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Research Article

Ethiopian Water Hyacinth Leaf Extract as a Potential Tannery Effluent Treatment Material

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Industrial effluents have a serious problem on our ecosystem. Tannery effluent contains a huge amount of pollutant compounds such as toxic substances which need to be treated using either synthetic or natural products. The present study focussed on the treatment of tannery effluents using water hyacinth plant leaf extract. Though some researchers have tried to use this extract for the same, the researchers have experimented only to treat that of Cr^{3+} and there are a bit of difference in the methodology they followed. In addition, the scope of this research was wider. In this study, fresh raw WH leaves were collected from around Lake Tana, Ethiopia, cleaned and made to powder and then extraction was performed using different solvents. The solvent effects were examined using the ANOVA test. The tannery wastewater was treated with the extracts and parts of the effluents were kept as a control for comparison. Treated and untreated tannery effluents were compared using standard methods such as SLC 22, SLC 8, APHA 2540C, APHA 2540D, and Hack LCK 139 to determine Cr^{6+}, Cr^{3+}, TDS, TSS, and TKN, respectively. The highest amount of Cr^{6+}, Cr^{3+}, and TKN were removed at 30% water hyacinth leaves extracted by distilled water solvent and that of the least was found at hyacinth leaves extract by ethanol solvent but by acetone in BOD and COD treatment. In addition, though it was out of the permissible limit, by using the same amount of the material extracted by distilled water solvent some amounts of BOD and TDS were removed from the wastes compared to that of untreated tannery effluents. Generally, water hyacinth leaf extract is found effective material for the treatment of tannery effluents and can be used in the sector industries. Future studies may be required for setting the most optimum extract concentration for better results.

1. Introduction

In industries, toxic wastes are released from different chemical processes into the environment [1]. It has negative effects on the health of humans and animals [2]. Leather manufacturing contains chemical and mechanical processes in order to convert raw hides and skins into a stable leather material that will suitable for a wide variety of applications [3]. In the process of turning animal hides into leather, almost every tannery uses a considerable amount of chemicals. Sodium sulfite, basic chromium sulfate, ammonium sulfide, ammonium chloride, bactericides, sodium chloride, wetting agents, enzymes, and other chemicals are used in tanneries in large amounts [4]. In the chrome tanning process, around 276 chemicals and 14 heavy metals are used all of which contribute significantly to water contamination [5]. According to a research findings report, only 20% of the chemicals used in the tanning process are absorbed by the leather and the rest will be released as waste [6]. The several components in the tannery wastewater have an impact on agriculture and livestock as well as creating serious health problems in tannery employees such as eye illnesses, skin irritations, kidney failure, and intestinal problems [7].

The majority of tanneries use a chromium-based tanning process that needs a lot of water and chemicals [8], and around 90% of the industries are releasing their effluents into water bodies, streams, and land without any treatment mechanisms [9]. The tanneries produce 30–35 liters of wastewater per kilogram of skin or hide, with an estimated annual amount of 400 million cubic meters of liquid waste discharge [10].

For example, the case of Ethiopia's physicochemical analysis study revealed that most Ethiopian tannery effluents showed that several wastewater quality parameters (COD, BOD, sulfide, total nitrogen, total chromium, TDS, and TSS) are beyond the country's industrial treatment standards [8]. Basic chromium sulfate is a tanning agent used by 90% of tanning industries [11], and the unabsorbed part of it will be discharged with the wastewater [12]. In Ethiopia, around 10% of the existing tanning industries treat their wastewater to any degree while the majority discharge their wastewater into nearby water bodies, streams, and open land without any kind of treatment [13]. This makes industrial and chemical pollution to become a major problem in the country and one of the great environmental concerns [14]. Therefore, the removal of chromium and related pollutant chemicals and materials from tannery wastewater is highly advisable.

According to the World Health Organization for drinking water quality recommendations [15], one of the many metals of most immediate concern is chromium [16]. Although some heavy metals are essential as trace elements, their biotoxic effects on human biochemistry are a major source of concern. If the concentration of heavy metals exceeds their limits in the drinking water, it can affect human health [17]. As a result, heavy metal removal from aqueous solutions has gotten a lot of attention in recent years [18]. Therefore, wastewater treatment is essential to resolve the effects of the mentioned toxic byproducts on the environment. Wastewater treatment is the process of partially removing and changing the solids in wastewater from highly complex putrescible organic solids to mineral or relatively stable organic solids through decomposition [19]. Several conventional treatment methods, such as the biological process was used to treat wastewater from the tannery industry [20–22], oxidation process [23, 24], chemical process [25], etc. One of the biological wastewater treatment systems is phytoremediation [26], and its the concept of removing toxins from the environment using plant-based systems and microbiological processes [27]. The majority of heavy metal removal methods are quite expensive and injurious to health [14]. Natural plant extracts have been used for water purification for many years. The majority of these extracts come from tree and plant seeds, leaves, bark or sap, roots, and fruit [28]. In Ethiopia, water hyacinth plant is harmful to water, and it is invading Lake Tana since 2011 [29], and the area covered at the time of inception was approximately 80 to 100 ha [30]. In addition, water hyacinth plant has recently got a lot of attention in order to use it as a source of income in many parts of the world [30–33].

In addition, this plant and its extract have been used for wastewater treatment in phytoremediation techniques using constructed wetland [34, 35]. Sudanese researchers [36] studied the effects of extraction solvents on total contents and activities of extracts from Sudanese medicinal plants because the choice of appropriate extraction solvent is essential for the desired activity of the extracts [36]; however, their study was focused on the plant extract medicinal applications. Likewise, in this study, the researchers believed that the proper choices of extraction solvents are required to extract the WH leaf material for tannery wastewater treatment. In the case of Ethiopia, some researchers have tried to use these plant extracts for wastewater treatment to treat only Cr^{3+} [37]. However, in this study, in addition to investigating its leaf extracts as a potential treatment material for tannery effluent treatment, the effects of the extraction solvents on the potential of the extracted material to remove different toxic and pollutant chemicals from tannery wastewater are also emphasized. Some other researchers tried to use the same for the treatment of wastewater other than tannery waste but there is a difference between these wastes and tannery wastes in pollutant contents because tannery effluents have many chemicals discharged with the effluents [8]. The research output may result in decreasing the rate of the plant's attack on water bodies and usage of treated tannery effluents for alternative usages. In the study, the researchers collected water hyacinths plant leaves around Lake Tana, Bahir Dar City, Ethiopia, and cleaned them, dried them, and extracted the required treating material from the leaves by using ethanol acetone, distilled water, and extracting solvents. These solvents have been used by previous researchers in materials extraction from given plants [38–41].

