Journal of Engineering and Sustainable Development
Vol. 29, No. 01, January 2025
https://jeasd.uomustansiriyah.edu.iq/index.php/jeasd
ISSN 2520-0917
Research Article
https://doi.org/10.31272/jeasd.1220

Using Lime to Remove Chromium from Tannery Factory Industrial Wastewater in Baghdad

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Article Info

Received	**25/05/2023**
Revised	**30/11/2024**
Accepted	**24/12/2024**

Abstract

A jar test experiment was conducted on tannery factory wastewater using hydrated lime $Ca(OH)_2$ as a treatment material to remove chromium. The Saeeda factory in the Zaafaraniya area was the field for bringing models and applying this research content. The effluent characteristics were analyzed according to the American Public Health Association (APHA), the American Water Works Association (AWWA), and the Water Environment Federation (WEF). The results after analysis showed that calcium hydroxide (lime) removes chromium from industrial wastewater of tanning factories by up to 63.822%. The working conditions and parameters for performing the tests were based on axes, such as the gradient speed achieved at 480 s^{-1} for 30 minutes at 20°C. Experiments have shown that calcium concentration can remove chromium through multiple mechanisms. However, the presence of calcium also works together with chromium through the presence of chromium ions, which will lead to a reduction of calcium ions by 6.734%, but this does not mean risking adding chromium salts to achieve the best removal of chromium by hydrated lime.

Keywords: Calcium hydroxide; Chemical treatment; Chrome; Coagulation; Industrial Wastewater; Tanning

1. Introduction

Although the leather industry presents a significant chance of jobs for people, it also guides the creation of large amounts of wastewater into the water bodies. Many salts and chemicals are used in leather manufacturing, including sodium chloride, lime, sodium sulfate, fat, ammonium sulfuric acid, chromium sulfate, and many other dyes [1]-[3]. Various kinds of tanning methods exist, but Chrome is the most famous. This tanning will give the lather more durability, stiffness, flexibility, and lifetime. The central figure of tannery wastewater, which gives the identity of tannery wastewater, is the chrome ion [4]-[6]. Chromium is a chemical component with the sign Cr and atomic number 24. Chrome is a shiny silver-grey metal. The arrangement of trivalent chromium as an essential nutrient for humans is controversial, but hexavalent chromium is toxic and carcinogenic. It also negatively influences the environment, and wild vinery construction sites need environmental improvement. Cr has the atomic number 24. It is the initial part of group 6. Furthermore, it's grey, steely, complex, and a brittle transition metal [7]-[9].

The industry is highly water intensive also. Due to physical and chemical reactions, just 20% of the substances used in the tanning process are absorbed by hides and skins [10], [11]. Water consumption in the leather industry is high; each ton of hides /skin, whether large or small, requires more than 15,000 liters daily. Each ton of hides, whether large or small, requires more than 15,000 liters of water daily. The primary meanings of this water being discharged into water bodies are high concentrations of Biological oxygen demand (BOD), Chemical oxygen demand (COD), High concentration of total solids associated with chromium salts remaining after saturation, and their role in completing the dyeing process [12], [13]. The effluent of the tannery industry will find its way to the watercourse and significantly change ecosystem characteristics [14]-[16].

The characteristics described correspond to 30-35 L per Kg of skin/hide. Table 1 displays the overall characteristics of tannery wastewater [17], [18].

Table 1. Physical-chemical characteristics of tannery wastewater. Adopted by [19]-[21].

