Cleaner Tannery Wastewater Using Chemical Coagulants

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Abstract: ***This investigation evaluated the efficiency of primary coagulants, such as Ferrous sulfate ($FeSO_4 \cdot 7H_2O$), Ferric chloride ($FeCl_3 \cdot 6H_2O$) and Calcium hydroxide Ca $(OH)_2$ as a coagulant aid. These chemical coagulants were used in different doses and combinations to reach the optimization of the coagulation and precipitation process, in terms of removal of chromium and other undesirable pollutants, such as ammonia, chlorides, sulfates, Chemical Oxygen Demand (COD), Total Suspended Solids(TSS), Total Dissolved Solids (TDS), hydrogen sulfide gas(H_2S). The study was conducted during October 2013 – November 2014. The correlation Pearson between all indicators of raw effluents showed that Total alkalinity and ammonia ions($r = 0.896$), TSS and NH_4^+ ($r = 0.869$), TSS and Cl^- ($r = 0.883$), sulfate and pH, NH_4^+, TSS respectively, ($r = 0.821$), ($r = 0. 807$), ($r = 0.824$), H_2S and COD ($r =0.918$) were strongly positively correlated. The correlation Pearson between all indicators of treated effluents showed a very strong correlation between E.Coli and St.Faecalis ($r =0.992$), also Total alkalinity and COD, chromium, respectively with ($r = 0.918$), ($r =0.883$), chromium and COD($r = 0.947$), were strongly positively correlated. $FeSO_4$ seemed to be less effective than $FeCl_3$, with regard to the SVI. The Sludge Volume Index was the only parameter that was weakly negatively correlated with other parameters. This study concluded that the chemical combination of $FeSO_4$ and $Ca(OH)_2$ at 150 mg/L and 1000mg/L was more effective than $FeCl_3$ and $Ca(OH)_2$ for the treatment of the tannery effluents with a high efficiency in the removal of chromium, E.Coli and St. Faecalis, ammonia ions, chloride, H_2S, TSS, COD and sulfate. A small disadvantage was observed with regard to the COD and TDS.***

