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Characterization of Tannery Effluent and Efficiency Assessment of Central Effluent Treatment Plant (CETP) at Savar in Bangladesh

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***Abstract* - The industry discharges a large volume of effluent, many of which contain lots of chemicals and toxic substances that have the potential to cause distress to the environment. The study focused on analyzing various physicochemical parameters of the effluent discharge from the Central Effluent Treatment Plant (CETP) at the Savar Tannery Industrial Zone. The effluent was collected four times (pre-monsoon, monsoon, and post-monsoon) a year, from 2021-2022. The effluent was inspected for vital water quality parameters, such as pH, COD, BOD, TDS, TSS, NO_3^-, SO_4^{2-}, HCO_3^-, PO_4^{3-}, Cl^-, Na, Ca, Cr, Fe, Cu, Zn, and Pb. Most of the parameters exceed the standard permissible limit of the Department of Environment, Bangladesh (DoE, BD), NQES, and ISW-BDS for inland water. The mean concentrations of COD, BOD, TSS, and Cr were 337, 97.5, 209, and 6.1 mg/L, and these values were far above the permissible limit with a removal efficiency of 51%. The study observed that industrial discharge of unproperly treated effluent deteriorates the surface water quality and causes huge threats to aquatic life and sustainable water resource management.**
***Keywords:* CETP, Effluent, Heavy Metals, Pollutants, Tannery**

I. INTRODUCTION

Rapid industrialization and urbanization, particularly in developing nations, have increased awareness between pollution, public health, and the environment (WHO, 1982). Industries produce a lot of effluents, depending on the type of industry. The most water-intensive industries in the world are leather, textiles, pulp, paper mills, fertilizer, dyeing, sugar, chemicals, and petroleum refineries (Shakil and Mostafa, 2021a, b; Islam and Mostafa, 2018 and 2021; Monira *et al.,* 2022). Lower and upper-middle-income countries, like Bangladesh, India, Pakistan, and China, rely heavily on their leather industries (Chowdhury *et al.,* 2013). At present, the leather industry is one of the most polluting industries in the world. The leather industry wastewater is characterized by its high BOD, COD, TDS, and TSS and a high percentage of dissolved organic and inorganic matter (Akan *et al.,* 2009). So, this untreated wastewater will create problems for the environment. The quality of soil, surface water, and groundwater was systematically deteriorated by the release of untreated or improperly treated industrial effluent into the environment (Islam and Mostafa 2020). Untreated wastewater must be properly treated before discharging into the environment. In this context, an effective effluent treatment plant plays an important role in maintaining surface and groundwater quality as well as the environment. Generally, a common effluent treatment plant (CETP) is designed to help industries better control pollution. For this reason, an efficient effluent treatment plant is very necessary for its liquid waste management. The Central Effluent Treatment Plant (CETP) has been established at the Savar tannery estate, aiming to reduce pollution in the nearby areas of the city. The industries discharge the effluent through a pipeline, and it enters the CETP for treatment. After the treatment, it releases from the CETP and falls into the Dhaleshwari river. The samples were collected after the treatment by the CETP, just before falling into the Dhaleshwari River.

The CETP can process about 25,000 m^3 of liquid waste per day. But 40,000 m^3 of waste is produced by the tanners inside the estate every day (Monira *et al.,* 2022; Hossain *et al.,* 2019). The warning that about 15,000 cubic meters of untreated waste are currently being dumped into the nearby Dhaleshwari River is quite depressing. Concerns about the efficient operation of the CETP and other supporting elements like the dumping yard and chrome recovery section in ensuring environmental compliance have consequently developed as a burning problem of the relocation process from Hazaribagh to Hemayetpur. About 155 tannery industries have been transferred from Hazaribagh, Dhaka, to the Savar Tannery Estate at Hemayetpur to save the Buriganga river from further pollution, and 132 industries are now active in the production of leather goods (Mollik, 2022). Heavy metals, chromium, and other organic and inorganic substances that are discharged into the river pollute the river near the CETP. So, the efficiency of the Savar CETP is questionable. As of now, there are no details on the impact of tannery industrial effluent on the aquatic life at the Savar tannery estate. The study focused to analyze the discharge effluent from the CETP of the Savar Industrial zone in Bangladesh and its impacts on aquatic life.

II. MATERIALS AND METHODS

A. Study Area

The study zone is located in the tannery industrial estate at Savar Upazila, situated in the northwest part of Dhaka city, Bangladesh. It is located at 23°51′30″N 90°16′00″E / 23.8583°N 90.2667°E / 23.8583; 90.2667. Fig. 1 shows the sampling location of the study zone.