2. Materials and Methods

2.1. Materials. The raw leaves and stems of healthy water hyacinths were collected from around Lake Tana near Kristos Samra Monastery, Gonder, Ethiopia. The plant leaves were cleaned from physical foreign bodies, rinsed to remove impurities, and chopped into small chips for faster drying. As shown in Figure 1, drying the leaves was carried out outdoors for seven days in which the temperature ranges between 25°C and 104°C and oven-dried at 104°C for hrs. Distilled water, acetone, and ethanol were used as solvent materials for the extraction.

2.2. Collection of Sample Tannery Wastewater. A sample of tannery wastewater was collected at effluent exit points of Bahir Dar tannery in Ethiopia. Sample bottles were rinsed with water to minimize the risk of external contamination before sampling and the bottles are prelabeled. The samples were collected at 2 : 00 a.m., when the tannery was running at full capacity, and the wastewater flow was expected to be at its peak. The chrome effluent was deep blue in color at the time of sampling, while the general effluent was light brownish in color. During collection, the temperature of the wastewater samples was recorded at 25 degrees Celsius using a calibrated thermometer. The effluent samples were sealed and stored in a refrigerator for further use and later usage.

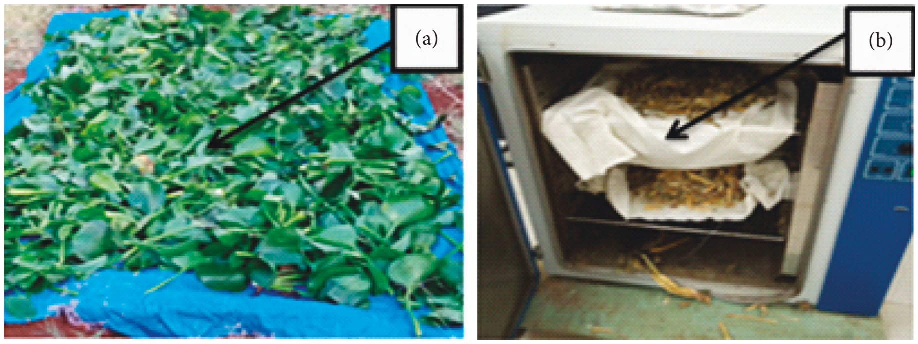

Figure 1: (a) Freshwater hyacinth leaves in sun drying and (b) water hyacinth parts in oven drying.

Figure 2: (a, b) Water hyacinth leaves in powder grinding and (c) powder form of the WH leaves.

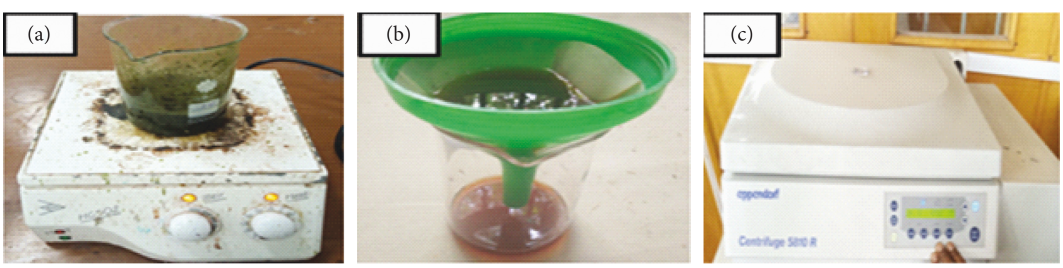

Figure 3: (a) Magnetic stirrer. (b) Whatman paper filtration. (c) Centrifugation filtration.

2.3. Preparation of the Plant Extracts. Before extraction, the dried leaves were grounded in a high-speed multifunction grinder with a mesh size of 50–300 mesh shown in Figure 2. The main reason behind grounding the plant part was to maximize the surface area available for extractions which increases the extraction rate. The powdered samples are placed in small plastic bags for later experimental usage.

Distilled water, acetone, and ethanol solvents were used for different plant extract preparation [38, 40]. Amount of 50 g of water hyacinth leaves powder were soaked with (500 ml) separate solvents of distilled water, acetone, and ethanol in a glass beaker and incubated for 48 hours. The mixtures were then stirred for 1 hour [39] at room temperature and filtered using Whatman 1 paper, 24 cm disc [41]. As shown in Figure 3, the mixtures were then centrifuged (4000 rpm, 25°C) for 15 minutes [42]. Finally, 300 ml active component per one cycle of extraction was obtained. This active component of the extract has a phenolic chemical structure which is the main content of the extract that gives it antioxidant activities [43]. The extracts obtained were kept in bottles at 20°C for further analysis.

2.4. Tannery Effluents Treatment Method. The amount 70% and 90% of tannery effluent were treated with 30% (30 ml) and 10% of distilled water and ethanol and acetone extract of water hyacinth leaves, respectively, and the result is presented in Table 1. Separate solutions were prepared by treating tannery effluents with 10% (10 ml) and 30% (30 ml) of plant extract of distilled water, ethanol, and acetone for three consequent days [46]. As shown in Figure 4, each solution was then shaken for 24 hrs at room temperature ($25 \pm 2^{°C}$) at 150 rpm using a BioSan multifunctional orbital shaker PSU-20i [47] in order to increase the opportunity for solution reaction. The same mount untreated tannery effluents were used as a control experiment for comparison purposes with the treated one. Each solution was then allowed to stand at 4°C for further analysis.

Table 1: The typical characteristics of Tannery wastewater (control) and treated tannery effluents.

