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Investigation of Physicochemical and Microbial Water Quality at Some Selected Tannery Industries in Savar

Effat Tyeba[1*], Nasrin Akter[2], Murad Ahmed Farukh[1] and Md Abdul Baten[1]

[1]Department of Environmental Science, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh.
[2]Department of Agroforestry, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh.
*Correspondence: effat.23221325@bau.edu.bd, Tel: +8801794183748

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Abstract: Water is the most vital resource for life on Earth. Water quality in the Dhaleshwari River, adjacent to the Bangladesh Small and Cottage Industries Corporation (BSCIC) Tannery Industrial Estate, was assessed due to concerns over microbial presence and heavy metal contamination. Fifteen water samples were collected during the post-monsoon season and were examined using numerous methods. (November of 2024). The total carcinogenic risk was inconsiderable, whereas 95% of samples presented a medium non-carcinogenic risk through skin absorption, as revealed by the study. Though physicochemical parameters were within acceptable limits and biological features were above allowable values. Physicochemical parameters were within acceptable limits, and biological features were above allowable values. All samples exhibited high amounts of heavy metals: Zn (3.196 - 9.946 mg/L), Pb (4.356 - 9.56 mg/L), Cd (4.413 - 5.9 mg/L), Cr (3.196 - 6.73 mg/L), Cu (3.92 - 5.406 mg/L), Ni (2.306 - 3.703 mg/L), and Fe (46.946 - 194.94 mg/L), suggesting considerable contamination, whereas some physicochemical parameters were within acceptable bounds and biological features above allowable values. All samples were determined to be unfit for domestic use based on water quality ratings (WQI varied from 72,679.18 to 89,206.77) and ecological evaluations (ERI ranged from 49,037.16 to 64,620.27) that found significant hazards to aquatic life, notably chromium. The findings of the study emphasize the importance of improved wastewater treatment and regulatory activities to combat environmental degradation and preserve local ecosystems.

Keywords: Heavy metals; *E. coli*, Human health risk assessment, WQI, ERI, ICPMS.

INTRODUCTION

Water is vital for financial development, environmental sustainability, and human survival. However, because around 2.2 billion people continue to rely on untreated surface water sources and lack access to securely managed drinking water services, global water security is under threat (Hasan *et al.*, 2020). Surface water features such as rivers, lakes, and streams are critical for maintaining ecological balance, encouraging biodiversity, facilitating groundwater recharge, and supporting industrial and agricultural activities (Islam *et al.*, 2021) (Hossain *et al.*, 2021). Rapid urbanization and industrial expansion in Bangladesh have significantly harmed surface water quality, owing mostly to untreated residential, agricultural, and industrial wastes (Chowdhury *et al.*, 2025). The tanning industry is recognized as one of the major industrial sectors that contaminates the environment (Monira *et al.*, 2023). The substantial chemical processing of leather produces large volumes of solid, liquid, and gaseous wastes that are contaminated with organic pollutants, hazardous microorganisms, and heavy metals (Shaibur, 2023). The primary pollutants released by tannery effluents that gravely damage aquatic ecosystems and jeopardize human health include chromium, lead, cadmium, arsenic, dyes, ammonia, phenols, and other dangerous substances (Hossain *et al.*, 2021). Bangladesh's tannery industry, which is mostly concentrated in Savar and the surrounding industrial districts, greatly boosts the nation's economy by producing jobs and export income, but it also severely damages the local waterways (Lejri *et al.*, 2022). Untreated tannery effluent discharge into rivers results in sediment contamination, microbial growth, and the bioaccumulation of dangerous metals, all of which eventually affect aquatic life and transfer toxins to humans through the food chain (Nur-E-Alam *et al.*, 2018) (Rabbani *et al.*, 2021). Exposure to these pollutants has been associated with a number of health impacts, including respiratory, neurological, reproductive, and dermatological disorders (Jaman *et al.*, 2024) (Moktadir *et al.*, 2024). This research aims to (1) investigate the physicochemical parameters of the surface water of the adjacent tannery industrial areas in the Dhaleshwari River, focusing on microbiological and physicochemical characteristics, including heavy metals. (2) evaluate the surface water quality through the Water Quality Index (WQI), Heavy Metal Pollution Index (HMPI), and Heavy Metal Evaluation Index (HMEI); and (3) assess the ecological and human health risk derived from heavy metal contamination.