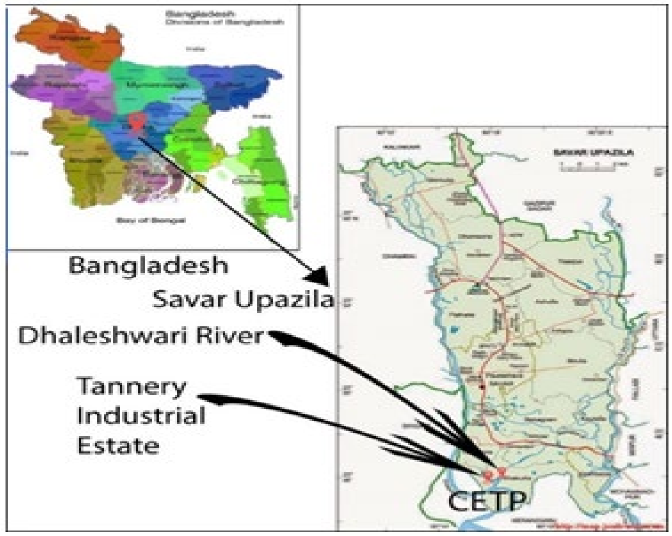

Fig. 1 Location map of the study zone

B. Sample Collection

Tannery industries discharge the effluent through a pipeline that enters the CETP for treatment. These industries generated a huge volume of tannery effluent that must need proper treatment. The study was conducted from September 2021 to September 2022, and the samples were collected four times during this period. A composite mixture of the tannery industrial effluent as well as the effluent from the outlet of CETP was collected in clean plastic bottles and stored in a refrigerator to avoid degradation before the chemical analysis in the Water Research Lab in the Institute of Environmental Science and the Central Research Lab of the University of Rajshahi, Bangladesh.

C. Characteristics of Tannery Effluent

The collected effluent samples were inspected for various physicochemical parameters like electrical conductivity (EC), chemical oxygen demand (COD), biological oxygen demand (BOD_5), total suspended solids (TSS), pH, and total dissolved solids (TDS). pH, DO, TDS, and EC values were measured on the spot using digital multi-meters. TSS was measured following the standard methods (APHA 1998). The BOD_5, COD, Cl^-, bicarbonate (HCO_3-), hardness, sulfate (SO_4^{2-}), and phosphate (PO_4^{3-}) were determined by standard methods of analysis (APHA-AWWA-WPCF 2005).

The concentrations of Na, K, Ca, Zn, Cu, Cr, Fe, Pb, Ni, Cd, Mn, and As ions in the effluent were estimated by the AAS method (APHA 1998).

III. RESULTS AND DISCUSSION

A. pH and DO

The pH values of treated composite tannery effluent ranged from 6.6 to 8.3, with a mean of 7.5 (Table I). The mean value of pH was within the standard value of the discharge limit of the Department of Environment, Bangladesh (DoE, BD), NQES, and ISW-BDS permissible limits for inland water. The usage of lime, Na_2CO_3, Na_2S, and NaOH during the processing of hides and skins was the cause of the slightly alkaline composition of these composite tannery effluents. The studied effluent samples had a mean dissolved oxygen content of 0.9 mg/L, which is well below the recommended standard limits established by the DoE, BD, NEQS (2000), and ISW-BDS-ECR. The highest and lowest values of dissolved oxygen (DO) were 1.2 and.5 mg/L, respectively (1997). The discharged composite effluent was highly contaminated and potentially detrimental to aquatic life, according to the DO value (1 mg/L).

B. EC, TDS, and TSS

The study results delivered that the concentration of TDS ranged from 6405 to 6617 mg/L which exceeded the (2100 mg/L, DoE, BD) standard permissible limits, indicating the presence of large amounts of dissolved solids. The mean TDS concentration was 6486 mg/L, which is almost triple compared to the standard permissible limit. Rouf *et al.,* (2013) stated that the TDS concentration of the tannery effluent was 3455 mg/L in the sample's sources from various points in the Hazaribagh tannery industrial zone, which was half the TDS concentration of the present study. The TSS contents of the analyzed composite tannery effluent ranged from 82 to 322 mg/L with a mean value of 209 mg/L (Table I). These values exceeded the permissible limit set by the DoE, BD (150 mg/L), indicating enormous amounts of suspended solids present in the discharge effluent. The higher values of TSS and TDS in the tannery estate were due to the presence of various organic and inorganic substances. The high levels of TSS and TDS in the effluent indicated that the effluent must be properly treated before discharging into the surface water bodies. The electrical conductivity (EC) values of the composite effluent samples ranged from 9300 to 12700 µs/cm in the study period and were higher compared to the prescribed standard limit (1200 DoE, 288 mg/L NEQS, 2000). The higher EC content in the tannery effluent samples revealed the presence of a sufficient amount of sodium and chromium salts employed in the pickling and tanning operations or phases, which may have increased the tannery effluent samples' electrical conductivity (Priya, 2010). The average EC (10415 s/cm) of all composite samples was far higher than the accepted limits, indicating an extremely toxic environment for aquatic life.