Reference	pH	TDS	solids	Suspended solids	suspended solids	COD	BOD	TKN	Nitrogen	AmmonicaJ/ nitrogen Chromium	Sulfide
[19], [20]	7.4			2690	1260	3700	1470		180	95±55	440
	7.08±0.28		10265±1 460	2820±140	1505±90	4800±350		225±18	128±20		
[21]	7.0-8.7	13,300-19,700		600-955		4100-6700	630-975	144-170		11.5-14.3	
[22]		15,152		2004	1660	8000	930			11.2	228
[23]	7.70	36,800		5300	1300	2200		270			
[24]	10.72	6810				11153.67	2906		162.15	32.87	507.5
[25]	7.79			915	578	2155		228	168	50.9	35.8
[26]	10.5	17,737	18,884	1147		3114	1126		33.0	83.00	55.00
[27]	7.7					2426		370	335	29.3	286
[27]	8.2-8.5	14750	19775	5025		5650					

Except for pH, all values are in (mgL^{-1})

2. Patterns and Properties of Tannery Industry Wastewater (TIWW)

During tanning, no less than 300 kg of complexes are up per ton of hides. Because the amount of chemicals needed in this industry is high (300 kg/ton) [22], [23], tannery wastewater includes various heavy metals, ranging from toxic to hazardous, lime and suspended materials, and solids from salts [24]-[27]. In the same way, some scientists described the characteristics of tannery wastewater in terms of weights and gave some values.

The primary identity of tannery wastewater is the chromium ion. Chrome ions hurt microorganisms, so their presence will obstruct the chance of eutrophication and cause deterioration in the quality of the waterways [28]-[31]. This article aims to implement local, affordable materials in the surrounding area to make chemical treatments and reduce chromium ion concentration.

3. Aim of Using the Chemical Treatment

Chemical treatment is one of the different processes that may be applied to tannery wastewater to remove pollutants. Pollutants in tannery wastewater vary depending on economic skills and factories' organization and management staff [32], [33]. Once built, Chromium (III) hydroxide is insoluble in the samples; meanwhile, it doesn't have the same coagulation activity as noted in equations (1, 2). This feature will be particulate with alum hydroxide in the treatment processes by coagulation [34]-[37]. The capacity of lime is not limited to working only as an assistant treatment, but it might remove Cr^{2+}. The removal mechanisms will be through making new compounds of hydrated lime connected with chromium hydroxide, and because the boundary is alkaline, the formation of chromium hydroxide occurs more frequently [38]-[41]. This phenomenon can be more clearly seen in Fig 1.

$$\boldsymbol{Cr(OH)3 + OH- \rightarrow CrO-2 + 2\,H2O} \quad (1)$$

In acid:

$$Cr(OH)3(OH2)3 + 3\,H+ \rightarrow Cr(OH2)3 + 6 \quad (2)$$

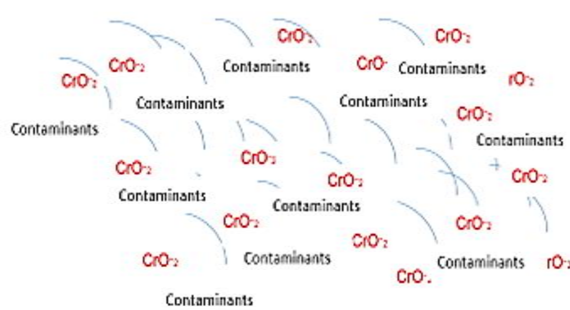

Figure 1. The role of aluminum and chromium hydroxides, which are gelatinous, in scavenging pollutants.

4. Materials and Methods

The samples collected from the saffron factory were analyzed by the American Public Health Association (APHA), the American Water Works Association (AWWA), and the Water Environment Federation (WEF) [39] and are shown in Table 2.

Table 2. Characteristics of Saeeda plant tannery discharge

Element	Tannery effluent
COD, mg/L	5300-5800
BOD, mg/L	3250-3800
Suspended solids (SS), mg/L	2700-2900
Cr^{2+}, mg/L	90-120
Total Chromium mg/L	722-745
$SO_4^{\ 2-}$	1800-2200
Cl-, mg/L	5100-6300
pH	8-9
Conductivity, ms/cm	10-12

The jar test technique model JLT 6 Leaching test VELPS scientific has been used to occupy the work in this article.

