in lower rice output, decreased production of animals, and decreased fish culture, has seriously affected productivity during the past few years.

It is important to understand that the heavy metal contamination in soil, water and crops in the industrial area for the proper management plan. However, very few works were conducted on the heavy metal concentration on water, soil and rice in the industrial area (Laboni et al., 2023; Kabir et al., 2022; Afrin et al., 2021, Proshad et al., 2018; Mottalib et al., 2016; Sarkar et al. 2015). So, we were conducted a study to determine the heavy metal concentration on some area of the tannery and textile mills at Savar and Narayanganj districts. Therefore, present study aims to achieve the following objectives:

- To determine the different heavy metals such as Cr, Cd, Pb, and Cu content in water, soil and rice samples and
- To interpret the results from the level of contamination.

CHAPTER II

REVIEW OF LITERATURE

Akter *et al.* (2019) collected samples from two different steel industries of Narayanganj District, Bangladesh. Elements to be found in the studied samples are: K, Ca, Cr, Mn, Fe, Co, Ni, Cu and Pd. Heavy metal with higher concentration was found in the study area and the concentration of heavy metal decreases with depth. The main objective of the research work is to explore and identify heavy elements presence in soil samples affected by the industrial area for human health.

Baghaie and Fereydoni (2019) conducted a study to assess the heavy metals including lead (Pb), cadmium (Cd), and arsenic (As) in crop plants. Result showed that, the highest and lowest Pb daily intake and Pb risk index was related to the consumption of cabbage and basil, respectively. And the highest daily intake of Cd and As was related to lettuce consumption, while the lowest daily intake of these metals was related to the consumption of coriander. Among the studied heavy metals, As had the highest hazard quotient (HQ) for non-carcinogenic diseases. The highest HQ belonged to As through lettuce consumption and the lowest one belonged to As through coriander consumption (58 g/day). The HQ for female was higher than that for male. According to the results, the total hazard quotient (THQ) of non-carcinogenic diseases from the total studied vegetables was above the standard level. On the other hand, the HQ for female was higher than that for male.

Hasan *et al.* (2019) investigated a study focused on evaluating the hazard arising from exposure to metals due to industrial contamination. Tissue samples of hair and nails were collected from both the Leather industry workers and residents in the vicinity of the industries. Using chromium as an indicator of contamination/exposure from the Leather industry, it was the most significant metal contaminant for industry workers ranging from 21.85 to 483 $mgkg^{-1}$ and for industry-neighboring residents at 6.01 to 296.16 $mgkg^{-1}$. Both the workers and neighboring residents were found to be excessively exposed ($P < 0.05$) to chromium compared with the investigated control group of people living in a distant village area which had no industrial establishments.

Li *et al.* (2019) expressed that soil heavy metal pollution has become a worldwide environmental issue that has attracted considerable public attention, largely from the increasing concern for the security of agricultural products. These elements enter the soil agro-ecosystem through natural processes derived from parent materials, and through anthropogenic activities. Heavy metal pollution poses a great threat to the health and well-being of organisms and human beings due to potential accumulation risk through the food chain. Remediation using chemical, physical, and biological methods has been adopted to solve the problem. Phytoremediation has proven to be a promising alternative to conventional approaches as it is cost effective, environmentally friendly, and aesthetically pleasing. To date, based on the natural ability of extraction, approximately 500 taxa have been identified as hyperaccumulators of one or more metals. In addition, further research integrating biotechnological approaches with comprehensive multidisciplinary research is needed to improve plant tolerance and reduce the accumulation of toxic metals in soils.

Proshad *et al.* (2019) conducted research to assess the ecological and health risk of heavy metals (Cr, Ni, Cu, As, Cd and Pb) from agricultural soils in the industrial areas of Tangail district, Bangladesh. The mean concentrations of Cr, Ni, Cu, As, Cd andPb in different soil sampling sites were found 6.73, 29.74, 24.69, 4.79, 2.50 and 19.90 $mgkg^{-1}$, respectively. The mean concentration of the studied heavy metals was found underneath as far as possible set by the Dutch standard, Canadian guidelines and Australian guidelines with the exception of Cd. The geo-accumulation index, contamination factor and toxic unit analysis were discovered low contamination for all metals with the exception of Cd. Potential ecological risk (PER) of soils from all sampling sites showed low to very high risk.

Uddin *et al.* (2019) conducted a study is to establish a database about the contamination status of heavy metals in popular vegetables and their growing soil in Satkhira, Bangladesh; to assess the associated health risks of consumers through target health quotient (THQ) and target cancer risk (TCR) analyses. The average concentration of Mn, Fe, Cu, Zn, Cd and Pb is 33.91, 356.71, 10.27, 33.59, 0.57 and 9.76 mg kg^{-1} in vegetables and 239.34, 3399.38, 22.48, 65.63, 0.68, 11.53 mg kg^{-1} in growing soil. The concentration of heavy metals has been compared with the standard value recommended by WHO/FAO and it is found that the average concentrations of Fe, Pb, and Cd in the leafy, fruit and root vegetables exceeded the permissible limit. Moreover, the value of THQ, non-carcinogenic parameter, is greater than 1.0 for Fe and Pb in leafy, fruits and root vegetables.

Hossain *et al.* (2018) conducted an experiment to assess the impact of solid waste disposal on surrounding environment of Matuail landfill site of Dhaka city. The Cu, Zn and Pb concentrations were high in the dumping (360 μgg^{-1} Cu, 806 μgg^{-1} Zn and 382 μgg^{-1} Pb) and abandoned (199 μgg^{-1} Cu, 452 μgg^{-1} Zn and 519 μgg^{-1} Pb) areas that exceeded the permissible limits. The concentrations of DO, BOD, COD and TDS of the untreated leachate were found 1.34 mgL^{-1}, 96 mgL^{-1}, 1343 mg L^{-1} and 7120 mgL^{-1} respectively that exceeded inland surface water standard but after treatment theconcentrations of DO, BOD and TDS in the treated leachate pond were found within the permissible limit. The presence of heavy metal in leachate is not contaminated asit is below the toxic limit. The bioaccumulation of fish from treated pond is extremely high of Fe, Mn, Pb and Ni that exceeded the WHOs permissible limit.

Islam *et al.* (2017) investigated heavy metals in the industrial sludges were to assess ecological risk using inductively coupled plasma mass spectrometer (ICP-MS). The ranges of Cr, Ni, Cu, As, Cd, and Pb in the samples were 1.4–9469.7, 4.8993.8, 12.8– 444.4, 2.2–223.8, 1.9–46.0 and 1.3–87.0 mg kg^{-1}, respectively. As a whole, the average concentrations of heavy metals were in the decreasing order: Cr > Ni > Cu > As > Pb > Cd. The contamination factor (Cfi) of Cd ranged from 11.2 to 28.9 mg/kg reveal the examined sludges were strongly impacted by Cd. The Cfi value demonstrated that sludges from the tannery, dye, metal processing and battery manufacturing industries were moderate to very high contamination by Cr, Ni, Cu and As.

Mottalib *et al.* (2016) conducted an experiment and found that out of eight metals examined in tannery effluent contaminated soil in Dhaka Leather industrial area, concentration of heavy metals ($mgkg^{-1}$) were found ranged from 994-1120 for Cr; 34.35-39.66 for Cu; 46.70-55.16 for Pb; 24.10-26.73 for Ni; 0.32-0.54 for Cd; 1.49- 2.21 for As; 0.44-1.10 for Sb and 20812-21216 for Fe.

Suryawansh *et al.* (2016) studied the concentration levels and sources of heavy metals contamination in road dust samples collected from various locations including four different activity areas: industrial, highways, residential and mixed use in Delhi, India. Metal content in road dust was analyzed by inductively coupled plasma atomic emission spectroscopy. The results showed high concentration levels of Ni, Cr and Pb in industrial areas. Contamination factor analysis showed that road dust samples are significantly contaminated by Zn and Pb. The potential ecological indices indicated high contamination of Cd and moderate contamination of Pb in road dust, but low contamination of Cr, Cu, Ni and Zn. The pollution index of most of the metals was higher than 1, indicating deterioration of road dust quality of Delhi city due toanthropogenic emissions.

Nuruzzaman (2012) observed that concentration of N (2.7%) below 120 cm in tannery waste.

Karim *et al.* (2014) collected samples from two open dumping sites at Matuail, Dhaka and Khulna and analyzed for total heavy metals content (Cd, Co, Cr, Cu, Mn, Ni, Pb and Zn) and also heavy metal fraction (water extractable, exchangeable and bio- fraction). The results of the analysis showed that the total metals content in municipal solid waste at the Matuail dumping site is higher than Khulna dumping site and the metals are predominantly associated with fine soil fraction. The total heavy metals content in municipial solid waste in the study sites were less than the total metals content in municipial solid waste at the dumping sites reported from Japan, India and Thailand. The study results showed that both sites contain high bio-available fraction of metals, which may easily be entered into a food chain and may cause health hazards.

Rakib *et al.* (2014) carried out an experiment to assess the heavy metals in Dhaka Metropolitan city. He 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.

Naser *et al.* (2012) investigated that, the heavy metal contents at the same distance from the road was 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) carried out a survey for the assessment of heavy metal contamination. He found that 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 mgkg^{-1}, respectively. While average concentration of Fe, As, Mn, Cu, Zn, Cr, Pb, Hg, Ni and Cd in the wet season was17,103,2,326.2, 305, 90, 194, 34.2, 23.83, 133.2, 5.5 and 1.04 mgkg^{-1}, respectively.

Das *et al.* (2011) examined that Zn concentration in tannery effluents was lower than in textile effluents while in adjacent river water is varied both seasonally and specially.

Mondol *et al.* (2011) conducted an experiment on Tejgaon industrial area is located within the Dhaka City Corporation and is about 5 km north of the city center. Heavy metal concentration at different sampling points varied in different seasons and the maximum amount was observed in the dry season (January). Total Fe, Pb, Cd, Mn, Ni, Zn, Cu and Cr concentrations in water samples during dry season ranged from 0.11-2.78, 0.733-2.171, 0.05-0.1, 0.019-0.34, 0.02-0.17, 0.01-0.348, 0.10-0.846, and 0.02-0.09 mg/l respectively. The present study revealed that the pollution level was very much alarming and increasing slowly day by day. According to WHO guidelines, during both wet and dry seasons 100% water samples were found in excess of tolerable level for Pb (0.01 mg/l). 63, 42, 79, 58 and 95% water samples were found in the group of excess of tolerable level during dry season for Cu, Ni, Cd, Cr and Mn. Only 26% of the plant samples had Ni (< 20 $mgkg^{-1}$) in the normal range and 74% (20-30 $mgkg^{-1}$) plant samples were found in the group of in excess of tolerable level" during dry season which was 63% (20-30 $mgkg^{-1}$) during wet season. Cadmium and Pb in plant samples found in the group of in excess of tolerable level" was 26, 79% (> 10 $mgkg^{-1}$), and 33, 59% (> 20 $mgkg^{-1}$) during wet and dry season, respectively. Plant samples accumulated more and tolerated higher amounts of Cr during dry season. Average concentration of Fe, Mn and Zn at different locations and plant species were 220.81, 279.33 and 239.81 $mgkg^{-1}$ and 212.0, 313.43 and 159.19 $mgkg^{-1}$ during wet and dry seasons, respectively.

Suruchi and Khanna (2011) stated that heavy metals such as cadmium, copper, lead, chromium and mercury are important environmental pollutants, particularly in areas with high anthropogenic pressure. Their presence in the atmosphere, soil and water, even in traces can cause serious problems to all organisms and heavy metal bio accumulation in the food chain especially can be dangerous to the human health. Heavy metals are very harmful because of their non-biodegradable nature, long biological half lives and their potential to accumulate in different body parts. Most of the heavy metals are extremely toxic because of their solubility in water even in low concentrations. Heavy metals are persistent environmental contaminants which may be deposited on the surfaces and then adsorbed into the tissues of vegetables. Plants take up heavy metals by absorbing them from deposits on the parts of the plants exposed to the air from polluted environment as well as from contaminated soil.

Ahmad *et al.* (2010) investigated the spatial and temporal distribution of heavy metals in water, sediment and fish (dry weight basis) of Buriganga River, Bangladesh by atomic absorption spectrophotometer. In water concentration of Pb, Cd, Ni, Cu and Cr varied seasonally and spatially from 58.17to 72.45µg/L, 7.08 to 12.33µg/L, 7.15 to 10.32µg/L, 107.38 to 201.29µg/L and 489.27 to 645.26µg/L, respectively. Cr was the most abundant in the water of Balughat during pre-monsoon, whereas, Cd was the most scarce in the water of

Shawaryghat during monsoon. The sediment also showed spatial and temporal variation of Pb, Cd, Ni, Cu and Cr ranged from 64.71 to 77.13 $mgkg^{-1}$, 2.36 to 4.25 $mgkg^{-1}$, 147.06 to 258.17 $mgkg^{-1}$, 21.75 to 32.54 $mgkg^{-1}$ and 118.63 to 218.39 $mgkg^{-1}$, respectively. Among all the metals studied in sediment, Ni was the highest at Foridabad during pre-monsoon and Cd was the lowest at Shawaryghat during monsoon. In six species of fish studied, the concentration of Pb, Cd, Ni, Cu and Cr varied seasonally from 8.03 to 13.52 $mgkg^{-1}$, 0.73 to 1.25 $mgkg^{-1}$, 8.25 to 11.21 $mgkg^{-1}$, 3.36 to 6.34 $mgkg^{-1}$ and 5.27 to 7.38 $mgkg^{-1}$, respectively. Of the five metals studied Pb concentration was the highest in *Gudusiachapra* during monsoon, in contrast, Cd concentration was the lowest in *Cirrhinusreba* during post-monsoon. Some of the heavy metal concentrations are higher than the recommended value, which suggest that the Buriganga is to a certain extent a heavy metal polluted river and the water, sediment and fish are not completely safe for health.