MATERIALS AND METHODS

BSCIC Tannery Industrial Estate, Savar, spans 200 acres (80 hectares) and is in the Dhaka district at 23.7872° N and 90.2456° E. The Tannery Industrial Estate in Savar is situated 23.5 kilometers northwest of Dhaka, the capital city of Bangladesh, on the bank of the Dhaleshwari River in the southwest of the city. Each station's latitude and longitude were recorded using GPS. The distance of around 800 meters between each of the five sample locations was a major factor in their selection. Map 3.1 displays the locations of a few tannery enterprises.

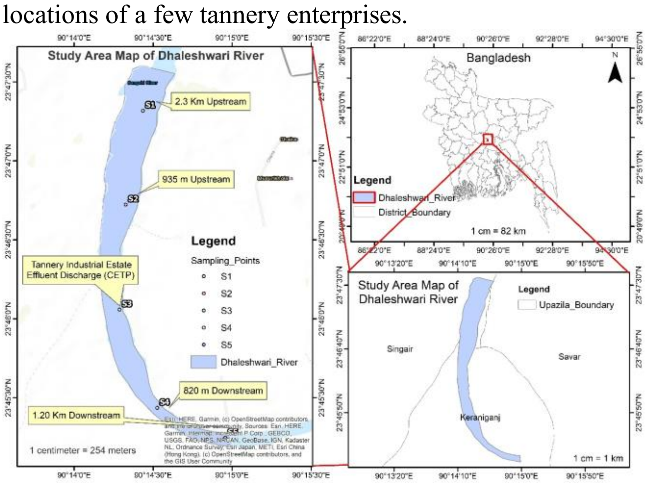

Figure 1 Map of the Study Area

Sample Collection:
Surface water sampling was conducted on November 25, 2024, during the winter season along the Dhaleshwari River in Savar, Dhaka, Bangladesh. A total of 15 water samples were collected from five monitoring sites (with three replications) chosen for their proximity to tannery industrial effluent outflow locations. The samples were collected using one-liter plastic bottles. The locations were around 800 meters apart and spanned a three-kilometer stretch of water. Sampling locations were two upstream sites at 2.3 km (S1) and 935 m (S2), the CETP discharge point (S3), and two downstream sites at 820 m (S4) and 1.20 km (S5) from the discharge position. All stations' geographical coordinates were obtained using a Global Positioning System. Confidentiality concerns restricted the release of particular industry names.

Physicochemical Analysis
APHA (2012) developed standard methods for assessing physicochemical parameters, including temperature, pH, EC, TDS, DO, BOD_5, and salinity. The Environmental Science Laboratory at Bangladesh Agricultural University employed calibrated multiparameter meters and DO analyzers to collect data.

Heavy Metal Analysis
Water samples were digested with HNO_3 and HCl, using typical acid digestion procedures. The digested samples were filtered and analyzed for Fe, Pb, Cr, Cd, Ni, Zn, and Cu using Inductively Coupled Plasma Mass Spectrometry (ICP-MS) at Bangladesh Agricultural University's Central Laboratory. We achieved quality control by evaluating blank samples simultaneously.

Analysis
Microbial water quality was assessed using the following methods: heterotrophic plate count (HPC), total coliform count (TCC), fecal coliform detection, and bacterial isolation. We tested HPC using Plate Count Agar at 37°C for 18 hours and reported it as CFU 100 mL^{-1}. We employed the Most Probable Number (MPN) approach to determine the total and fecal coliform counts. At Bangladesh Agricultural University's Department of Microbiology and Hygiene, we used selective media such as EMB, TCBS, and SS agar to isolate and identify bacteria like Escherichia coli (Kashem *et al.*, 2022).

Water Quality and Pollution Indices
The Water Quality Index (WQI), a weighted mathematical approach, was utilized to evaluate water quality (Zakir *et al.*, 2020). Heavy metal contamination was quantified using the Heavy Metal Contamination Index (HMPI), Heavy Metal Evaluation Index (HMEI), Heavy Metal Toxicity Index (HMTI), and Environmental Water Quality Index (EWQI) (Bodrud-Doza *et al.*, 2016). The indices assessed water suitability and pollution severity based on physicochemical and heavy metal parameters.

Ecological Risk Assessment
The pollution index (PI) and the Ecological Risk Index (ERI), which contained toxic-response coefficients for specific metals to quantify cumulative ecological risks to aquatic ecosystems, were used to evaluate the possible ecological risk associated with heavy metal contamination (Bhuyan *et al.*, 2023).