Physicochemical waste parameters	Treated tannery effluent by water hyacinth (WH) leaves extract using different extraction solvents: Distilled water extract of WH leaves (10%)	Acetone extract of WH leaves (10%)	Ethanol extract of WH leaves (10%)	Distilled water extract of WH leaves (30%)	Acetone extract of WH leaves (30%)	Ethanol extract of WH leaves (30%)	Untreated sample: Tannery wastewater (control)	Permissible discharge limit [44, 45]
pH	6.64	7.24	7.71	6.98	7.33	7.52	6.9	6–9
Cr^{3+} (mg/l)	2.85	2.9	3.0	1.84	2.84	2.85	3.6	1.5–2.0
Cr^{6+} (mg/l)	0.03	0.04	0.19	0.02	0.05	0.15	0.06	0.05
TDS (mg/l)	2163	2197	2848	2134	2124	2764	2342	1000
TSS (mg/l)	215	210	256	140	182	244	150	50
TKN (mg/l)	11	53	290	5.4	58	134	6	60
COD	979	22913	13729	1042	29823	14250	1086	500
BOD	57.2	135	164	35.3	133.3	108.3	38	200

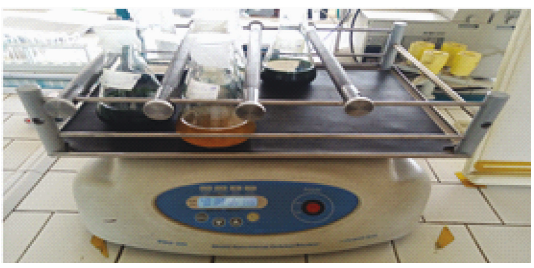

Figure 4: (a) BioSan multifunctional orbital shaker.

2.5. Determination of Waste Parameters. Tannery effluent (control) and treated wastewater characterization were determined using the following standard test procedures and required sample solutions were taken from each stock solution.

2.5.1. pH Values Measurement. pH indicates the acidic or alkaline nature of any water body. The pH of untreated and treated wastewater was determined by using a pH meter.

2.5.2. Chromium (III) Determination. The amount of chromium (III) in controlled and treated tannery wastewater was measured using a titrimetric method according to the Society of Leather Chemistry (SLC 8) [48].

2.5.3. Chromium (VI) Measurement. the volume of chromium (IV) of both wastewaters was measured using a UV-visible spectrometer and the SLC 22 method (Society of Leather Chemists).

2.5.4. Total Dissolved Solids (TDSs) Measurement. TDS in the initial and treated tannery wastewater was determined according to the APHA 2540C (American Public Health Association) standard procedure.

Total suspended solids (TSSs) measurement: the TSS treated and untreated tannery wastewater was determined using the APHA 2540D standard method. The crucible and filter paper were first dried for 1 hour at 104°C, then cooled in a desiccator, and the weight was measured and registered. 100 ml wastewater was filtered onto filter paper after being weighed in a measuring cylinder. The residue sample on the filter paper was placed in an oven at 105°C for 1 hr, the filter paper and crucible in the desiccator were cooled, the weight was measured, and then, the TSS was determined by calculation using the following equation and is expressed in mg/l [49, 50]:

$$\text{TSS (mg/l)} = [0,1]\,\frac{(\text{Weight of filter paper + residue after drying})-\text{weight of crucible before D}^{*}1000^{*}1000}{\text{Volume of sample taken (ml)}}. \quad (1)$$

2.5.5. Total Kjeldahl Nitrogen (TKN). The TKN values of both wastes were determined according to the Hack LCK 139 standard method.

2.5.6. Biochemical Oxygen Demand (BOD). Biochemical oxygen demand (BOD) of an effluent is the milligram of oxygen required to biologically stabilize one liter of that in 5 days at 20°C [51, 52]. The BOD concentration in the untreated and treated tannery wastewater was determined using an open reflux procedure.

2.5.7. Chemical Oxygen Demand (COD) Determination. COD is the amount of oxygen needed to oxidize the oxidizable chemicals contained in one liter of effluent under specific conditions, expressed in milligrams [52, 53]. A bottom flask was filled with 20 mL of sample wastewater and 1 g of H_2SO_4, and the 5 mL sulfuric acid reagent was slowly added to dissolve H_2SO_4. After that, a 25 ml solution of 0.04167 M $K_2Cr_2o_7$ was applied to the mixture. Cooling water was turned on and the bottom flask was connected to the condenser. Swirling and mixing were continued while applying the remaining sulfuric acid reagent (70 ml) through the open end of the condenser. The excess $K_2Cr_2O_7$ was then titrated with FAS using 6 drops of ferroin indicator after cooling to room temperature.

$$\text{COD (mgO2/L)} = \frac{\text{ml of FAS used for blank} - \text{ml of FAS used for sample} * M * 8000}{\text{Sample volume (ml)}}. \quad (2)$$

where 8000 = milli equivalent weight of oxygen (8) × 1000 mL/L.

3. Result and Discussion

3.1. pH Values. The required pH measurement and analysis were to understand whether the pH of the treated wastes is within the required range or not. From the previously documented research findings, the pH of the tannery wastewater is basic and its high organic content can pollute the environment significantly and that of pure water is near neutral (7.0) [54, 55]. Its value before and after treatments with 10% and 30% water hyacinth leaves extracts with any type of extraction solvents used is basic and within the permissible limits (6–9). As results presented in Table 1, the pH values of treated wastes are near neutral, particularly that of treated effluent by the material extracted by 30% distilled water solvent was near to the pH of pure water which indicates the treated effluent by that amount of extract was near to clean/pure water stage. This shows that if the pH of the effluent is within the permissible limits for parameters in the tannery effluents, it is acceptable and the extracts have a promising result as a potential tannery effluent treatment material.

According to the results presented in Table 1 and Figure 5, the concentration of Cr^{3+} and Cr^{6+} in the untreated tannery wastewater was 3.6 mg/l and 0.06 mg/l, respectively. The permissible limit for Cr^{3+} in the tannery effluents mentioned in the rightmost column of Table 1 is 1.5–2.0 mg/l and that of Cr^{6+} is 0.05 mg/l which is stipulated by the World Health Organization and Ethiopian Environmental Protection Authority [44, 45]. However, after treatment of the effluents using the extracts, the amounts of the pollutant chemicals and materials reduced below that of untreated values and lie within the permissible limits. In the present study, 30% of WH material extracted by distilled water had the highest Cr^{3+} removal efficiency (37.2%), which has given a better result compared to that of Nath et al. [56]. In their study of pollutant removal efficiency of water hyacinth plants in the batch treatment of Calcutta city sewage, the removal efficiency of chromium was 32% [57]. However, another study conducted by Narain et al. [58] revealed 80.26% and revealed 79% chromium removal from tannery effluent through phytoremediation, respectively. The different results may be due to the difference between the methods and amounts which the researchers followed in their studies. In addition, other researchers reported that better Cr(VI) removal was achieved by phytoremediation [59], and Kumar and Chauhan [60] reported on the removal of Cr(VI) by adsorption using dried WH root. Generally, this research discovered an interesting result in the removal of chromium ions using leaf extracts compared to previous results. However, it has resulted in a lower efficiency compared to that of other researchers based on the phytoremediation method.