Mohuya *et al.* (2010) determined concentrations of cadmium (Cd), chromium (Cr), copper (Cu), nickel (Ni), and lead (Pb) in the pelagic water of Gulshan-BaridharaLake were. The samples were collected from ten different spots in summer (April, 2007) and monsoon (August, 2007) seasons. The concentrations of Cd, Cr, Cu, Ni and Pb in the lake water varied from 0.068-0.091, 0.048-0.225, 0-6.135, 0-0.062 and 0.023-0.067 mg/l during the summer season, respectively. Mean values of the samples collected from mid-points for Cd, Cr, Cu, Ni and Pb of ten stations in summer were 0.083, 0.100, 2.336, 0.074, and 0.046 mg/l respectively. In monsoon the concentration of above-mentioned heavy metals varied from 0.016-0.019 mg Cd/l, 0.005-0.035 mg Cr/l, 0.002-0.018 mg Cu/l, 0.007-0.159 mg Ni/l and 0.052-0.151 mg Pb/l. Mean values of these heavy metals in monsoon were 0.018, 0.018, 0.011, 0.037 and 0.093, mg/l, respectively. The depletion factor was less than unity for Pb and exceptionally high for Cu. Finally, the study revealed that among the heavy metals only Pb concentration exceeded the standard level during the monsoon, otherwise concentrations of all other four heavy metals (viz. Cd, Cr, Cu and Ni) exceeded the standard level of drinking, fishing and surface water as set up by WHO, GOB, USEPA, DOE and FWPCA, for the summer period.

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.

Ahmad and Goni (2009) estimated concentrations of Cu, Zn, Pb, Cr, Cd, Fe, and Ni have been in soils and vegetables grown in and around an industrial area of Bangladesh. The order of metal contents was found to be Fe > Cu > Zn > Cr > Pb > Ni > Cd in contaminated irrigation water, and a similar pattern Fe > Zn > Ni > Cr >Pb > Cu > Cd was also observed in arable soils. Metal levels observed in different sources were compared with WHO, SEPA, and established permissible levels reported by different authors. Mean concentration of Cu, Fe, and Cd in irrigation water and Cd content in soil were much above the recommended level. Accumulation of the heavy metals in vegetables studied was lower than the recommended maximum tolerable levels proposed by the Joint FAO/WHO Expert Committee on Food Additives (1999), with the exception of Cd which exhibited elevated content. Uptake and translocation pattern of metal from soil to edible parts of vegetables were quite distinguished for almost all the elements examined.

Elahi (2008) stated that Municipal waste water usually high in concentration of several metals like as, Ni, Pb Cr and Cd. Their unlikely use in Agricultural and land for irrigation may lead to result in accumulation in the surface soil (Gupta *et al.*, 2008).

Adriano (2006) reported in his study that, heavy metals usually have two main ways to enter into the agro ecosystem via- non-aerial and aerial, Aerials includes aerosols, suspended matters, Air borne Dusts and Non-aerial comprise pesticides, fertilizers, industrial waste and effluents and other soil amendments.

Havorak *et al.* (2006) explored the Pb/Zn smelter for heavy metal contamination and observed that area of Arnoldestion soil (Karnnten, Austria) were heavily metal polluted by the lead and Zinc smelting while plant took Pb in low amount. Plant toxicity by Zn was in normal range and for animal feedings, Cadmium exited the threshold level.

Islam *et al.* (2004) studied that 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) collected 19 soil samples from Bhaluka region of Mymensingh. They investigated that the detected heavy metal ranges in soil were As 3.90-25.50 ppm, Cr 80-117 ppm, Cu 1.20-49 ppm, Mo 2.00-2.2 ppm, Ni 44-76 ppm, Pb 12-34 ppm, Sr 31.0-120.0 ppm, Th 12.0-26 ppm, U 1.60-5.8 ppm, V 134-273 ppm, Y 33-54 ppm, Zn 35-129 ppm and Zr 130-370 ppm.

Bibi *et al.* (2003) found that the detected heavy metal ranges in soil of different depth 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 practice 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 sun shine soil, predominant vegetation, nearby roads, urban centers and 6 mines in Huelva, Spain. They found that average Pb and Cd contents in soil were 2.90 and 0.19 $mgkg^{-1}$, respectively. There was no such significant variation in heavy metal contents between samples.

Elik (2003) analyzed the street dust samples of Sivas city, Yurkey analyzed that the mean concentration of Pb, Zn, Cu and Cd in soil were 197.0, 206.0, 68.0, 84.0 and 2.60 $\mu gg^{-1,}$ respectively.

Hoque (2003) carried out an experiment for the determination of the status of As and other heavy metals and vegetables of five intensively growing areas of Chapainawabganj, he investigated that the mean concentration of Pb, Cd, Fe and Mn in soils were 16.2, 0.26, 4030 and 62.72 μgg^{-1}, respectively.

Huy *et al.* (2003) reported that from untreated water of sewage used in irrigation was one of the major causes of increasing crops and soil metals and shorter periods of sewage water in irrigation go high of individual metals in soils by 2-80% and increased metals in crops by 14-209%.

Khian *et al.* (2003) reported that the tannery not only causing the availability of Cr but also the metals like- Cd, As, Cu, Pb and Zn, in a great extent. The investigation found that in the top soil the factory that uses wastes, are high exposed to the metals.

Jahiruddin *et al*. (2002) investigated that soils of Gangetic alluvium contain more As than that of Brahmaputra alluvium and the former soils had more than 20 $mgkg^{-1}$As, whereas the later soils had As level below 20 $mgkg^{-1}$ which was below maximum acceptable limit for agricultural soils. They also found that the mean concentration ($mgkg^{-1}$) 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).

Dolly and Ford (2001) stated that the greatest common sources of urban environment area from atmospheric testimony of lead ensuing from the blister of lead petrol, Removal of Pb successions and dye of makeover work. The flashing and washer's used corrugated iron roots, metallic wheel, past practices of waste are the least common sources.

Sattar and Blume (2000) carried out an experiment 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 mgkg-1), Cd (0.69–1.00 mgkg-1), Cr (42–74 mgkg-1) and Mn (26–716 mgkg-1).

Sultana (2000) investigated isotope-aided studies on the effects of radiation processed sewage sludge application on crop yields and bio availability of heavy metal content of BAU soil. BAU soil contains 0.25, 14.0, 21.0 and 19.0 mgkg-1 aqua regia extracted heavy metal for Cd, Pb, Cu and Zn, respective.

Kashem and Singh (1999) conducted a study to investigate the heavy metal contamination of soil and vegetation in the vicinity of industries around Dhaka city in Bangladesh. Categorically soils, grass (*Cynodendoctylon* L), water hyacinth (*Eichhorniacrassipes* L), rice (*Oryza sativa* L), and arum (*Alocasia esculenta* L) were collected from tannery, ceramic, textile, dying and sulphuric acid producing industrialsites. The concentrations of total Cd, Cu, Mn, Ni, Pb and Zn ranged from 0.1–1.8, 28– 217, 106–577, 25–112, 17–99 and 53–477 $mgkg^{-1}$ soil, respectively among the industrial sites. The concentrations of some heavy metals ranged from background levels to levels in excess of tolerable limits in agricultural soils. The concentrations of total Cu, Mn, Ni, Pb and Zn decreased with increasing distance from the disposal points of the tannery and the textile dying industries. Cd, Cu, Mn, Ni, Pb and Zn showed highly significant ($p < 0.01$) positive correlations with their total and DTPA-extractable contents in soils. The concentrations of most heavy metals were also higher in the vegetation samples of tannery area and the content of Pb (13–45 $mgkg^{-1}$) in grass samples exceeded the toxic limit. In correlation matrix, plant concentrations of Cu, Mn, Pb and Zn were significantly correlated with their total and extractable contents in soils.

Sattar and Bhume (1999) reported that the total Pb concentrations of road dusts at city areas varied from 57.70 - 212 $mgkg^{-1}$, but from rural areas 6.20 – 17.10 $mgkg^{-1}$, low Pb was observed from rural area.

Marshall (1998) conducted a survey to the heavy metal pollution of roadside soils in Bangladesh. Accumulation of Pb, Ni, Cr, Cu and Zn in roadside soils along Dhaka-Mymensingh highway, possibly due to the heavy traffic of vehicles. On the other hand, sporadic high Zn accumulation was noticed in soils along Dhaka-Aricha, Dhaka-Chittagong and Dhaka-Mymensingh highways, which was ascribed to theindustrial discharge.

El-Hassanin *et al.* (1993) conducted a study investigated the extent of pollution introduced by Pb, Cd, Zn and B to the sandy soils of Abu Rawash and El-Gabal El-Asfar areas, Egypt, which have been irrigated with sewage water for up to 67 yr. Results revealed that prolonging the periods of irrigation was associated with significant increases in the total and available forms of Pb, Cd, Zn and B. These elements tended to accumulate in the surface layers, with the exception of B which increased at lower depths. The relative percentage of the available to total element forms reflected the low solubility and availability of both Pb and B compared with Cd and Zn. However, in all cases, the concentrations of these elements have not accumulated to toxic levels after 67 yr of sewage irrigation. Nevertheless, care and good management should be considered in the future with continuous use of sewage water for irrigation.

Thomas *et al.* (1992) stated that- Chromium is much immobile in soil the form that is highly added with the tannery is trivalent chromium. Sludge compost and vermi-compost that is affected by tannery on qualitative and quantitative composition of soil organic substance. In many countries, many of them uses the factory effluents and wastes as manure in soil, but it in turns add the metals to the soil.

From the above literature, we can understand that rice, vegetables and soils are contaminated by heavy metal in most of the industrial areas.

CHAPTER III
MATERIALS AND METHODS

This study was conducted from July to August 2022 to determine the status of heavy metals in some industrialized areas of the Savar and Narayanganj districts. The fine points of materials and methods for the study are presented in this chapter.

3.1 Sample collection

3.1.1 Water sampling and processing

Water samples were collected from seven sites viz., Aboni leather, 100 m from Aboni leather, A.S Leather export Ltd., Prince leather, Crust & Finished leather, Ruma leather, Ibrahim Leatherof Savar tannery area and five sites from Narayanganj district, viz., IsRA knitting Ltd, SP washing Ltd., Waseq textile mills Ltd., Onus garments Ltd., Multitex Knit com (Figure 1). Water from boreholes was pumped for 2 minutes before obtaining a 500 ml sample for analysis. Water from the dams was sampled 10-15 cm below the water surface using labelled acid-washed plastic containers to avoid unpredictable changes in characteristics as per standard procedures (Reza and Singh, 2010).

The water was labelled according to the source from which it was obtained and also the region from which it was obtained. The water was acidified (pH < 2.0) with analytical-grade of nitric acid in order to preserve metals and avoid precipitation. The water samples were stored at a 5ºC temperature awaiting the transportation to the laboratory for analysis.

3.1.2 Soil sampling

Soil sample were collected from seven sites of Savar tannery viz., Fthaf leather, Yousuf Leatherco., Techplan leather, Rose leather, Tanjin Leather Goods ltd, Venice Leather Goods Ltd., Mukta tennary ltd and five sites of Narayanganj industrial area viz., IsRA knitting Ltd, SP washing Ltd., Waseq textile mills Ltd., Onus garments Ltd. and Multitex Knit com (Figure 1). At each sampling point, approximately 0.5 kg of soil was collected 0-15 cm in depth using a stainless-steel sampler. Soil samples along the roads were collected at a distance of one meter away from the road and within an area of one square meter. Three samples were collected from each point, thoroughly mixed in a clean plastic container to obtain a representative sample dried, crushed and sieved with 2 mm mesh before being stored in labeled polythene bags prior to the analysis.

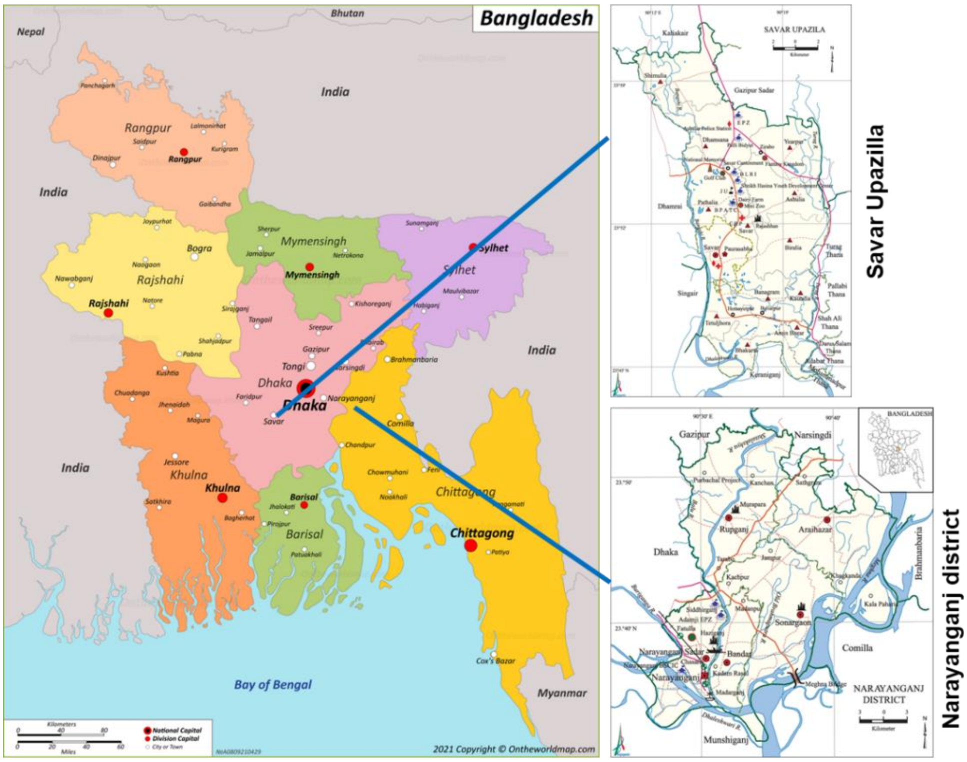

Figure 1. Map showing the sampling area of the present study.