4.1. Tanning Site: Object Saeeda in Zaafaraniya Area

This site laboratory consists of a large tanning factory that specializes in cow skins and buffalo and a small tanning factory for sheep, goats, and plant leather garments and skins, which was founded in 1989 by a Turkish company and specializes in manufacturing leather garments Bmokhtl models and types such as (Aalghemsalh, pants, Lilac A variety of different materials.) and laboratory garment and respect sewed allowances work. The rib and plant bags, belts and specialized industry, school bags and Alseverih and diplomatic bags business people and others as well as leather belts and plant pumping PVC and respect to the production of various plastic Alanalh and plant p.v and specialized production Analh polyurethane and also there is a unit of industrial processing and also the unity of liquefaction to provide drinking water for the site [42], [43].

4.2. Materials

The materials used in this article are:

- Slaked lime Ca $(OH)_2$ has been used with an activity of (55%) produced in the Mosul Sugar Factory as liquid with a concentration of 1%.
- Behaving Synthetic samples with a capacity of 1000 ml each were prepared, and each sample was added to a beaker in the six-beaker device.
- Tubes were arranged proportional to the dose of the added alum solution, and the increments were placed from left to right.
- Then, the device was turned on,
- The maximum dose was determined by performing a residual turbidity examination.
- Jar Test Model JLT 6 Scientific VELP Filtration Test,

Coagulation– Flocculation and sedimentation, a one-liter model, was tested to demonstrate the effectiveness of the experiments in this research. Table 2 shows samples were prepared with characteristics and qualities similar to the international specifications and characteristics of liquid wastes for tanning factories.

4.3. Jar Test Technique

This procedure was attained after settling the appraisals. The determinants of treatment that have been implemented on jar test techniques are;

- high mixing speed of 150 rpm for the time of 3 min.
- Gentles mixed at 30 rpm for 20 min.
- Staying for 20 min.

4.4. Procedure of Work

After alum became the most popular in science for removing turbidity and contaminated materials, examining the jar became the most popular.

As mentioned above, the lime in this research depends mainly on the nature of the wastewater discharged from the tanning factories. These factors include physical and chemical factors and other characteristics such as the concentration of organic and inorganic substances.

4.5. Sampling

To maintain the model's properties without reaction, I added 1.5 ml of nitric acid to the model. Because the models were transported a distance to the laboratory, snow played a role in preserving the neighborhood environment so that the models remained without any change in properties. The samples were incubated at a low temperature close to 5 ± 0.2. The samples used in these experiments are based on one litter.

4.6. Chrome Test

HACH, the global company for water testing, has a high level of testing and analysis. The HACH mechanism has become a pioneer in measuring chromium concentration, and that is why Specification No. 8024 was adopted in the HACH mechanism for measuring chromium concentration in this research. It has used Melique water for dilution samples to make more simplicity of test. On the other hand, the Alkaline Hypobromite Oxidation Method and the Chrome Concentration Method are used to complete tests. Method 8024 is also used with the HACH apparatus to measure total chromium. It used melique water for dilution samples to simplify the test and avoid any interaction or rejection of measurement [44].

5. Results and Discussions

As shown in Fig. 2, the optimum concentration of HL will be about 2.083 ml. This value will give a hydrated lime concentration of about 0.8 gm/L.

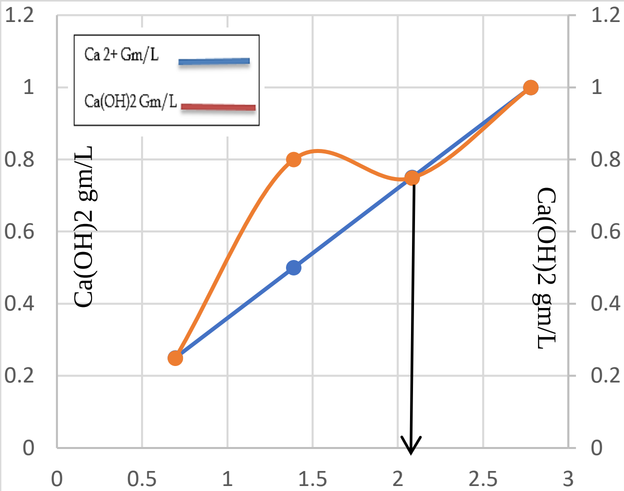

Figure 2. Correlation between added Hydrated Lime (mg/L) and different species of calcium.