Health Risk Assessment
The USEPA (2004) guidelines were used to examine the risks to human health that come with skin contact with contaminated river water. Adults and children were evaluated for non-carcinogenic risks using the Chronic Daily Intake (CDI), Hazard Quotient (HQ), and Hazard

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Index (HI). For Pb, Cr, and Cd, carcinogenic hazards were assessed using cancer slope factors (Jaman *et al.*, 2024).

Microbial Risk Classification

Using WHO and USEPA recreational water quality recommendations, water quality was categorized according to E. coli concentrations. (Moktadir *et al.*, 2024).

RESULTS

Physicochemical and Biological Properties of Sample Water

Physicochemical, including heavy metals, and microbial properties of Dhaleshwari River water, collected from five distinct points, were evaluated in this study. The results were organized in Table 1. The temperature of sample water ranged from 23.6°C to 28.6°C, with an average of 25.54°C. The pH levels spanned from 7.12 to 7.70, which was within the acceptable limit. Total Dissolved Solids (TDS) (1666.7-1815.8 ppm) and Electrical Conductivity (2381-2594 µS cm^{-1}) exceeded both Bangladeshi and WHO-suggested limits at each point. In the case of biological oxygen demand (BOD), it varied from 1.78 to 4.02 parts per million, and the dissolved oxygen (DO) levels were reasonable. A moderate variation in salinity (1.52-1.66 ppt) was noticed. Zinc concentrations between 3.196 and 9.946 ppm, lead levels from 4.356 to 9.556 ppm, and copper amounts ranging from 3.92 to 5.406 ppm indicated extensive contamination. Iron ranged from 46.946 to 194.94 ppm, showing a significant quantity; on the other hand, nickel and chromium levels were consistently higher than the permitted level (Monira *et al.*, 2022).

Significant contamination was found by microbiological examination, with total coliform counts ranging from 7.53×10^4 to 2.85×10^5 CFU 100 ml^{-1} and total viable counts ranging from 4.06×10^4 to 7.93×10^4 CFU 100 ml^{-1}. E. Coli was found in every sample, and 80% of the locations had fecal coliforms. Based on similarities in quality, water was divided into three groups using hierarchical clustering. According to the study, variations in water quality were significantly affected by iron and zinc. While the heavy metal contamination index ranged from 122,417 to 161,089, indicating severe contamination. The Water Quality Index varied from 72,679.18 to 89,206.77, representing extremely poor conditions (Figure 2).

Table 1. Measured values of physicochemical and biological parameters of River Water

	Measured values				Water Quality Standards		
	Minimum	Maximum	Mean	Standard Deviation	Bangladesh Standard[1]	WHO Standard[2]	Standard for Inland SW[3]
Temperature (°C)	23.6	28.6	25.54	1.89	20-30	_	_
pH	7.12	7.7	7.3	0.23	6.5-8.5	6.5 – 8.5	6-9
EC (µS cm^{-1})	2381	2594	2497	85.56	1000	750	1200
TDS (ppm)	1666.7	1815.8	1747.9	59.89	<600	500	2100
DO (ppm)	6.2	7.48	6.934	0.561	6	_	4.5-8
DO_5 (ppm)	2.43	5.47	4.238	1.294	_	_	_
BOD (ppm)	4.02	1.78	2.696	1.101	2	_	50
Salinity (ppt)	1.52	1.66	1.59	0.055	_	_	_
Zn (ppm)	3.196	9.946	7.71	2.648	5	_	5.0
Pb (ppm)	4.356	9.556	6.289	2.327	0.05	0.01	0.1
Cu (ppm)	3.92	5.406	4.45	0.0095	1	2	0.5
Cd (ppm)	4.413	5.9	5.163	0.5858	0.005	0.003	0.05
Fe (ppm)	46.946	194.94	150.641	60.33	0.3-1	0.3	2.0
Cr (ppm)	3.196	6.73	5.227	1.394	0.05	0.05	0.5
Ni (ppm)	2.306	3.703	2.85	0.624	0.1	0.07	1.0
TVC (CFU 100ml^{-1})	4.06×10^4	7.93×10^4	5.82×10^4	1.42×10^4	_	_	_
TCC (CFU 100ml^{-1})	7.53×10^4	2.85×10^5	1.89×10^5	9.009×10^4	0	0	0
HPC (CFU 100ml^{-1})	5.46×10^5	6.46×10^5	6.0×10^5	3.68×10^4	_	_	_