TABLE I PHYSICOCHEMICAL PARAMETERS OF TANNERY INDUSTRIAL EFFLUENT

Parameters *(mg/L)	Effluent Periods					Permissible limit		
	Sep 21	Dec 21	March 22	Sep 22	Mean±SD	DoE (1997) Standard	ISW-BDS-ECR (1997)	NEQS
pH	7.4	6.6	8.3	7.5	7.5±0.7	6-9	6-9	6-9
DO	0.5	0.8	1.2	0.9	0.85±0.3	4-6	4.8-9	4-6
EC µs/cm	12700	9300	10180	9480	10415±1569.9	1200	1200	288
TDS	6437	6405	6617	6435	6486±292	2100	2100	3500
TSS	223	322	82	222	209±120	150	-	150
BOD	80	53	137	120	97.5±38.1	50	-	50
COD	312	208	489	310	337±142	200	-	200
Hardness	635	730	672	932	742.25±132.4	-	-	-

*Parameters unit: mg/L, except pH and EC

C. Biological and Chemical Oxygen Demand (BOD_5 and COD)

The values of BOD_5 in the effluent samples were in the range of 53-137 mg/L (Table I). A maximum of 137 mg/L of BOD_5 was found in the effluent of the Savar tannery industrial area. All the BOD_5 values of the tannery effluent obtained were higher than the discharge standard for tannery effluent (50 mg/L, DoE, BD). The high value of BOD_5 indicates the presence of a large quantity of organic and inorganic substances in the tannery effluent. The larger content of organic ingredients consumed a huge quantity of O_2 and increased the level of BOD_5. A similar study was reported by Gosh and Hossain (2019).

In the present study, the average value of COD observed was 337 mg/L in the composite mixture of the effluent discharged by the tannery industries, which is two times higher than DoE, and BD discharge standard limits. The results also indicated that the COD level at all monitoring tannery industries did not meet the standard discharge limit into inland surface water (permissible limit: 200 mg/L, DoE BD). The high COD level commonly indicates the concentration of organic and inorganic matter in wastewater that is not decomposed by microorganisms (Islam *et al.,* 2014). Fish and other aquatic species experience discomfort in respiration due to a decrease in oxygen levels. The pH is altered and BOD_5 and COD levels are raised when effluent is dumped into aquatic habitats. As a result, the tannery effluent needs to be thoroughly treated before it may be released into nearby bodies of water.

D. Total Hardness

The total hardness of the study ranged from 635 to 932 mg/L in the composite tannery effluent during the study period (Table I). The highest total hardness observed was 932 mg/L in the discharge effluent. Gosh and Hossain (2019), illustrated that the total hardness of the tannery effluent for the same industrial estate was 490 mg/L, which was lower by about half the present study. The larger context of the total hardness of the effluent indicates high levels of carbonate, bicarbonate, and liquified salts in the effluents (Bosnic *et al.,* 2000).

E. Anionic Parameters

The average chloride (Cl^-) concentration in the effluent of the Savar tannery industrial estate was found to be 1667 mg/L during the study period. The incidence of a higher amount of chloride content in tannery effluent was the consequence of adding the surplus quantity of NaCl for the primary preservation and pickling procedures of the skins and hides. Thus, it remained a pollution load on the surrounding environment (Saritha and Meikandaan, 2013). Hence, a higher value of chlorides in the composite effluent increased the chloride contamination of the adjacent surface water bodies.

The results of the present research represent that the concentration of nitrate, sulfate, phosphate, and bicarbonate ions in the tannery effluent samples of the Savar tannery industrial area ranged from 3.25-4.65, 1830-1870, 6.9-7.5 mg/L and 100-730 mg/L respectively (Table II). Whitehead *et al.,* (2021), illustrated that the average concentrations of phosphate, nitrate, sulfate, and chloride in the tannery effluent in Bangladesh were 17.6, 61.7, 2783.6, and 6631.7 mg/L, respectively, which poses some similarities with the present study results. The values of chloride and sulfate in the effluent samples from the tannery industrial estate exceeded the discharge limits set by the NEQS and DoE.