Keywords: tannery, coagulant, effluent, pollutant, chemical

1. Introduction

Among all different industrial processes, tannery wastewaters are ranked as having the highest pollutants. In developing countries, many industrial units operate in a small and medium scale [1]. For tanneries, the focal points are water consumption, efficient use and substitution of potentially harmful process agents and waste reduction within the process in conjunction with recycling and re-use options [2]. In waste management and treatment, Best Available Techniques (BAT) in order of priority are: prevention, reduction, re-uses, recycling/recovery, and thermal treatment for certain types of waste. Sophisticated treatment and processing techniques play an important part in achieving improved environmental performance [2]. The environmental impact of tanneries originates from liquid, solid and gaseous waste streams and from the consumption of raw materials, such as raw hides, energy, chemicals and water [2]. The uncontrolled release of tannery effluents to natural water bodies increases environmental pollution and health risks. In the sector, the water used greatly varies depending on the type of applied manufacturing technology. Advanced technologies involve processes usually termed low-waste or cleaner technologies [3]. Cleaner Production is defined as the continuous application of an integrated preventive environmental strategy applied to processes, products and services to increase overall efficiency and reduce risks to humans and the environment [4].For production processes, Cleaner Production involves the conservation of raw materials and energy, the elimination of toxic raw materials, and the reduction in quantities and toxicity of wastes and emissions [4]. Due to the inherent characteristics of tannery effluents, various physic-chemical techniques have been studied for their applicability to the treatment of wastewater [5]. Wastewaters form in all wet operations and the amount of these wastes flows; they are distinctly different in quantity and content [6]. Coagulation-flocculation is one of the most important physic-chemical treatments of industrial wastewaters. Coagulation uses salts, such as aluminum sulfate (alum), ferrous or ferric (iron) salts, which bond to the suspended particles, making them less stable in suspension, i.e., more likely to settle out [7]. Thus, advanced oxidation processes, such as UV, ozone (O_3), photo catalytic oxidation, and Fenton reagent have been used as pre-oxidation or post-oxidation of tannery wastewater. However, due to the high cost of these processes, coagulation-flocculation still remains the most widely used one at present [8]. The proper determination of coagulant and flocculants types and dosages will not only improve the resulting water characteristics, but also decreases the cost of treatment [9]. It is also important to understand some advantages of the coagulation process, e.g. the addition of treatment chemicals may increase the total volume of sludge; large amounts of chemicals may need to be transported to the treatment location, and polymers used can be expensive [10]. The biggest problem in the chemical treatment of wastewater is the selection of the chemicals, which must be added to the wastewater in order to separate the dispersed pollutants. The problem nearly always cumulates in finding a suitable coagulant as this must be easy to handle, store, and prepare [10]. Coagulant chemicals come in two main types - primary coagulants and coagulant aids. Chemically, coagulants are either metallic salts or polymers, which are man–made organic compounds are made up of a long chain of smaller molecules [11]. Primary coagulants are always used in the coagulation/flocculation process. Coagulant aids, in contrast, are not always required and are generally used to reduce flocculation time [11]. Almost all coagulant aids are expensive, so care must be taken to use the proper amount of these chemicals, e.g. lime is a coagulant aid used to increase the alkalinity of water. The increase in alkalinity results in an increase in ions in the water, some of which are positively charged [11]. Bentonite is a type of clay used as a weighting agent in water high in color and low in turbidity and mineral content. The bentonite joins with the small flock, making the flock heavier and thus making it settle more quickly [11]. Due to high correlation between the tannery wastewater and its environmental impact, cost effective alternative technologies for their treatment are required [12]. The current survey focused on the implementation of cleaner processes using chemical coagulants, taking into account the low cost treatment of the tannery effluents. This investigation evaluated the efficiency of primary coagulants, such as Ferrous sulfate ($FeSO_4 \cdot 7H_2O$), Ferric chloride ($FeCl_3 \cdot 6H_2O$) and Calcium hydroxide Ca $(OH)_2$ as a coagulant aid. These chemical coagulants were used in different doses and combinations to reach the optimization of the coagulation and precipitation process, in terms of removal of chromium and other undesirable pollutants, such as ammonia, chlorides, sulfates, Chemical Oxygen Demand (COD), Total Suspended Solids(TSS), Total Dissolved Solids (TDS), hydrogen sulfide gas(H_2S),the determination of pH and Total alkalinity. Furthermore, the current study included an investigation of bacteriological species such as Escherichia Coli and Streptococcus Faecalis. An evaluation of the amount of sludge production for each combination of industrial coagulants used is also included. Indeed, the coagulation process is not always perfect and may result in treated wastewaters with characteristics that didn't meet the proposed effluents standard. Consequently, further treatment is often necessary [9].

2. Material and Methods

2.1 Study area

The study area is comprised of two tanneries in Berat, Albania. The most important of them is located at (N 40^0 41' 22.3476") Latitude and (E 19^0 58' 34.3236") Longitude, in a building with a large capacity (surface area: 860 m^2). The smaller, less productive tannery, is located at (N 40^0 40' 36.1488") Latitude and (E 20^0 1'10.7616") Longitude, in Vodica village, approximately 5km away from the city of Berat.

2.2 Materials

The study was conducted during October 2013 – November 2014, the samples were collected in 1L polyethylene bottles pre-cleaned by washing them with non ionic-detergents and rinsed well with distilled water and then treated with diluted HNO_3. Effluents originated from the main drain before they were discharged into the river, at different times, so their characteristics varied significantly. All chemicals used as primary coagulants, Ferrous sulfate ($FeSO_4 \cdot 7H_2O$), Ferric chloride ($FeCl_3 \cdot 6H_2O$) and Calcium hydroxide Ca $(OH)_2$ as a coagulant aid, were selected to a high degree of analytical purity.