[1] DPHE, 2019

[2] WHO, 2011

[3] Hasan *et al.,* 2020; Standard for discharged waste from Industrial Units into the inland surface water (drains/ponds/tanks/waterbodies/ditches, canals, rivers, springs, and estuaries): The Environment Conservation Rules, Bangladesh, 1997 (BECR 1997)

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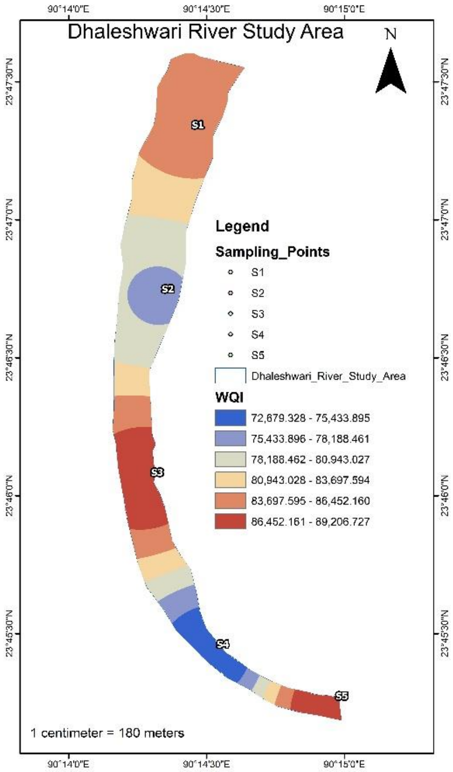

Figure 2 Spatial distribution of WQI (Water Quality Index)

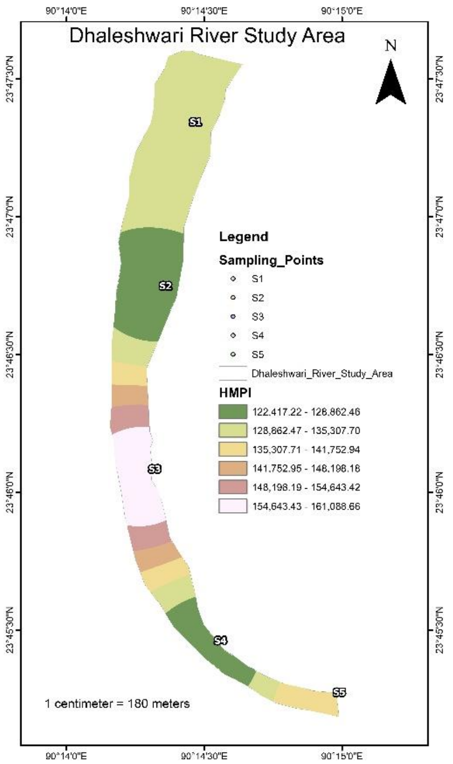

Figure 3 Spatial distribution of HMPI (Heavy-metal Pollution Index)

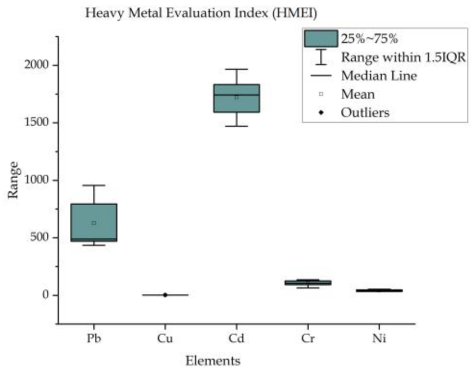

Figure 4 Graphical representation of HMEI (Heavy-metal Evaluation Index)

Ecological and human health assessments have shown significant non-carcinogenic risks and severe environmental dangers, particularly for children (Figure 4). With the exception of one site that was classified as low risk, adults were primarily classified as medium risk for carcinogenic risk, whereas children were classified as medium risk at all sites.

