Soil Contamination and Environmental Risk Assessment from Relocated Tannery Industries in Savar, Dhaka, Bangladesh

Afrose Sultana Chamon*

Professor, Department of Soil, Water and Environment, University of Dhaka, Bangladesh

***Corresponding author**

DOI: https://dx.doi.org/10.47772/IJRISS.2025.914MG00160

Received: 04 September 2025; Accepted: 06 October 2025; Published: 11 October 2025

ABSTRACT

The hazaribagh tanneries were relocated to Savar aimed to protect the heavily polluted Buriganga River from further contamination caused by unregulated industrial effluents. However, despite the relocation, the newly established Tannery Industrial Estate in Savar now discharges an estimated 12,000 to 15,000 cubic meters of untreated waste directly into the Dhaleshwari River each day. To evaluate the extent of soil contamination, concentrations of selected heavy metals—chromium (Cr), cadmium (Cd), copper (Cu), lead (Pb), nickel (Ni), and zinc (Zn)—were measured in the surrounding areas. Chromium (Cr), Cadmium (Cd), Copper (Cu), Lead (Pb), Nickl (Ni) and Zinc (Zn) concentration in soil samples at savar sampling area ranged from 51.20 to 9090.00 and 20.03 to 1635.00, 0.0 to 1.67 and 0.0 to 0.3, 3.40 to 54.36 and 8.28 to 50.62, 4.43 to 315.34 and 4.67 to 26.25, 7.47 to 59.33 and 14.94 to 90.12 and 7.47 to 59.33 and 14.94 to 90.12 mg kg^{-1}, in dry and wet season, respectively. The highest metal conc. was observed in main disposal point and decreasing value was observed with increasing distance in dry and wet season with significant differences among different sampling spots and in most of the cases metal concentration in soil crossed the Maximum Permissible Limits (MPL) for soil. The Pollution Load Index (PLI) values of studied zone in dry season was 0.73 i.e nearest to 1.0 which confirmed that the soils are being polluted and will be deteriorated the quality of the zone if the present situation of discharging of wastes and effluents continues at newly relocated savar tannery area.

The Central Effluent Treatment Plant (CETP) established at Savar frequently malfunctions, discharging untreated or partially treated tannery wastewater into the Dhaleshwari River. A major issue is the absence of a chrome recovery unit, resulting in the release of toxic chromium compounds. The government should enhance CETP performance by enforcing strict compliance, installing a chrome recovery unit, and ensuring regular monitoring through collaboration with academic and research institutions.

Keywords: Hazaribagh, Savar, Relocation, Heavy Metals, Pollution Load Index.

INTRODUCTION

Pollution control issues are relatively recent in Bangladesh, as the country over the last twenty years has been slowly shifting from agricultural economy to one more dependent on urban commerce and industry. The leather industry has been developing on a large scale since the 1970s and is currently worth around $1.90 bn with 40% of the total demand being met from imports (LightCastle Partners, 2019). On July 15, 2001, the Honorable High Court (HC) gave the first order to take effective measures against Hazaribagh tannery pollution as well as to shift the tanneries within one year. Until July 08, 2017, the HC failed several times to shift the Hazaribagh tanneries to Savar. The waste and effluents at newly relocated Savar Tannery Industrial Estate are discharging in the natural systems i.e. Deleswari river in most cases without any treatment and thereby causing environmental pollution especially due to heavy metals and organic toxins. The hazardous waste and effluents are generally discharged in low lying areas, along the road sides or in the vicinity of the industrial installations, creating pollution especially of heavy metals (Cr, Zn, Pb, Cd, Fe, Mn, Ni etc.) (DOE, 1991).

The new area has a CETP (Common Effluent Treatment Plant), but it is not functioning correctly since it lacks a Chrome Separation Plant (Dhaka Tribune, Dec. 26, 2018). Existing operations and CETP functionality are not monitored and there are no preparations or guidelines for solid waste management. Currently, solid waste is dumped into a field and contaminates the soil. The CEPT in Savar has the capacity to treat, if properly functional, 2500 cubic meters of waste per day (Dhaka Tribune, Dec. 26, 2018), but the tannery industries produce more than double that during the large religious festival- Eid Ul Azha.

The adjacent Dhaleshwari pollution is an indispensable issue because there is no way to refine and manage solid waste, salt and chromium. A Chinese Company working on this project has given a proposal to the Government to implement a Solid Waste Management system by 2019. Around 100 factories from Hazaribagh are still not in the list of allotment. Several factories have been continuing their operation in Hazaribagh by taking illegal power connections lines from the nearby households and from dishonest government electricity distributer (LightCastle Partners, May 27, 2019).

The worst fact is that, the pollution of the Dhaleshwari River would increase to a larger extent after Eid-Ul-Azha. Savar Tannery Park's pollution has been expanding beyond the Buriganga, Dhaleshwari and Kaliganga. While, there is no confirmation when these factories would run with proper ETP implementation. Despite the investigators continuous movement, some issues like poor planning and management, ETP limitations, employment, education and health have not been properly highlighted. Since the CETP of Savar is a biological treatment plant, its efficiency depends on the amount of waste; the time taken for modules to process; and the amount of caustic soda as well as other ingredients, which is either faulty or non-existent (BAPA, 2017; Chamon, 2023). No plans or arrangements have been made for treating salt either, so wastewater being released into the Dhaleshwari River contains a high salinity (Dhaka Tribune, Dec. 26, 2018; Chamon, 2023a).

Wastewater from industries or other sources carries appreciable amounts of toxic heavy metals such as Cd, Cu, Zn, Cr, Ni, Pb, and Mn in surface soil which create a problem for safe rational utilization of agricultural soil (Yadav *et al.,* 2002; Singh *et al.,* 2004; Chen *et al.,* 2005; Mapanda *et al.,* 2005; Luo *et al.,* 2012). Long-term use of industrial or municipal wastewater in irrigation is known to have a significant contribution to the content of trace and heavy elements such as Cd, Cu, Zn, Cr, Ni, Pb, and Mn in surface soil (Mapanda *et al.,* 2005) and crops grown close to the surrounding areas (Chamon, 2023b). As a result, excessive accumulation of trace elements in agricultural soils through wastewater irrigation may not only result in soil contamination but also affect food quality and safety (Muchuweti *et al.,* 2006; Sharma *et al.,* 2006; Sharma *et al.,* 2008).

Toxic metals are known to have serious health implications, including carcinogenesis induced tumor promotion, and hence the growing consciousness about the health risks associated with environmental chemicals has brought a major shift in global concern towards prevention of heavy metal accumulation in soil, water and vegetables (Chamon, 2023; Ahmed *et al.,* 2009; Mortula and Rahman, 2002; Rahman *et al.,* 2012). The surrounding ecosystem at Savar has been severely damaged, especially the water bodies. Fish and other organisms are barely present as the water is infected by poisonous chemicals and waste. The drains, canals and the river Dhaleswari and in the downstream the Buriganga – have lost the ability to host aquatic species (Chamon et al., 2023).

The need for the present research emerged from the results of the previous works (Chamon, *et al.,* 2005a-b). These investigations showed that tannery industrial effluents and wastes lead to significant pollution of soils, water and plants around tannery area (Chamon, *et al.,* 2005a,b).Heavy metals and trace elements are also a matter of concern due to their non-biodegradable nature and long biological half-lives. The aim of the present research work was to measure the concentration and intensity of pollution along with seasonal variation of different heavy metals around Savar tannery area using different indices such as the index of geoaccumulation (I_{geo}), contamination factor (CF), degree of contamination (CD) and pollution load index (PLI).

MATERIALS AND METHODS

Soil Sample Collection

A total of 15 soil samples were collected based on assumption of pollution intensity and types of samples around

Savar tannery area. Spots were located upstream and downstream of the Dhaleswari river started from the main solid wastes dumping site, adjacent to the CEPT. Spot 1 is considered the main disposal point and the increasing numbers of the spots indicate increasing distance from the main point mentioning upstream and downstream of the Dhaleswari river. Samples were collected twice (wet and dry season) on the basis of the local environmental conditions. The sampling spots were kept fixed throughout the whole sampling periods. Soil samples (with 3 replications) were collected from 0-15 cm depths of a profile with the help of spade. The sampling points were geo referenced with GPS (Geographical Positioning System) and marked on the map (Map 1) (Table 1).

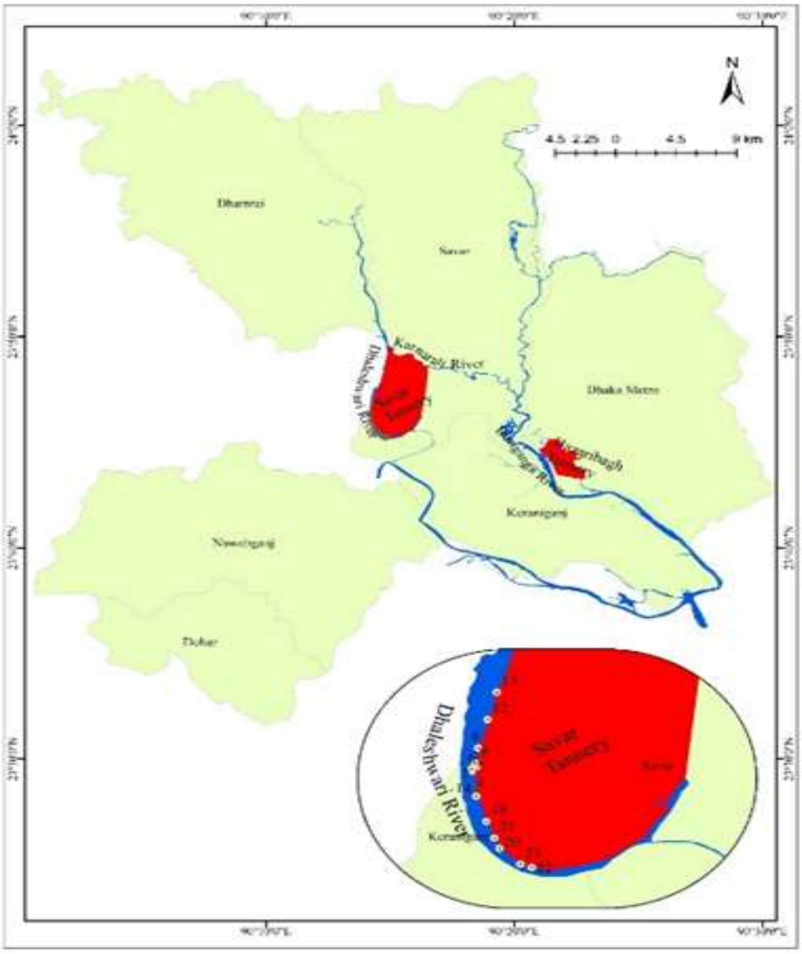
Soil Sample Preparation for Physicochemical Analysis

The soil samples collected were air dried ground and screened to pass through 2 mm sieve and then mixed thoroughly to make it a composite sample. Dry root, grasses and other substances were discarded from the sample. Each soil sample was further ground and screened to pass through 2.0 mm sieve and was used for physical and chemical analysis

Prior to measuring pH and electrical conductivity (EC), soil samples were mixed with distilled water and shaken for 30 minutes using a shaking plate. The pH and EC were then measured using a portable multiparameter meter (Model: Sense Ion 156, HACH, USA). The organic matter (OM) content of the sediment samples was determined using the wet oxidation method described by Walkley and Black (1934).