2.3 Methods

2.3.1 Treatment process

A total of 21 effluent samples were treated with different doses of $FeSO_4 \cdot 7H_2O$, $FeCl_3 \cdot 6H_2O$) and Ca $(OH)_2$ to evaluate the optimum coagulant dose for the coagulation process. 1000 ml of some samples were treated respectively with 100mg/L, 150mg/L and 200mg/L of Ferrous sulfate and 1000mg/L of Calcium hydroxide as a coagulant aid, and some others were treated with the same dose of Ferric chloride and Ca $(OH)_2$. Each coagulant was mixed well with 1000mL of the effluent sample for 5 minutes in a beaker on a magnetic stirrer. The mixture then sat undisturbed for 24 hours at room temperature. After settling and interacting with the coagulants, the effluent sample remained in a 1000 mL graduated transparent cylinder for 30 minutes. The settled sludge volume was then measured in mL/L and the supernatant liquids were separated from the deposited sludge and passed through slow filter paper (125 mm diameter, Macherey- Nagel). After coagulation, sedimentation, and filtration, collected effluents were analyzed for various physic-chemical and bacteriological parameters.

2.3.2 Physic-chemical analysis

To evaluate the treatment efficiency of inorganic coagulants on tannery wastewater, the following physic-chemical and bacteriological parameters were analyzed: pH, Total alkalinity, COD $_{(IMn)}$, ammonia ions, chlorides, sulfates, TSS, TDS, H_2S gas, total chromium, E. Coli and St. Faecalis. The pH was determined by a "Selecta" pH-meter (accuracy 0.01). Total alkalinity was determined with the standard method [13]. COD was analyzed with the permanganate index [14]; (note that dilution is applied in many cases). Ammonia ions were determined by the Nesslerization method [15]. Chlorides were analyzed with the standard method of titration (Argentometria) [15]. Sulfate analysis was performed by precipitation with $BaCl_2$ to filtered effluent [15]. H2S was determined by titration of $Na_2S_2O_3$ 0.1N [15].TSS were determined with filtration and the gravimetric method [16].Conductivity Meter "JENWAY", Model 4150(accuracy $\mp$ 0.5% $\mp$ 2 digits) was used to determine TDS. Total chromium was analyzed by Atomic Absorption Spectroscopy (AAS-200 Varian). E. Coli and St. Faecalis were determined with the dilution method with multiple tubes [17]. Sludge Volume Index (in terms of settled sludge volume) was also measured for all the combinations and doses of coagulants and was calculated according to reference [18]. All the methods used for the analysis of effluents characteristics, were performed at laboratory conditions (25$\mp$ 2℃).

2.3.3 Statistical Analysis

The obtained data were subjected to descriptive statistical analysis (95% confidence limit). The computations were achieved with the use of Microsoft Excel to determine the mean, range values, median, standard deviation, threshold and coefficient of variation. Correlation was performed with the Simple Pearson correlation method using the Statistical Package for Social Sciences (SPSS).

3. Results and Discussion

A summary of basic statistics of raw and treated tannery effluents is presented in Table 1 in order to evaluate the efficiency of the coagulation- precipitation process for the treatment of industrial tannery wastewater. Correlation analysis is very useful in establishing the physic, chemical and bacteriological parameters association before and after the coagulation process.