TABLE II ANIONIC PARAMETERS OF TANNERY INDUSTRIAL EFFLUENTS

Parameters (mg/L)	Effluent Periods					Permissible limit		
	Sept 21	Dec 21	March 22	Sept 22	Mean ± SD	DoE (1997) Standard	ISW-BDS-ECR (1997)	NEQS
HCO_3^-	115	100	730	113	315 ± 359.5	-	-	-
PO_4^{3-}	7.5	7.1	6.9	7.3	7.2 ±0.3	10	-	-
SO_4^{2-}	1870	1830	1850	1850	1850 ± 20		-	5
Cl^-	2510	1300	1190	2515	1667 ± 732.42	600	-	600
$N\text{-}NO_3^-$	3.25	4.65	4.1	3.23	4 ± 0.71	10	-	50

TABLE III CATIONIC PARAMETERS OF TANNERY INDUSTRIAL EFFLUENT

Parameters (mg/L)	Periods					Permissible limit	
	Sept 21	Dec 21	March 22	Sept 22	Mean ± SD	DoE (1997) Standard	ISI-2000
Na	1852	1647	1944	1810	1814±152	-	-
K	1.0	1.0	1.0	2.5	1.4±0.8	-	-
Ca	87	85	95	143	102.5±27.3	-	-
Cu	0.9	0.95	0.93	0.98	0.94±0.03	0.5	2
Zn	0.9	0.95	0.93	0.90	0.92±0.02	5	5
Cr	5.8	6.3	6.4	5.9	6.1±0.3	0.5	0.1
Fe	1.9	2.7	1.9	1.7	2.05±0.4	2	-
Pb	0.18	0.29	0.29	0.20	0.24±0.1	0.01	0.2
Ni	0	0	0	0	0	-	3.0
Cd	0	0	0	0	0	-	.1
Mn	0.2	0.3	0.2	0.2	0.2±0.1	-	.2
As	0	0	0	0	0	-	.1

TABLE IV REMOVAL EFFICIENCY OF MAJOR PARAMETERS

Parameters (mg/L)	Influents (Avg)	Effluent (Avg)	% Removal	DoE (1997) Standard	ISW-BDS-ECR	NEQS
EC µs/cm	11872.5	10415	12%	1200	1200	288
TDS	6817	6486	4.8%	2100	2100	3500
TSS	1655.5	209	87%	150	-	150
BOD	572	97.5	83%	50	-	50
COD	1646	337	79.5%	200	-	200
Cr	79.2	6.1	92%	.5	-	-
Na	1884	1814	3.7%	-	-	-
Overall removal efficiency: [(12+4.8+87+83+79.5+92%)/7]100%= 51%						

F. Cationic Parameters

The concentration of metallic ions in the composite tannery effluents, which were gathered from the CETP's output at the Savar tannery industrial area, is displayed in Table III. In accordance with the findings, the concentration of metal ions during the research period varied from Ca 85 to 143 mg/L, K 1.0 to 2.5 mg/L, Fe 1.7 to 2.7 mg/L, Pb.18 to.29 mg/L, Mn.20 to.30 mg/L, Cr 5.8 to 6.4 mg/L, Na 1810 to 1944 mg/L, Zn.90 to.95 mg/L, and Cu.90 to. Based on mean values, the composite tannery effluents' metallic ion content was in the following order: Na>Ca>Cr>Fe>K>Cu>Zn>Pb>Mn. Metals emitted from the leather industry are responsible for numerous risks to human health and aquatic life. Monira *et al.,* (2023) represent the value of untreated effluents of composite tannery effluents of Savar tannery industrial estate from those values we calculate the removal efficiency of major parameters or pollutants (Table IV) and which is about

51%. From this, we can say that most countries have an ETP, but their efficiency is not satisfactory. To improve the effectiveness, combined approaches that combine physical, chemical, and biological treatment procedures should be adopted (Plooy *et al.,* 2014).

G. Impacts of Tannery Effluents

The study found that the effluent contained high EC values with an average value of 10415 mg/L **(**Table v**)**. Higher EC values indicate that the water contains huge amounts of dissolved ions (Shannon *et al.,* 2020). The higher electrical conductivity values of the effluent, therefore, indicated the presence of more salts in the effluent. The effluent contains a high level of TSS values with an average value of 209 mg/L (Table V). Moreover, total suspended solids can cause turbidity, which reduces the amount of light available for photosynthetic activity by impairing light penetration or perforation in the aquatic system. The soil fertility, soil porosity, texture, and water-holding capacity may all be adversely affected by the high TSS value (Chowdhury *et al.,* 2015).

