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Research Article

Physicochemical Characterization and Heavy Metal Analysis of Effluents from the Tannerie Abidjanaise (Bonoua, Côte d'Ivoire)

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Abstract

The tanning industry, although essential for leather production, is one of the most polluting due to the significant discharge of effluents containing toxic chemicals. The objective of this study was to analyze physicochemical parameters and metals of composite samples from effluents of the Tannerie Abidjanaise (Côte d'Ivoire). All parameters of the effluents were measured using standardized methods. Hexavalent chromium (Cr (VI)) and other heavy metals (Copper, Iron, Manganese, Nickel, Plomb, Total chromium, Zinc) have been determined by means of an ion chromatograph and an Inductively Coupled Plasma Optical Emission Spectroscopy (ICP OES), respectively. Environmental Risk Assessment of Tannerie Abidjanaise were done with the heavy metal evaluation index (HEI). The Kruskal-Wallis test was made to bring out the relation between in value of all parameters of the different sampling. The mean concentration of temperature, pH, and SSM were 26.7, 7.04 and 414 mg/L, respectively. The average level of Total nitrogen, COD and BOD5 were 238 mg/L, 720 mg/L, and 249 mg/L, respectively. All of these parameters were higher than that of standard permissible limits. The BOD5 and COD ratio ranged from 0.3 to 0.4 indicated the low biodegradability of the effluents. The tannery effluents have TCr and Cr (VI) value with average concentrations of 122 mg/L and 49 mg/L, respectively. Like iron (average of 7.3 mg/L), TCr and Cr (VI) were higher than the standard permissible limits prescribed by National standards. Copper, lead, manganese, and zinc were determined at very low levels, while arsenic, cadmium, and nickel were below their detection limits. There is no significantly difference between the value of the different sampling for all parameters according to Kruskal-Wallis test. Tannerie Abidjanaise's effluents present environmental risk to heavy metals provides according to HEI methodology.

Keywords

Tannery, Effluents, Physicochemical Parameters, Heavy Metals, Characterization

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1. Introduction

The tanning process aims to transform raw hides into stable, rot-proof products, namely leather [1]. Leather manufacturing is a significant activity that meets local and international demand for leather goods, such as shoes and drums [2]. The growth of this industry's products is intrinsically linked to population development and the increasing demand for leather and leather products [3]. However, the tanning industry is generally described as one of the most polluting industries, generating a wide variety of high pollutant loads [4]. The tanning process is a wet process that uses significant amounts of chemicals and consumes large quantities of water, and produces approximately 90% of wastewater in the form of effluent [5]. These effluents are perceived as an enormous ecological danger due to their high pollution in terms of dissolved and suspended solids, salinity, nitrogen, conductivity, sulphate, sulphide, chloride, biological oxygen demand, chemical oxygen demand, and chromium [6, 7]. According to [8] only about 20% of the chemicals used in the tanning process are actually absorbed by the leather; the rest are released as waste. Chromium, the most popular tanning agent and a major component of tannery effluents, tends to accumulate in living organisms, causing serious illness and environmental pollution [9]. It primarily exists in the +2, +3, and +6 oxidation states. Trivalent chromium (+3), the most stable form, is essential to mammals in trace amounts and is not very mobile in aquatic systems due to its low solubility. Hexavalent chromium (+6), on the other hand, is highly toxic to aquatic plants, animals, and bacteria [8-10]. Many case studies have shown that this form of chromium is genotoxic, carcinogenic and mutagenic even at low concentrations [11, 12]. Tannery effluents, rich in hexavalent chromium, degrade aquatic and terrestrial ecosystems, threatening biodiversity and the health of local populations [13]. In the majority of underdeveloped nations, the tannery effluents are dumped into aquatic environment untreated. However, a rigorous management of these wastewaters is therefore essential to limit their impact on the environment and living beings. The aim of this study is to examine the composition of effluents from the Tannerie Abidjanaise (Côte d'Ivoire) in order to identify the physicochemical and metallic contaminants of concern discharged by this industrial unit.