Table 1. Soil Sampling Points Description in Dry and Wet Season

Point No	Soil sampling points Details
1	Source Point/ solid waste dumping site 1
2	Source Point/ solid waste dumping site 2
3	Effluent from solid wastes near river bank
4	Effluent directly mixing with river water
5	Effluent disposal point near ETP Pipe
6	Near ETP disposal pipe
7	Agri. land near ETP disposal pipe
8	0.5km up stream from ETP disposal point
9	1km up stream from ETP disposal point
10	0.5km down stream from ETP disposal point 1
11	0.5km down stream from ETP disposal point 2
12	0.5km down stream from ETP disposal point 3
13	1km down stream from ETP disposal point
14	1.5km down stream from ETP disposal point
15	2km down stream from ETP disposal point



Map 1. Sample collection points in dry and wet season around Savar Tanneries

A total of 15 soil samples were collected based on assumption of pollution intensity and types of samples around Savar tannery area. Spots were located upstream and downstream of the Dhaleswari river started from the main solid wastes dumping site, adjacent to the CEPT. Spot 1 is considered the main disposal point and the increasing numbers of the spots indicate increasing distance from the main point mentioning upstream and downstream of the Dhaleswari river. Soil samples were digested with HCl:HNO_3 (3:1), mixture in closed systems. Then the samples were cooled to room temperature and filtered by Whattman No.1 filter paper. Cr, Cd, Cu, Zn and Pb concentration were measured in the extracts by Atomic Absorption Spectroscopy (AAS) (Blum *et al.* 1996) after calibrating with the chemical standard solution.

Assessment of Soil Quality

To evaluate the pollution status of river sediments, several indicators were calculated, including the Contamination Factor (CF), Degree of Contamination, Index of Geo-Accumulation (Igeo), and Pollution Load Index (PLI). Additionally, the physicochemical properties and concentrations of selected heavy metals in the sediments were analyzed to assess overall sediment quality.

Index of Geoaccumulation (I_{geo})

The index of geoaccumulation (I_{geo}) actually enables the assessment of contamination by comparing the current and pre-industrial concentrations originally used with bottom sediments (Muller, 1969); it can also be applied to the assessment of soil contamination.

The geoaccumulation index (Igeo) values were calculated for different metals as introduced by Muller (1969) is as follows: Where, Cn is the measured concentration of element n in the sediment and Bn is the geochemical background for the element n which is either directly measured in precivilization sediments of the area or taken from the literature (average shale value described by Turekian and Wedepohl, 1961). The factor 1.5 is introduced to include possible variations of the background values). The method assesses the degree of metal pollution in terms of seven enrichment classes (Table 2) based on the increasing numerical values of the index. It is computed using the following Equation as:

$$I_{geo} = \log_2\left\{\frac{Cn}{1.5Bn}\right\}$$

Where, C_n is the measured concentration of the element in the pelitic sediment fraction (<2 µm) and B_n is the geochemical background value in fossil argillaceous sediment (average shale). The constant 1.5 allows us to analyze natural fluctuations in the content of a given substance in the environment as well as very small anthropogenic influences.

In the present paper we applied the modified calculation based on the equation given in (Taylor and Mclennan, 1995), where C_n denoted the concentration of a given element in the soil tested, while B_n denoted the concentration of elements in the earth's crust (Taylor and Mclennan, 1995). For some elements like As, Hg and Sb the average concentration in the Earth's crust is much higher than the average concentration in the shale accepted by Muller (1969) as a reference value. Here the focus is between the concentration obtained and the concentration of elements in the Earth's crust, because soil is a part of the layer of the Earth's crust and its chemical composition is related to that of the crust.

Table 2. Index of geoaccumulation (I_{geo}) for contamination levels in soil (Muller, 1981).

I_{geo} Class	I_{geo} Value	Contamination Level
0	$I_{geo} \leq 0$	Uncontaminated
1	$0 < I_{geo} < 1$	Uncontaminated/moderately contaminated
2	$1 < I_{geo} < 2$	Moderately contaminated
3	$2 < I_{geo} < 3$	Moderately/strongly contaminated
4	$3 < I_{geo} < 4$	Strongly contaminated
5	$4 < I_{geo} < 5$	Strongly/extremely contaminated
6	$5 < I_{geo}$	Extremely contaminated

Contamination Factor : The contamination factor (CF) is the ratio obtained by dividing the measured concentration of individual metal in the soil by the background value given by Turekian and Wedepohl (1961) and the CF for single metal was calculated by the following formula (Tomilson *et al.*, 1980):

CF = Measured metal concentration (C_m)/ Background concentration of the metal (B_m)

Hakanson (1980) demonstrated 4 grade ratings of soil in relation to CF values such as low (CF <1), moderate (1 ≤ CF <3), considerable (3 ≤ CF <6), and very high (CF ≥ 6) as given in Table 3.

Table 3. Different contamination factor (CF) for soil (Hakanson, 1980).

Value	Contamination Factor level/Soil Ratings Grade
C < 1	Low contamination factor indicating low contamination

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue XIV September 2025 | Special Issue on Management

$1 \leq C < 3$	Moderate contamination factor
$3 \leq C < 6$	Considerable contamination factor
$6 \leq C$	Very high contamination factor

Contamination Degree (CD): The contamination degree (CD) for each point was calculated as sum of all CF (Ahdy and Khaled, 2009) and was assessed using following equation:

$$\mathbf{CD} = \sum_{1}^{n} \boldsymbol{CF}$$

Moreover, Tomilson *et al.* (1980) stated 4 classes of soil depend on the CD levels, such as CD <6(low), 6 ≤ CD <12(moderate), 12 ≤ CD <24(considerable), and CD ≥ 24(very high). The CD is aimed at providing a measure of the degree of overall contamination in surface layers in a particular sampling site. The CD was divided into four groups as given in Table 4.

Table 4. Different Classes of soil based on Degree of Contamination (CD) level (Tomlinson *et al.,* 1980).

CD level	**Soil Class based on CD Level**
CD < 6	Low
6 ≤ CD < 12	Moderate
12 ≤ C < 24	Considerable
CD ≥ 24	Very high degree of contamination

Pollution Load Index (PLI)

The pollution load index (PLI) proposed by Tomlinson *et al*. (1980) has been used in this study to measure PLI in sediments of Tsurumi River. The PLI for a single site is the *n*th root of *n* number multiplying the contamination factors (CF values) together. The CF is the quotient obtained as follows:

$$\mathbf{CF} = \mathbf{C}_{\text{Metal concentration}} / \mathbf{C}_{\text{Background concentration of the same metal}}$$

The pollution load index (PLI) was proposed by Tomlinson *et al*. (1980) for detecting pollution which permits a comparison of pollution levels between sites and at different times. The PLI was obtained as a concentration factor of each heavy metal with respect to the background value in the soil. In this study, the world average concentrations of the metals studied reported for shale (Turekian and Wedepohl, 1961) were used as the background for those heavy metals. According to Angula (1996), the PLI is able to give an estimate of the metal contamination status and the necessary action that should be taken. A PLI value of ≥100 indicates an immediate intervention to ameliorate pollution; a PLI value of ≥50 indicates a more detailed study is needed to monitor the site, whilst a value of <50 indicates that drastic rectification measures are not needed. The formulas applied are as the following Equation:

$$\textbf{PLI for a Site} = \sqrt[n]{\textbf{CF1 x CF2 x CF3} \ldots \ldots \ldots \textbf{X CFn}}$$

And such site indices can be treated in exactly the same way to give a zone or area index. Therefore,

$$\textbf{PLI for a Zone} = \sqrt[n]{\textbf{Site1 x Site2 x Site3} \ldots \ldots \ldots \textbf{X Site n}}$$

Where, n equals the number of contamination factors and sites, respectively.

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue XIV September 2025 | Special Issue on Management

The pollution load index (PLI) for assessing estuarine quality as proposed by Tomlinson *et al*. (1980) is given below (Table 5) which can also be used for the assessment of **soil Pollution Load Index** as reported by Tusher *et al.* (2017):

Table 5. Pollution Load Index (PLI) level (Tomlinson *et al.*, 1980)

PLI level	Eestuarine quality Level
PLI = 0	Perfection
PLI = 1	Baseline level of Pollutants Presence
PLI > 1	Progressive Deterioration of Estuarine Quality

Statistical Analysis

The results of the experiment were statistically evaluated by using ANOVA (Analysis of Variance) and Duncan's Multiple Range Test in IBM SPSS statistics version 20 as outlined by Gomez and Gomez (1984). The letter was used for testing the significance of differences between mean values. The 0.05 level of probability was chosen for the statistical judgment.

RESULTS AND DISCUSSION

Physicochemical properties of soils: Generally, a loamy-clay to Silty loam, red colored soil is the dominant types of soil in the savar region. The study area belongs to Dhamrai (Normal soil) and Melandoho (Contaminated soil from savar) (SRDI, 2017) soil series. Physical, chemical and physicochemical properties of the Dhamrai and Melandoho (SRDI, 1995) soil series are given in Table 6 and Table 7.

Table 6: Physical, chemical and physicochemical properties of the studied Dhamrai (Asma 2018) and Melandoho soils (SRDI 1995)

(a) Physical properties	Dhamrai	Melandoho
Land type	Med. Low	MH
AEZ	9	9
Cropping patterns	R-F-F	R-F- R
1. Moisture percentage	29.72%	
2. Particle size distribution		
Sand	14.89%	21%
Silt	66.87%	63%
Clay	18.24%	16%
3. Textural class	Silty loam	
(b) Chemical and Physicochemical Properties		
1. pH (Soil: water = 1: 2.5)	5.5-7.1	5.5-7.6

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue XIV September 2025 | Special Issue on Management

2. EC	22.4 uS	--
3. % OC	1.67	0.988
4. Organic matter	2.92%	1.70%
5. Total N	0.19 %	0.093%
6. Total P (µg/mg soil)	16	35
7. Total K (meq/100g soil)	0.45	0.41
8. Total S (meq/100g soil)	72	49
9. Total Ca (meq/100g soil)	10.4	8.9
10. Total Mg (meq/100g soil)	2.94	2.48
11. Total Ni (mg/kg)	30	-
12. Total Cu (µg/mg soil)	13	9.4
13. Total Fe (µg/mg soil)	368	338
14. Total Mn (µg/mg soil)	87.0	45.3
15. Total Zn (µg/mg soil)	3.0	2.7
14. Available N	0.013%	-
15. Available P	1.4 ppm	-
16. Available K	0.006%	-
17. Available S	0.006%	-
18. Available Ca	0.002%	-
19. Available Mg	0.015%	-
20. CEC (meq/100g soil)	34.8	25.4

Table 7. Physical, Chemical and physicochemical properties of soils collected from different points.