3.1.3 Rice grain sampling

Rice grain samples were collected from four different locations in the adjacent areas of Yousuf Leatherco. and Tanjin LeatherGoods ltd. from Savar tannery area and Waseq textile mills Ltd. and Multitex Knitcom from Narayanganj industrial area (Figure 1). 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.

3.2 Sample digestion

3.2.1 Water digestion

The water sample bottles were shaken thoroughly in their plastic containers by use of hand. A volume of 100 ml of the sample was measured using a 100 ml volumetric flask and put in a conical flask and 5 ml of concentrated nitric acid was then added. The mixture was heated slowly on a hot plate and evaporated to about 20 ml ensuring that the water did not boil. A further 5 ml of concentrated nitric acid was added and the beaker was covered with a watch glass while heating continued. Nitric acid continued to be added until the solution appeared light-coloured and clear. Lastly, 2 ml of concentrated hydrochloric acid was added and heated slightly to dissolve any remaining residue. Few drops of hydrogen peroxide were then added to ensure complete digestion had taken place. The solution was filtered and the filtrate was transferred to a 100 ml volumetric flask to cool and the filtrate was made up to the mark with distilled water (Radojovenic and Bashkin, 2006).

3.2.2 Soil digestion

Well-mixed samples of 1 g each were weighed using a Scientech Zeta series electronic balance (manufactured in the year 2000). The samples were put into a 250 ml digestion chamber and digested with 24 ml of aqua regia and then evaporated to near dryness. Then it was kept. The soil samples were then dissolved in 10 ml of 2% nitric acid, filtered and then diluted to 100 ml with distilled water (Begum *et al*., 2009).

3.2.3 Rice grain digestion

A sub-sample weighing 0.5 g was transferred into a dry clean digestion vessel. Then 5 ml of Nitric acid added to the sample and was allowed for standing overnight under fume hood. On the following day, the vessels were placed on a heating block and heated at a temperature slowly raised to 120° C for two hours. After cooling, 2 ml of hydrogen per oxide was added into it and kept for few minutes. Again, the vessel was heated at 120°C. Heating was momentarily stopped when the dense white fumes occurred, after which the volume was reduced to 3-4 ml. The digest was cooled, diluted to 50 ml with deionized water and filtered through Whatman No. 42 filter paper into plastic bottle.

3.3. Instrument

Analytik Jena's novAA 400P Atomic Absorption Spectrophotometer was used to determine the total content of copper, chromium, lead, and cadmium in the vegetable and soil digest (Analytik Jena's novAA 400P, 2012, country of origin: Germany). The hollow cathode lamps in AAS were used for estimations in a wide range of situations, depending on the element that was being analyzed. The concentration of heavy metals was reported in parts per million (mg/kg). Table 1 shows the detailed instrumental conditions for determining copper, chromium, lead, and cadmium.

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

Element	Cu	Cr	Pb	Cd
Wavelength (nm)	324.8	357.9	217.0	228.9
Slit (nm)	1.2	0.2	1.2	0.7
Lamp	HCL	HCL	HCL	HCL
Lamp current (mA)	2	4	2	2
Flame	Air-Ac	Air-Ac	Air-Ac	Air-Ac
Burner Head (mm)	100	100	100	100
Burner height (mm)	6	8	6	6
Read time (seconds)	3	3	3	3

3.4. Determination of total Cd, Pb, Cr and Cu

Total Lead concentration was determined from the digest by Analytic Jena's novel 400P Atomic Absorption Spectrophotometer at 217.00 nm (country of origin: Germany).

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.

The following equation calculates the final concentration of metals in water, soil, and rice samples collected from different crop fields in the study sites.

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

Where C is the concentration 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).

3.5 Method Validation

The digestion method and atomic absorption spectroscopy analysis (AAS; model-AA-7000) were validated by recovery method. One gram of randomly selected soil powder was spiked with three different concentrations of heavy metals one at a time (1.0, 1.5, 2.0 ppm) each run in with the AAS 44 machine. This was followed by the digestion of the spiked samples and determination of metal concentration using AAS. Blank or unspiked samples were digested through the same process and analyzed by same AAS. The amount that was recovered after digestion of the spiked samples was used to calculate % recovery (Al-weher, 2008).

3.6 Data analysis

Mean concentrations of heavy metals in soil, water and rice grain were analyzed using excel computer package.

3.7. Heavy metal limits

Standard limits of heavy metal limits is presented in Table 1 with references

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

Source	**Pb** mg/kg	**Cd** mg/kg	**Cr** mg/kg	**Cu** mg/kg	**References**
Soil	60	1	100	100	Ministry of the Environment Finland (2007)
Irrigation water	0.5	0.01	0.1	0.2	Ayers and Westcot (1985)
Rice grain	0.1	0.05	2.3	40	FAO/WHO, 2011

3.8 Sum of pollution index (SPI)

The pollution index (Pi) is the ratio of metal concentration in a biotic or abiotic medium to that of the regulatory Standard of International bodies such as World Health Organization (WHO), United States Environmental Protection Agency (USEPA) Food and Agriculture Organization (FAO) (Jamali *et al*., 2007).

Mathematically, Pi is expressed as:

$Pi = C_{plant} / C_{FAO/WHO\text{-}standard}$

Where Pi is the individual pollution index of study metal,
C_{plant} is the concentration of the metal in plant.
$C_{FAO/WHO\text{-}standard}$ is the value of the regulatory limit of the heavy metal by FAO/WHO

Sum of Pollution index (SPI) described by Qingjie *et al*. (2008) was used for the present application.

SPI = PiPb+ PiZn+ PiNi + PiCr + PiCd + PiAs

Where, Pi = Single factor pollution index of heavy metals

3.9. Metal pollution index (MPI)

To examine the overall heavy metal concentrations of soil, water and rice grain the metal pollution index (MPI) was computed by Usero *et al*., 1997. This index was obtained by calculating the geometrical mean of concentrations of all the metals.

$MPI\ (mg\ kg^{-1}) = (C_1 \times C_2 \times C_3 \times \ldots\ldots\ldots.. \times C_n)^{1/n}$

Where, C_n = Concentration of metal n in the sample

CHAPTER 4
RESULTS AND DISCUSSION

In this study, we investigated the heavy metals contamination in soil, water and crops in the adjacent areas of the Savar tannery area and Narayanganj industrial areas. The findings of the study are presented here under the following headings

4.1. Lead (Pb) concentration in water, soil, and rice grain:

4.1.1. Lead (Pb) concentration in water

We have investigated the lead (Pb) concentration of the water in seven sites from savar tannery areas viz., Aboni leather, 100 m from Aboni leather, A.S Leather export Ltd., Prince leather, Crust & Finished leather, Ruma leather, Ibrahim leather, and five sites from Narayanganj district, viz., IsRA knitting Ltd, SP washing Ltd., Waseq textile mills Ltd., Onus garments Ltd., Multitex Knit com (Figure 1). The lead (Pb) concentration in water from 12 different sampling locations is shown in Figure 2. The highest Pb concentration (0.32 mg/kg) was found in Aboni Leather from the Savar tannery area and the lowest (0.6 mg/kg) was found in Onus Garments Ltd. from Narayanganj industrial area. In this study, we found the Pb concentration in water from Savar Tannery and Narayanganj industrial area studied location ranged from 0.16 mg/kg – 0.32 mg/kg and 0.06 mg/kg – 0.21 mg/kg, respectively.

The Pb concentration in water from all of the studied locations was lower than the FAO/WHO permissible limits (0.5 mg/kg) (Ayers and Westcot, 1985). This type of result was also found in another study in Bangladesh such as Ahmed et al. (2012) found 0.107- 0.177 mg/kg Pb concentration in the water of Karnofuly river; Sarkar et al. (2016) found 0.015 mg/l in Turag-river of Tongi heavy industrial area and Ahmed et al (2010) found 0.06 mg/l in Buriganga river at Balughat, Shawaryghat and Foridabad station. This result indicates that we can use the studied locations' water as irrigation

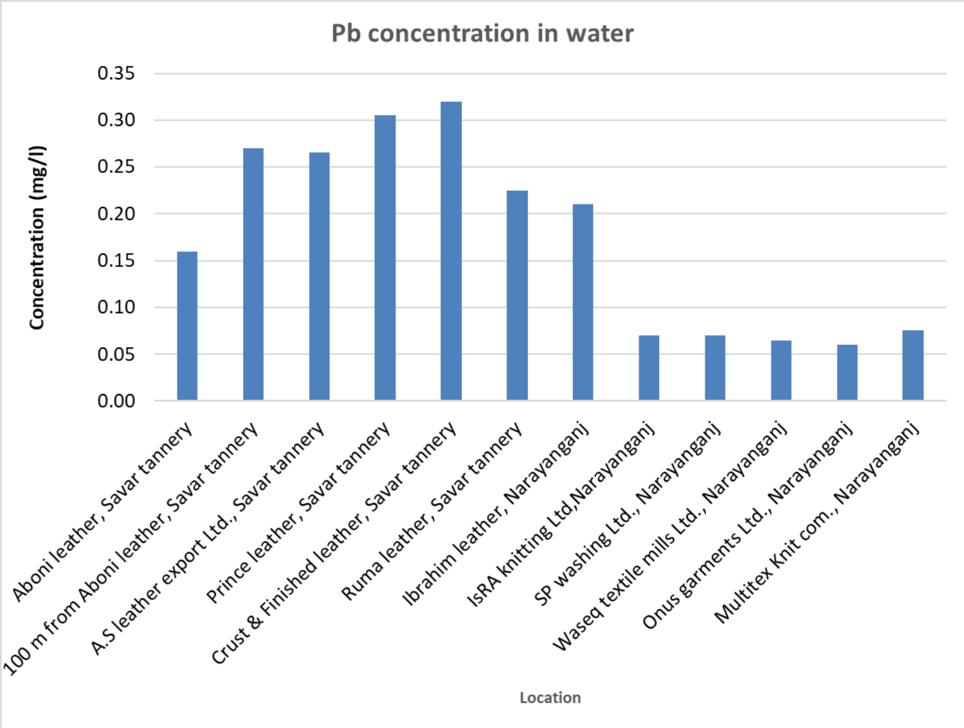

Figure 2. Lead (Pb) concentration found in water samples of the studied sites

4.1.2. Lead (Pb) concentration in soil

We have investigated the lead (Pb) concentration on the soil in seven sites from savar tannery areas viz., viz., Fthaf Leather, Yousuf Leather Co., Techplan Leather, Rose Leather, Tanjin Leather Goods Ltd, Venice Leather Goods Ltd., Mukta tennary ltd and five sites of Narayanganj industrial areas viz., IsRA knitting Ltd, SP washing Ltd., Waseq textile mills Ltd., Onus garments Ltd. and Multitex Knit com.

The lead (Pb) concentration in soil from 12 different sampling locations is shown in Figure 2. The highest Pb concentration (28.4 mg/kg) was found in Multitex Knit com. from Narayanganj industrial area and the lowest (16.05 mg/kg) was found in Rose Leather from Savar tannery area. In this study, we found the Pb concentration in soil from locations of Savar tannery and Narayanganj industrial area ranged from 16.05 mg/kg – 22.85 mg/kg and 21.95 mg/kg – 28.4 mg/kg, respectively (Figure 3).

The Pb concentration in soil from all of the studied locations was lower than the permissible limits (60 mg/kg) (Ministry of the Environment Finland, 2007). The result indicates that the using of soil for cultivation in the study area has no health risk. This type of result was also found in another study in Bangladesh such as Begum et al. (2014) found 9.6 mg/kg Pb in the cultivation soil of Bogra; Alamgir et al. (2015) found 7.3 mg/kg in Chattogram and Naser et al. (2012) found 17.8 mg/kg in Gazipur

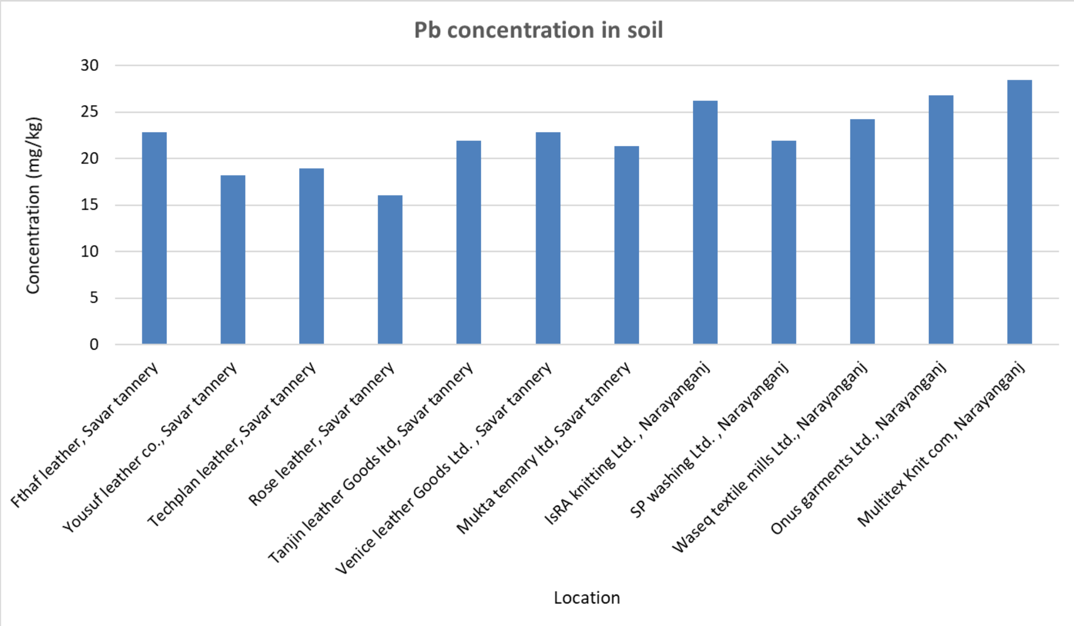

Figure 3. Lead (Pb) concentration found in soil samples of the studied locations

4.1.3. Lead (Pb) concentration in rice grain

We have investigated the lead (Pb) concentration on rice grain in four different locations viz., Yousuf Leatherco. and Tanjin LeatherGoods ltd. From Savar tannery area, and Waseq textile mills Ltd. And Multitex Knitcom from Narayanganj industrial area. The lead (Pb) concentration in rice from four different sampling locations is shown in the figure 4 The lead (Pb) concentration in soil from four different sampling locations is shown in figure 4. The highest Pb concentration (12.88 mg/kg) was found in Waseq textile mills Ltd. From Narayanganj industrial area and the lowest (8.42 mg/kg) was found in Yousuf Leatherco from Savar tannery area. In this study, we found the Pb concentration in rice grain from locations of Savar tannery and Narayanganj industrial area ranged from 8.42 mg/kg –9.2 mg/kg and 11.33 mg/kg – 12.88 mg/kg, respectively.