To achieve these experiments, some factors have been rendered to current research [45]-[51].

- Duration period of flash mixing: 3 min.

The laboratory temperatures, ten degrees Celsius and 30 degrees Celsius, were ideal for determining the *G* value of the flash mixture (122.79 s-1 205.7 s-1).

- The time for achieving optimal slow blending and speed is 30 min.
- Settling time is 20 minutes.

As noted in Fig. 3, the active area of the reaction will be 1.4 ml HL and 2.1 ml HL. In this area, the calcium concentration will be about 0.5-0.75 Gm/L. These calculations and figures are included in Table 3. It is an expression of Fig. 3.

Table 3. The treatment reaction uses hydrated lime (HL).

Material (Solution)	Equation	Amount Gm/L
HL 0.694 ml	HL 0.694 ml --- $Ca(OH)_2$ = 0.25 g/L -- Ca2+ (3)	$Ca(OH)_2$ = 0.249
HL 1.389 ml	HL 1.389 ml ----$Ca(OH)_2$ = 0.5 g/L L ---Ca^{2+} (4)	$Ca(OH)_2$ = 0.8
HL 2.083 ml	HL 2.083 ml ----$Ca(OH)_2$ = 0.75 g/L --Ca^{2+} (5)	$Ca(OH)_2$ = 0.749
HL 2.78 ml	HL 2.78 ml ------$Ca(OH)_2$ = 1 g/L ----- Ca^{2+} (6)	$Ca(OH)_2$ = 1

Fig. 3 shows that the chrome concentration decreases by adding hydrated lime. This concept could be explained in different ways. Chrome ions have a positive charge, which gives them an additional advantage besides their physical characteristics. The attraction forces between chrome ions and colloidal materials create a new shape of compounds that can agglomerate to large sizes.

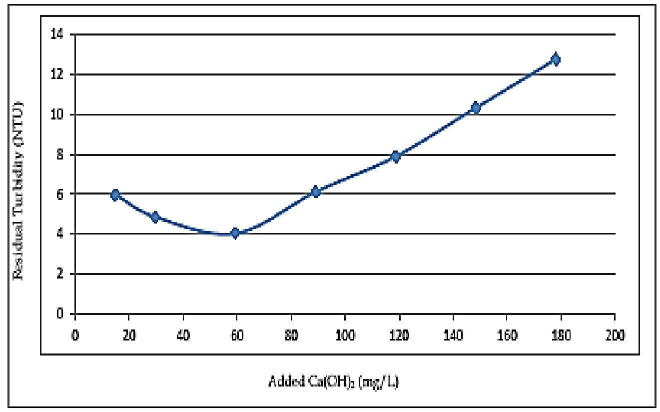

Figure 3. Hydrated lime (mg/L) removes turbidity and residual turbidity concentration (NTU).

As shown in Fig. 3, the removal of chromium ions will increase with increasing HL. This phenomenon could be explained by the attraction between positive ions of HL hydration once added to the sample. The hydration will lead to calcium hydroxide forms, which can hunt chromium ions into a calcium hydroxide net. This fact can be noted in Fig. 4. The tracking of chromium ions does not occur due to physical action alone. The capture of chromium ions does not happen only because of the trapping by the gelatinous mesh of the calcium forms. Explanation means multiple activities are working simultaneously to remove chromium ions. Physical work called adsorption works in the same way as adhesion. All of these mechanisms enhance the chances of reducing the chromium ion concentration.

The chromium hydroxides combined with the lime hydroxides, which make a net of chemical compounds, precipitate the chromium together. The mechanisms could give the results shown in Fig. 3.