Table 1: Physical, chemical, and microbiological characteristics of raw and treated tannery effluents

Parameters	*Minimum*	*Maximum*	*Mean*	*Median*	*Standard Deviation*	*Coefficient of Variation*	*Threshold X + 2S*
pH	8.4-8.5	11.5-12.3	9.47-10	9.05-9.5	0.88-1.16	0.092-0.116	11.23-12.32
Total Alkalinity (mg/L $CaCO_3$)	265-458	3300-5000	1152.6-1321.52	835-1046	978.06-1009.84	0.848-0.764	3108.72-3341.2
NH_4^+ (mg/L)	1-0.25	30-6.5	6.88-1.79	1-Mar	7.9-1.87	1.15-1.044	22.68-5.53
Chloride (mg/L)	410.2-248.2	30425-7799	6632.5-2194.83	3456.37-1772.5	8573.9-2045.88	1.29-0.932	23780.3-6286.59
$COD_{(IMn)}$ (mg/L O_2)	61.6-9.6	3200-2720	583.55-403.89	408-304	698.3-565.94	1.196-1.401	1980.15-1535.77
Sulfate (mg/L)	65.01-14.4	2106.05-1415.6	754.24-608.26	668.27-680.62	625.1-422.99	0.828-0.695	2004.4-1454.24
TSS (mg/L)	65-43	3383-1057	663.61-254.79	328.5-195	941.36-277.99	1.42-1.091	2546.33-810.77
TDS (mg/L)	1451-1260	50900-58900	16536.28-17403.76	15041-17280	13163.44-13110.76	0.796-0.753	42863.16-43625.28
Total Chromium (mg/L)	4.25-0.03	60-11.6	13.685-1.803	10.75-0.28	12.91-4.213	0.94-2.336	39.5-10.23
H_2S gas (mg/L)	73.1-13.6	3060-1173	381.61-209.81	165.75-117.3	712.26-317.27	1.866-1.51	1806.13-844.35
Escherichia Coli (MPN)[a]	348-0	1609-70	1382-12.95	1609-2	448.3-25.82	0.32-1.99	2278.6-64.59
St. Faecalis (MPN)	140-0	1609-49	811.1-8.14	918-0	344.09-17.74	0.424-2.18	1499.28-43.62
SVI[b](mL /mg)	17.07	2906.97	435.74	180.99	655.31	1.51	1746.36

[a] *MPN – Most Probable Number*
[b] *SVI- Sludge Volume Index*

Table 2: Correlation coefficient Pearson (r) for all parameters of raw tannery effluents (n=18)

Parameters	*Temp*	*pH*	*Total Alk*	*NH_4^+*	*Cl^-*	*COD*	*SO_4^{-2}*	*TSS*	*TDS*	*Total Cr.*	*H_2S*	*E.Coli*	*St.Faec.*
Temp	1	.525*	.568*	.544*	0.218	.488*	0.337	0.403	0.466	-0.228	.502*	-0.267	-0.094
pH	.525*	1	.738**	.740**	.499*	.734**	.639**	.486*	.642**	0.066	.695**	-0.103	0.025
Total alk.	.568*	.738**	1	.896**	.703**	.692**	.821**	.793**	0.443	0.169	.536*	0.294	.498*
NH_4^+	.544*	.740**	.896**	1	.785**	0.467	.807**	.869**	0.302	0.055	0.314	0.132	0.437
Cl^-	0.218	.499*	.703**	.785**	1	0.213	.771**	.883**	0.256	-0.074	-0.019	0.248	.539*
COD	.488*	.734**	.692**	0.467	0.213	1	0.444	0.232	.645**	0.043	.918**	0.179	0.178
SO_4^{-2}	0.337	.639**	.821**	.807**	.771**	0.444	1	.824**	0.326	0.193	0.18	0.292	.503*
TSS	0.403	.486*	.793**	.869**	.883**	0.232	.824**	1	0.204	0.015	0.035	0.179	.506*
TDS	0.466	.642**	0.443	0.302	0.256	.645**	0.326	0.204	1	0.056	.652**	-0.326	-0.221
Total Cr.	-0.228	0.066	0.169	0.055	-0.074	0.043	0.193	0.015	0.056	1	0.086	0.161	0.085
H_2S	.502*	.695**	.536*	0.314	-0.019	.918**	0.18	0.035	.652**	0.086	1	-0.03	-0.085
E.Coli	-0.267	-0.103	0.294	0.132	0.248	0.179	0.292	0.179	-0.326	0.161	-0.03	1	.867**
St.Faec.	-0.094	0.025	.498*	0.437	.539*	0.178	.503*	.506*	-0.221	0.085	-0.085	.867**	1