2. Materials and Methods

2.1. Study Area

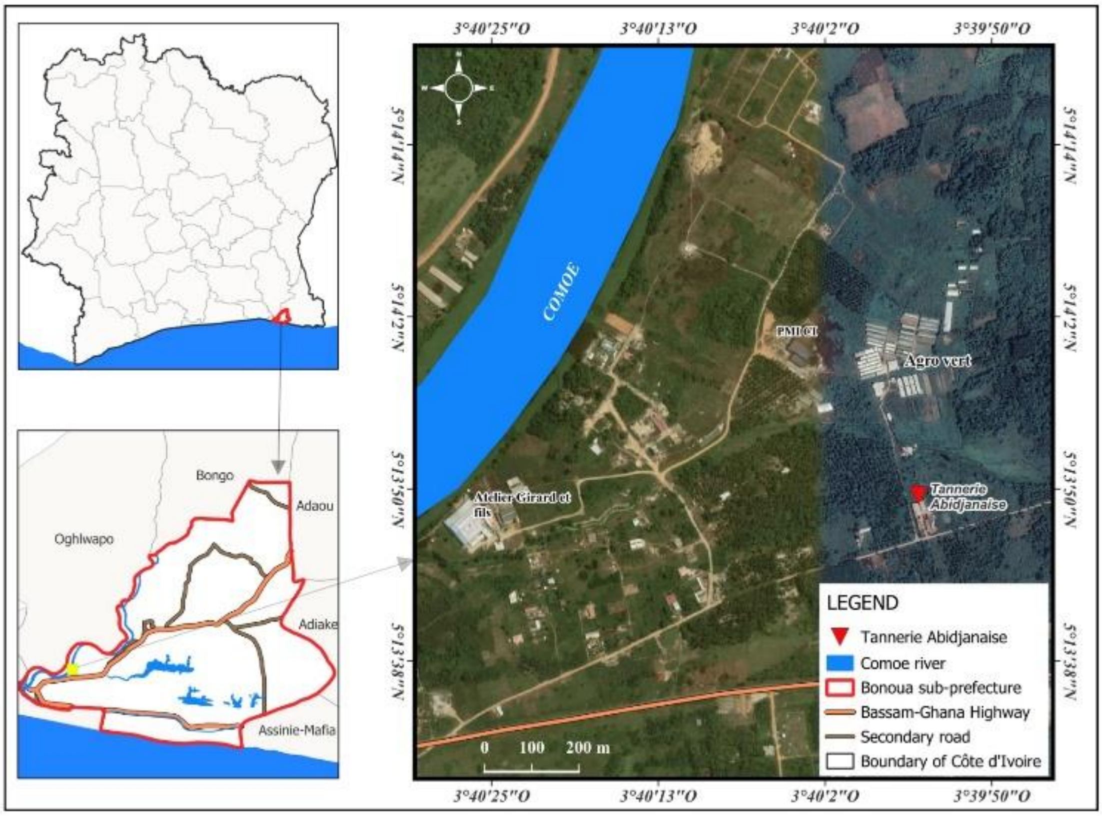

Figure 1. *Localization of the study area.*

The Tannerie Abidjanaise is located in the Bonoua region in south-eastern Côte d'Ivoire, 60 km from Abidjan (the economic capital of Côte d'Ivoire) (Figure 1). With an area of 2 209 km², the region lies between latitudes 5°14' and 5°31' North and longitudes 3°13' and 3°51' West [14]. The region is crossed by the Comoe River and the Bia and Me Rivers, which flow into lagoons that serve as a gateway to the Atlantic Ocean. The Tannerie Abidjanaise samples were taken more precisely in Yaou, a place located 8 km from the town of Bonoua.

2.2. Wet-blue Production Process

Tannerie Abidjanaise's hide-processing manufacturing process comprises several stages and leads to a semi-finished leather called wet-blue. Figure 2 shows the wet-blue production process with the stages during which wastewater is discharged (W).

2.3. Sampling Procedure and Field Measurements

Wastewater from the tannery is stored in a basin at the factory exit before being discharged into the environment. The HACH-AS950 automatic sampler (HACH, Loveland, USA) was used to collect 24-hour composite wastewater samples. Effluent samples were collected in acid-washed and pre-rinsed polyethylene bottles. Field parameters, temperature, pH, total dissolved solids (TDS), and electrical conductivity (EC) were measured on-site using a calibrated multi-parameter AZ 86031 Combo Water Meter. A total of 04 composite wastewater samples were collected from July to October 2024. All samples were sealed, stored, and transported to the laboratory within 24 h at 4°C in icepacked coolers for analysis, and where they were warmed to room temperature before being analyzed. Those intended for metal analysis were acidified with nitric acid (HNO_3, 65%) (1 ml of acid in 1000 ml of sample).