As the data analyzed in Table 2, based on ANOVA rule of a single factor analysis, if F>F is critical or if *P* value is less than 0.005, it indicates that the factors have a significant effect. As the statement is true in this research analysis of Table 1, therefore, when changing the solvent types used during the leaf material extraction, it significantly affects the material efficacy to treat the toxic/pollutant materials of the tannery wastes. Therefore, it can be concluded that the extraction solvent type has a significant effect on the waste (Cr^{3+} and Cr^{6+}) treatment efficacy of the materials.

3.2. Total Dissolved Solids (TDSs) and Total Suspended Solids (TSSs). The values presented in Figure 6 are discussed below.

Total dissolved solids (TDSs) are either naturally present in water or are the consequence of industrial water treatment. TDS contains minerals and chemical compounds that may provide benefits such as nutrition or are contaminants such as harmful metals and organic pollutants [61]. According to the result presented in Figures 6 and 7, the TDS value in untreated tannery wastewater was 2342 mg/l, which is out of the discharge limit (1000 mg/L) set by the Ethiopian Environmental Protection Authority [45] and World Health Organization [44]. In the present study, tannery effluents waste treatment with 10% and 30% of distilled water leaves extract reduced the untreated tannery wastewater TDS concentration from 2342 mg/l to 2163 mg/l (7.6%) and to 2134 mg/l, respectively, and 10% and 30% of acetone leaves extract reduced to 2197 mg/l and 2124 mg/l, respectively. On the other hand, the treatment efficacy of ethanol extracted material has the lowest TDS removal values.

As presented in Table 1 and Figure 7, the TSS in the original effluents of the tannery wastes was found at 150 mg/l and after it is treated with 10% and 30% leaves extract by distilled water solvents were found at 215 mg/l and 140 mg/l, respectively, and treatment of the effluent with 10% and 30% of acetone extracted leaves were found at 210 mg/l and 182 mg/l, respectively, and that of ethanol extracted leaves of 10% and 30% were 256 mg/l and 244 mg/l, respectively, as these results show the TSS values in all treated effluents were not properly treated. The most possible reason is due to the

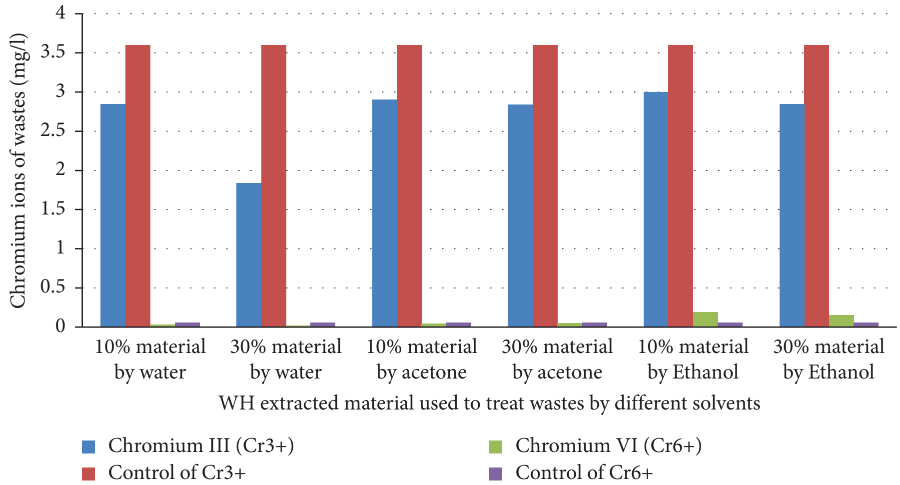

Figure 5: The effect of extraction solvents on chromium (III) and chromium (VI) removal of the tannery waste samples.

Table 2: ANOVA results of the effect of the solvent on the WH leaf extract efficacy.

Summary

Groups	Count	Sum	Average	Variance
Chromium III (Cr3+)	6	16.28	2.713333	0.186626667
Control of III (Cr3+)	6	21.6	3.6	0
Chromium VI (Cr6+)	6	0.48	0.08	0.00512
Control of VI (Cr6+)	6	0.36	0.06	0

ANOVA

Source of Variation	SS	df	MS	*F*	*P*-value	*F* crit
Between Groups	59.5248	3	19.8416	413.9128016	0.0001	3.098391
Within Groups	0.958733333	20	0.047937			
Total	60.48353333	23				

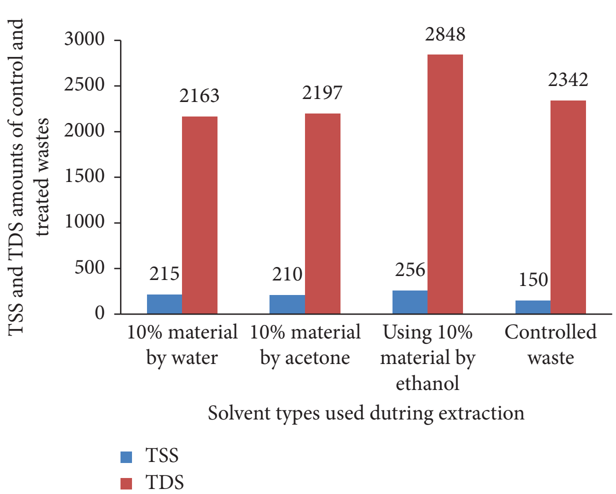

Figure 6: TDS and TSS values of controlled and treated wastes by using leaf 10% materials extracted by different extraction solvents.