Spot No	% Moisture	pH	Textural Class	EC (dS/m)	OM%
1	25.2	8.26	Silt Loam	6.7	11.6
2	23.12	7.7	Silt Loam	6.2	10.8
3	22.5	7.32	Silt Loam	4.5	9.10
4	18.12	7.72	Silt Loam	3.8	7.68
5	21.5	6.21	Silt Loam	3.9	4.90

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue XIV September 2025 | Special Issue on Management

6	23.42	7.06	Clay Loam	3.5	3.80
7	22.5	7.72	Clay Loam	3.7	2.92
8	19.12	7.21	Silt Loam	3.3	2.13
9	27.5	7.06	Silt Loam	3.5	1.80
10	24.40	7.04	Silt Loam	3.8	1.72
11	22.2	7.7	Silt Loam	2.9	1.80
12	25.12	7.7	Silt Loam	2.5	1.75
13	22.5	7.32	Silt Loam	2.8	1.55
14	17.12	7.72	Clay Loam	3.6	1.67
15	27.5	7.21	Clay Loam	4.53	1.83
Wet Season					
1	36.5	8.03	Silt Loam	6.2	10.2
2	35.12	7.47	Silt Loam	5.8	7.63
3	36.2	7.56	Silt Loam	4.1	5.90
4	28.9	7.87	Silt Loam	4.2	3.90
5	29.6	6.95	Silt Loam	3.7	2.92
6	22.6	7.25	Clay Loam	3.2	2.13
7	35.12	7.87	Clay Loam	2.9	1.80
8	26.2	6.45	Silt Loam	2.5	1.72
9	28.9	7.25	Silt Loam	2.4	1.80
10	32.2	7.23	Silt Loam	3.7	1.75
11	34.12	7.47	Silt Loam	3.2	1.55
12	35.5	7.56	Silt Loam	3.7	1.67
13	28.9	7.87	Silt Loam	3.2	1.11
14	29.6	6.05	Clay Loam	2.9	0.98
15	21.6	7.25	Clay Loam	3.78	1.10

A breach in the embankment of a pond, used by the Central Effluent Treatment Plant (CETP) for dumping solid waste generated by the Savar Tannery Industrial Estate, is likely worsening the pollution levels in Savar (The Daily Star, 2018), as currently, the accumulated solid waste generated in the last one year remains dumped at a

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue XIV September 2025 | Special Issue on Management

pond at the boundaries of the tannery estate. Due to a breach in the embankment, the waste is now seeping into the river. About the solid waste dumping station, Mostafa said the breached embankment was repaired many times but it broke because of heavy rains (Dhaka Tribune, Dec. 26th, 2018). Locals alleged that untreated solid wastes from the temporary dumping station were mixing with river water used by people for bathing and washing clothes. Though the dumping ground was enclosed by a high embankment, it was broken. An official from the DoE said their tests showed that the quality of water reduced dramatically since the tannery factories began operation. A sickening stench hung heavy in the air in the area where the waste was dumped when the correspondents visited the spot (Dhaka Tribune, Dec. 26th, 2018).

Moisture content, pH, Texture, Organic matter and EC (Electrical Conductivity)

Soil characteristics of the savar tannery area are presented in Table 7. The moisture content (%) of the soil at various sampling points were ranging from 17.12 to 27.5 and 21.6 to 36.5 % respectively, in dry season and wet season. The pH did not vary appreciably between sampling points, ranging from 6.21 to 8.26 and 6.05 to 8.03 in dry and wet season, respectively (Table 7). A wide range of pH from 7.2 to 12.0 and 7.3 to 9.9 were observed by Nuruzzaman *et al.,* (1998) in tannery effluents and waste water. This may be due to buffering capacity of these soils containing high amounts of organic matter. Various tanning and coloring materials are mainly responsible for wide range of pH variation. The soil series of the savar study area belongs to Dhamrai and Melandoho soil series and there were no noticeable differences in particle size fraction as well as sand, silt and percentage between the wet and dry season of soil samples (Table 7) The texture of the collected soil samples were mainly silt loam/clay loam as presented in Table 6&7.

Higher organic matter content (%) was observed at various sampling points of savar tannery study area. The organic matter content (%) in various sampling points were ranging from 1.55 to 11.6 and 1.10 to 10.2, in dry season and wet season (Table 22). In dry season maximum accumulation of tannery wastes was observed at sampling point 1 (OM-11.6 %) and gradually decreasing values were observed from source point 1 to downstream from the source point. Same findings were also observed in wet season where highest value of organic matter was observed at the source point i.e at the sampling point 1 (10.2%). Nuruzzaman *et al.* (1998) reported a value of organic matter (%) of 10.3% at source point of Hazaribagh tannery area. Deposition and decomposition of huge quantities of tannery effluents and solid wastes are mainly responsible for the organic matter content of the soil. Higher EC means higher amounts of soluble Na, Ca and Mg. Electrical Conductivity greater than 4 dS/m is harmful for plant growth (Stomberg *et al*. (1984). The EC (dS/m) in various sampling point were ranging from 2.5 to 6.7 and 2.4 to 6.2 dS/m respectively, in dry season and wet season (Table 7). Higher values of EC at Hazaribagh tannery area also reported before by many authors (Nuruzzaman *et al.,* 1998; Chamon *et al.,* 2005a).

Seasonal Variation in Heavy Metal Concentration in Soils

Chromium (Cr) concentration in soil: Chromium (Cr) concentration in soil at savar sampling area ranged from 51.20 to 9090.00 and 20.03 to 1635.00 mg kg^{-1} respectively, in dry and wet season (Figure 1). Highest Cr conc. was observed in main disposal point i.e. at spot 1 and decreasing value was observed with increasing distance in dry and wet season with significant differences among different sampling spots. Similar results were also observed in wet season.

Chamon *et al., (*2005b) reported higher Cr concentration at Hazaribagh area. Similar findings were also reported by many authors. 59,333.33 mg kg^{-1} of Cr concentration in soil was reported by Elahi *et al*. (2010). Increasing values of Cr concentration at Hazaribagh tannery area were also observed by Mondol *et al.* (2018) (95,513.87 and 63,413.09 mg kg^{-1} in dry season and wet season). Comparative lower value of Cr was observed at the same sampling point in wet season. Lower value of Cr may be observed due to dilution of Cr in soil by rain water.

Higher Cr concentration may be occur due to use of higher amount chromium sulphate ($[Cr(H_2O)_6]_2(SO_4)_3$), regarded as one of the most efficient and effective tanning agent, during liming, pickling and curing stage. Huge amount of Cr phosphate also used at liming process of hides & skins stage in order to remove the hairs, nails and other keratinous matters and remove the natural grease and fats (Asia, 2012).

Cr concentration found in 11 sampling points in dry and 3 sampling points in wet season crossed the MAC (Maximum allowable concentration) for soil (100 mg/kg) (Kloke, 1980) (Table 23) in this study.

It was evident that very high level of Cr were found in spot 1 which serves as a settling basin and gradually concentration went down with increasing distance of spots from spot 1. But again high concentration was noted in spot 15 (Figure 1) because of new establishment of tannery industries and open dumping of tannery as well as city wastes and effluents on that site. There were also some brick kiln industries and marine ship breaking activities were going on at spot 15 of the study area during this period.

In both seasons the waste water is flushed out into the Dhaleswari river, causing pollution of the river water and ultimately affecting the aquatic flora and fauna. Likewise the dumping of the solid wastes is seriously affecting the soil and plants, besides vitiating the air, ground water and human health (Immamul Huq, 1998).

The sludge dewatering house has no impact as the electro-mechanical part is yet to be installed at savar. The electrical control cabinet is waiting to be imported from China, reported by tannery estate officials *(*The Daily Star, August 03, 2019*)*. Besides, three chromium recovery units, with a treatment capacity of 350 cubic meters each, still cannot recover the contaminating chemical. According to experts, a partially completed CETP has little effect in tannery waste management as well as protecting the environment (The Daily Star, August 03, 2019).

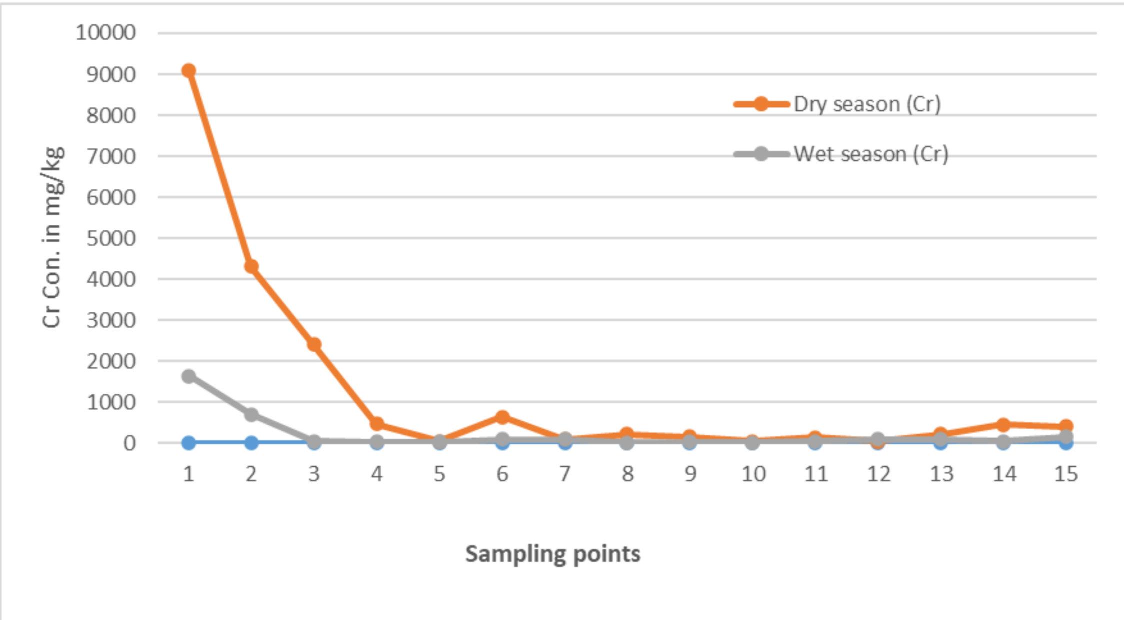


Figure 1. Seasonal variation in Chromium (Cr) concentration in soil at newly relocated Savar tannery area (Dry and wet season).

Cadmium (Cd) concentration in soil: Cadmium (Cd) concentration in soil at savar sampling area ranged from 0.0 to 1.67 and 0.0 to 0.3 mg kg^{-1} respectively in dry and wet season (Table 8). The highest Cd concentration was observed beside agricultural land where Bottle Gourd was cultivated during sampling i.e. at spot 7, where effluent are discharged from CETP and the land is irrigated with the effluents and decreasing value was observed with increasing distance. Significant differences were found among different sampling spots except some sampling spot during dry season. The case was difference in case of wet season. No Significant differences were observed among sampling points (Table 8). The tests of significance of different sampling point were calculated by DMRT at 5% level.

Lower value of Cd concentration that observed at wet season may be occurred due to dilution of Cd of soil by rain water.

Cd concentration in the studied spots were below the MAC (Maximum Allowable Concentration for soil (3.00 mg/kg) (Kloke, 1980) value though huge amount of cadmium sulphate are used during curing and finishing stage. Huge amount of cadmium phosphate also used. Both cadmium sulphate and cadmium phosphate are used to polish the hide and skin (Asia, 2012).

Copper (Cu) concentration in Soil: Copper (Cu) concentration in soil at savar sampling area ranged from 3.40 to 54.36 and 8.28 to 50.62 mg kg^{-1} respectively, in dry and wet season (Table 8). Highest Cu concentration was observed 1.5 and 2 km downstream i.e. at spot 14 and 15. Increasing value was observed with increasing distance from CETP to downstream in both seasons. Significant differences were found among different sampling spots. The tests of significance of different sampling point were calculated by DMRT at 5% level. Copper (Cu) concentration was found zigzag in most of the spots in dry season and wet season and were below the MAC value of elements in agricultural soils (100 mg kg^{-1}) (SEPA, 2005).

Zigzag value of Cu that was observed at wet season may be occurring due to dilution of Cu of soil by rain water, carrying copper from other industrial installations. Copper (Cu) concentration at all sampling points (both in dry and wet season) did not cross the MAC (Maximum allowable concentration) for soil (100 mg/Kg) (Kloke, 1980).