2.4. Laboratory Analysis

In the laboratory, total phosphorus (TP) and total nitrogen (TN) were carried out using a VARIAN Cary 50 BIO UV Spectrophotometer according to NF EN ISO 6878:2005 and NF EN 25663:1994, respectively. The analysis of suspended solid matter (SSM) was conducted by filtering the wastewater through 0.45 µm membrane filters, and then keeping filter papers at 103°C for 24 hours and calculating the weight difference. The level of five-day biological oxygen demand (BOD_5) was calculated via WTW OxiTop and AQUALITIC incubator devices according to the NF EN ISO 5815-2:2003 method. The chemical oxygen demand (COD) was determined using the potassium dichromate consumption technique based on the NF T90-101:2001 with a JP Selecta digester. A Thermo Scientific Dionex ICS-5000+ ion chromatograph with UV-Vis detector (IC/UV-Vis) was used to analyze the hexavalent chromium (Cr (VI)) by the EPA method 7199:1996. Concentrations of heavy metals (Copper, Iron, Lead, Manganese, Nickel, Total Chromium, Zinc) were determined using a Thermo Scientific ICAP 6000 Inductively Coupled Plasma Optical Emission Spectroscopy (ICP OES) performing with ISO 11885 (2007) method protocol. The results were compared with effluent limit values of Ivoirian Environmental Protection Authority.

2.5. Environmental Risk Assessment of Tannery Wastewater

The heavy metal evaluation index (HEI) was used to determine the overall water quality concerning metal contamination. The HEI was computed using Equation (1):

$$\mathrm{HEI}=\sum_{i=1}^{n} Hc/Hmax \tag{1}$$

where Hc is the measured value, and Hmax is the maximum permissible limit of each trace metal. Based on the computed value of HEI, there are three levels of contamination: (i) HEI > 20, high contamination, (ii) HEI 10-20, medium contamination and (iii) HEI < 10, low contamination [15].

2.6. The Kruskal-Wallis Test

The Kruskal-Wallis test is a non-parametric test commonly used to compare two or more independent groups [16]. The non-parametric Kruskal-Wallis test is executed by ranking the data and performing a parametric test on the ranks to determine whether all groups have the same median, or whether at least one median is different [17].

In this study, the Kruskal-Wallis test was applied to compare monthly concentrations (July to October) of various parameters in the water. The null hypothesis for this test is that there is no significant difference between months for each parameter. The significance level is α = 0.05 (i.e., 5%).

Raw hides

Beamhouse operations	**Soaking** Cleansing, desalting and rehydrating the skin	W	 **Drum**
	Unhairing / liming Chemical removal of hair and skin epidermis and increased skin reactivity (pH >10).	W	
	Fleshing Removal of subcutaneous skin tissue		 **Weed wacker**
Chromium tanning	**Deliming** Skin neutralisation (pH 7-9)	W	 **Drum**
	Maceration Biochemical and enzymatic action	W	
	Picklage Skin acidification (pH 2.5-3.0)		
	Chromium tanning • Penetration of chromium into the skin (pH 2.5-3.0) • Fixation of chromium on fibres (pH 3.5 to 4.0)	W	
Wet finishing	Sammying, splitting, shaving		 **Wet-blue**

Figure 2. *Wet-blue production process.*

3. Results and Discussion

3.1. Physicochemical Parameters of Effluent Samples

Table 1 shows the results of the physico-chemical parameters analysed.

3.1.1. Temperature, pH and Electrical Conductivity of Effluents

Temperature is an important element for the survival of aquatic animal species [18]. The temperature value is constant and ranges between 26.3 and 27.3 ℃ with an average of 26.7 ±0.4. These values are in compliance with Ivorian legislation (<40 ℃). According to Saeed *et al*. [19], this indicates that the tannery effluents are unlikely to cause thermal pollution. Furthermore, the work of Amanial [20] indicates temperature results for tannery effluents between 24 and 30 ℃.