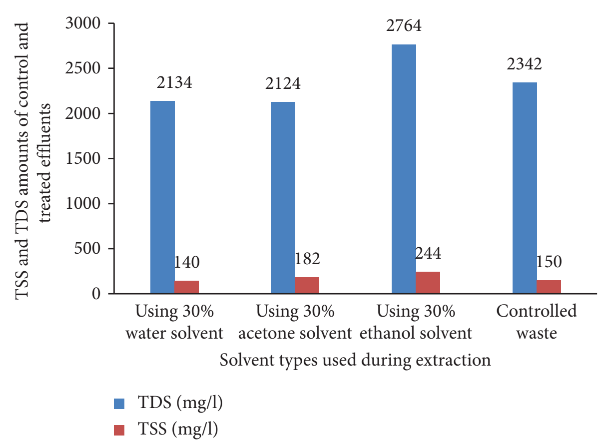

Figure 7: TDS and TSS values of controlled and treated wastes by using leaf 30% materials extracted by different extraction solvents.

type of the extractive solvent used and incompatibility of the newly extracted material with the TSS of the effluents. Similarly, Lissy and Madhu [62] observed an increment in TDS and TSS values after treatment with a water hyacinth plant using a phytoremediation method. The increment of the TDS and TSS in this study might be due to the presence of tannery chemicals such as carbonates, bicarbonates, calcium, sodium, potassium, and iron in the effluent. However, still, the researchers believed that the WH leaf extract can reduce the TSS and TDS values at their best ratio.

3.3. Total Kjeldahl Nitrogen (TKN). The total Kjeldahl nitrogen (TKN) of the untreated tannery wastes was 6 mg/l and can be improved to 5.4 mg/l after its treatment with 30% extracted material by distilled water extraction solvent. On the other side, the wastes treated with 10% and 30% acetone extract yielded 53 mg/l and 58 mg/l, respectively. Comparatively, in the current study, the treatment using 30% extracted material using distilled water as a solvent of extraction improved the TKN reduction recorded by previous researchers by the phytoremediation method [63] by 8.4%. The results of all trials using these different extraction solvents but the same amount of extracts except that of 30% distilled water solvents TKN values have not shown improvement, and they were beyond the wastewater permissible limit (60 mg/L) set by the Ethiopian Environmental Protection Authority [45]. However, the material extracted with 30% distilled water solvents can reduce TKN to 16.6% and was higher than the 8.4% TKN reduction recorded by Cornwell et al. [63] using the same plant extract. However, by performing phytoremediation using water hyacinth, Schulz et al. [64] reported 19% TKN removal, Bramwell and Devi Prasad [65] reported 27.6% TKN removal, and Jianbo et al. [34] reported 21.78% TKN removal in their wastewater treatment study. The most possible reason is due to the treatment process in phytoremediation and methods are different from that of the WH leaf extract as well as the contaminants in the wastes being treated were different compared to tannery wastewater. In addition, it clearly indicates that the type of solvents used during material extraction greatly affects the effectiveness of the material.

3.4. Chemical Oxygen Demand (COD) and Biochemical Oxygen Demand (BOD). According to the results presented in Table 1, a relative best result was found by treating the effluents with the materials extracted by 10% and 30% distilled water extraction solvent. Even though 9.79% and about 4% of the COD levels of waste were reduced by the newly extracted materials by 10% and 30% distilled water, respectively, the COD levels of the tannery waste treated by the extracted material by acetone and ethanol extraction solvents exceeded the Ethiopian Environmental Protection Authority's allowable limit (500 mg/L) [45]. Using the same extracts, BOD was changed to 35.3.2 mg/l and 57.2 mg/l compared to ineffective leave extracts by acetone and ethanol solvents, as the values are presented in Table 1. Water hyacinth acetone and ethanol extract will not be used as a potential extraction solvent for COD reduction from wastewater based on the findings of this report. The reason is due to high levels of COD in tannery wastewater indicate that the effluent is not appropriate for the existence of aquatic species [66] and the COD results of treated wastewater were higher than the World Health Organization's provisional discharge limit for tannery effluent to water bodies [44]. However, the extract of water hyacinth leaves has limited potential in removing COD from tannery wastewater, and further research is required to determine the optimal concentration of the extract. In case of BOD levels of this study, as presented in Table 1, all of the BOD results of the treated effluents were under the permissible limit (200 mg/L) set by the Ethiopian Environmental Protection Authority [45].

Based on the existed literature, the treated wastewater had more BOD than the untreated wastewater. Gamage and Yapa [67] and Chakrabarty et al. [68] introduced water hyacinth on tannery wastewater using phytoremediation using constructed wetlands and it has shown a reduction in BOD after 15 days of sedimentation. All of the treated effluent BOD findings in this study were within the Ethiopian Environmental Protection Authority's permissible limit (200 mg/L) [45]. However, as compared to the control effluent, the BOD value of treated wastewater increased to some extent in the current report but was not effective as required as it is due to the reason stated by Raj et al. [66]. Therefore, this study recommends the WH leaf extracts remove Cr^{3+}, $Cr6^{+}$, and TKN than TDS, TSS, BOD, and COD from tannery effluents using distilled water extraction solvents.