The Pb concentration in rice grain from all of the studied locations was much higher than the permissible limits (0.1 mg/kg) (FAO/WHO, 2011). These results indicate the rice grain form all of the studied locations are not safe for consumption. This type of result was also found in another study in Bangladesh such as Hasan et al. (2022) found 34.09-7.90 mg/kg Pb in the rice grain of Gazipur; Kormoker et al. (2022) found 0.35-18.05 mg/kg in Tangail district.

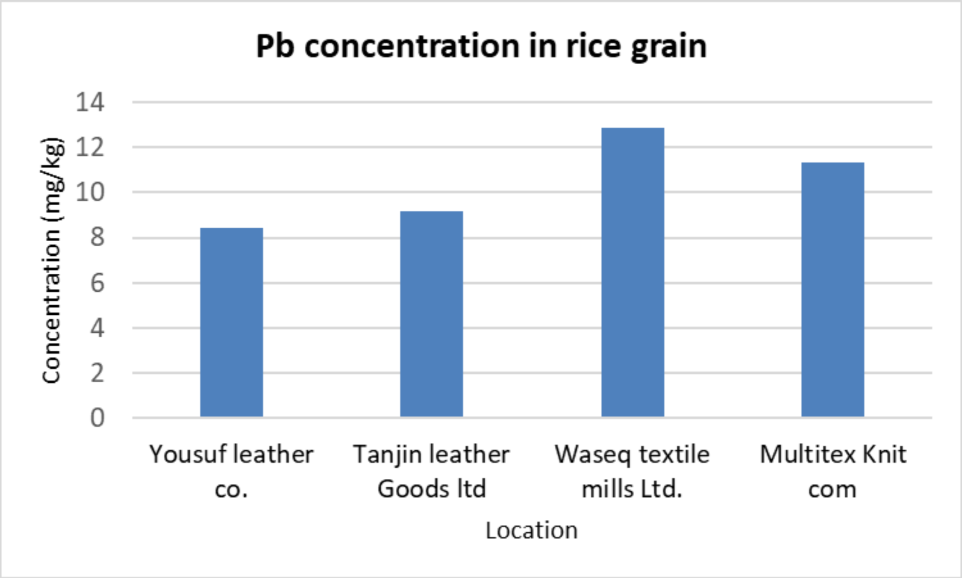

Figure 4. Lead (Pb) concentration found in rice samples of the studied locations

4.2. Cadmium (Cd) concentration in water, soil, and rice grain of the studied locations

4.2.1. Cadmium (Cd) concentration in water

We have investigated the Cadmium (Cd) concentration on the water in seven sites from savar tannery areas viz., Aboni leather, 100 m from Aboni leather, A.S Leather export Ltd., Prince leather, Crust & Finished leather, Ruma leather, Ibrahim leather, and five sites from Narayanganj district, viz., IsRA knitting Ltd, SP washing Ltd., Waseq textile mills Ltd., Onus garments Ltd., Multitex Knit com. The Cd concentration in water from 12 different sampling locations is shown in figure 5. The highest Cd concentration (0.15 mg/kg) was found A.S Leather export Ltd from Savar tannery area and the lowest (0.06 mg/kg) was found in IsRA knitting Ltd from Narayanganj industrial area. In this study, the Cd concentration in water from the savar tannery and Narayanganj industrial area from the studied location ranged from 0.10 mg/kg – 0.15 mg/kg and 0.04 mg/kg – 0.05 mg/kg, respectively.

The Cd concentration in water from all of the studied locations was higher than the maximum permissible limits (0.01 mg/kg) (Ayers and Westcot, 1985). This result indicates that the cadmium concentration in water at the study sites might have health. This type of result was also found in another study in Bangladesh such as Ahmed et al. (2009) found 5.29-8.20 mg/kg Cd in the water of Dhaleswari River.

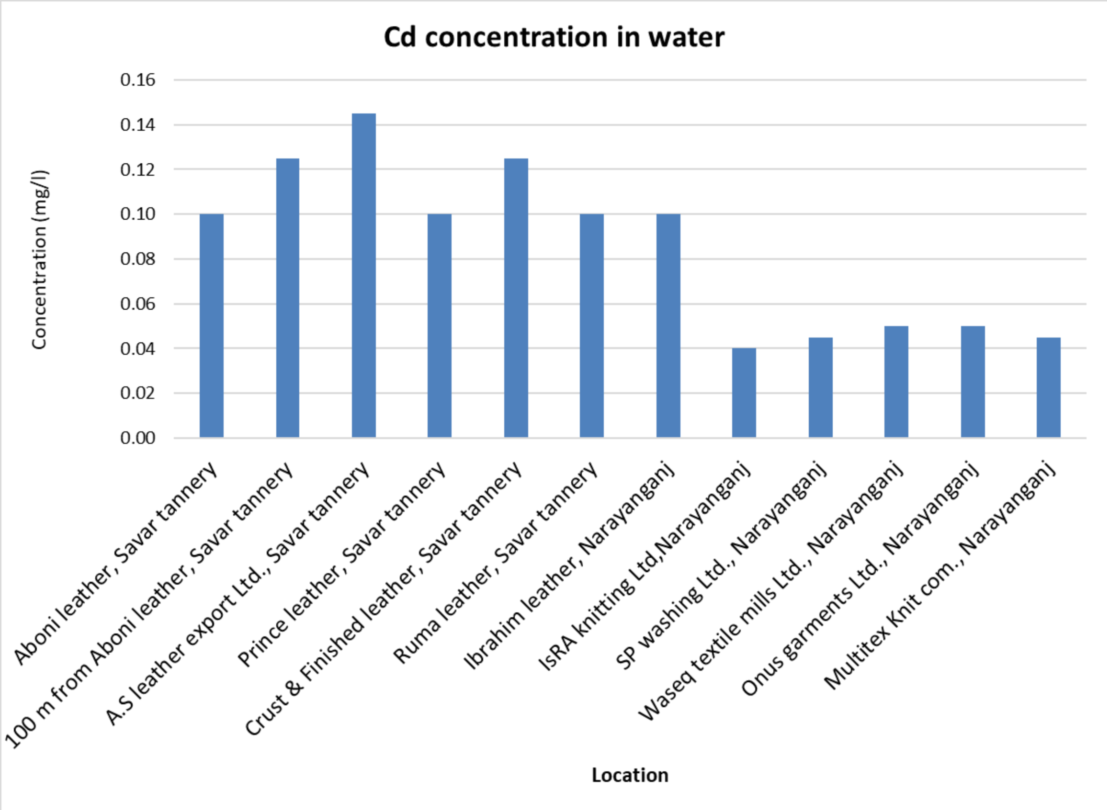

Figure 5. Cadmium (Cd) concentration found in water samples of the studied locations

4.2.2. Cadmium (Cd) concentration in soil

We have investigated the cadmium (Cd) concentration on the soil in seven sites from savar tannery areas viz., viz., Fthaf leather, Yousuf Leatherco., Techplan leather, Rose leather, Tanjin Leather Goods ltd, Venice Leather Goods Ltd., Mukta tennary ltd and five sites of Narayanganj industrial areas viz., IsRA knitting Ltd, SP washing Ltd., Waseq textile mills Ltd., Onus garments Ltd. and Multitex Knit com.

The Cd concentration in soil from 12 different sampling locations is shown in Figure 6. The highest Cd concentration (5.95 mg/kg) was found in Rose Leather from Savat tennary area and the lowest (0.91 mg/kg) was found in Rose Leather from Savar tannery area. In this study, the Cd concentration in soil from locations of Savar tannery and Narayanganj industrial area ranged from 4.13 mg/kg – 5.95 mg/kg and 0.91 mg/kg – 0.97 mg/kg, respectively.

The Cd concentration in soil from the study sites on the Savar tannery area was higher than the maximum permissible limits (1 mg/kg) (Ministry of the Environment

Finland, 2007). This result indicates that the cadmium concentration in Savar study sites might have health risk. And the Cd concentration in soil from the study sites on the Narayanganj industrial area was lower than the maximum permissible limits (1 mg/kg) (Ministry of the Environment Finland, 2007). This result indicates that the uses of soil for cultivation in the Narayanganj study sites do not have health risks. This type of result was also found in another study in Bangladesh such as Al Mamun et al. (2021) found 0.83-4.80 mg/kg Cd in the soil of Tangail district

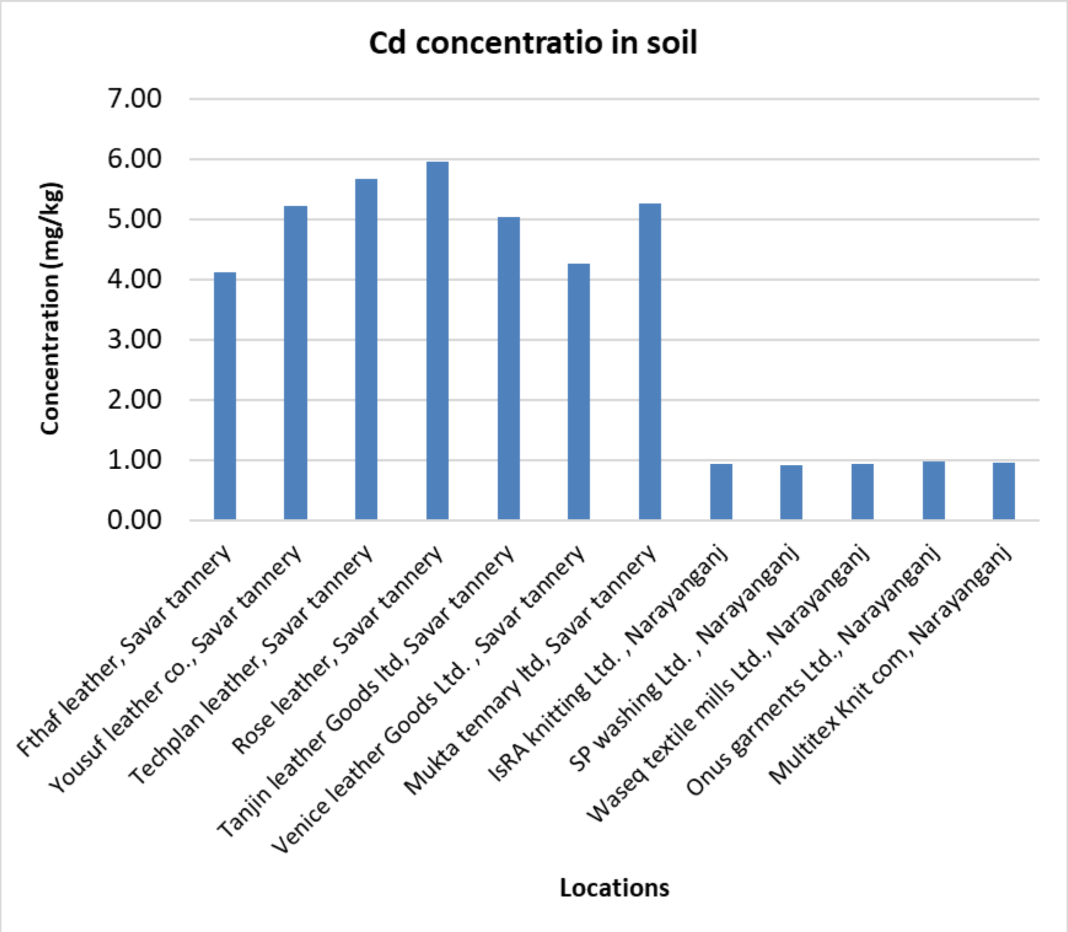

Figure 6. Cadmium (Cd) concentration found in soil samples of the studied locations

4.2.3. Cadmium (Cd) concentration in rice grain

We have investigated the cadmium (Cd) concentration on rice grain in four different locations viz., Yousuf Leatherco. and Tanjin Leather Goods ltd. From Savar tannery area, and Waseq textile mills Ltd. and Multitex Knitcom from Narayanganj industrial area. The Cd concentration in rice from four different sampling locations is shown in the figure 7. The highest Cd concentration (0.52 mg/kg) was found in Tanjin Leather

Goods ltd. from the Savar tannery area and the lowest (0.41 mg/kg) was Waseq textile mills Ltd. from Narayanganj industrial area. In this study, the Cd concentration in rice grain from locations of Savar tannery and Narayanganj industrial area ranged from 0.51 mg/kg –0.52 mg/kg and 0.41 mg/kg – 0.43 mg/kg, respectively.