The pH ranges from 5.25 to 8.45 with an average of 7.04 ± 1.60. These effluents meet the discharge standard for this parameter. The pH of samples of July and September are acidic while those of samples August and October are basic. The lowest pH value may be due to addition of sulphuric acid during the pickling stage. In contrast, the highest pH value may be to the use of an excessive amount of lime and sodium sulfide in leather tannery processes [18]. Electrical conductivity (EC) values are in the range of 10.45-30.75 mS/cm with a mean value of 20.66±8.29 mS/cm. For Noorjahan and Siddiqui [21], these high values suggest the presence of adequate amounts of organic and inorganic compounds and salts, mainly sodium and chromium salts used in pickling and tanning processes, which may have increased the electrical conductivity of the effluent samples. This could result in a highly toxic environment for the biota of the receiving aquatic environment [22]. Further interpretation of EC would require a reference point or established guidelines to assess its significance for environmental discharge [23].

3.1.2. Total Dissolved Solids and Suspended Solids Matters

The value of total dissolved solids (TDS) ranges from 6650 to 19550 with an average of 13138 ±5267. These values are high. The high value was due to pickling and chromium tanning and the low value to fat liquoring [18]. According to Patel *et al*. [24], high levels of TDS are aesthetically not accepted by the society it may create distress in humans and livestock. High TDS value increases the salinity of water and thus may render it unhealthy for drinking and irrigation purposes [25].

This makes the discharge of wastewater into surface water harmful. Consumption of water with high concentrations of TDS has been reported to cause disorders of alimentary canal, respiratory system, nervous system, coronary system besides causing miscarriage and cancer [26]. So if the TDS is higher than the toxicity level must be higher, which breaks the ecological cycle and causes ecological imbalance. It should be minimized as much as possible [27].

Table 1. *Physicochemical parameters of tannery effluents.*

Parameters	Units	July	August	Sept.	Oct.	Mean±SD	[28]
Temperature	℃	26.5	26.6	27.3	26.3	26.7 ±0.4	40
pH	-	6.11	8.45	5.25	8.35	7.04 ±1.60	5.5-9.5
EC	mS/cm	30.75	10.45	20.68	20.76	20.66 ±8.3	-
TDS	mg/L	19550	6650	13150	13200	13138 ±5257	-
SSM	mg/L	235.0	60.0	120.0	1242.5	414.5 ±556.8	50-150
Totalt nitrogen	mg/L	278.52	173.44	225.28	277.12	238.59 ±50.00	50
Total phosphorus	mg/L	4.42	2.12	0.82	25.14	8.13 ±11.44	15
COD	mg/l	920	580	670	710	720 ±144	300-500
BOD_5	mg/l	330	205	220	240	249 ±56	100-150

TDS: Total Dissolved solids - SSM: Suspended solid matters - COD: Chemical oxygen demand - BOD_5: Five-day Biological oxygen demand
Sept.: September - Oct.: October

The value of suspended solids matter (SSM) measured in the effluent of the Tannerie Abidjanaise varies from 60.0 to 1242.5 mg/L with an average of 138.3 ±556.8. They exceed the lower limit (50 mg/L) of the [28]. High concentrations of suspended solids may settle out onto a streambed or lake bottom and cover aquatic organisms, eggs, or macro-invertebrate larva. This coating can prevent sufficient oxygen transfer and result in the death of buried organisms [29]. Indeed, suspended solids matter have a negative effect on aquatic life. The discharged suspended solids matter settles on the riverbed and kill aquatic organisms that live at the bottom of the river. Floating solids interfere with the ability of the river to self-purify by regenerating the absorption of oxygen from the atmosphere. Suspended solids matter also interfere with the photosynthetic activity of plankton and aquatic plants in a river. The composition of solids present in tannery effluent mainly depends upon the nature and quality of hides and skins processed in the tannery [30]. To mitigate these impacts, the adoption of pretreatment technologies, such as rotary screens or microfiltration, is recommended from the dehairing and deliming stages, reducing the pollutant load at the source [31].