Table 8. Heavy metal concentrations in both in dry and wet season

	Season							
Point	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
No	**Cd**		**Cu**		**Ni**		**Zn**	
1	0.00 a	0.0001 a	12.33 d	24.94 d	59.33 e	17.45 a	253.00 c	92.51 g
2	0.19 ab	0.05 a	9.70 c	16.58 b	14.39 abc	22.77 a	38.38 ab	48.25 b
3	0.18 ab	0.0001 a	3.40 a	19.03 bc	7.47 a	21.93 a	18.45 a	74.75 de
4	0.00 a	0.05 a	30.00 f	22 cd	23.67 abcd	90.12 b	101.00 ab	80.96 f
5	0.19 ab	0.3 a	17.14 e	34.55 e	22.27 abcd	37.75 ab	60.39 ab	67.26 c
6	0.00 a	0.0001 a	28.33 f	19.03 bc	49.67 de	21.93 a	159.00 bc	74.75 de
7	1.67 d	0.3 a	28.33 f	20.35 bc	49.33 de	20.38 a	448.33 d	70.71 cd
8	0.15 ab	0.0001 a	6.56 b	11.73 a	12.37 ab	19.77 a	37.54 a	47.86 b
9	0.15 ab	0.0001 a	45.38 h	8.275 a	37.58 abcde	14.94 a	92.87 ab	33.40 a
10	0.42 bc	0.2 a	37.64 g	11.73 a	36.56 abcde	19.77 a	122.10 ab	47.86 b
11	0.15 ab	0.22 a	44.62 h	34.55 e	41.75 bcde	37.75 ab	92.32 ab	67.26 c
12	0.53 c	0.25 a	37.20 g	35.35 e	33.65 abcde	44.57 ab	121.26 ab	73.14 de
13	0.27 abc	0.05 a	44.24 h	40.88 f	38.18 abcde	38.75 ab	88.53 ab	77.78 ef
14	0.29 abc	0.05 a	54.36 j	49.19 g	44.39 cde	48.15 ab	100.31 ab	89.22 g
15	0.18 ab	0.0001 a	51.11 i	50.62 g	43.59 bcde	52.1 ab	96.28 ab	92.45 g

Means with the same letter (s) in a column do not differ significantly from each other at 5% level by DMRT.

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue XIV September 2025 | Special Issue on Management

Lead (Pb) concentration in Soil: Lead (Pb) concentration in soil at sampling area ranged from 4.43 to 315.34 and 4.67 to 26.25 mg kg^{-1} respectively, in dry and wet season (Fig. 2). Highest Pb concentration was observed in spot 9 (1 km upstream from CETP), which crossed the MAC (Maximum allowable concentration) for soil (100 mg/Kg) (Kloke, 1980). Pb concentration in Spot 7 was also exhibited higher (128.33 mg kg^{-1}) value than MAC value (100 mg/Kg) (Kloke, 1980) and decreasing value was observed with increasing distance. Significant differences were found among different sampling spots. The case was different in case of wet season. Significant differences were observed among sampling point (Fig. 2). The tests of significance of differences at of different sampling points were calculated by DMRT at 5% level.

Comparative lower value of Pb was observed at the same sampling point in wet season due to dilution of Pb in soil by rainfall. Lead (Pb) concentration at two sampling points in dry season crossed the MAC (Maximum allowable concentration) for soil (100 mg/kg) (Kloke, 1980). 44.2 and 68.1 mg kg^{-1} of Pb concentration in soil was reported by Ullah *et al.* (1999) and Nuruzzanman *et al*. (1998) at Hazaribagh Tannery area.

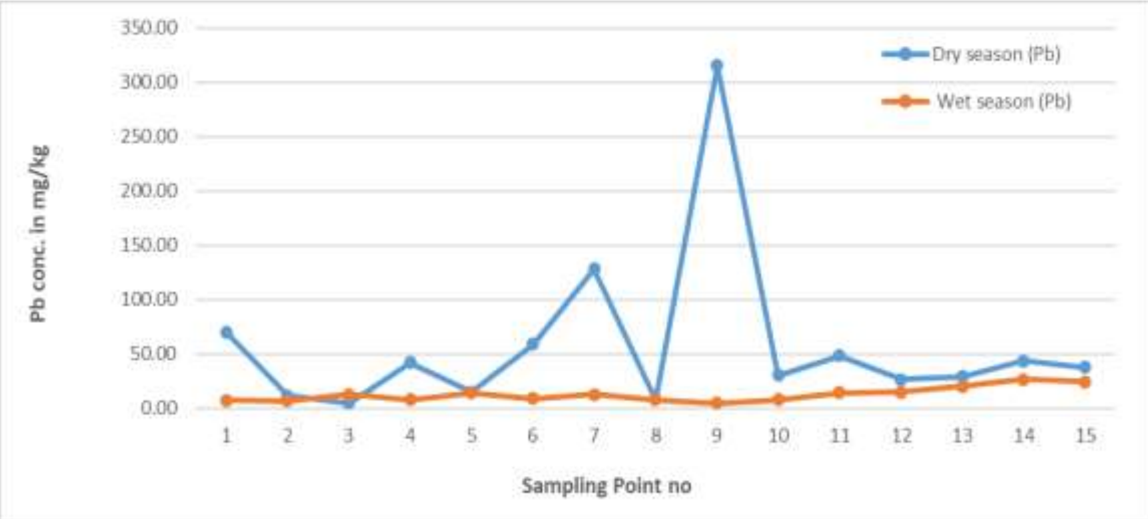


Figure 2. Seasonal variation in lead (Pb) concentration in soil at newly relocated Savar tannery area

Assessment of Soil Contamination/Pollution Risk

The present work assessed the heavy metal contamination of the soil of the study area in the close vicinity of the newly relocated savar tannery area in both dry and wet seasons using different indices *viz*.,

- **Index of geoaccumulation (I_{geo}),**
- **Contamination Factor (CF),**
- **Contamination Degree (CD), and**
- **Pollution Load Index (PLI).**

Samples were collected from the surface layer of soil and analyzed by Atomic Absorption Spectrophotometer (AAS).

Index of geoaccumulation (I_{geo}) : Average I_{geo} and contamination levels of different soil are given in Fig. 3 which represents the sampling point wise I_{geo} value in two seasons. I_{geo} is distinctly variable and suggests that soil around the study area ranged from uncontaminated to strongly/extremely contaminated with respect to the analyzed metals. I_{geo} revealed that all the samples examined in both seasons in respect of Cr fell into class 0—extremely contaminated in dry season and class 0—strongly contaminated in wet season (Fig. 3a).

I_{geo} values for Cd in the dry season ranged from −0.6 to 1.9 and fell into class 0—moderately contaminated but in wet season all the samples fell into I_{geo} class 0 i.e. uncontaminated (Fig. 3b). Increasing Cd concentration in dry season might be related to industrial activity, atmospheric emission and deposition of organic and fine grain sediments (Khan *et al.,* 1992; Mohiuddin *et al.,* 2010). Other probable sources of Cd include leacheates from defused Ni-Cd batteries and Cd plated items (Stoeppler, 1991).

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue XIV September 2025 | Special Issue on Management

I_{geo} revealed that all the samples examined in both seasons in respect of Cu fell into class 0—uncontaminated in both season (Fig. 3c). I_{geo} values for Cu in the dry season ranged from −2.74 to 1.28 with a mean value of 0.31 and most of the samples in both seasons fell into class 1 of uncontaminated to moderately contaminated was also reported (Rahman *et al.,* 2012).

I_{geo} for Pb in dry season is distinctly variable and suggests that soils around the study area ranged from uncontaminated to strongly contaminated with respect to the analyzed Pb metal concentrations but in wet season all the samples fell into I_{geo} class 0 i.e. uncontaminated (Fig. 3d).

During the dry and wet season I_{geo} for Cr and Pb belong to moderately/strongly contaminated. This high index is caused mainly by the tannery/metallurgical industries; hence its content in the areas affected by industrial activity may be elevated. In the wet season, Cr showed an uncontaminated state, but uncontaminated/moderately contaminated in the dry season was also reported (Rahman *et al.,* 2012). A similar trend to was also found for Pb concentration (Mohiuddin *et al.,* 2010; Rahman *et al.,* 2012).

Lead (Pb) is considered as a good indicator of pollution by urban run-off water. The use of leaded gasoline has been mainly responsible for the Pb pollution load during the 20th century in urban area (Mukai *et al*., 1994). In Japan from 1980s addition of Pb to gasoline was forbidden but still now main source of Pb is considered to be fuel even if other origins are taken into account (Legret and Pagotto, 1999).

I_{geo} of Zn in the dry season was ranged from class 0 (uncontaminated) to 2 (moderately contaminated) but in wet season all soils fell to I_{geo} class 0 (Table 28). Nickel (Ni) followed uncontaminated index over two seasons (Table 28). Average concentration of metals during the dry season in the surface layer of the soil is higher than that in the wet season. A similar trend was also found for Ni at savar area was reported earlier (Rahman *et al.,* 2012).

The Daily star (April 28, 2016) reported that much of industrialization in Savar are based on the river and canals with the continuously adherence to waste, color of water and soil of those rivers and canals have been changed. DoE (1991) reported industrial until in Savar, Ashulia and Amin bazar are the sources of pollution.

Kifan *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.

Elahi (2010) 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 (Chamon et al., 2005ab).

Fig. 3 (a-d). Index of Geoaccumulation (Igeo) values of soils around the study area

Contamination Factor (CF) level of soils of the study area

CF for Chromium (Cr) & Cadmium (Cd) in dry and wet season: The assessment of the overall contamination of the studied area soil was based on Contamination Factor (CF) level. In the dry season, the soil was classified as very highly contaminated to low contamination in both seasons with Cr but for Cd, CF level ranged from low to considerable and low to moderate contamination level in dry and wet season, respectively (Fig. 4).

The maximum values of the contamination Factor (CF) level denoted very high contamination for Cr, Cu and Pb and low contamination level for Zn and Ni in dry season (Fig. 4). In the wet season except for Cr, Cu, Pb and Cd, the contamination factor of all other metals decreased. However, there was a very limited change in the overall scenario. Cr was additionally added to the first category, Cd shifted from a slightly contamination to moderately contamination factor and Cr fell into the highly contaminated group.