The Cd concentration in rice grain from all of the studied locations was much higher than the permissible limits (0.05 mg/kg) (FAO/WHO, 2011). These results indicate the rice grain from all of the studied locations have health risks. This type of result was also found in another study in Bangladesh such as Shahriar et al. (2023) found 0.31-2.06 mg/kg Cd in the rice grain of the Rajshahi city area

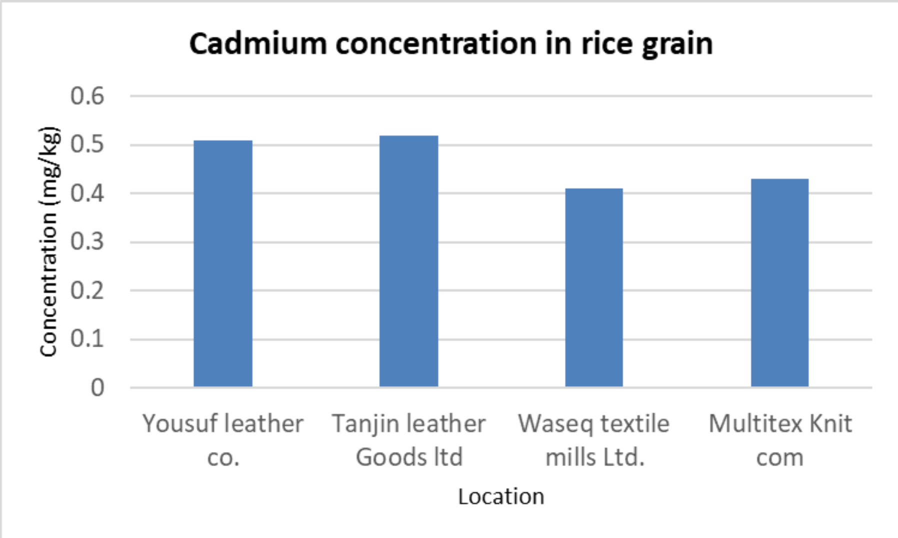

Figure 7. Cadmium (Cd) concentration found in rice samples of the studied locations

4.3. Chromium (Cr) concentration in water, soil, and rice grain of the studied locations

4.3.1. Chromium (Cr) concentration in water

We have investigated the chromium (Cr) concentration on the water in seven sites from savar tannery areas viz., Aboni leather, 100 m from Aboni leather, A.S Leather export Ltd., Prince leather, Crust & Finished leather, Ruma leather, Ibrahim leather, and five sites from Narayanganj district, viz., IsRA knitting Ltd, SP washing Ltd., Waseq textile mills Ltd., Onus garments Ltd., Multitex Knit com. The Cr concentration in water from 12 different sampling locations is shown in figure 8. The highest Cr concentration (8.05 mg/kg) was found Crust & Finished Leather from Savar tannery area and the lowest (1.27 mg/kg) was in Waseq textile mills Ltd. from Narayanganj industrial area. In this study, the Cr concentration in water from Savar tannery and Narayanganj industrial area ranged from the studied location ranged from 3.71 mg/kg – 8.05 mg/kg and 1.27 mg/kg – 1.93 mg/kg, respectively.

The Cr concentration in water from all of the studied locations was higher than the maximum permissible limits (0.1 mg/kg) (Ayers and Westcot, 1985). This result indicates that the chromium concentration of water has health risk. This type of result was also found in another study in Bangladesh such as Azim et al. (2009) found 4.36 mg/l Cr in the water of the Buriganga river, and Islam and Gnauk (2008) found 4.77 mg/l in the water of Shitalakhya river.

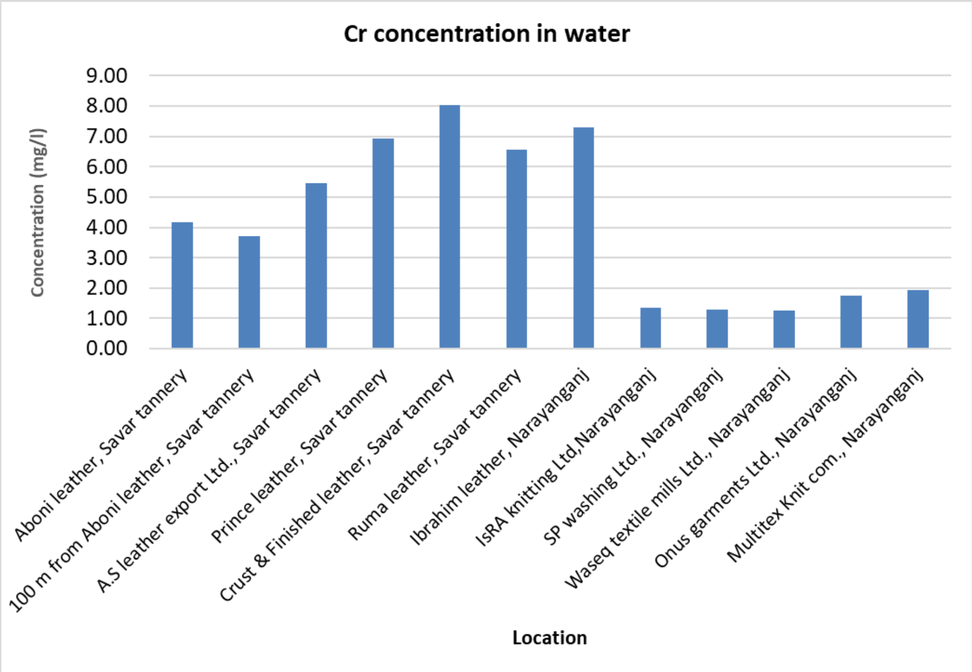

Figure 8. Chromium (Cr) concentration found in water samples of the studied locations

4.3.2. Chromium (Cr) concentration in soil

We have investigated the chromium (Cr) concentration of the soil in seven sites from savar tannery areas viz., viz., Fthaf leather, Yousuf Leatherco., Techplan leather, Rose leather, Tanjin Leather Goods ltd, Venice Leather Goods Ltd., Mukta tennary ltd and five sites of Narayanganj industrial areas viz., IsRA knitting Ltd, SP washing Ltd., Waseq textile mills Ltd., Onus garments Ltd. and Multitex Knit com.

The Cr concentration in soil from 12 different sampling locations is shown in Figure 9. The highest Cr concentration (10115.9 mg/kg) was found in Fthaf Leather from Savar tannery area and the lowest (29.8 mg/kg) was found in Multitex Knitcom from

Narayanganj industrial area. In this study, the Cr concentration in soil from locations of Savar tannery and Narayanganj industrial area ranged from 9049.95 mg/kg – 10115.9 mg/kg and 29.8 mg/kg – 32.05 mg/kg, respectively.

The Cr concentration in soil of the Savar tannery study sites was extensively higher than the permissible limits (100 mg/kg) (Ministry of the Environment Finland, 2007). The uses of the soil of those higher Cr contaminant locations have health risks. The Cr concentration in the soil of the Narayanganj industrial area study sites were lower than the permissible limits (100 mg/kg) (Ministry of the Environment Finland, 2007). The uses of the soil of those lower Cr contaminant locations do not have health risk. This type of result was also found in another study in Bangladesh such as Mottalib et al. (2016) found 976 mg/kg Cr in the soil of the Hazaribagh tennary area, and Begum and Huq (2016) found 132.5 mg/l in the soil of surrounding textile area of Barisal and 38.26 mg/kg in the surrounding cement industry of Barisal.

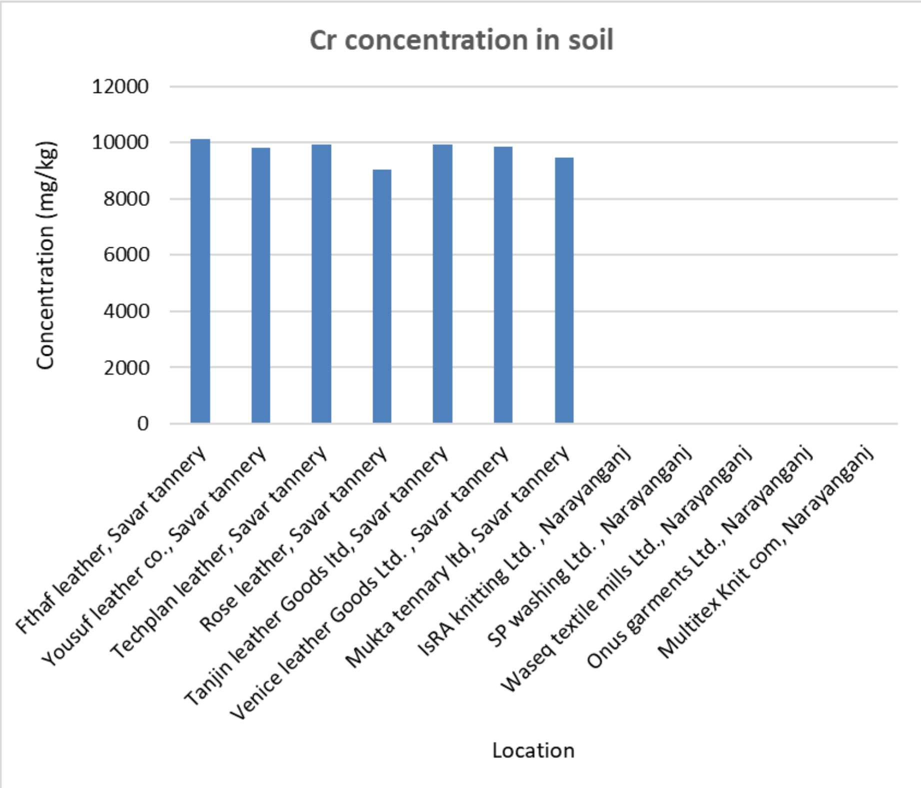

Figure 9. Chromium (Cr) concentration found in soil samples of the studied locations

4.3.3. Chromium (Cr) concentration in rice grain

We have investigated the chromium (Cr) concentration of rice grain in four different locations viz., Yousuf Leather co. and Tanjin Leather Goods ltd. From Savar tannery area, and Waseq textile mills Ltd. and Multitex Knit co. from Narayanganj industrial area. The Cr concentration in rice from four different sampling locations is shown in Figure 10. The highest Cr concentration (46 mg/kg) was found in Yousuf Leather co. from the Savar tannery area and the lowest (37 mg/kg) was Waseq Textile Mills Ltd. from Narayanganj industrial area. In this study, the Cr concentration in rice from locations of Savar tannery and Narayanganj industrial area ranged from 42 mg/kg –46 mg/kg and 37 mg/kg – 41 mg/kg, respectively.

The Cr concentration in rice grain samples from all the studied sites were much higher than the permissible limits (2.3 mg/kg) (FAO/WHO, 2011). In the tannery and leather industry, about 85% of the leather produced in the world is tanned using Cr (Sundar et al., 2011) and conventional tanning using chromium (Cr) happens to have several impacts on the environment as it carries residual Cr into the wastewater which ultimately transfers into the soil (Wu et al. 2014; Homa et al., 2016). Finally, the heavy metal transfers to the rice grain from the soil. From the above discussion, we can say that the rice consumption from the study sites might be a health risk. Hasan et al. (2022) also found this type of result, they found 19.78 mg/kg Cr in the soil of Savar, 11.54 mg/kg Gazipur and 23.67 in the Ashulia.

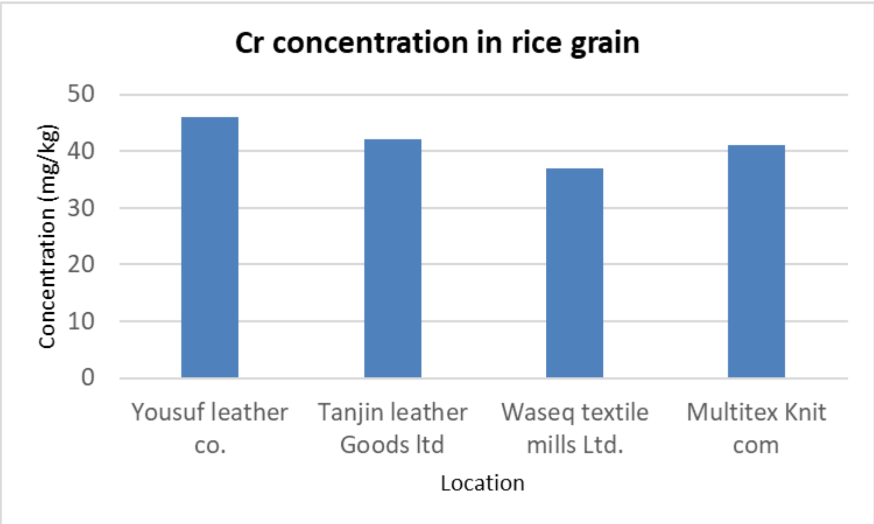

Figure 10. Chromium (Cr) concentration found in rice samples of the studied locations

4.4. Copper (Cu) concentration in water, soil, and rice grain of the studied locations

4.4.1. Copper (Cu) concentration in water

We have investigated the copper (Cu) concentration on the water in seven sites from savar tannery areas viz., Aboni leather, 100 m from Aboni leather, A.S Leather export Ltd., Prince leather, Crust & Finished leather, Ruma leather, Ibrahim leather, and five sites from Narayanganj district, viz., IsRA knitting Ltd, SP washing Ltd., Waseq textile mills Ltd., Onus garments Ltd., Multitex Knit com. The Cu concentration in water from 12 different sampling locations is shown in figure 11. The highest Cu concentration (0.49 mg/kg) was found in Aboni Leather from Savar tannery area and the lowest (0.04 mg/kg) was in IsRA knitting Ltd from Narayanganj industrial area. In this study, the Cu concentration in water from Savar tannery and Narayanganj industrial area ranged from the studied location ranged from 0.17 mg/kg – 0.49 mg/kg and 0.04 mg/kg – 0.08 mg/kg, respectively.

The Cu concentration in water from the study sites of the Savar tannery area were higher than the maximum permissible limits (0.1 mg/kg) (Ayers and Westcot, 1985). This result indicates that the Cu concentration in Savar study sites has a health risk. On the other hand, the Cu concentration in water from the study sites in Narayanganj industrial area was lower than the maximum permissible limits (0.1 mg/kg) (Ayers and Westcot, 1985). This result indicates that the cadmium concentration in the Narayanganj study sites does have not any health risk.