3.1.3. Total Nitrogen and Phosphorus

All total nitrogen values obtained exceed the National standard (50 mg/L). They actually range from 173.44 to 278.52 mg/L. These values have an average of 238.59 ± 50.00 mg/L. However, a high level of total nitrogen can cause eutrophic conditions [20]. Total phosphorus values were within standards, except for sample of October (25.14 mg/L). Elevated phosphorus can accelerate aquatic plant growth and alter water quality [32]. Both nitrogen and phosphorus contribute to eutrophication, with the C:N:P ratio (40:7:1) being a key factor [33]. Phosphorus is often the limiting nutrient, and its excess can disrupt calcium metabolism, leading to bone loss in humans and animals [34].

3.1.4. DBO$_5$, DCO and Biodegradability Index

The concentrations of biochemical oxygen demand varied from 205 to 330 mg/L, with an average of 249±56 mg/L. Chemical oxygen demand values were higher across all samples, ranging between 580 and 920 mg/L, with an average of 720 ± 144 mg/L. All BOD$_5$ and COD values from the tannery effluents obtained were above the upper discharge limits by the [28] (Figure 3). The permissible limits are 100-150 for BOD$_5$ and 300-500 for COD. These relatively high levels of BOD$_5$ and COD observed in the effluents could be due to the large amount of organic matter coming from the various chemicals used during hide treatment. Indeed, it has been reported that a significant proportion of the chemicals used, often used in excess, in the tanning process are not actually absorbed in the process and released into the environment [35, 36]. Effluents from tanneries may contain biorefractory substances and chemicals that inhibit biomass [37]. The wet-blue production stages in this tannery involve the use of a number of chemicals, including formic and sulfuric acids, chromium sulfate, enzymes, soap and bactericidal agents. The COD level commonly indicates the concentration of organic matter in wastewater which is weakly decomposed by microorganisms as it is not decomposed for more COD level [38]. So, it is essential to proceed with the treatment of the tannery effluents before being discharged into adjacent water bodies. At these BOD$_5$ and COD levels (from in this study) in the receiving water, the reduction in oxygen could stress aquatic organisms.

The figure 4 shows that the BOD$_5$ and COD ratio of the tannery effluents was found to be between 0.3 and 0.4, indicating low biodegradability [22]. For Rudaru *et al.* [39], if BOD$_5$/COD ratio is between 0.3-0.6, it's necessary to treat the wastewater biologically and the acclimation of the microorganisms will help in the degradation process.

This observation is confirmed by COD/BOD$_5$ ratios of 3. Indeed, biodegradability coefficients (COD/BOD$_5$) between 3 and 5 characterize effluents that are moderately biodegradable [40] to non-degradable [41].

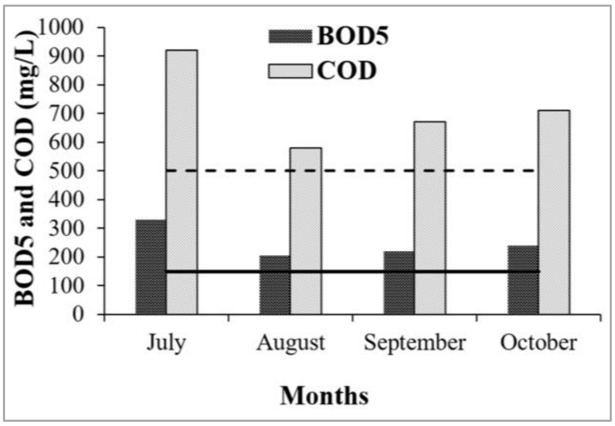

Figure 3. *Concentrations of BOD$_5$ and COD in tannery effluents with national standard for BOD$_5$ (NS-BOD$_5$) and COD (NS-COD).*