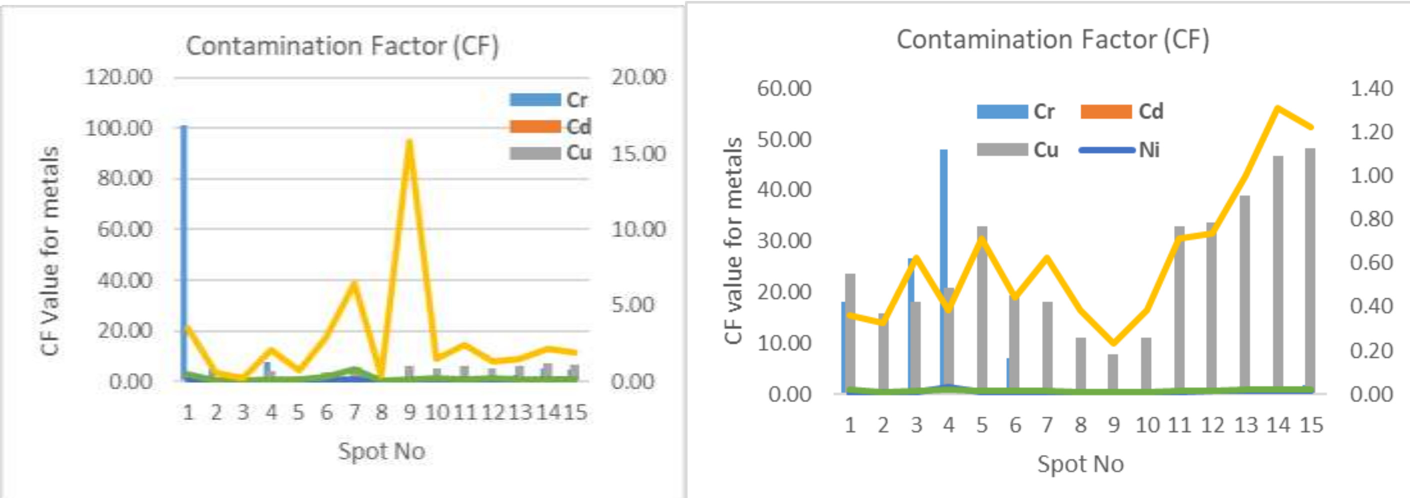


Fig. 4. Contamination Factor (CF) level of soils of the study area

Contamination Factor (CF) for Ni, Zn, Cu & Pb in dry and wet season: According to Contamination Factor (CF) level, soil in the close vicinity of the Dhaka Export Processing Zone (DEPZ) in both dry and wet seasons was classified as moderately contaminated with Zn, Cr, Pb and Ni, considerably contaminated with Cu and highly contaminated with As and Hg, reported by Rahman *et al.* (2012). The general trend of the mean CF was Hg > As > Cu > Zn > Ni > Cr > Pb > Fe > Mn > Cd and As > Hg > Cu > Cd > Zn > Ni >Pb > Fe > Mn in dry and wet seasons, respectively (Rahman *et al*., 2012). Because of heavy rainfall, dilution and other run-off during the wet season, metals from the upper layer of the soil were flushed out to some extent through the canal into the adjoining vast flood zone and hence all the indices values were lower in this season compared to the dry season.

Contamination Degree (CD): The maximum CD value was found 108.31 at spot 1 i.e solid wastes dumping site 1 whereas the minimum CD (1.78) was found at spot 3. The CD values for all metals in all points over the all sites were found higher than 6 to lower than 24 which indicated moderate to considerable level of contamination apart from the spot 1, might be due to the receiving of extensive amount of Tannery, municipal and industrial waste water in the study areas (Table 9).

Assessment of Pollution Load Index (PLI): The pollution load index (PLI) proposed by Tomlinson *et al.* (1980) has been used in this study to measure PLI in soils of the study area. The PLI for a single site is the *n*th root of *n* number multiplying the contamination factors (CF values) together. The PLI values indicated immediate intervention to ameliorate pollution in both seasons. The CD and PLI values of the soil is given in Table 9 provides a simple, comparative means for assessing a site quality: a value of zero (0.0) indicates perfection, a value of one (1.0) indicate only baseline levels of pollutants present and values above one > 1.0) would indicate progressive deterioration of the site and estuarine quality (Tomlinson *et al*., 1980). PLI values of soils of the studied region ranged from 0.22-2.08 and 0.07-1.09 in dry and wet season (Table 9). The PLI values of studied zone in dry season was 0.73 i.e nearest to 1.0 which confirmed that the soils are being polluted and

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue XIV September 2025 | Special Issue on Management

will be deteriorated the quality of the zone if the present situation of discharging of wastes and effluents continues at newly relocated savar tannery area. On the other hand the PLI values of the studied zone in wet season was 0.33 i.e <1.0 indicate only baseline levels of pollutants present, were lower in this season compared to the dry season, because of dilution (Table 9 and Fig 5).

However, the PLI of the zone or total area of the downstream of Dhaleshwari River was also increasing day by day, indicating that Cr, Cu, Pb, Cd, Ni and Zn were the major 6 pollutants. The PLI can provide some understanding to the public of the area about the quality of a component of their environment, and indicates the trend over time and area. In addition, it also provides valuable information and advice for the policy and decision makers on the pollution level of the area.

Zn and Cr are heavy metals and their sources in industrial locations are usually anthropogenic (Mondol *et al.,* 2018). The main anthropogenic sources of Zn are related to the non-ferric metal industry and agricultural practice (Kabata-Pendias, 2000). The Cr content of topsoil is known to increase due to pollution from various sources of which the main ones are attributable to industrial wastes such as Cr pigment and tannery wastes, electroplating sludge, leather manufacturing wastes, and municipal sewage sludge *etc*. Cr behavior in soil is controlled by soil pH and redox potential, while long term exposure to Cr can cause liver and kidney damage (Rahman *et al.,* 2012). The observed Zn and Cr concentrations in studied soil around tannery areas, savar, probably comes from tannery industries and construction materials in the form of alloys for protective coating for iron and steel. These metals are also used in the industries of DEPZ pigment and reducing agents; cotton processing, soldering and welding flux; rubber industry, glass, enamels, plastics, lubricants, cosmetics, pharmaceuticals, agents for burns and ointments (Ahmed *et al.,* 2011). Both (Zn and Cr) metals were unevenly distributed in the DEPZ area was reported by Ahmed *et al.* (2011). Zinc and Cr showed higher concentration in a similar area according to Ahmed and Gani (2010).

As soil is an important constituent of the human biosphere, any harmful change to this segment of the environment seriously affects the overall quality of human life. The most adverse effect of heavy metals is that they can be introduced into the food chain and threaten human health. Agricultural products growing on soils with high metal concentrations are represented by metal accumulations at levels harmful to human and animal health as well as to the bio-environment. The impact of anthropogenic heavy metal contamination on agriculture soil around Savar tannery area was evaluated in this study using seasonal variation and indices.

All the indices more or less revealed that the study area was seriously affected by different metals. Dry seasons resulted in some multi-fold higher values of the overall indices (Fig. 5). To evaluate seasonal effects, concentrations and indices (CF, CD, PLI) were compared between dry and wet seasons using two-way ANOVA (Season, Spot) with effect sizes and 95% CIs; results showed significant season main effects for Cr, Pb, Zn, and Ni with lower wet-season values consistent with dilution. Per-spot paired comparisons (dry vs wet) and fold-changes confirmed the largest seasonal shifts at Spots 1 and 4 near discharge points, aligning with operational hydrology".

Table 9. Contamination Degree (CD) and Pollution Load Index (PLI) for a Site/ studied zone

Spot no	**Dry Season**			
	Contamination Degree (CD) (Abdy and Khaled, 2009; Tusher et al., 2017)	**Soil Class according to the CD level** (Tomlinson *et al.,* 1980; Tusher *et al.,* 2017)	**PLI value for a site**	**Soil Quality Acccording to PLI for a site** (Tomlinson *et al.,* 1980)
1	108.31	CD ≥ 24 (Very high)	0.65	PLI>0 to<1 indicates baseline levels of pollutants present
2	7.37	6≤ CD<12 (Moderate)	0.57	

3	1.78	CD < 6 (Low)	0.22	PLI>0 to<1 indicates baseline levels of pollutants present PLI>0 to<1 indicates baseline levels of pollutants present PLI>0 to<1 indicates baseline levels of pollutants present PLI>0 to<1 indicates baseline levels of pollutants present PLI>0 to<1 indicates baseline levels of pollutants present PLI>1 indicates progressive deterioration of the site PLI>0 to<1 indicates baseline levels of pollutants present PLI>1 indicates progressive deterioration of the site PLI>0 to<1 indicates baseline levels of pollutants present PLI>1 indicates progressive deterioration of the site PLI>0 to<1 indicates baseline levels of pollutants present PLI>1 indicates progressive deterioration of the site
4	11.96	6≤ CD<12 (Moderate)	0.33	
5	3.02	CD < 6 (Low)	0.48	
6	7.05	6≤ CD<12 (Moderate)	0.30	
7	19.10	12≤ CD<24 (Considerable)	2.08	
8	4.14	CD < 6 (Low)	0.41	
9	20.56	12≤ CD<24 (Considerable)	1.40	
10	5.26	CD < 6 (Low)	0.80	
11	8.29	6≤ CD<12 (Moderate)	1.25	
12	5.88	CD < 6 (Low)	0.90	
13	7.26	6≤ CD<12 (Moderate)	1.09	
14	11.04	6≤ CD<12 (Moderate)	1.43	
15	9.90	6≤ CD<12 (Moderate)	1.25	
Spot no	Wet Season			
1	20.31	12≤ CD<24 (Considerable)	0.18	PLI>0 to<1 indicates baseline levels of pollutants present PLI>0 to<1 indicates baseline levels of pollutants present PLI>0 to<1 indicates baseline levels of pollutants present PLI>1 indicates progressive deterioration of the site PLI>0 to<1 indicates baseline levels of pollutants present
2	2.11	CD < 6 (Low)	0.33	
3	28.91	CD ≥ 24 (Very high)	0.20	
4	51.19	CD ≥ 24 (Very high)	1.09	
5	4.31	CD < 6 (Low)	0.70	
6	9.02	6≤ CD<12 (Moderate)	0.15	
7	4.17	CD < 6 (Low)	0.64	
8	1.66	CD < 6 (Low)	0.07	

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue XIV September 2025 | Special Issue on Management

9	1.42	CD < 6 (Low)	0.06	PLI>0 to<1 indicates baseline levels of pollutants present
10	2.33	CD < 6 (Low)	0.36	
11	4.05	CD < 6 (Low)	0.67	PLI>0 to<1 indicates baseline levels of pollutants present
12	4.79	CD < 6 (Low)	0.79	PLI>0 to<1 indicates baseline levels of pollutants present
13	4.51	CD < 6 (Low)	0.65	
14	4.85	CD < 6 (Low)	0.68	PLI>0 to<1 indicates baseline levels of pollutants present
15	5.95	CD < 6 (Low)	0.20	PLI>0 to<1 indicates baseline levels of pollutants present
PLI for the Zone in Dry Season			0.73	PLI>0 to<1 indicates baseline levels of pollutants present
PLI for the Zone in Wet Season			0.33	PLI>0 to<1 indicates baseline levels of pollutants present

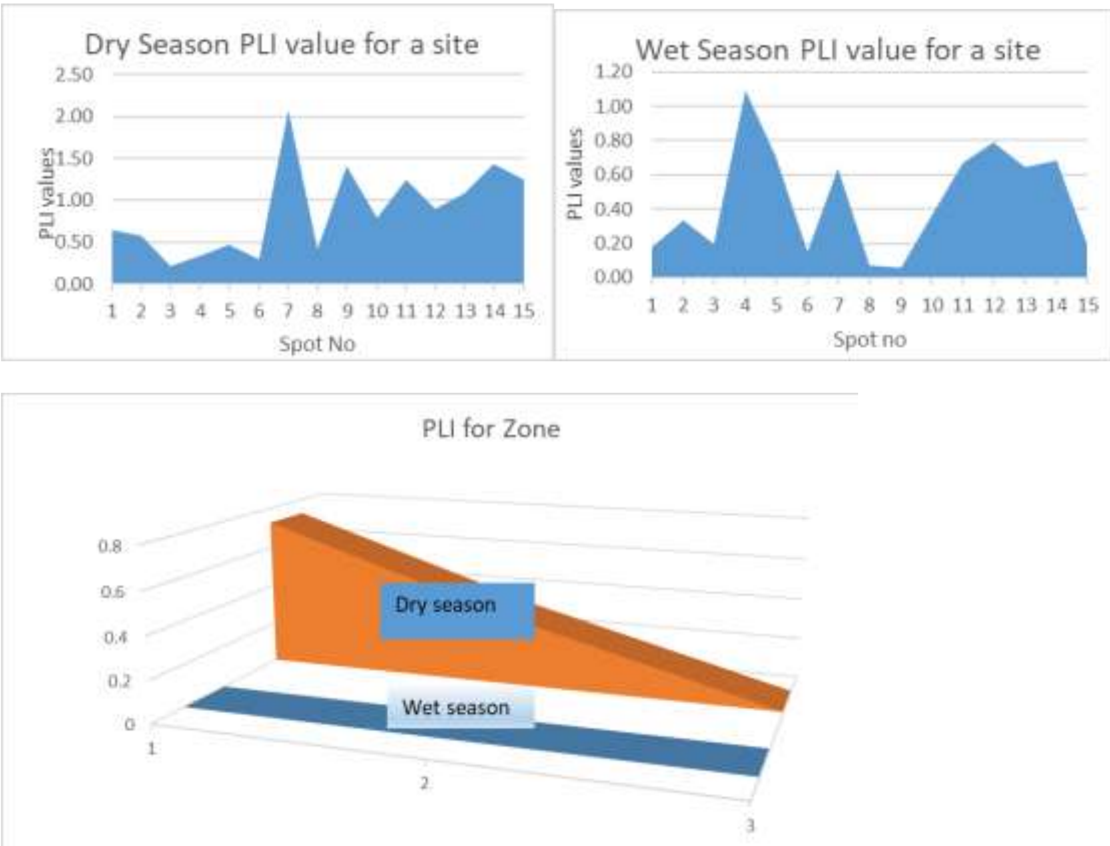


Fig. 5. Pollution Load analysis of the studied soil

Predictive Model And Geospatial Analysis Of Chromium (Cr) Contamination In Soils Collected From Savar Tannery Industrial Area:

Predictive model and geospatial analysis of Chromium (Cr) contamination in Savar soils is presented in Fig. 6. The left panel shows the projected increase of Cr concentration at Spot 1 (main dumping site) over the next 10

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue XIV September 2025 | Special Issue on Management

years assuming untreated effluents continue. The right panel illustrates a hypothetical geospatial distribution of Cr contamination across sampling sites during the dry season, highlighting severe hotspots (red circles) near the dumping point and downstream areas. These metals with high concentrations in the studied soils may have been mixed with groundwater by leaching. High concentrations of heavy metals in soils around industrial facilities originate from an anthropogenic source which is associated with unrestrained solid release and untreated or poorly treated fluid wastes from these industrial facilities.

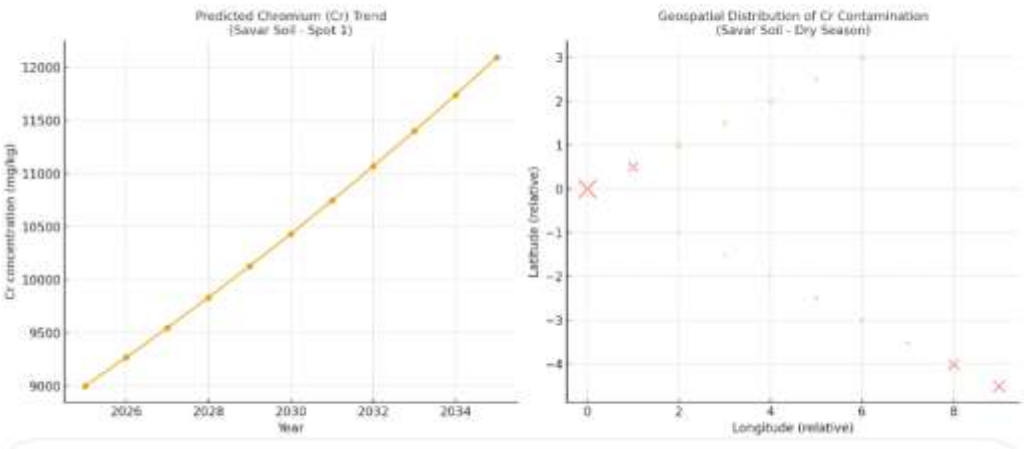


Figure 6. Combined predictive model and geospatial analysis of Chromium (Cr) contamination in Savar soils.

Human Health Risk Assessment Chamon, 2023):

Human health risks assessment due to consumption of contaminated vegetables in the newly relocated Savar tannery area (Chamon, 2023) was made by comparing the concentration of the contaminants (Fig 6) recorded from the analysis with national and international safe limits (Kacholi and Sahu, 2018; Bermudez, 2011) by using different parameters like average daily intake (ADI) (Fig. 6), hazard quotient (HQ) and Hazard index (HI) (Fig 7). The order of increasing concentration of studied metals in different vegetables in comparison with MPL (sauerbeck, 1982) in (both seasons) edible crops was reported by Chamon (2023) (Fig 6) as follows:

Chromium (Cr): Kalmi>Gourd 2> Gourd 1> Red amaranth shoot>MPL (1-2)

Chromium (Cr): Gourd shoot 1>Gourd shoot 2>Red amaranth shoot>MPL (1-2)

Copper (Cu): Gourd 1> Gourd 2> Red amaranth shoot>MPL (15-20)

Copper (Cu): Gourd shoots 1>Gourd shoots 2>Kalmi>Red amaranth shoot>MPL (15-20)

Lead (Pb): Gourd shoot 1 and Gourd 1>Kalmi>Gourd 2>Red amaranth shoot>MPL (10-20)

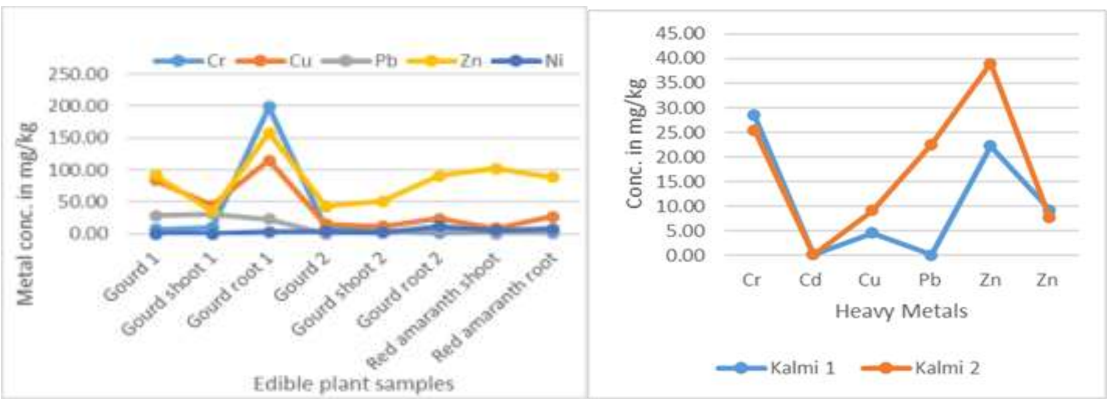
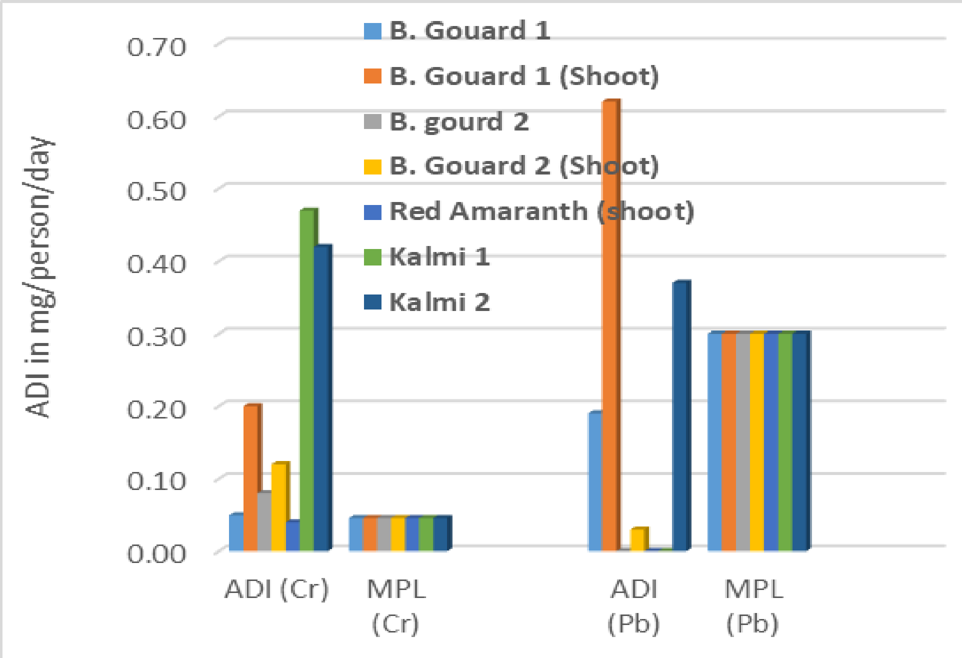


Fig. 7. Heavy Metals concentration in vegetable samples (wet and dry season) collected from savar tannery area (Kalmi was collected only in wet season) (Chamon, 2023).



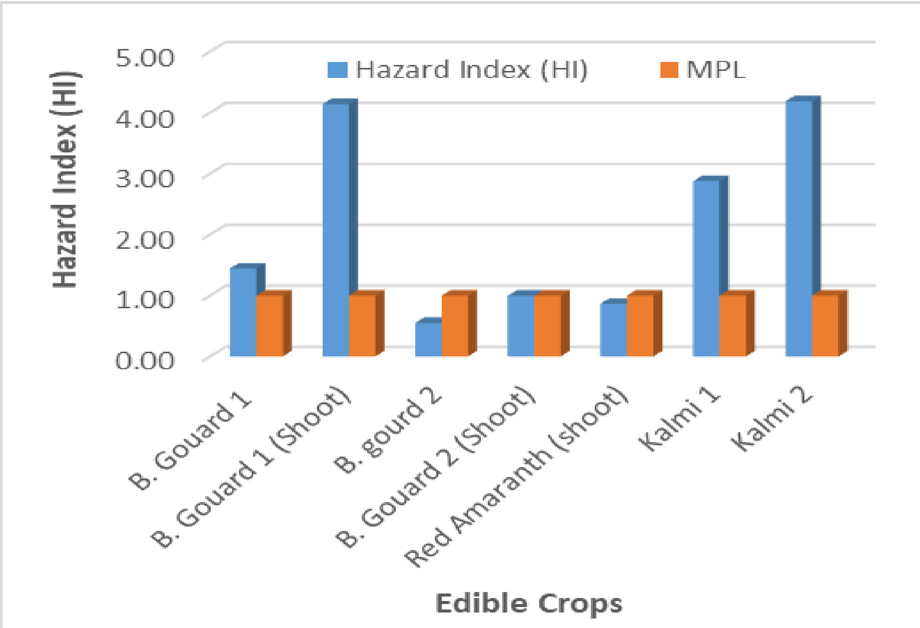


Fig. 8. Average daily intake (ADI) and Hazard index (HI in vegetable samples collected from savar tannery area (Chamon, 2023).

The study also conducted by Chamon (2023) revealed that concentration of the studied heavy metals (Cr, Cd, Pb, Ni, Cu, Zn) exceeded the Maximum Permissible Limit (MPL) in most vegetables and Hazard Index (HI) exceeded unity (>1) mostly in stem and leafy vegetables reorted by chammon (2023) (Fig 6)

Suffice it to say that hexavalent chromium is some 500-1000 times more toxic than trivalent chromium. If it could somehow get rid of this hexavalent chromium from tannery waste—or from poultry feed, for that matter—it would be safe to consume chicken and, more importantly, this would pave the way for the utilisation of solid tannery waste (reported by Lutfor Rahman, The Daily Star, July 30, 2019). Fortunately, it is quite easy to reduce hexavalent chromium to a trivalent one, which is the more stable of the two. Two conditions have to be satisfied:

One, a reducing agent has to be added, and two, the medium should be made acidic. Inorganic reducing agents and inorganic acids should be avoided as they may themselves be toxic. Instead, we can use ascorbic acid, which is vitamin C, as the reducing agent, and a stronger acid like citric acid may be used to bring down the pH to the desired level. Lemons, which contain both ascorbic and citric acids, may be directly applied along with additional amounts of citric acid to create the proper reducing atmosphere (reported by Lutfor Rahman, The Daily Star, July 30, 2019).