This type of result was also found in another study in Bangladesh such as Begum and Huq (2016) found 378-501mg/l in the water of Dhaleswari river, and Azim et al. (2009) found 0.02 mg/kg Cu in the water of the Buriganga river

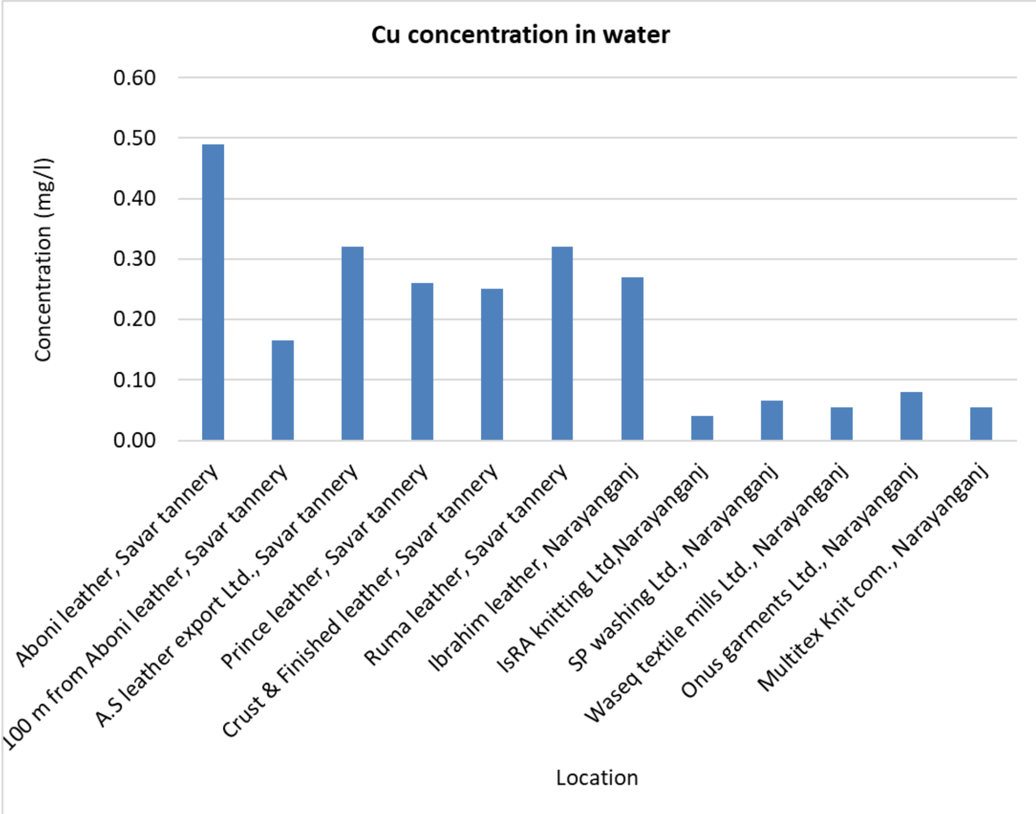

Figure 11. Copper (Cu) concentration found in water samples of the studied locations

4.4.2. Copper (Cu) concentration in soil

We have investigated the copper (Cu) concentration of the soil in seven sites from savar tannery areas viz., Fthaf leather, Yousuf Leatherco., Techplan leather, Rose leather, Tanjin Leather Goods ltd, Venice Leather Goods Ltd., Mukta tennary ltd and five sites of Narayanganj industrial areas viz., IsRA knitting Ltd, SP washing Ltd., Waseq textile mills Ltd., Onus garments Ltd. and Multitex Knit com.

The Cu concentration in soil from 12 different sampling locations is shown in figure 12. The highest Cu concentration (62.8 mg/kg) was found in Fthaf Leatherfrom Savar tannery area and the lowest (25.6 mg/kg) was found in Multitex Knitcom from Narayanganj industrial area. In this study, the Cr concentration in soil from locations of Savar tannery and Narayanganj industrial area ranged from 36.6 mg/kg – 62.8 mg/kg and 25.6 mg/kg – 28.1 mg/kg, respectively.

The Cu concentration in soil from all of the studied locations was lower than the permissible limits (100 mg/kg) (Ministry of the Environment Finland, 2007). The uses of the soil of those higher Cu contaminant locations do not have any health risks. This type of result was also found in another study in Bangladesh such as Kormoker et al (2021) found 0.99- 64.19mg/l in the soil of the Chouras, Kushtia and 2-52.54 mg/kg at Porahati, Jhenaidah.

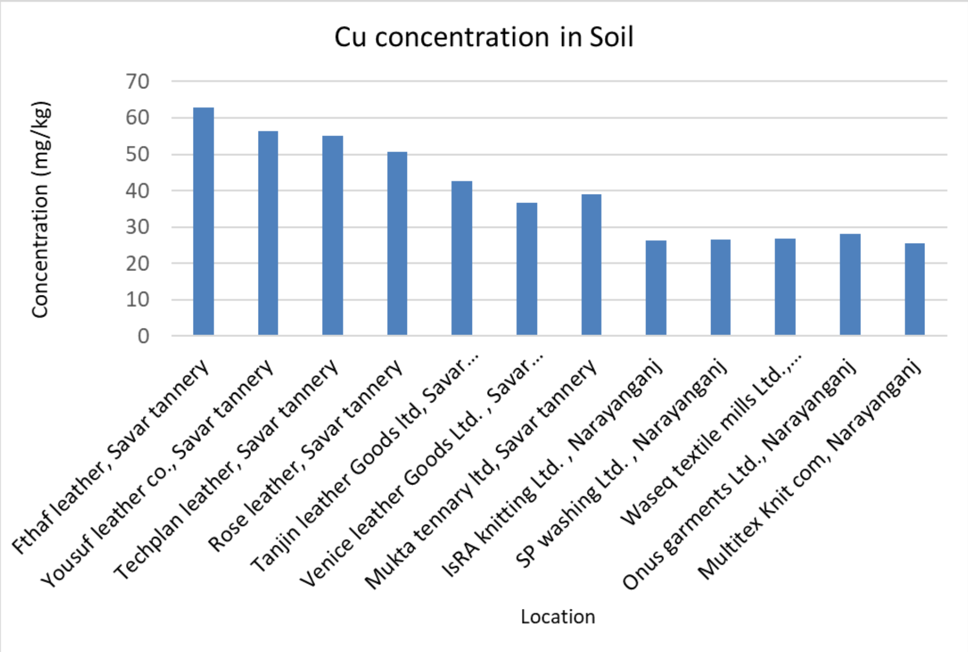

Figure 12. Copper (Cu) concentration found in soil samples of the studied locations

4.4.3. Copper (Cu) concentration in rice grain

We have investigated the copper (Cu) concentration of rice grain in four different locations viz., Yousuf Leatherco. and Tanjin Leather Goods ltd. From Savar tannery area, and Waseq textile mills Ltd. and Multitex Knitcom from Narayanganj industrial area. The Cr concentration in rice from four different sampling locations is shown in the Figure 13. The highest Cr concentration (19.1 mg/kg) was found in Yousuf Leatherco. from Savar tannery area and the lowest (17.8 mg/kg) was Multitex Knitcom from Narayanganj industrial area. In this study, the Cu concentration in rice from locations of Savar tannery and Narayanganj industrial area ranged from 18.8 mg/kg –19.1 mg/kg and 17.8 mg/kg – 18.7 mg/kg, respectively.

The Cu concentration in rice grain from all of the studied locations lower than the permissible limits (40 mg/kg) (FAO/WHO, 2011). From the above discussion, we can say that the rice consumption from the rice grain studied location do not have health risk. Hasan et al. (2022) also found this type of result, they found 38.2 mg/kg Cu in the soil of Savar, 25.34 mg/kg Gazipur and 19.74 in the Ashulia.

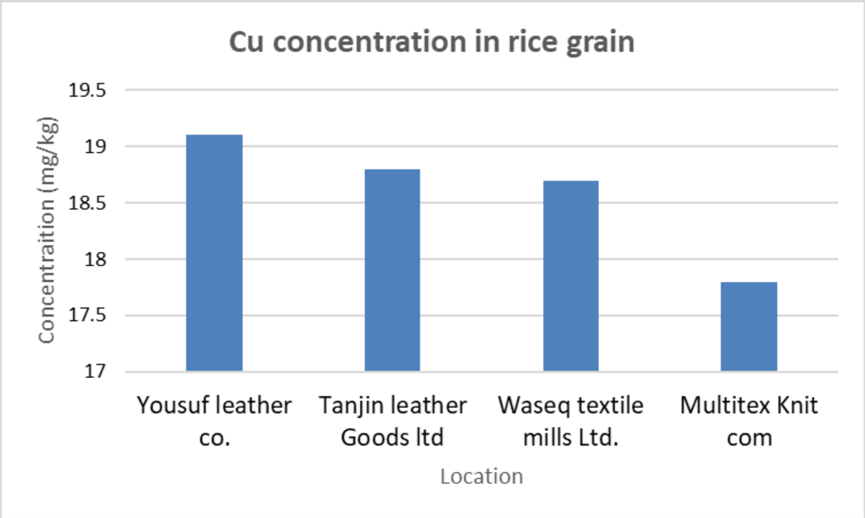

Figure 13. Copper (Cu) concentration found in rice samples of the studied locations

4.5. Heavy metal transfer from soil to rice grain:

The soil-to-plant transfer is one of the key components of human exposure to metals through the food chain. Transfer Factor (TF) is a parameter to describe the transfer of trace elements from soil to plant body. In the present study, the transfer factor of different heavy metal from soil to rice grain are presented in figure14.

The TF value ranges are Pb: 0.40–0.53, Cd: 0.06– 0.43, Cr: 0.00–1.38 and Cu: 0.34–0.70. Metals with high TF are easily transferred to crops unlike metals with low TF. The trend of TF for heavy metals in studied rice grain samples from all of the studied locations was in order: Cr>Cu>Pb>Cd.

The mobility of metals from soil to plants is a function of the physical and chemical properties of the soil and of the rice species and is altered by innumerable environmental and human factors (Zurera et al. 1987).

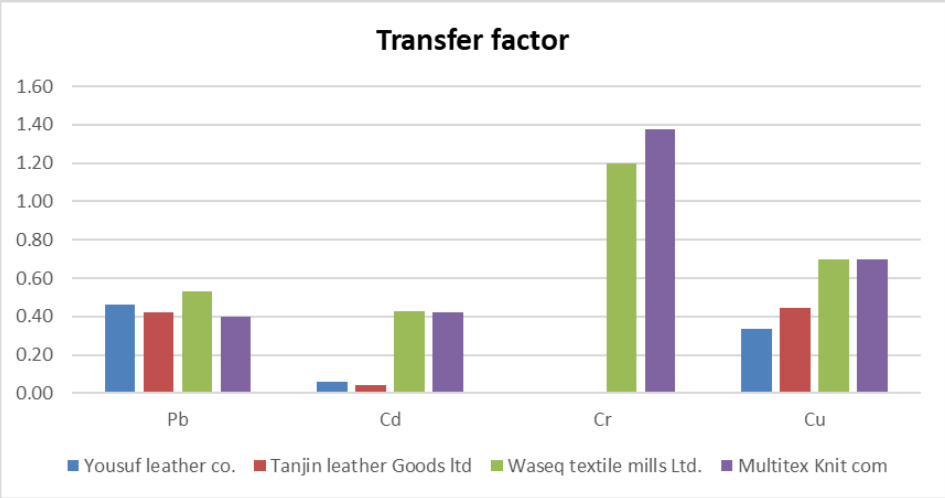

Figure 14. Transfer factor of heavy metal from soils into rice grain

4.6. Sum of Pollution index (SPI)

The pollution index of each of the Heavy metals was calculated to assess the pollution degree of different HMs in soils, water and rice

4.6.1. Sum of pollution index of soil

The lowest pollution index (SPI) (1.38) in soil was found in the SP washing Ltd., Narayanganj soil samples and the highest SPI (72.31) was found in the soil sample of the Techplan leather, Savar tannery (Figure 15)

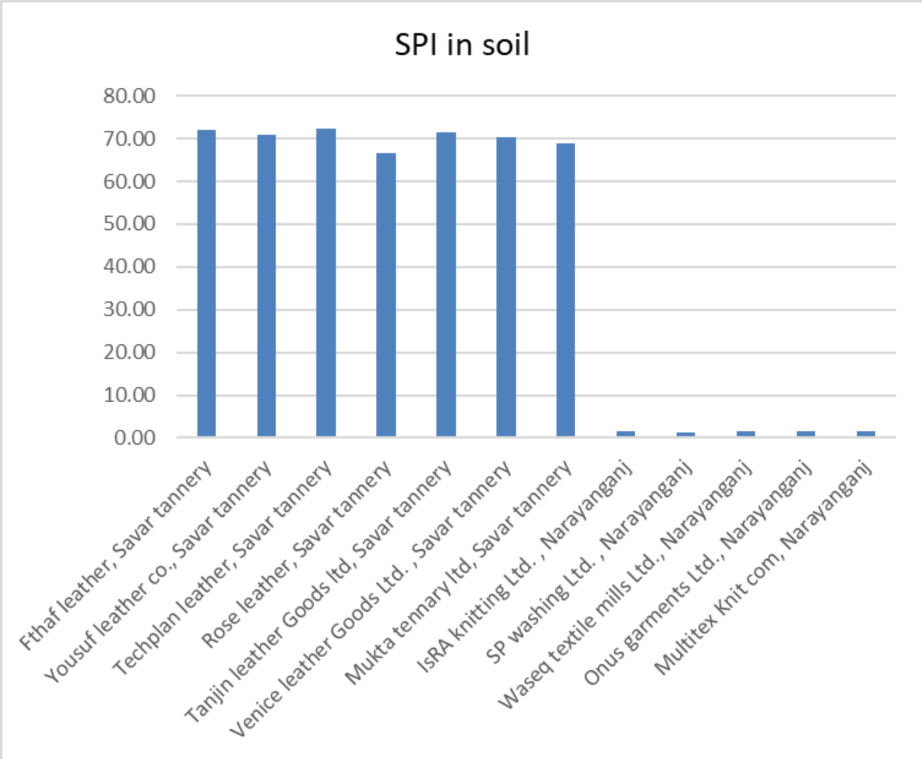

Figure 15. Pollution index in soil samples

4.6.2. Sum of Pollution index of water

The lowest pollution index (PI) (0.05) in water samples was found in the IsRA knitting Ltd of Narayanganj area water samples and the highest PI (0.18) was found in the water sample of the A.S Leather export Ltd. of Savar tannery (Figure 16).