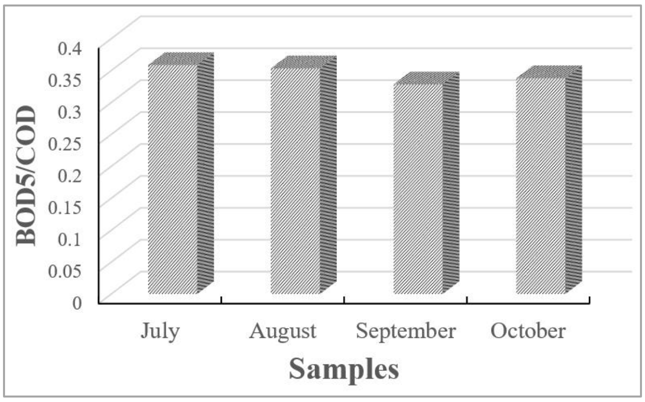

Figure 4. *Biodegradability index of tannery effluents.*

3.2. Concentrations of Traces Metallic Constituents

Table 3 presents the concentrations of arsenic, cadmium, iron, copper, lead, manganese, nickel, zinc, as well as hexavalent and total chromium in the tannery effluents. Of all these metals, Total Chromium (TCr) and Chromium VI (Cr (VI)) exhibit the highest concentrations.

Table 2. *Concentrations of traces metallic constituents of tannery effluents.*

Parameters	Units	July	August	September	October	[28]
Arsenic	mg/L	<0.005	<0.005	<0.005	<0.005	-
Cadmium	mg/L	<0.0005	<0.0005	<0.0005	<0.0005	-
Total chromium (TCr)	mg/L	91.8	105.0	93.2	198.0	1.5
Chromium VI (Cr(VI))	mg/L	23.0	44.0	33.0	95.0	0.1
Copper	mg/L	<0.005	0.033	<0.005	0.065	0.5
Iron	mg/L	2.93	10.8	6.79	8.66	5
Manganese	mg/L	0.406	0.449	0.485	0.511	1
Nickel	mg/L	<0.005	<0.005	<0.005	<0.005	0.5
Lead	mg/L	0.008	0.012	0.011	0.012	0.5
Zinc	mg/L	<0.05	0.085	0.073	0.113	2

3.2.1. Concentrations of Chromium

Figure 5 shows the concentration of chromium in the tannery effluents collected from the retention basin at the exit of the tannery. The results show that the concentrations of TCr ranged from 93.2 to 198.0 mg/l with an average of 122.0 ± 51 mg/L. Chromium VI (Cr (VI)) level varied from 23.0 to 95.0 mg/L with an average of 48.8±32.0 mg/l. Both TCr and Cr (VI) concentration in each sample were found to be higher than permissible limits of the [28] of 1.5 and 0.1 mg/L, respectively. As previously mentioned in a study [42], chromium sulphate (Cr_2 $(SO_4)_3$) is used as a tanning agent.

The presence of Cr (VI), although in lower concentrations than total chromium, remains a concern due to its high toxicity and carcinogenic potential, classified as such by the International Agency for Research on Cancer [43]. Cr (VI) can form through the oxidation of Cr (III) under aerobic conditions or in the presence of oxidising agents, as observed in effluent storage basins [44]. This chemical transformation highlights the importance of controlling effluent redox conditions to prevent the generation of Cr (VI) [45].

It is well known that wastewaters generated from tannery industries are the major source of chromium pollution. So it is not safe to discharge tannery effluents into water bodies without proper treatment because they alter the physico-chemical properties of the water creating harmful effect to aquatic ecosystem and the people residing in tanning industrial area are at high risk facing deleterious health effects even on dilution [46]. The high proportion of Cr (VI) is particularly worrisome due to its mobility, solubility, and strong oxidizing potential, making it a potent carcinogen and mutagen [47]. Its presence may result from direct use or, more likely, oxidation of Cr (III) under high pH, strong oxidizers, or poor process control. Environmental conversion of Cr (III) to Cr (VI) can be facilitated by manganese oxides [48].

3.2.2. Other Traces Metallic Constituents

After chromium, iron is the most abundant metal, with concentrations ranging from 0 to 10.8 mg/L and an average of 7.3 ± 3.3 mg/L. The levels observed in August, September, and October, as well as the mean value for all samples, are higher than the permitted value (5 mg/L). These relatively high values could be attributed to the use of iron-containing chemicals (ferrous salts for degreasing) or corrosion of industrial equipment, as described by [49] in their study on the degradation of metal infrastructure in acidic environments. Although less toxic than other metals, high concentrations of iron can cause water discoloration and sludge formation, disrupting biological treatment systems [50].