4. Conclusion

From the study results, it can be concluded that the Ethiopian water hyacinth leaf extract has a very good ability to remove toxic pollutants such as Cr^{6+}, Cr^{3+}, and TKN from tannery effluents. The effect of aqueous and solvent-based extracts of water hyacinth leaves for tannery effluent treatment was investigated using ANOVA and implied that the solvent types and amounts used during extraction greatly affect the effectiveness of the leaf extracts. Distilled water, acetone, and ethanol were used as solvents to extract the active components present in the WH plants leaf. The highest amount of Cr^{6+}, Cr^{3+}, and TKN were removed at 30% WH leaf extract by distilled water solvents Their values were within the permissible discharge limit (1.5–2.0 mg/l for $Cr^{3+,}$ 0.05 mg/l for Cr^{6+}, and 60 mg/l for TKN) and the values of Cr^{6+}, Cr^{3+}, and TKN of the treated effluent by the WH leaf materials extracted by distilled water extraction solvent were 1.84 mg/l of Cr^{3+}, 0.02 mg/l $Cr6^{+}$, and 5.4 mg/l for TKN compared to that of the untreated effluent values which have 3.6 mg/l Cr^{3+}, 0.06 mg/l $Cr6^{+}$, and 6 mg/l, TKN respectively. The 30% WH leaf extract using ethanol solvent was ineffective to treat mentioned chemicals compared to the same quantity of the WH leaf extracts by the other solvents. Though the result was out of the permissible limit, by using the same amount of the WH leaf extract using distilled water extraction solvent, 7.6% of BOD and 8.8% of TDS were removed from the tannery wastes. Treatment using the leaf extracts was almost ineffective to remove TDS, TSS, BOD, and COD of the tannery effluent compared to the control waste and permissible limits. The pH of the treated effluent is more neutral than that of the untreated wastes. Comparatively, the leaf extracts with acetone and distilled water as extraction solvents have shown the best result compared to that of the extract with ethanol solvent extracts. According to the results of this study, it is recommended that water hyacinth plant leaf extract can be used for removing pollutants such as $Cr3^{+}$, $Cr6^{+}$, and TKN than TDS, TSS, BOD, and COD in the tannery effluents and distilled water extraction solvents is recommended to extract the material. Generally, the findings of the research are very important to the tanneries and act as a base for future researchers for the best results.

Abbreviations

WH: Water hyacinth
BOD: Biochemical oxygen demand
TDSs: Total dissolved solids
TSSs: Total suspended solids
TKN: Total Kjeldahl nitrogen
APHA: American public health association
SLC: Society of leather chemistry.

Data Availability

The data collected and analyzed during this study are included in the paper and can be accessed more from the authors through a rational request.

Conflicts of Interest

The authors declare that they have no competing interests.

Authors' Contributions

All the authors have contributed to the conceptualization, investigation, data collection, and analysis in the study and have read and approved the final manuscript.

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References

[1] T. T. Shen, *Industrial Pollution Prevention*, Springer, Berlin, Germany, 1995.
[2] N. Ünlü and M. J. J. O. H. M. Ersoz, "Adsorption characteristics of heavy metal ions onto a low cost biopolymeric sorbent from aqueous solutions," *Journal of Hazardous Materials*, vol. 136, no. 2, pp. 272–280, 2006.
[3] J. Zhang and W. Chen, "A faster and more effective chrome tanning process assisted by microwave," *RSC Advances*, vol. 10, no. 39, pp. 23503–23509, 2020.
[4] A. A. Werkneh's, "Tannery waste water treatment: a review," *Environmental Science and Pollution Research*, vol. 1, pp. 1488–1494, 2014.
[5] K. Mohammed and O. J. S. A. Sahu, "Recovery of chromium from tannery industry waste water by membrane separation technology: Health and engineering aspects," *Scientific African*, vol. 4, Article ID e00096, 2019.
[6] M. Chowdhury, M. G. Mostafa, T. K. Biswas, A. Mandal, and A. K. Saha, "Characterization of the effluents from leather processing industries," *Environmental Processes*, vol. 2, no. 1, pp. 173–187, 2015.
[7] M. Nur-E-Alam, M. A. S. Mia, F. Ahmad, and M. Rahman, "An overview of chromium removal techniques from tannery effluent," *Applied Water Science*, vol. 10, no. 9, pp. 205–222, 2020.
[8] T. A. Abate, A. F. Desta, and N. G. Love, "Evaluating tannery wastewater treatment performance based on physicochemical and microbiological characteristics: an Ethiopian case study," *Water Environment Research: A Research Publication of the Water Environment Federation*, vol. 93, no. 5, pp. 658–669, 2021.
[9] F. T. Gemeda, D. D. Guta, F. S. Wakjira, G. Gebresenbet, and P. Research, "Occurrence of heavy metal in water, soil, and plants in fields irrigated with industrial wastewater in Sabata town, Ethiopia," *Environmental Science and Pollution Research*, vol. 28, no. 10, pp. 12382–12396, 2021.
[10] M. B. Aregu, S. L. Asfaw, and M. M. Khan, "Identification of two low-cost and locally available filter media (pumice and scoria) for removal of hazardous pollutants from tannery wastewater," *Environmental Systems Research*, vol. 7, pp. 10–14, 2018.
[11] M. Prokein, M. Renner, E. Weidner, T. Heinen, and E. Policy, "Low-chromium-and low-sulphate emission leather tanning intensified by compressed carbon dioxide," *Clean Technologies and Environmental Policy*, vol. 19, no. 10, pp. 2455–2465, 2017.
[12] M. A. Hashem, A. Islam, S. Mohsin, and S. Nur-A-Tomal, "Green environment suffers by discharging of high-chromium-containing wastewater from the tanneries at Hazaribagh, Bangladesh," *Sustainable Water Resources Management*, vol. 1, no. 4, pp. 343–347, 2015.
[13] T. Alemu, E. Lemma, A. Mekonnen, and S. Leta, "Performance of pilot scale anaerobic-SBR system integrated with constructed wetlands for the treatment of tannery wastewater," *Environmental Processes*, vol. 3, no. 4, pp. 815–827, 2016.
[14] T. A. Abate, A. F. Desta, and N. G. Love, *Evaluating Tannery Wastewater Treatment Performance Based on Physicochemical and Microbiological Characteristics: An Ethiopian Case Study*, Wiley Online Library, Hoboken, New Jersey, US, 2020.
[15] W. H. Organization, *Guidelines for Drinking-Water Quality*, World Health Organization, Addis-Ababa, Ethiopia, 1993.
[16] Z. Ismail and A. M. Beddri, "Potential of water hyacinth as a removal agent for heavy metals from petroleum refinery effluents," *Water, Air, and Soil Pollution*, vol. 199, no. 1-4, pp. 57–65, 2009.
[17] A. M. L. Pn, G. Madhu, and U. Development, "Removal of heavy metals from waste water using water hyacinth," *International journal on transportation and Urban Development*, vol. 1, p. 48, 2011.
[18] R. A. I. Abou-Shanab, J. S. Angle, and P. VAN Berkum, "Chromate-tolerant bacteria for enhanced metal uptake by *Eichhornia crassipes* (Mart.)," *International Journal of Phytoremediation*, vol. 9, no. 2, pp. 91–105, 2007.
[19] A. Sonune and R. Ghate, "Developments in wastewater treatment methods," *Desalination*, vol. 167, pp. 55–63, 2004.
[20] M. Wiemann, H. Schenk, and W. Hegemann, "Anaerobic treatment of tannery wastewater with simultaneous sulphide elimination," *Water Research*, vol. 32, no. 3, pp. 774–780, 1998.
[21] G. Farabegoli, A. Carucci, M. Majone, and E. Rolle, "Biological treatment of tannery wastewater in the presence of chromium," *Journal of Environmental Management*, vol. 71, no. 4, pp. 345–349, 2004.
[22] A. Dahake and M. Hedaoo, "Application of Water Hyacinth (Eichhornia Crassipes) in Wastewater Treatment-a Review,"