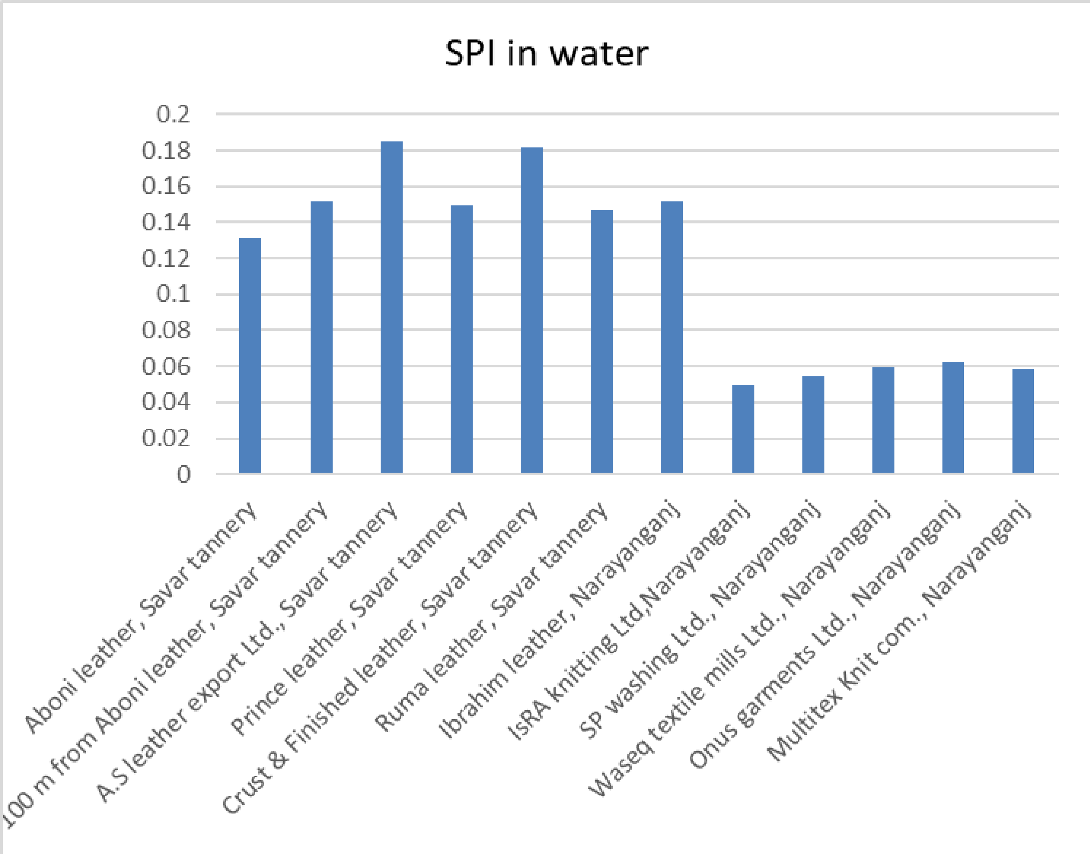

Figure 16. Pollution index in water samples from the studied locations

4.6.2. Sum of pollution index of rice grain

The lowest pollution index (SPI) (110.68) in rice grain was found in Yousuf Leather co. of Savar tannery rice samples and the highest SPI (153.35) was found in the rice samples of the Waseq textile mills Ltd. of Narayanganj industrial area.

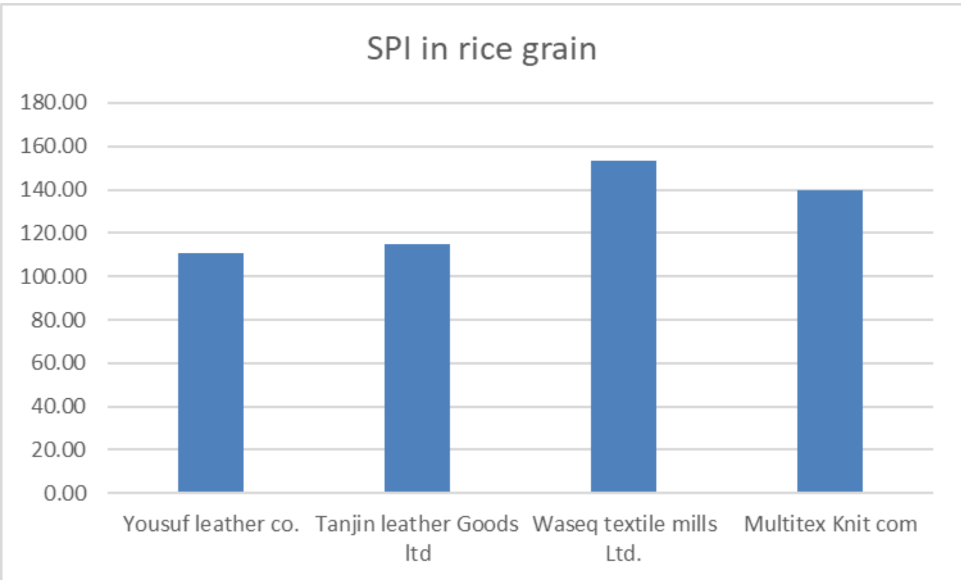

Figure 17. Pollution index in rice samples

4.7. Metal pollution index

Metal pollution index Metal pollution in samples is reliably estimated using the metal pollution index (MPI).

4.7.1. Metal pollution index of soil

The lowest Metal pollution index (MPI) (24.2 mg/kg) in soil was found in the SP washing Ltd of Narayanganj soil samples and the highest MPI (42.8 mg/kg) was found in the soil sample of the Fthaf Leatherof Savar tannery (Figure 18)

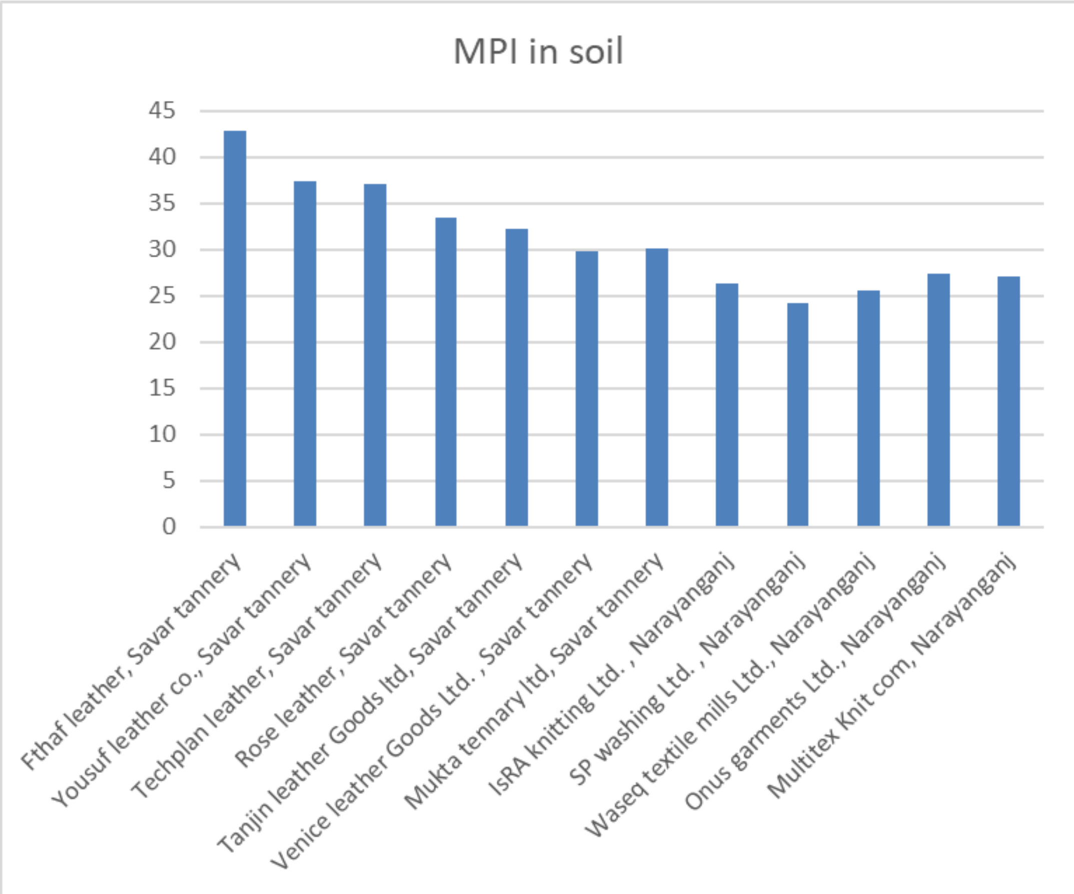

Figure 18. Metal pollution index (mg/kg) in soil samples

4.7.2. Metal pollution index of water

The lowest metal pollution index (MPI) (0.06 mg/l) was found in the Waseq textile mills Ltd of Narayanganj water samples and the highest MPI (0.33 mg/l) was found in the water sample of the Aboni leather, Savar tannery (figure 19).

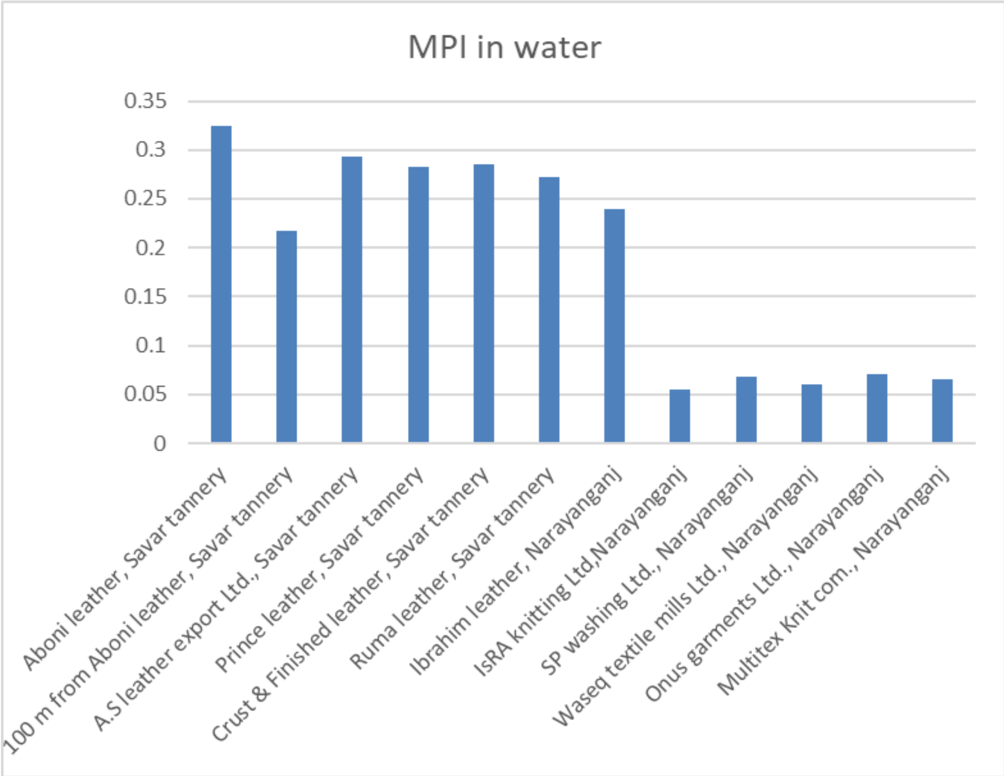

Figure 19. Metal pollution index (mg/l) in water samples from the studied locations

4.7.3. Metal pollution index of rice grain

The lowest metal pollution index (MPI) (11.13 mg/kg) was found in the Tanjin Leather Goods ltd in rice grain and the highest MPI (13 mg/kg) was found in the rice sample of Yousuf Leatherco. area (figure 20)

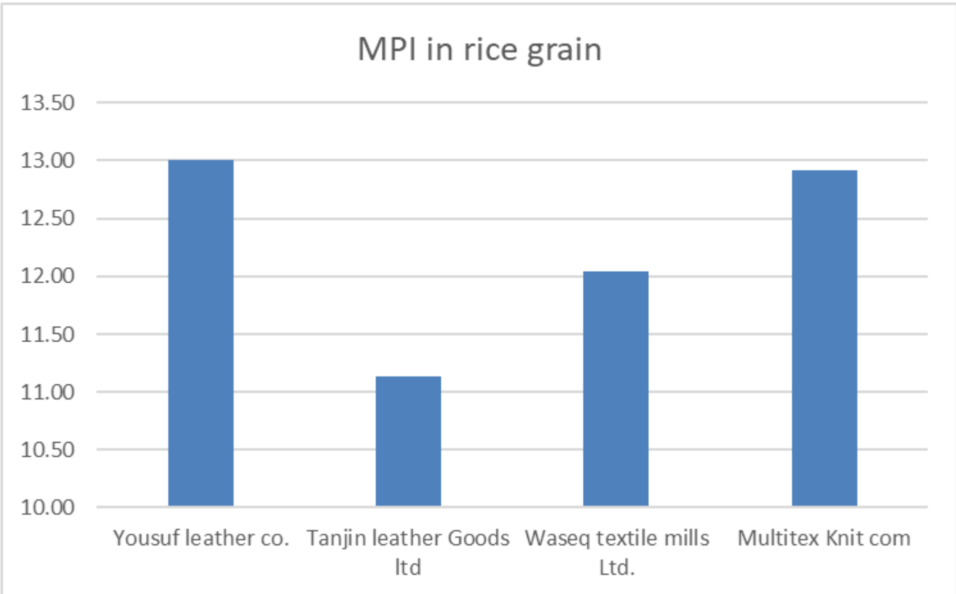

Figure 20. Metal pollution index (mg/kg) in rice samples

CHAPTER V

SUMMARY AND CONCLUSION

In the present study, we investigated the heavy metals contamination in soil, water and crops in the adjacent areas of the Savar tannery and Narayanganj industrial area. Water samples were collected from seven sites viz., Aboni leather, 100 m from Aboni leather, A.S Leather export Ltd., Prince leather, Crust & Finished leather, Ruma leather, Ibrahim Leather of Savar tannery area and five sites from Narayanganj district, viz., IsRA knitting Ltd, SP washing Ltd., Waseq textile mills Ltd., Onus garments Ltd., Multitex Knit com. Soil sample were collected from seven sites of Savar tannery viz., Fthaf leather, Yousuf Leatherco., Techplan leather, Rose leather, Tanjin Leather Goods ltd, Venice Leather Goods Ltd., Mukta tennary ltd and five sites of Narayanganj industrial area viz., IsRA knitting Ltd, SP washing Ltd., Waseq textile mills Ltd., Onus garments Ltd. and Multitex Knit com. Rice grain sample were collected from four different locations viz., Yousuf Leatherco. and Tanjin Leather Goods ltd. from Savar tannery area and Waseq textile mills Ltd. and Multitex Knitcom from Narayanganj industrial area)