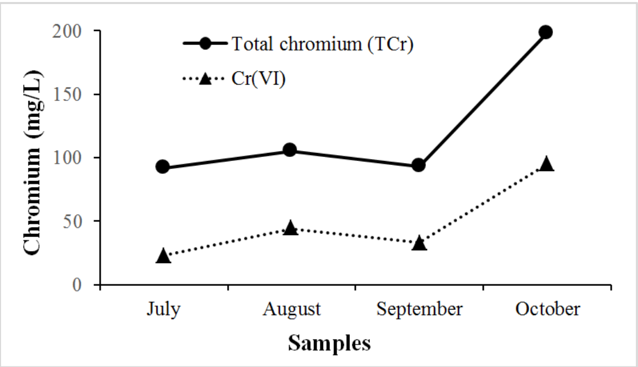

Figure 5. *Evolution of chromium VI (Cr(VI) and total chromium (TCr)) in tannery effluents.*

Arsenic, cadmium and nickel were not quantified in any samples, remaining consistently below limits of detection. This absence is a positive indicator, as cadmium is a highly toxic metal, even in minute concentrations, with harmful effects on the kidneys and bones. Its absence suggests rigorous management of chemical inputs, in line with the practices recommended by Shaibur [51]. The same observation can be made for arsenic witch is classified to have carcinogenic potential by the International Agency for Research on Cancer [52].

With regard to copper, manganese, lead, and zinc, the concentrations determined are all below the national standard values, 0.5, 1, 0.5 and 2 mg/L, respectively. This is positive because high concentration of lead may result in metallic poisoning that manifests in possible human carcinogenic, birth defects, mental retardation, autism, psychosis, allergies, dyslexia, hyperactivity, weight loss, shaky hands, muscular weakness, abdominal pain [26]. For zinc, acute toxicity of zinc may result in sweet taste, throat dryness, cough, weakness, generalized aching, chills, fever, nausea and vomiting [53]. Švec *et al*. [54] note that care must be taken with manganese, which is necessary for the growth of algal cells but becomes toxic at high concentrations.

Copper shows low but sporadic concentrations quantified only in August (0.033 mg/L) and October (0.065 mg/L). Its presence, although irregular, could be due to the use of finishing products or contamination of raw materials. The concentrations of this metal as low as 1-2 μg/L have been shown to have adverse effects on a variety of aquatic organisms [55].

3.2.3. Metallic Environmental Risk Assessment

The index is an important tool to assess and evaluate the combined effects of heavy metals on water quality [56]. The overall status of water quality with regards to the content of heavy metals is presented in Figure 6. The HEI value ranged from 292.20 to 1084.45 with an average value of 570.85. The highest HEI value recorded at the sampling of October while lower at July. The results showed a warning situation of environmental risk from Tannerie Abidjanaise wastewater.

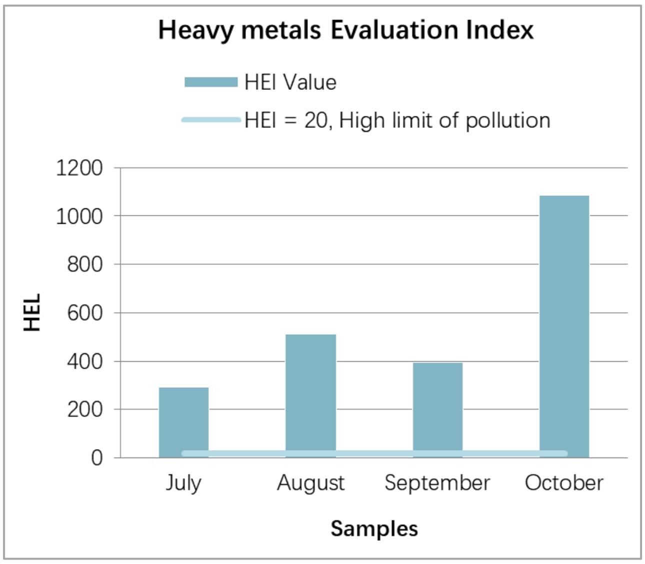

Figure 6*. HEI values of Heavy metal of Tannerie Abidjanaise's wastewater.*

3.3. Kruskal-Wallis Test of Ranks

Table 3 presents the results of the application of Kruskal-Walis test considering the variation of parameters concentration across the months. Results of a Kruskal-Wallis test showed that there was no statistically significant difference (with p=0.3916 > 0.05) in distribution the concentration of all parameters study [57].