A higher level of BOD and COD in the effluent decreased the DO level of water, mentioning the existence of both inorganic and organic pollutants at high levels in the effluent (Pandey *et al.,* 2003). Low DO decreases fish populations and unbalances the aquatic ecosystem (Connolly *et al.,* 2004). The concentrations of BOD and COD were very much higher than the standard limits. The study results showed that the high BOD values suggested that the tannery effluent had significant organic and inorganic contaminants. Akan *et al.,* (2007) illustrated that higher levels of BOD and COD in tannery effluent enhance the oxidation of organic and inorganic compounds that utilize dissolved oxygen, resulting in O_2 reduction, and may lead to hypoxic conditions, which would have a negative impact on the aquatic ecosystem. Under such a condition, no aquatic biota can survive (Trivedy *et al.,* 2009). Algal bloom, eutrophication, microcystin, etc. are caused by excess nitrate and phosphate (EPA, 2021). Toxic organic pollutants are responsible for Bioaccumulation and hepatotoxic, carcinogenic, cytotoxic, mutagenic, and genotoxic effects and aquatic stress (Yadav and Chandra, 2018).

TABLE V IMPACTS OF THE EFFLUENT DISCHARGED FROM THE TANNERY INDUSTRIES

Parameters	Value	Impacts	References
Low DO	.6	Acute stress and death of aquatic organisms, fisheries decrease, ecosystem disturbance	Connolly *et al.,*2004
High EC	10996	The high volume of dissolved ions causes harm to the aquatic environment	Shannon *et al.,*2020
High TSS	1756	Changing water-holding capacity, soil porosity, and texture, and decreasing soil fertility	Chowdhury *et al.,*2015
High BOD, COD	553,1646	DO level decreasing, fisheries decrease, toxicity and death of aquatic organisms	Trivedy *et al.,*2009
High No_3-N	60.18	Algal bloom, eutrophication, and anoxia of surface water body, blue baby syndrome	EPA, 2021
High Po_4^{3}-	28.3	Algal bloom, eutrophication, microcystin	EPA, 2021
Toxic organic pollutants	-	Bioaccumulation and hepatotoxic, carcinogenic, cytotoxic, mutagenic, and genotoxic effects and aquatic stress.	Yadav and Chandra, 2018
High Cr	58	Carcinogenic leads to kidney disorders, ulcers, nervous disorders, and aquatic disorder	Javed M 2005
High Na	1884	Salinity increases, heart diseases, high blood pressure, and aquatic stress.	Chowdhury *et al.,*2015

IV. CONCLUSION

The pollution due to the discharge of poorly treated tannery effluent in Bangladesh is the foremost environmental alarm. The study aimed to analyze various physicochemical parameters of the composite tannery industrial effluent of the Savar Tannery Industrial Zone after treatment at the Central Effluent Treatment Plant. The study results showed high values of EC, TSS, TDS, TH, BOD_5, COD, NO_3^-, $SO_4^{2-,}$ HCO_3-, PO_4^{3}-, $Cl^{-,}$ and metals like Na, Cr, Ca, Cu, Zn, Fe, Pb, K, and Mn in the composite tannery effluent at the Savar tannery estate. The values of the physicochemical parameters were above the standard permissible limits of effluent discharge prescribed by the ISW-BDS-ECR (1997), DoE, BD, and NEQS (2000). The effluent had mean values of 209 mg/L for total suspended solids (TSS), 6486 mg/L for total dissolved solids (TDS), and 7.5 mg/L for pH. Biological oxygen demand (BOD), chemical oxygen demand (COD), and dissolved oxygen (DO) averaged 0.9, 97.5 mg/L, and 337 mg/L, respectively. The concentration of anions, such as NO_3-, SO_4^{2}-, HCO_3-, PO_4^{3}-, and Cl^-, was 4, 1850, 315, 7.2, and 1667 mg/L, respectively. The average electrical conductivity (EC) was 10415 µS/cm. The cation concentrations in the tannery effluent were in the following order: Na>Ca>Cr>Fe>K>Cu>Zn>Pb>Mn. The removal efficiency for major pollutants was found to be 51%. The poorly treated tannery effluent is not suitable for discharging into nearby surface water bodies. Such performances pose threats to aquatic life, humans, and the environment. The study observed that the discharge effluent should be properly treated before discharge into surrounding water bodies, and the performance of the CETP should be monitored regularly to achieve a sustainable ecosystem.

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