The Pb concentration (0.16–0.32 mg/kg Savar, 0.6– 0.21 mg/kg in Narayanganj) in water from all the studied locations was lower than the permissible limit while Cd concentration (0.10– 0.15 mg/kg in Savar and 0.04 – 0.05 mg/kg in Narayanganj), Cr concentration (3.71 – 8.05 mg/kg in Savar and 1.27 – 1.93 mg/kg in Narayanganj) and the Cu concentration (0.17 – 0.49 mg/kg in Narayanganj) in water from all of the studied locations from Savar tannery and Narayanganj industrial area was higher than the permissible limits except the Cu concentration (0.04 – 0.08 mg/kg) in the sites of the Narayanganj area was lower than the maximum permissible limits which indicate that the using of water as irrigation from those area has a health risk. The Pb concentration (16.05–22.85 mg/kg in Savar and 21.95–28.4 mg/kg in Narayanganj) and Cu concentration (36.6 – 62.8 mg/kg in Savar and 25.6– 28.1 mg/kg in Narayanganj) in soil from all of the studied locations was lower than the permissible which means the Pb and Cd did not affect he soil in this area. On the other hand, the Cd concentration (4.13– 5.95 mg/kg) and Cr concentration (9049.95– 10115.9 mg/kg in Savar) in soil from all of the studied locations from Savar tannery study sites were much higher than the maximum permissible limits which indicate that the using of soil as cultivation in this area have health risks. The Cd concentration (0.91 mg/kg – 0.97 mg/kg) and Cr concentration (29.8– 32.05 mg/kg) in soil from the study sites in Narayanganj Industrial was lower than the maximum permissible limits which revealed that Cd and Cr did not affect the soil of those areas. The Pb concentration (8.42–9.2 mg/kg in Savar and 11.33– 12.88 mg/kg in Narayanganj), Cd (0.51–0.52 mg/kg in Savar and 0.41– 0.43 mg/kg in Narayanganj) and Cr concentration (42 –46 mg/kg in Savar and 37 – 41 mg/kg in Narayanganj) in rice grain from all of the studied locations was much higher than the permissible limits which indicate that Pb, Cd and Cr contaminated rice grain form all of the studied locations and those are not safe for consumption. However, the Cu concentration of Savar and Narayanganj 18.8–19.1 mg/kg and 17.8– 18.7 mg/kg respectively in rice grain from all of the studied locations was lower than the permissible limits (40 mg/kg). The trend of TF for heavy metals in studied rice grain samples from all of the studied locations was in order: Cr>Cu>Pb>Cd.

In case of the sum of soil pollution index, the lowest pollution index (SPI) (1.38) in soil was found in the SP washing Ltd., Narayanganj soil samples and the highest SPI (72.31) was found in the soil sample of the Techplan leather, Savar tannery. The lowest pollution index (PI) (0.05) in water samples was found in the IsRA knitting Ltd of Narayanganj area water samples and the highest PI (0.18) was found in the water sample of the A.S Leather Export Ltd. of Savar tannery. The lowest pollution index (SPI) (110.68) in rice grain was found in Yousuf Leather Co. of Savar tennary rice samples and the highest SPI (153.35) was found in the rice samples of the Waseq textile mills Ltd. of Narayanganj industrial area. In the case of Metal pollution index, the lowest Metal pollution index (MPI) (24.2 mg/kg) in soil was found in the SP washing Ltd of Narayanganj soil samples and the highest MPI (42.8 mg/kg) was found in the soil sample of the Fthaf Leather of Savar tannery. The lowest metal pollution index (MPI) (0.06 mg/kg) was found in the Waseq textile mills Ltd of Narayanganj water samples and the highest MPI (0.33 mg/kg) was found in the water sample of the Aboni leather, Savar tannery. The lowest metal pollution index (MPI) (11.13 mg/kg) was found in the Tanjin Leather Goods ltdin rice grain and the highest MPI (13 mg/kg) was found in the rice sample of Yousuf Leather Co. area. Proper management plan should be taken to control the heavy metal concentration in the studied location of Savar and Narayaganj district**.**

CHAPTER VI

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CHAPTER VII

APPENDICES

Appendix I. Lead concentration in water

Location	Concentration (mg/kg)
Aboni leather, Savar tannery	0.16
100 m from Aboni leather, Savar tannery	0.27
A.S leather export Ltd., Savar tannery	0.27
Prince leather, Savar tannery	0.31
Crust & Finished leather, Savar tannery	0.32
Ruma leather, Savar tannery	0.23
Ibrahim leather, Narayanganj	0.21
IsRA knitting Ltd,Narayanganj	0.07
SP washing Ltd., Narayanganj	0.07
Waseq textile mills Ltd., Narayanganj	0.07
Onus garments Ltd., Narayanganj	0.06
Multitex Knit com., Narayanganj	0.08

Appendix II. Lead concentration in soil

Location	Concentration (mg/kg)
Fthaf leather, Savar tannery	22.8
Yousuf leather co., Savar tannery	18.2
Techplan leather, Savar tannery	18.9
Rose leather, Savar tannery	16.05
Tanjin leather Goods ltd, Savar tannery	21.95
Venice leather Goods Ltd., Savar tannery	22.85
Mukta tennary ltd, Savar tannery	21.3

IsRA knitting Ltd., Narayanganj	26.2
SP washing Ltd., Narayanganj	21.95
Waseq textile mills Ltd., Narayanganj	24.25
Onus garments Ltd., Narayanganj	26.8
Multitex Knit com, Narayanganj	28.4

Appendix III. Cadmium concentration in water

Location	**Concentration (mg/kg)**
Aboni leather, Savar tannery	**0.10**
100 m from Aboni leather, Savar tannery	0.13
A.S leather export Ltd., Savar tannery	0.15
Prince leather, Savar tannery	0.10
Crust & Finished leather, Savar tannery	0.13
Ruma leather, Savar tannery	0.10
Ibrahim leather, Narayanganj	0.10
IsRA knitting Ltd, Narayanganj	0.04
SP washing Ltd., Narayanganj	0.05
Waseq textile mills Ltd., Narayanganj	0.05
Onus garments Ltd., Narayanganj	0.05
Multitex Knit com., Narayanganj	0.05

Appendix IV. Cadmium concentration in Soil

Location	Concentration (mg/kg)
Fthaf leather, Savar tannery	4.13
Yousuf leather co., Savar tannery	5.21
Techplan leather, Savar tannery	5.66
Rose leather, Savar tannery	5.95
Tanjin leather Goods ltd, Savar tannery	5.04
Venice leather Goods Ltd., Savar tannery	4.26
Mukta tennary ltd, Savar tannery	5.27
IsRA knitting Ltd., Narayanganj	0.94
SP washing Ltd., Narayanganj	0.91
Waseq textile mills Ltd., Narayanganj	0.94

Onus garments Ltd., Narayanganj	0.97
Multitex Knit com, Narayanganj	0.95

Appendix V. Chromium concentration in water

Location	Concentration (mg/kg)
Aboni leather, Savar tannery	**4.17**
100 m from Aboni leather, Savar tannery	3.71
A.S leather export Ltd., Savar tannery	5.46
Prince leather, Savar tannery	6.93
Crust & Finished leather, Savar tannery	8.05
Ruma leather, Savar tannery	6.55
Ibrahim leather, Narayanganj	7.30
IsRA knitting Ltd,Narayanganj	1.34
SP washing Ltd., Narayanganj	1.28
Waseq textile mills Ltd., Narayanganj	1.27
Onus garments Ltd., Narayanganj	1.76
Multitex Knit com., Narayanganj	1.93

Appendix VI. Chromium concentration in soil

Location	Concentration (mg/kg)
Fthaf leather, Savar tannery	10115.85
Yousuf leather co., Savar tannery	9800.3
Techplan leather, Savar tannery	9928.6
Rose leather, Savar tannery	9049.95
Tanjin leather Goods ltd, Savar tannery	9917.75
Venice leather Goods Ltd., Savar tannery	9837.35
Mukta tennary ltd, Savar tannery	9472.55
IsRA knitting Ltd., Narayanganj	31.7
SP washing Ltd., Narayanganj	32.05
Waseq textile mills Ltd., Narayanganj	30.95
Onus garments Ltd., Narayanganj	30.9
Multitex Knit com, Narayanganj	29.8

Appendix VII. Copper concentration in water

Location	Concentration (mg/kg)
Aboni leather, Savar tannery	**0.49**
100 m from Aboni leather, Savar tannery	**0.17**
A.S leather export Ltd., Savar tannery	0.32
Prince leather, Savar tannery	0.26
Crust & Finished leather, Savar tannery	0.25
Ruma leather, Savar tannery	0.32
Ibrahim leather, Narayanganj	0.27
IsRA knitting Ltd,Narayanganj	0.04
SP washing Ltd., Narayanganj	0.07
Waseq textile mills Ltd., Narayanganj	0.06
Onus garments Ltd., Narayanganj	0.08
Multitex Knit com., Narayanganj	0.06

Appendix VIII. Copper concentration in soil

Location	Concentration (mg/kg)
Fthaf leather, Savar tannery	62.8
Yousuf leather co., Savar tannery	56.5
Techplan leather, Savar tannery	55.2
Rose leather, Savar tannery	50.75
Tanjin leather Goods ltd, Savar tannery	42.5
Venice leather Goods Ltd., Savar tannery	36.6
Mukta tennary ltd, Savar tannery	38.95
IsRA knitting Ltd., Narayanganj	26.3
SP washing Ltd., Narayanganj	26.45
Waseq textile mills Ltd., Narayanganj	26.8
Onus garments Ltd., Narayanganj	28.1
Multitex Knit com, Narayanganj	25.6

Appendix IX. Heavy metal concentration in rice grain

Rice Grain	**Pb (mg/kg)**	**Cd(mg/kg)**	**Cr (mg/kg)**	**Cu (mg/kg)**
Yousuf Leather Co.	8.42	0.3	46	19.1
Tanjin leather Goods ltd	9.2	0.2	42	18.8
Waseq Textile Mills Ltd.	12.88	0.4	37	18.7
Multitex Knit com	11.33	0.4	41	17.8

Appendix X. Sediment pollution index (SPI) in water and soil

Water samples		**Soil samples**	
Location	SPI	**Locations**	SPI
Aboni leather, Savar tannery	0.13	Fthaf leather, Savar tannery	72.09
100 m from Aboni Leather, Savar tannery	0.15	Yousuf leather co., Savar tannery	71.01
A.S leather export Ltd., Savar tannery	0.18	Techplan leather, Savar tannery	72.31
Prince leather, Savar tannery	0.15	Rose leather, Savar tannery	66.70
Crust & Finished leather, Savar tannery	0.18	Tanjin leather Goods ltd, Savar tannery	71.54
Ruma leather, Savar tannery	0.15	Venice leather Goods Ltd., Savar tannery	70.17
Ibrahim leather, Narayanganj	0.15	Mukta tennary ltd, Savar tannery	68.77
IsRA knitting Ltd,Narayanganj	0.05	IsRA knitting Ltd., Narayanganj	1.43
SP washing Ltd., Narayanganj	0.05	SP washing Ltd., Narayanganj	1.39
Waseq textile mills Ltd., Narayanganj	0.06	Waseq textile mills Ltd., Narayanganj	1.42
Onus garments Ltd.,	0.06	Onus garments Ltd.,	1.47

Narayanganj		Narayanganj	
Multitex Knit com., Narayanganj	0.06	Multitex Knit com, Narayanganj	1.43

Appendix XI. Metal pollution index (mg/kg) of soil

Water		**Soil**	
Locations	**MPI**	**Locations**	**MPI**
Aboni leather, Savar tannery	0.33	Fthaf leather, Savar tannery	42.8
100 m from Aboni leather, Savar tannery	0.22	Yousuf leather co., Savar tannery	37.35
A.S leather export Ltd., Savar tannery	0.29	Techplan leather, Savar tannery	37.05
Prince leather, Savar tannery	0.28	Rose leather, Savar tannery	33.4
Crust & Finished leather, Savar tannery	0.29	Tanjin leather Goods ltd, Savar tannery	32.225
Ruma leather, Savar tannery	0.27	Venice leather Goods Ltd., Savar tannery	29.725
Ibrahim leather, Narayanganj	0.24	Mukta tennary ltd, Savar tannery	30.125
IsRA knitting Ltd,Narayanganj	0.06	IsRA knitting Ltd., Narayanganj	26.25
SP washing Ltd., Narayanganj	0.07	SP washing Ltd., Narayanganj	24.2
Waseq textile mills Ltd., Narayanganj	0.06	Waseq textile mills Ltd., Narayanganj	25.525
Onus garments Ltd., Narayanganj	0.07	Onus garments Ltd., Narayanganj	27.45

Multitex Knit com., Narayanganj	0.07	Multitex Knit com, Narayanganj	27