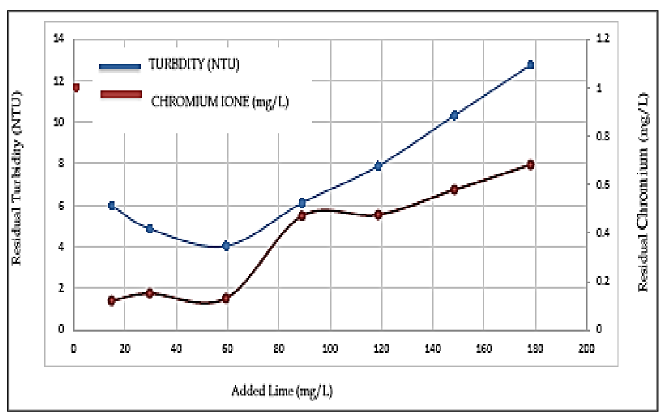

Figure 4. Effectiveness of added lime (mg/L) in removing turbidity (NTU) and removing chromium.

As shown in Fig. 3 and Fig. 4, smear is the foremost term in tannery wastewater; Calcium reduction is the main essence of this work.

As indicated by the previous sources, the velocity gradient value was calculated as the *G* value [52]-[54] to express the intensity of slow and fast mixing. Camp and Stein (1943) established the G value theory. This value is the basis for the design of coagulation and coagulation tanks [54]-[55] and is defined by Equation (7).

$$G = \sqrt{W}/\mu \quad (7)$$

Which W= Parting function,
μ = absolute viscosity Kg/m.sec
The results are shown in Fig. 4. These words have been translated into relationships shown in Fig. 5.
Equation (8) can be represented in another term which is,

$$G = (\sqrt{Cd\ A\rho v^3})/2\mu v \quad (8)$$

Where is v = Linear velocity of paddle brushes relative to fluid velocity, and this can be calculated from this equation (9),

$$v = 2\,\pi r n/60 \quad (9)$$

Where,
r = Rotational radius (m), n = Number of rotations in minutes, A = Area of blade (m^2), ρ = Density of fluid, V = Volume of liquid (m^3).

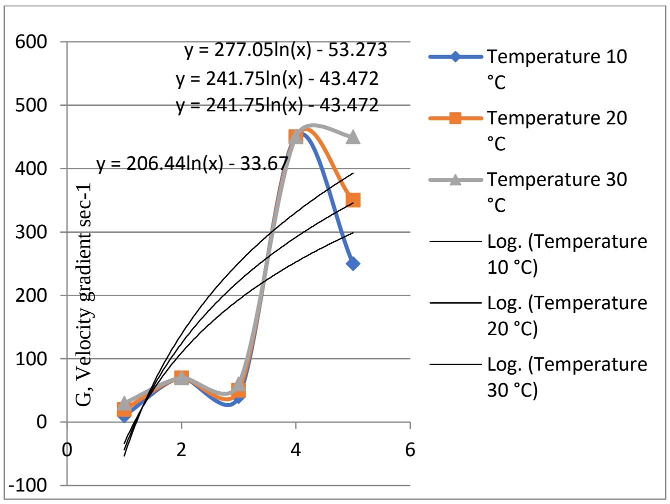

Figure 5. The interrelation between different **t**emperatures and the velocity gradient of the paddle is expressed as *G*.

It could be concluded that the optimum lime figure to remove Chrome at 20 °C is about 0.75 mg/L, which means HL = 2.083 ml. The last activity will reduce residual Chrome by 45.4 % at an optimum gradient velocity of about 480 sec-1 for 30 minutes before fracturing the flock of calcium. From Fig. 6, the role of *G* in achieving optimum treatment can be seen, as shown in Fig. 7.