Two, Solid tannery waste contains both untanned components like raw trimmings and fleshings (66 percent) and tanned components like splits, shavings and crusts (34 percent). To be used for poultry feed, they are boiled together, dried and then ground. The resulting product, called protein concentrate, is then mixed with soya oil cake, ground rice, and dry fish to produce poultry feed. In the proposed method, the same procedure may be adopted except that boiling should be done in the presence of water, and that towards the end of the boiling step, required amounts of ascorbic and citric acids should be added. A very important part of the procedure is to separate the solid part through filtration or any convenient means from the liquid part. It is the solid part that has to be ground and used in poultry feed (reported by Lutfor Rahman, The Daily Star, July 30, 2019). The poultry feed prepared in this way should be safe because it would contain no or a negligible amount of hexavalent chromium. The amount of trivalent chromium would also be much less than what it was initially, as most of it would go into solution, from which chromium can be recovered through standard methods.

The sludge dewatering house has no impact as the electro-mechanical part is yet to be installed at savar. The electrical control cabinet is waiting to be imported from China, reported by tannery estate officials (The Daily Star, August 03, 2019). Besides, three chromium recovery units, with a treatment capacity of 350 cubic meters each, still cannot recover the contaminating chemical. According to experts, a partially completed CETP has little effect in tannery waste management as well as protecting the environment (The Daily Star, August 03, 2019). “They have no alternative to discharging the partially treated tannery waste into the river. This is the main reason behind the pollution of the Dhaleshwari,” said Prof Khabir Uddin of environment science department at Jahangirnagar University (The Daily Star, August 03, 2019).

Prof Delwar Hossain, chief of the CETP consultant team, admitted that partially treated effluents are being discharged into the river. But he also blamed the factories for not following the guidelines. “We are yet to control chromium contamination because only 60 to 61 out of 121 operational tanneries are following our guidelines of discharging chrome-contaminated effluents through a separate pipeline,” he said. “Chrome recovery units are not effective and chrome contaminated-water is being discharged into the river” (The Daily Star, August 03, 2019), polluting the soils/whole environment around the tannery area**.**

The river had already seen increased pollution levels ever since the estate was set up near the river. Abdul Matin, general secretary of Bangladesh Poribesh Andolon (Bapa),(Dhaka Tribune, 2018) said the CETP couldn't effectively treat the liquid waste which was released into the river every day as there was a lack of monitoring and proper plans in place, pointing out the absence of a permanent solid waste dumping station.

Chromium (Cr) concentration at 15 sampling points (both dry and wet season) crossed the MAC (Maximum allowable concentration) (at savar) for water (0.05 mg/kg) (WHO, 2004) reported by Chamon (2023).

Benchmark comparison

To compare the Savar tannery area to other places around the world, we can look at the levels of chromium and other contaminants in the soil and compare them to international clusters where tanning effluents or sludge have historically affected soils, as well as best-available techniques (BAT) and environmental limits in widely used guidance (Table). The EU BAT-associated emission levels (BAT-AELs) say that treated total chromium should be less than 0.3–1 mg/L for direct discharges and that chromium should be removed from separate streams. The IFC EHS Guidelines for Tanning and Leather Finishing say that total chromium should be less than 0.5 mg/L and hexavalent chromium should be less than 0.1 mg/L at discharge. They also say that chrome float recycling and segregation should be core GIIP (Gowda et al., 2010).

International case studies reveal soil chromium levels ranging from hundreds to several thousand mg/kg in proximity to tanneries employing chrome tanning. Notably, hotspots in India (Kanpur/Unnao) exhibit total chromium concentrations between 161.8 and 6,227.8 mg/kg in agricultural topsoils, escalating to 40,500 mg/kg where sludge is integrated into the soil. Additionally, Ethiopia (Modjo) records both Cr(III) and Cr(VI) in soils and edible plants adjacent to the river receiving tannery effluent. In Morocco, untreated or inadequately treated tannery effluents with total chromium levels around 127 mg/L have been observed to surpass national discharge regulations, highlighting the necessity of efficient pretreatment and segregation prior to biological treatment (Paul et al., 2015).

Savar's dry-season soils reached 51.2–9,090 mg/kg Cr, which is higher than the average soil guideline values. Its CETP performance lacks chrome recovery and reliable precipitation, which means that simple, high-impact upgrades like segregated chrome-stream precipitation, float recycling, and, where possible, staged water recovery towards ZLD, as seen in Indian CETP clusters, are needed. These best-practice procedures are technically sound, well-documented, and meant to be adopted gradually in groups using shared infrastructure. When recovery and segregation are used, they have been shown to save chrome and lower the amount of chromium in effluent (RAJAMANI S. (1998)).

Table 10: Benchmark Comparison Table

Location/ standard	Context	Soil chromium (mg/kg)	Effluent chromium limits/observed	Treatment approach	Key notes	Relevance to Savar
Savar, Bangladesh	Soils near CETP and disposal points	51.2–9,090 (dry); 20.0–1,635 (wet) (This Study)	CETP lacks chrome recovery; recurrent bypass/underperformance reported in media and prior studies (Chamon, 2023)	CETP with frequent malfunction; no chrome recovery unit (This Study)	Multiple sites exceed common guideline values; high spot at main disposal (Chamon, 2023)	Demonstrates urgent need for chrome segregation/precipitation and recovery to cut soil loading (Chamon, 2023a,b) (This Study)
Kanpur/ Unnao, India	Agricultural soils irrigated or near sludge/effluent	161.8–6,227.8 in topsoils; up to 40,500 in sludge-embedded soil (Gowd et al., 2010)	Noted Cr(VI) hotspots in soils linked to sludge and canals (Gowd et al., 2010)	Legacy of partial treatment and sludge dumping (Gowd et al., 2010)	Highlights extreme hotspots from sludge embedding (Gowd et al., 2010)	Warns against sludge dumping; underscores strict solid-waste containment and engineered landfilling (Gowd et al., 2010)
Modjo, Ethiopia	River-receiving area with urban gardening	Soils contain Cr(III) and Cr(VI) above controls; edible plants impacted (Adugnaw et al., 2021)	River total Cr up to 20.6 mg/L upstream of discharge in study transect (Adugnaw et al., 2021)	Limited segregation; variable treatment (Adugnaw et al., 2021)	Demonstrates Cr(VI) presence and food-chain risks Adugnaw et al., 2021)	Emphasizes need for Cr(III) fixation, pH/redox control, and preventing Cr(VI) formation/leakage (Adugnaw et al., 2021)
Morocco (effluent example)	Tannery effluent characterization	—	Total Cr ~127 mg/L; exceeds national discharge limits (Alouiz et al., 2024)	Inadequate pretreatment noted (Alouiz et al., 2024)	High influent loads overwhelm plants (Alouiz et al., 2024)	Reinforces necessity of segregated chrome precipitation prior to biological stages (Alouiz et al., 2024)
EU BAT-AEL (standard)	Treated direct discharges	—	Total Cr <0.3–1 mg/L (monthly avg) (EU BAT, 2007)	On-/off-site chromium precipitation; segregated streams (EU BAT, 2007)	Industry reference for permits and compliance (EU BAT, 2007)	Practical target for Savar's CETP upgrades and monitoring plans (EU BAT, 2007)

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue XIV September 2025 | Special Issue on Management

IFC EHS (standard)	Treated discharges (GIIP)	—	Total Cr ≤0.5 mg/L; Cr(VI) ≤0.1 mg/L; COD 250 mg/L [IFC, 2007]	Segregation, float recycling, high-exhaustion tanning [IFC, 2007)]	Project finance-aligned GIIP [IFC, 2007]	Provides interim targets and operational controls for CETP and units [IFC, 2007]
Tamil Nadu CETP/ZLD clusters	Common infrastructure (leather/textile)	—	Achieve recycling with RO/evaporation and reject management (ZLD) [UNIDO, 2007]	CETP + RO + evaporator; brine/salt reuse [UNIDO, 2007]	Demonstrated cluster-scale compliance pathway [[UNIDO, 2007]	Medium-term roadmap for Dhaleshwari cluster to cut river abstraction/discharge [UNIDO, 2007]

Recommended practice measures

The chromium levels in Savar's dry-season soil (51.2–9,090 mg/kg) are in the same range as those in India's

Kanpur/Unnao cluster (161.8–6,227.8 mg/kg) and are much lower than the highest levels found in sludge-embedded hotspots (40,500 mg/kg). This shows that there is a lot of risk, but also a chance to stop it from getting worse by controlling sludge and effluent. Using segregated chrome precipitation and chrome recovery to bring the CETP in line with EU BAT-AELs (0.3–1 mg/L total Cr) and IFC EHS limits (0.5 mg/L total Cr; 0.1 mg/L Cr(VI)) is a direct approach to see measurable improvement (Gowd et al., 2010). The following Best-practice measures should undertake to control pollution of the environment:

- Segregate chrome-bearing streams and apply chromium precipitation on concentrated liquor, aiming for treated total Cr <0.3–1 mg/L for direct discharge; add weekly-to-monthly monitoring of chromium and sulphide per BAT monitoring guidance(Gowd et al., 2010)
- Implement chrome float recycling and indirect chrome recovery with MgO precipitation and acid regeneration per UNIDO designs to reduce fresh chrome consumption and effluent loading while maintaining leather quality (UNIDO, 2007)
- Tighten CETP operations with mass balancing, composite sampling, and permit conditions aligned to BAT-AELs/IFC limits, and phase solid-waste controls to prevent sludge embedment in soils (IFC, 2007)
- To control soil contamination, legislative measures must be taken, legally binding the individual industries, forbidding discharge of untreated or poorly treated industrial effluents.
- Lowering the quality of soil health due to these industries can only be restricted if a zero discharge system ETP is implemented throughout the area. Immediate steps including regular monitoring of toxic metals in the agricultural soil is needed to check the environmental quality.
- Wastewater discharged from area could be recycled for the remediation of pollution in a sustainable and eco-specific way. Moreover, different remediation measures should be taking promptly to remove excising metal contamination.

Policy and practice additions

1. Immediate: Install chrome recovery, harden sludge storage, enforce CETP uptime with third-party audits, and provide safe irrigation/water substitutions for high-risk clusters indicated by HQ/CR and hotspot maps.

2. Medium-term: Mandate periodic risk-based monitoring (metal panels plus Cr speciation), farmer training on exposure reduction, and publish an annual risk and hotspot atlas to guide remediation budgets.

CONCLUSION

In Bangladesh the tannery industries afflict the soil and river water environment and thus lessen ecological balance. This study has revealed that the tanning activities involve serious environmental hazards. Finally, it could be said that adequate preventive measures should be taken in tannery industrial activities with a view to ensuring safe, sound and healthy environment for the greater benefit of Bangladesh.

ACKNOWLEDGEMENT

The author sincerely acknowledge the financial support provided by the University Grants Commission (UGC), Bangladesh, and the Bangladesh Council of Scientific and Industrial Research (BCSIR) for the analysis of the samples. The author also express her gratitude to the Department of Soil, Water, and Environment at the University of Dhaka for giving the essential laboratory facilities to conduct this research.