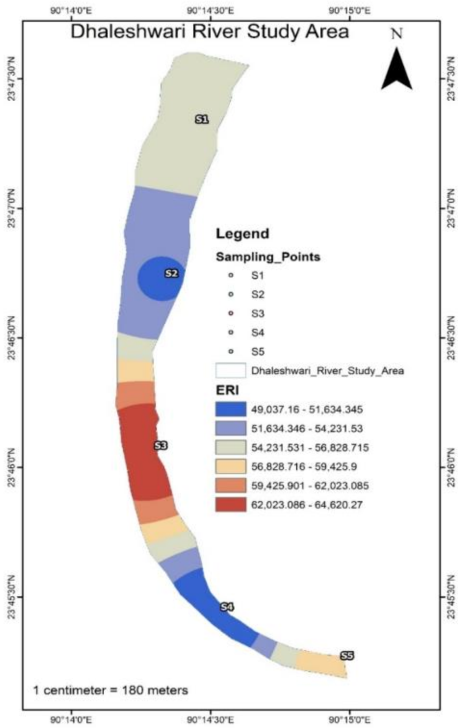

Figure 5 Spatial distribution of ERI (Ecological Risk Index)

Overall, the investigation demonstrated that the Dhaleshwari River had high pollution levels and was tainted with excrement, highlighting the urgent need for action.

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Table 2. Calculated Hazard Index (HI) values (dermal) for both adult and children with their description,

Sample ID	Dermal Absorption			
	HI Adult	Description	HI Child	Description
S1	6.35×10^{-2}	Very High	1.87×10^{-1}	Extremely High
S2	7.56×10^{-2}	Very High	2.23×10^{-1}	Extremely High
S3	9.83×10^{-2}	Very High	2.9×10^{-1}	Extremely High
S4	9.4×10^{-2}	Very High	2.77×10^{-1}	Extremely High
S5	8.62×10^{-2}	Very High	2.54×10^{-1}	Extremely High

DISCUSSION

Physicochemical Parameters of Water Samples

The Dhaleshwari River's physicochemical and biological properties are examined in this study, with particular attention paid to variables including temperature, pH, electrical conductivity (EC), dissolved oxygen (DO), total dissolved solids (TDS), heavy metal concentrations, and microbial contamination. With variations ranging from 23.6°C to 28.6°C, the average water temperature was found to be 25.5°C, indicating potential thermal impacts from adjacent industrial operations. The pH ranged from 7.12 to 7.7, which is ideal for aquatic environments (Al-Mizan *et al.*, 2020) (Hasan *et al.*, 2020 b).

EC values, nevertheless, varied from 2381 μScm^{-1} to 2594 μScm^{-1}, suggesting substantial inorganic pollution most likely from industrial discharge. The Dhaleshwari River near tannery zones was found to have identically elevated EC values by Islam *et al*. (2021). Rather than intermittent contamination incidents, the continuously high conductivity indicates ongoing industrial effluent flow. The TDS was found to be between 1666.70 and 1815.8 parts per million, which is higher than health requirements and indicates moderate pollution levels associated with industrial runoff. The DO range, which averaged 6.93 ppm and ranged from 6.2 to 7.48 ppm, indicated sufficient oxygenation but raised questions about tannery effluent pollution.

Furthermore, the river samples' Biological Oxygen Demand (BOD) assessments showed a high mean of 2.696 ppm, endangering aquatic life. The average salinity level was 1.596 ppt, highlighting the possible influence of runoff. Iron, zinc, lead, chromium, cadmium, copper, and nickel were found to be common contaminants in the heavy metal analysis, all of which were above the permissible limits recommended by the World Health Organization (WHO). Lead levels in particular showed concerning quantities at several locations, most notably S3, suggesting serious contamination risks. Similar elevated levels of Cd have been found in areas of the Dhaleshwari River impacted by tanneries (Bhuyan *et al.*, 2023) (Uddin and Jeong, 2021). The ecological toxicity and long-term bioaccumulation risks connected to tannery wastewater discharge are highlighted by the high concentration of Cd (Table 1).

From a microbial standpoint, Total Viable Count (TVC) revealed proliferating microbial populations downstream, with values from 7.53×10^4 to 2.85×10^5 CFU mL^{-1}. The substantial quantity of Cd draws attention to the ecological toxicity and long-term bioaccumulation issues associated with tannery effluent discharge. E. coli was identified in each sample, suggesting severe fecal contamination, and Total Coliform (TC) and Heterotrophic Plate Count (HPC) levels further indicated poor microbiological quality. Fickling-Caboi diagrams (Figure 7) and cluster analysis (Figure 6) revealed elevated metal concentrations that required action. According to this study, industrial activity, particularly from the nearby tannery sector in Savar, Dhaka, was largely accountable for the pollution. (Monira *et al.*, 2023).