International Research Journal of Engineering and Technology, vol. 05, pp. 2395–0072, 2018.
[23] S. Schrank, H. Jose, R. Moreira, and H. Schröder, "Applicability of Fenton and H2O2/UV reactions in the treatment of tannery wastewaters," *Chemosphere*, vol. 60, no. 5, pp. 644–655, 2005.
[24] I. Arslan-Alaton and S. Dogruel, "Pre-treatment of penicillin formulation effluent by advanced oxidation processes," *Journal of Hazardous Materials*, vol. 112, no. 1-2, pp. 105–113, 2004.
[25] Z. Song, C. Williams, and R. J. D. Edyvean, "Treatment of tannery wastewater by chemical coagulation," *Desalination*, vol. 164, pp. 249–259, 2004.
[26] N. Roongtanakiat, S. Tangruangkiat, and R. Meesat, "Utilization of vetiver grass (Vetiveria zizanioides) for removal of heavy metals from industrial wastewaters," *ScienceAsia*, vol. 33, no. 4, pp. 397–403, 2007.
[27] S. D. Cunningham, W. R. Berti, and J. W. Huang, "Phytoremediation of contaminated soils," *Trends in Biotechnology*, vol. 13, no. 9, pp. 393–397, 1995.
[28] M. Pritchard, T. Mkandawire, A. Edmondson, J. O'Neill, G. J. P. Kululanga, and Chemistry Of The Earth, "Potential of using plant extracts for purification of shallow well water in Malawi," *Physics and Chemistry of the Earth, Parts A/B/C*, vol. 34, no. 13-16, pp. 799–805, 2009.
[29] M. G. Dersseh, A. M. Melesse, S. A. Tilahun, M. Abate, D. C. J. E. H. Dagnew, and C. Variability, "Water Hyacinth: Review of its Impacts on Hydrology and Ecosystem Services—Lessons for Management of Lake Tana," vol. 19, pp. 237–251, 2019.
[30] D. Tewabe, "Preliminary survey of water hyacinth in lake," *Global Journal of Allergy*, vol. 1, pp. 013–018, 2015.
[31] R. Leng, *Duckweed: "A Tiny Aquatic Plant with Enormous Potential for Agriculture and Environment"*, FAO, Rome, Italy, Animal Production and Health Div.University of Tropical Agriculture Foundation, Phnom Penh, Cambodia, 1999.
[32] R. Sindhu, P. Binod, A. Pandey et al., "Water hyacinth a potential source for value addition: an overview," *Bioresource Technology*, vol. 230, pp. 152–162, 2017.
[33] V. Guna, M. Ilangovan, M. G. Anantha Prasad, and N. Reddy, "Water hyacinth: a unique source for sustainable materials and products," *Sustainable Chemistry & Engineering*, vol. 5, no. 6, pp. 4478–4490, 2017.
[34] L. Jianbo, F. Zhihui, and Y. Zhaozheng, "Performance of a water hyacinth (*Eichhornia crassipes*) system in the treatment of wastewater from a duck farm and the effects of using water hyacinth as duck feed," *Journal of Environmental Sciences*, vol. 20, no. 5, pp. 513–519, 2008.
[35] N. M. Sidek, S. R. S. Abdullah, S. F. S. Draman, M. M. M. Rosli, and M. F. J. Sanusi, "Phytoremediation of Abandoned Mining Lake by Water Hyacinth and Water Lettuces in Constructed Wetlands," *Jurnal Teknologi*, vol. 80, 2018.
[36] A. Dirar, D. Alsaadi, M. Wada, M. Mohamed, T. Watanabe, and H. P. Devkota, "Effects of extraction solvents on total phenolic and flavonoid contents and biological activities of extracts from Sudanese medicinal plants," *South African Journal of Botany*, vol. 120, pp. 261–267, 2019.
[37] F. Zewge, D. Woldemichael, and S. Leta, "Potential of water hyacinth (*Eichhornia crassipes* (Mart.) Solms) for the removal of chromium from tannery effluent in constructed pond system," *Journal of Science*, vol. 34, pp. 49–62, 2011.
[38] J. N. Eloff, "Which extractant should be used for the screening and isolation of antimicrobial components from plants?" *Journal of Ethnopharmacology*, vol. 60, pp. 1–8, 1998.
[39] G. Halász, B. Gyüre, I. M. Jánosi, K. G. Szabó, and T. Tél, "Vortex flow generated by a magnetic stirrer," *American Journal of Physics*, vol. 75, no. 12, pp. 1092–1098, 2007.
[40] K. Das, R. Tiwari, and D. Shrivastava, "Techniques for evaluation of medicinal plant products as antimicrobial agent," *Current methods and future trends*, vol. 4, pp. 104–111, 2010.
[41] M. Odey, I. Iwara, U. Udiba et al., "Preparation of plant extracts from indigenous medicinal plants," *Journal of Pharmacy & Bioallied Sciences*, vol. 1, pp. 688–692, 2012.
[42] Y. Wang, L. Zhu, Z. Dong et al., "Preparation and stability study of norfloxacin-loaded solid lipid nanoparticle suspensions," *Colloids and Surfaces B: Biointerfaces*, vol. 98, pp. 105–111, 2012.
[43] A. F. Ehigie, G. E. Adeleke, F. D. Ojeniyi, L. Ehigie, and N. Science, "Bioefficiency of Chromolaena odorata (Linn.) on hematological and lipid profiles in sublethal cyanide poisoning in male wistar rats," *Journal of Applied and Natural Science*, vol. 12, no. 1, pp. 13–18, 2020.
[44] J. Buljan, I. Kral, and G. Clonfero, *Introduction to Treatment of Tannery Effluents*, UNIDO, Vienna, Austria, 2011.
[45] EPA/UNIDO, *Provisional standards for industrial pollution control in Ethiopia*, EPA, Addis Ababa, Ethiopia, 2003.
[46] Y. Zhang, Z. Xiao, S. Lv, Z. DU, and X. Liu, "Simultaneous determination of 16 polycyclic aromatic hydrocarbons in reclaimed water using solid-phase extraction followed by ultra-performance convergence chromatography with photodiode array detection," *Journal of Separation Science*, vol. 39, no. 5, pp. 993–999, 2016.
[47] A. Krauklis, R. Ozola, J. Burlakovs et al., "FeOOH and Mn8O10Cl3 modified zeolites for as (V) removal in aqueous medium," *Journal of Chemical Technology & Biotechnology*, vol. 92, no. 8, pp. 1948–1960, 2017.
[48] M. R. Sarker, A. K. Deb, M. Chowdhury, and M. Hossain, "Investigation and evaluation of the quality features related to comfort of casual shoes in Bangladeshi leading retail brands using physical and chemical standard test methods," *Leather and Footwear Journal*, vol. 19, p. 11, 2019.
[49] J. M. Ebeling, K. L. Rishel, and P. L. Sibrell, "Screening and evaluation of polymers as flocculation aids for the treatment of aquacultural effluents," *Aquacultural Engineering*, vol. 33, no. 4, pp. 235–249, 2005.
[50] B. Trisakti, M. Irvan, and M. Turmuzi, "Effect of temperature on methanogenesis stage of two-stage anaerobic digestion of palm oil mill effluent (POME) into biogas," *IOP Conference Series: Materials Science and Engineering*, vol. 206, Article ID 012027, 2017.
[51] L. S. Clesceri, A. E. Greenberg, and R. R. and Trussell, *Standard Methods. For the Examination of Water and Wastewater*, American Public Health Association, Washington, DC, USA, 1989.
[52] B. Islam, A. Musa, E. Ibrahim, S. A. Sharafa, B. M. J. J. O. F. P. Elfaki, and INDUSTRIES, *Evaluation and characterization of tannery wastewater*, 2014.
[53] BOOKLET, *Chemical oxygen demand*, BOOKLET, Addis Ababa, Ethiopia, 1997.
[54] S. Leta, F. Assefa, L. Gumaelius, G. J. A. M. Dalhammar, and BIOTECHNOLOGY, "Biological nitrogen and organic matter removal from tannery wastewater in pilot plant operations in Ethiopia," *Applied Microbiology and Biotechnology*, vol. 66, no. 3, pp. 333–339, 2004.
[55] G. Durai, M. Rajasimman, and Technology, "Biological treatment of tannery wastewater- A review," *Journal of Environmental Science and Technology*, vol. 4, pp. 1–17, 2010.