Table 3*. Results of the Kruskal-Wallis test for all parameters study.*

Parameters	Units	July	August	September	October	P
Temperature	℃	26.5	26.6	27.3	26.3	0.3916
pH	-	6.11	8.45	5.25	8.35	0.3916
EC	mS/cm	30.75	10.45	20.68	20.76	0.3916
TDS	mg/L	19550	6650	13150	13200	0.3916
SSM	mg/L	235.0	60.0	120.0	1242.5	0.3916
Totalt nitrogen	mg/L	278.52	173.44	225.28	277.12	0.3916
Total phosphorus	mg/L	4.42	2.12	0.82	25.14	0.3916
COD	mg/l	920	580	670	710	0.3916
BOD_5	mg/l	330	205	220	240	0.3916
Arsenic	mg/L	<0.005	<0.005	<0.005	<0.005	0.3916

Parameters	Units	July	August	September	October	P
Cadmium	mg/L	<0.0005	<0.0005	<0.0005	<0.0005	0.3916
Total chromium (TCr)	mg/L	91.8	105.0	93.2	198.0	0.3916
Chromium VI (Cr(VI))	mg/L	23.0	44.0	33.0	95.0	0.3916
Copper	mg/L	<0.005	0.033	<0.005	0.065	0.3916
Iron	mg/L	2.93	10.8	6.79	8.66	0.3916
Manganese	mg/L	0.406	0.449	0.485	0.511	0.3916
Nickel	mg/L	<0.005	<0.005	<0.005	<0.005	0.3916
Lead	mg/L	0.008	0.012	0.011	0.012	0.3916
Zinc	mg/L	<0.05	0.085	0.073	0.113	0.3916

4. Conclusions

This study reveals that tannery effluent exhibits a complex physicochemical profile with significant environmental implications. While temperature and pH were within Ivorian National discharge limits, most parameters were concerning. High concentrations of EC, TDS, SSM, BOD5, COD, and Total nitrogen were found. The BOD5 and COD ratio indicated a substantial organic load and low biodegradability of effluents, challenging natural attenuation and biological treatment. The total chromium and Cr (VI) were on average 81 and 488 times higher than the standard permissible limits, prescribed by National standards, respectively. Iron was also found to be slightly higher than the permitted value. Copper, lead, manganese and zinc were determined at very low levels, while arsenic, cadmium, and nickel were below their detection limits. The effluents of Tannerie Abidjanaise should not be discharged into surface water and its surrounding environment without appropriate treatment. Environmental Protection Authority should also establish environmental protection laws which consider technical and financial capability of the industries so as to control industrial pollution. The study strongly recommends setting up a specific cost-effective eco-friendly treatment technology. In fact, Kruskal-Walis test show that there is no significantly difference between the value of all parameters study across the months. moreover, the effluent present environment risk according to the heavy metal evaluation index (HEI).

Abbreviations

COD	Chemical Oxygen Demand
Cr (III)	Trivalent Chromium
Cr (IV)	Hexavalent Chromium
DOB_5	Biological Oxygen Demand
EC	Electrical Conductivity
HNO_3	Nitric Acid
ICP OES	Inductively Coupled Plasma Optical Emission Spectroscopy
IC/UV-Vis	Ion Chromatography with Ultraviolet-Visible detector
SSM	Suspended Solids Matters
TCr	Total Chromium
TDS	Total Dissolved Solids
TN	Total Nitrogen
TP	Total Phosphorus

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Author Contributions

Goli Patricia Isabelle: Conceptualization, Investigation, Methodology, Writing - original draft

Meite Ladji: Conceptualization, Methodology, Writing - original draft

N'guettia Kossonou Roland: Writing - original draft, Writing - review & editing

Soro Donafologo Baba: Writing - review & editing

Aboua Kouassi Narcisse: Writing - review & editing

Dembele Ardjouma: Conceptualization, Supervison, Writing - original draft

Mamadou Kone: Supervison- Writing - review & editing

Traore Karim Sory: Conceptualization, Supervison

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Data Availability Statement

The data supporting the outcome of this research work has been reported in this manuscript.

Conflicts of Interest

All authors declare that there is no conflict of interest on this article.

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