According to the Water Quality Index (WQI) (Figure 2), all river sample locations have high pollution levels that make them unfit for drinking and agricultural irrigation, indicating a dual-source model of contamination. The dangers presented by toxic metals, especially cadmium, lead, and chromium, were further highlighted by heavy metal pollution indicators such as the Heavy Metal Pollution Index (HMPI) and Heavy Metal Toxicity Index (HMTI). The Environmental Water Quality Index (EWQI), which was evaluated at every site, revealed a significant decline in water quality that was mostly caused by industrial effects. Although all computed Hazard Quotient (HQ) values (Table-2) stayed within safe bounds, non-carcinogenic risk evaluations revealed greater health concerns to children, especially at site S1. However, the Carcinogenic Risk (CR) evaluations revealed alarming lifetime cancer risks, highlighting the need for environmental and health mitigation strategies, especially in highly industrialized regions like Savar. The microbiological risk rating showed that 80% of the water was contaminated with fecal coliforms and 100% of the water was contaminated with E. coli, indicating medium hazards that require regulatory oversight of industrial effluents. Pearson's correlation matrix (Table 3) (Table 4) analysis revealed substantial positive connections between numerous water quality parameters, stressing the role of heavy metal contaminants and exposing vulnerable groups such as children.

CONCLUSION

The Dhaleshwari River water near the tannery industrial area in Savar, Dhaka, was examined for physicochemical, microbiological, ecological, and human health issues. Major physicochemical indices, heavy metals, and microbiological markers all exceed permitted values, indicating a significant deterioration in water quality. Ecological risk evaluations revealed a very significant environmental threat in every area, while water quality

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indices declared all samples unfit for any purpose. High concentrations of lead, chromium, and cadmium were identified as the main causes of contamination. Children were more sensitive, with both carcinogenic and non-carcinogenic risks exceeding acceptable limits, according to human health risk research. Pollution is mostly caused by home discharges and untreated tannery effluent. To protect aquatic ecosystems and public health, immediate upgrades to wastewater treatment facilities, strict enforcement of regulations, and continuous environmental monitoring are necessary.

Conflict of Interest

There are no conflicts of interest declared by the authors.

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APPENDIX

Table 3 Pearson's Correlation Matrix (PCM) of measured parameters

Correlations

	pH	Temp.	EC	TDS	DO	DO5	BOD	Salinity	Zn	Pb	Cu	Cd	Fe	Cr	Ni	TVC	TCC	HPC
pH	1																	
Temp.	.01	1																
EC	.38	.88	1															
TDS	.38	.88	1.00**	1														
DO	.75	.3	.35	.35	1													
DO5	.61	-.57	-.41	-.41	.53	1												
BOD	-.33	.83	.66	.66	-.12	-.90*	1											
Salinity	.35	.89*	1.00**	1.00**	.32	-.45	.69	1										
Zn	-.92*	-.12	-.53	-.53	-.55	-.46	.26	-.5	1									
Pb	-.3	-.7	-.91*	-.91*	-.05	.56	-.68	-.92*	.48	1								
Cu	-.43	-.75	-.94*	-.94*	-.29	.24	-.43	-.93*	.67	.83	1							
Cd	.08	-.41	-.37	-.37	.04	.05	-.04	-.36	.23	.18	.61	1						
Fe	-.95*	-.18	-.57	-.57	-.63	-.44	.2	-.54	.99**	.5	.66	.15	1					
Cr	-.83	-.46	-.78	-.78	-.61	-.06	-.24	-.76	.81	.75	.71	-.08	.87	1				
Ni	-.43	.87	.64	.64	-.15	-.88*	.96*	.67	.3	-.6	-.48	-.29	.26	-.1	1			
TVC	-.83	-.18	-.34	-.34	-.91*	-.69	.35	-.3	.75	.04	.43	.24	.78	.58	.31	1		
TCC	-.59	.31	.26	.26	-.76	-.73	.47	.28	.25	-.41	-.35	-.55	.33	.26	.58	.61	1	
HPC	.21	.93*	.98**	.98**	.25	-.49	.71	.98**	-.41	-.86	-.93*	-.51	-.43	-.62	.74	-.26	.4	1

* Correlation is significant at the 0.05 level (2-tailed)
** Correlation is significant at the 0.01 level (2-tailed)