[56] K. Nath, S. Rao, S. Nair, R. Gilman, and D. Mullick, *Proceedings of the International Conference on Water Hyacinth*, United Nations Environment Programme, Nairobi, Kenya, 1984.

[57] N. W. Ingole, A. G. Bhole, and Technology—Aqua, "Utilization of water hyacinth relevant in water treatment and resource recovery with special reference to India," *Journal of Water Supply: Research and Technology-Aqua*, vol. 51, no. 5, pp. 283–295, 2002.

[58] S. Narain, C. Ojha, S. Mishra, U. Chaube, and P. K. Sharma, "Cadmium and chromium removal by aquatic plant," *International Journal of Environmental Sciences*, vol. 1, pp. 1297–1304, 2011.

[59] P. Saha, O. Shinde, and S. Sarkar, "Phytoremediation of industrial mines wastewater using water hyacinth," *International Journal of Phytoremediation*, vol. 19, pp. 87–96, 2017.

[60] P. Kumar and M. S. Chauhan, "Adsorption of chromium (VI) from the synthetic aqueous solution using chemically modified dried water hyacinth roots," *Journal of Environmental Chemical Engineering*, vol. 7, no. 4, p. 103218, 2019.

[61] P. K. Weber-Scannell and L. K. Duffy, "Effects of Total Dissolved Solids on Aquatic Organism: A Review of Literature and Recommendation for Salmonid Species," *American Journal of Environmental Sciences*, vol. 3, 2007.

[62] N. P. Lissy and B. D. G. Madhu, "Removal of heavy metals from waste water using water hyacinth," in *Proceedings of International Conference on Advances in Civil Engineering*, Trabzon, Turkey, 2010.

[63] D. A. Cornwell, J. Zoltek JR, C. D. Patrinely, T. D. Furman, and J. I. J. J. Kim, "Nutrient removal by water hyacinths," *JSTOR*, vol. 49, pp. 57–65, 1977.

[64] C. Schulz, J. Gelbrecht, and B. Rennert, "Constructed wetlands with free water surface for treatment of aquaculture effluents," *Journal of Applied Ichthyology*, vol. 20, no. 1, pp. 64–70, 2004.

[65] S. A. Bramwell and P. Devi Prasad, "Performance of a small aquatic plant wastewater treatment system under Caribbean conditions," *Journal of Environmental Management*, vol. 44, no. 3, pp. 213–220, 1995.

[66] E. Raj, D. Sankaran, S. Sreenath, S. Kumaran, and N. Mohan, "Studies on treated effluent characteristics of a few tanneries at Crompet," *IJEP*, vol. 16, pp. 252–254, 1996.

[67] N. Gamage and P. A. J. Yapa, "Use of water Hyacinth (Eichhornia crassipes (Mart) Solms) in treatment systems for textile mill effluents-a case study," *Journal of the National Science Foundation of Sri Lanka*, vol. 29, pp. 1-2, 2001.

[68] T. Chakrabarty, R. Afrin, M. Y. Mia, H. M. Zakir, and FISHERIES, "Phytoremediation of Chromium and some chemical parameters from Tannery effluent by using water Hyacinth (Eichhornia craassipes)," *Research in Agriculture Livestock and Fisheries*, vol. 4, no. 3, pp. 151–156, 2017.