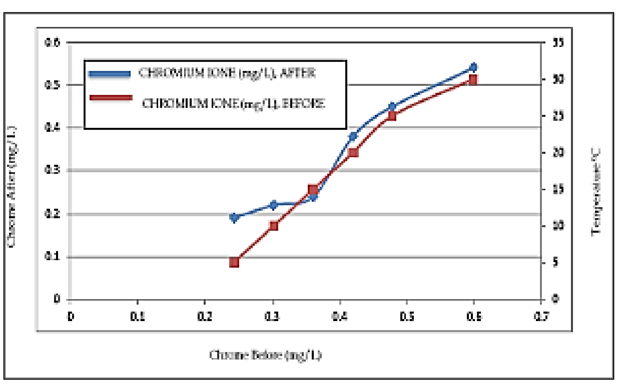

Figure 6. Relationship between Temperature °C and Chrome (mg/L), before and after Adding Lime.

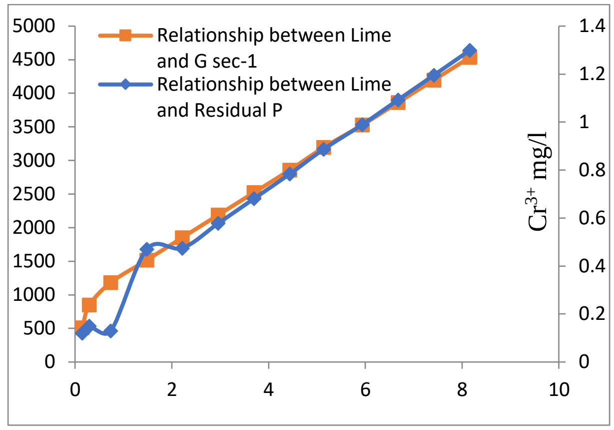

Figure 7. The effect of added lime on the remaining chromium Cr^{3+} on the one hand and the role of the velocity gradient *G* on the other hand.

The hydrated calcium hydroxide will build different species of calcium compounds in the bulk solution. The calcium compounds can make scavenging but less than aluminum compounds due to ion valence. The contaminants, which can settle due to size enlargement and enmeshment in the net of chemical compounds, will reduce the chrome concentration.

6. Conclusions

Calcium Hydroxide (Lime) to remove chromium from tannery wastewater plant up to 63.822%. The treatment's achievement was applied under specific conditions, such as gradient velocity at 480 sec-1 at 20 °C for 30 minutes—Chromes tended to stick with the calcium hydroxide floc and through different mechanisms. The presence of chrome ions reduced calcium ions by 6.734 %, but this does not mean risking adding chrome salts. The concept above refers to the role of chemical treatment in removing chrome ions using lime. The calcium ion can attain the most significant chrome removal at 20 °C. The presence of chrome ions will assist in reducing the concentration of chrome ions. The reduction of chrome concentration will be through the scaffolding of chrome ions in the amorphous net. With the ability of calcium ions to process a floc, the hunter could trap the chrome ions through the mesh strings. The positive charges of chrome ions increase the appeal process. All these steps will reduce the chrome ion concentration. The ability of chrome ions to form a floc but in a weak way and its tendency to stick with the calcium hydroxide floc and over a group of different procedures was shown by measuring the remaining chrome concentration.

Abbreviations

TWW tannery wastewater
APHA American Public Health Association
AWWA American Water Works Association
WEF Water Environment Federation

Acknowledgment

Great thanks to the Civil Engineering and Environmental Engineering departments in the College of Engineering at Al-Mustansiriyah University for their help and sustenance in accomplishing this clause and to all working at the lab.

Great, thanks to RMIT University and the labs for supporting me in finishing the article.

Conflict of interest

The author declares no conflicts of interest in publishing this research and everything related.

Author Contribution Statement

Ali A. Hasan proposed the research problem. Developed the theory and performed the computations, verified the analytical methods, and discussed the results

Ilham Al-Obaidi: verified the analytical methods and discussed the results.

Zainab M. Abed: supervised the findings of this work and contributed to the final manuscript.

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