Table 4 Pearson's Correlation Matrix (PCM) of analyzed parameters

	WQI	HMPI	HMTI	ERI	$HHRA_{DA}$	$HHRA_{DC}$
WQI	1					
HMPI	.82	1				
HMTI	.91*	.99**	1			
ERI	.89*	.99**	1.00**	1		
$HHRA_{DA}$	.58	.63	.62	.61	1	
$HHRA_{DC}$	.89*	.85	.91*	.90*	.38	1

* Correlation is significant at the 0.05 level (2-tailed)
** Correlation is significant at the 0.01 level (2-tailed)

$_{DA}$ Dermal Adult (Non-Carcinogenic)

$_{DC}$ Dermal Child (Non-Carcinogenic)

WQI: Water Quality Index
HMPI: Heavy Metal Pollution Index
HMTI: Heavy Metal Toxicity Index
ERI: Ecological Risk Index

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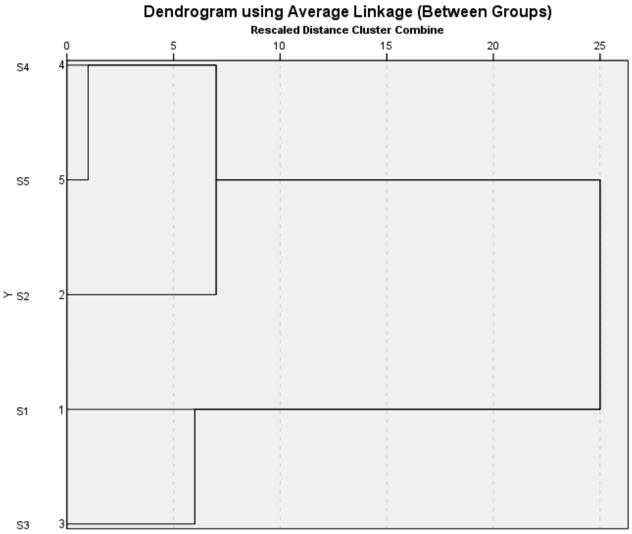
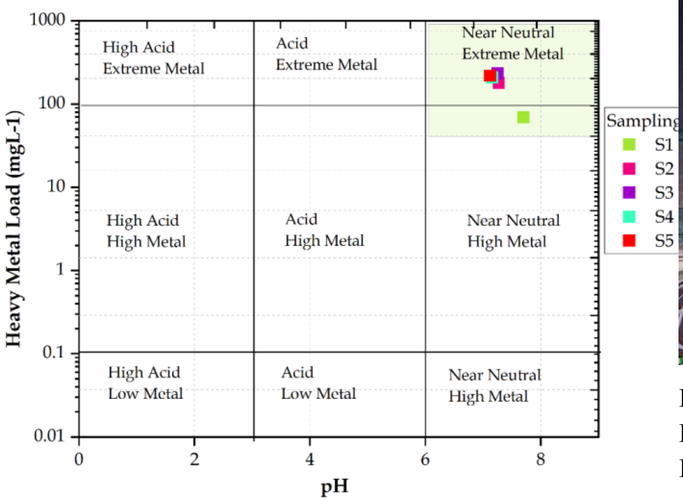


Figure 6 Dendrogram showing the hierarchical cluster of the sampling sites

(A)



(B)

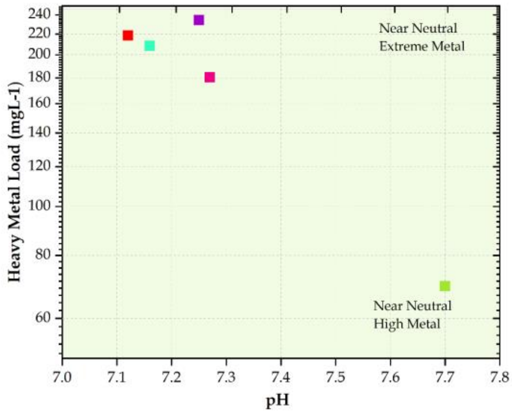


Figure 7 (A) Ficklin-Caboi diagram shows the surface water classification (B) Detailed diagram for near neutral-high metal and near neutral-extreme metal section (Shaded area)

Figure 8 Discharge-Point of BSCIC Tannery Industrial Estate (Central Effluent Treatment Plant Area)-Satellite Image.

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