Conflicts Of Interest: The authors declare no conflicts of interest.

REFERENCES

1. Adugnaw Maru Gezahegn,; Fekadu Fufa; Feyessa, Esayas; Alemayehu Tekeste,; Embialle Mengistie Beyene. 2021. Chromium Laden Soil, Water, and Vegetables nearby Tanning Industries: Speciation and Spatial Distribution.First published: 23 June 2021. The j. chemistry. https://doi.org/10.1155/2021/5531349
2. Ahmed J. U. and Goni, M. A. 2008. Heavy metal contamination in water, soil and vegetables of the industrial areas in Dhaka, Bangladesh. Environ. Monit. Assess. 166: 347-357.
3. Ahmed, G.; Miah, M. A.; Anawar, H. M.; Chowdhury, D. A.; Ahmad, J. U. 2011. Influence of multi-industrial activities on trace metal contamination: An approach towards surface water body in the vicinity of Dhaka Export Processing Zone (DEPZ). Environ. Monit. Assess. doi:10.1007/s10661-011-2254-9.
4. Alouiz, M.; Benhadj, D.; Elmontassir, M.; Sennoune, M.Y.; Amarouch and D. Mazouzi. 2024.Nature Environment and Pollution Technology an International Quarterly Scientific Journal Original Research Paper e-ISSN: 2395-3454 Original Research Paper https://doi.org/10.46488/NEPT.2024.v23i04.034 Open Access Journal Potential Low-cost Treatment of Tannery Effluents from Industry by Adsorption on Activated Charcoal Derived from Olive Pomace I.
5. Asia, A. 2012. Pollution of heavy metals on soil, water and plants by Hazaribagh Tannery Industries in Dhaka. MS Thesis. Dept. of Soil, Water and Environment, University of Dhaka, Bangladesh. Pp.120-125.
6. Bermudez GMA, Jasan R, Pl´a R, Pignataro ML (2011) Heavy metal and trace element concentrations in wheat grains: Assessment of potential non-carcinogenic health hazard through their consumption. J Hazard Mater 193: 264-271.
7. Blum, W. E. H.; Spiegel, H. and Wenzel, W. W. 1996. Bodenzutstandsinventur. Konception, Durchführung und Bewertung, Empfehlungen Zur Vereinheitlichung der Vorgangsweise in Österreich. Bundesministerium für Land und Forstwirtschaft, Wien.
8. Chamon A S. September 28, 2023a. Assessing the Human Health Risk from Heavy MetalContaminated Vegetables Grown Close to the Tannery Industrial Area Using the Hazard Index (HI) and Hazard Quotient (HQ). OAJMB, 8 (3). DOI: 10.23880/oajmb-16000274.
9. Chamon, A. S.; S Romana, MR Zubairy, WZ Prian, MA Hossain, MN Mondol. 2023. Dhaleshwari River Water Quality Due to Disposal of Tannery Wastes at Savar, Dhaka, Bangladesh. Int. j. adv. multidisc. res. stud.
10. Chamon, A. S.; Gerzabek, M. H.; Mondol, M. N.; Ullah, S. M.; Rahman, M. and Blum, W. E. H. 2005a. Influence of cereal varieties and site conditions on heavy metal accumulations in cereal crops on polluted soils of Bangladesh. Comm. Soil Sci. and Plant Analysis. 36: 889-906.
11. Chamon, A. S.; Gerzabek, M. H.; Mondol, M. N.; Ullah, S. M.; Rahman, M. and Blum, W. E. H. 2005b. Influence of soil amendments on heavy metal accumulation in crops on polluted soils of Bangladesh. Comm. Soil Sci. and Plant Analysis. 36: 907-924.

12. Dhaka Tribune. 2018. Tanneries relocation, non-compliance at Savar Leather Park weigh on export earnings described by Ibrahim Hossain Ovi. Dhaka Tribune. 2018/12/26.
13. DOE (Department of Environment). 1991. Environmental Quality Standards for Bangladesh. Report
14. EU BAT. 2013. European Commission. Commission Implementing Decision 2013/84/EU of 11 February 2013 establishing the best available techniques (BAT) conclusions under Directive 2010/75/EU for the tanning of hides and skins. Official Journal of the European Union, L 45, 16 February 2013, pp. 13–29.
15. Gomez, K. A. and Gomez, A. A. 1984. Statistical procedures for agricultural research (2nd ed.). John wiley and sons, NewYork. pp. 680.
16. Gowda,S.; Srinivasa b, M. ; Ramakrishna Reddy b; P.K. Govil. 2010. Assessment of heavy metal contamination in soils at Jajmau (Kanpur) and Unnao industrial areas of the Ganga Plain, Uttar Pradesh, India Journal of Hazardous Materials 174 (2010) 113–121.
17. Grant, L. D. 2009. Environmental toxicants: Human exposures and their health effects (3rd ed.). Wiley-Interscience. pp.792.
18. Hakanson, L. 1979. An ecological risk index for aquatic pollution control, a sedimentological approach. Water Research. 14:975-1001.
19. IFC. 2007. Environmental, Health, and Safety Guidelines Tanning and Leather Finishing April 30, 2007 1 World Bank Group Environmental, Health, and Safety Guidelines for Tanning and Leather Finishing. 1-15.
20. Immamul Huq, S. M. 1998. Critical Environmental Issues Relating to Tanning Industries in Bangladesh. In: Naidu et al. (eds), Towards Better Management of Soils Contaminated with Tannery waste, ‖ in Proceedings of a workshop held at the Tamil Nadu Agricultural University, Coimbatore, India, 31 January to 4 February, 1998.info@lightcastlebd.com.
21. Kabata-Pendias, A. 2000. Trace Element in Soils and Plants; CRC Press: Boca Raton, FL, USA, 2000; p. 413.
22. Kacholi DS, Sahu M (2018) Levels and health risk assessment of heavy metals in soil, water and vegetables of Dar es Salam, Tanzania. J Chem pp: 1-9. 10. Bermudez GMA, Jasan R, Pl´a R, Pignata ML (2011) Heavy metal and trace element concentrations in wheat grains: Assessment of potential non-carcinogenic health hazard through their consumption. J Hazard Mater 193: 264-271.
23. Khan, A. H.; Nolting, R. F.; Vander Gaast, S. J.; Van Raaphorst, W. 1992. Trace element geochemistry at the sediment water interface in the North Sea and the Western Wadden Sea. Netherlands Institute for Sea Research. NIOZ Report 1992-10, BARC Report 1992-1, BEON Report 18.
24. Kloke, A. 1980. Orientierungslaten fur tolerierGesamtgehalteeiniger.Element in Kulturboder.Mitteilungen der VDLUfA. Heft1-3: Pp. 9-11
25. Mapanda, F.; Mangwayana, E.N.; Nyamangara, J.; Giller, K.E. The effect of long-term irrigation using wastewater on heavy metal contents of soils under vegetables in Harare, Zimbabwe.
26. Mohiuddin, K. M.; Alam, M. M.; Istiaq, A. and Chowdhury, A. K. 2010. Heavy metal pollution load in sediment samples of the Buriganga river in Bangladesh. J. Bangladesh Agril. Univ. 13(2): 229-238.
27. Mondol, M. N.; Asia, A.; Chamon, A. S. and Faiz, S. M. A. 2017. Contamination of soil and plant by the Hazaribagh tannery industries. J. Asiat. Soc. Bangladesh, Sci. 43(2): 207-222.
28. Mukai, H.; Tanaka, A.; Fujii, T. and Nakao, M. 1994. Lead isotope ratios of airborne particulate matter as tracers of long-range transport of air pollutants around Japan. J. Geophys Res. 99(2): 3717-3726.
29. Muller, G. 1969. Index of Geoaccumulation in sediments of the Rhine River. Geo. J., 2,108–118
30. Nuruzzaman, M.; Gerzabek, M. H.; Islam, A.; Rashid. M. H. and Ullah, S. M. 1998. Contamination of Soil environment by the tannery industries. . Bangladesh J. Soil. Sci. 25:1. Pp.1-10.
31. Paul, D; Choudhary, B; Gupta, T; Jose, MT. 2015. Spatial distribution and the extent of heavy metal and hexavalent chromium pollution in agricultural soils from Jajmau, India.Environmental Earth Sciences.**Volume**73 (7)3565-3577 **DOI**10.1007/s12665-014-3642-6
32. Rahman, S. H.; Dilara, K.; Tanveer, M. A.; Shahidul, M. I.; Mohammad A. A. and Akbor, M. A. 2012. Assessment of heavy metal contamination of Agricultural soil around Dhaka Export Processing Zone (DEPZ), Bangladesh: Implication of seasonal variation and indices. Appl. Sci. 2: 584- 601.
33. Rajamani S. 1998. United Nations Industrial Development Organisation Regional Programme for Pollution Control in the Tanning Industry in South East Asia Technical Expert- Environmental Engineering UNIDO, Regional Programme Office, Madras, India. 1-12

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue XIV September 2025 | Special Issue on Management

34. Roa, M. S.; Gopalkrishnan, R.; Venkatesh, B. R. 2001. Medical geology—An emerging field in environmental science. In National Symposium on Role of Earth Sciences, Integrated and Related Societal Issues, Lucknow, India, 2–4 November 2001, GSI Spl. Pub. No. 65,; pp. 213–222.
35. Sauerbeck D (1982) The heavy metal levels in plants must not be exceeded. To avoid growth impairments? Agriculture Research special issue. 39th conference proceedings, pp: 108-129.
36. SEPA (Single Euro Payments Area). 2005. The Limits of Pollutants in Food; GB27622005; State Environmental Protection Administration: Beijing, China. Toxicol. 5: 334.
37. SRDI (Soil Resource Development Institute). 1995. Land and Soil resource user manual. Savar. Dhaka. Amader Bangla Press Ltd. Azimpur road. Dhaka. Bangladesh. Pp: 51-60.
38. Stoeppler, M. 1991. Cadmium. In: Merian E. (Ed), Metals and their compounds in the environments: Occurance, analyses and and biological relevance. VCH, New York. 803-851.
39. Stomberg, A. L.; Hempill Jr, D. D. And Volk, V. V. 1984. Yeild and elemental concentration of sweet corn growth on Tannery Waste amended Soil. J. Environ. Qual. (13): pp. 162-166.
40. Taylor, S. R.; Mclennan, S. M. 1995 The geochemical evolution of the continental crust. Rev. Geophys, 33, 241–265
41. The Daily Star. 3 August, 2019. Tannery waste taints Dhaleshwari. Moudud Ahmed Sujan.
42. Tomlinson, D. L.; Wilson, J. G.; Harris, C. R.; Jeffrey, D. W. 1980. Problems in the assessment of heavy metal levels in estuaries and the formation of a pollution index. Helgolaender Meeresunter. 33, 566–575.
43. Turekian, K. K.; Wedepohl, K. H. 1961. Distribution of the elements in some major units of the earth's crust. Bull. Geo. Soc. Am., 72, 175–192.
44. Tusher, T. R.; Piash, A. S.; Latif, M. A.; Kabir, M. H. and Rana, M. M. 2017. Soil Quality and Heavy Metal Concentrations in Agricultural Lands around Dyeing, Glass and Textile Industries in Tangail District of .Bangladesh. J. Environ. Sci. & Natural Resources, 10(2):109–116, ISSN 1999-7361.
45. UNIDO. 2007. Environmental, Health, and Safety Guidelines Tanning And Leather Finishing April 30, 2007 1 World Bank Group Environmental, Health, and Safety Guidelines for Tanning and Leather Finishing.