**. Correlation is significant at the P = 0.05; (2-tailed).*
***. Correlation is significant at the P = 0.01; (2-tailed).*
n- Number of samples

Table 2 and Table 3 showed the correlation Pearson between all indicators of raw and treated effluents. The results of the analysis from Table 2 showed that Total alkalinity and ammonia ions(r = 0.896), TSS and NH_4^+ (r = 0.869), TSS and Cl^- (r = 0.883), sulfate and pH, NH_4^+, TSS respectively, (r = 0.821), (r = 0. 807), (r = 0.824), H_2S and COD (r =0.918) were strongly positively correlated. Also, between bacteriological species, E.Coli and St.Faecalis had a strong positive relationship (r = 0.867). Other parameters, such as pH and Total alkalinity, NH_4^+, and COD, respectively with (r = 0.738), (r =0.740), (r = 0.734), were moderately positively correlated, and the rest were moderate and weakly positively correlated. Only a small part of them had weak negative correlations. Table 3 presented a very strong correlation between E.Coli and St.Faecalis (r =0.992), also Total alkalinity and COD, chromium, respectively with (r = 0.918), (r =0.883), chromium and COD(r = 0.947), were strongly positively correlated. Among other parameters such

Table 3: Correlation coefficient Pearson (r) for all parameters of tannery effluents after chemical treatment (n=21)

Parameters	*Temp*	*pH*	*Total alk.*	*$NH4^+$*	*Cl^-*	*COD*	*SO_4^{2-}*	*TSS*	*TDS*	*Total Cr.*	*H_2S*	*E.Coli*	*St.Faec.*	*SVI*
Temp	1	0.15	$.569^{**}$	0.252	0.33	0.382	0.346	0.235	$.568^{**}$	$.436^{*}$	0.303	0.344	0.351	0.073
pH	0.15	1	$.483^{*}$	0.371	-0.069	$.540^{*}$	0.364	-0.122	$.611^{**}$	$.591^{**}$	$.513^{*}$	$-.493^{*}$	$-.481^{*}$	-0.184
Total alk.	$.569^{**}$	$.483^{*}$	1	0.353	$.439^{*}$	$.918^{**}$	$.726^{**}$	0.317	$.751^{**}$	$.883^{**}$	0.126	0.116	0.129	-0.221
$NH4^+$	0.252	0.371	0.353	1	$.549^{*}$	0.269	$.586^{**}$	$.599^{**}$	0.077	0.139	0.328	0.333	0.332	-0.288
Cl^-	0.33	-0.069	$.439^{*}$	$.549^{*}$	1	0.217	$.616^{**}$	$.767^{**}$	0.197	0.096	0.071	$.528^{*}$	$.530^{*}$	-0.233
COD	0.382	$.540^{*}$	$.918^{**}$	0.269	0.217	1	$.555^{**}$	0.135	$.748^{**}$	$.947^{**}$	0.088	-0.016	-0.011	-0.232
$SO4^{2-}$	0.346	0.364	$.726^{**}$	$.586^{**}$	$.616^{**}$	$.555^{**}$	1	$.616^{**}$	0.424	0.402	0.014	0.269	0.272	-0.337
TSS	0.235	-0.122	0.317	$.599^{**}$	$.767^{**}$	0.135	$.616^{**}$	1	0.103	-0.002	0.009	$.653^{**}$	$.692^{**}$	-0.361
TDS	$.568^{**}$	$.611^{**}$	$.751^{**}$	0.077	0.197	$.748^{**}$	0.424	0.103	1	$.793^{**}$	0.328	-0.049	-0.017	-0.225
Total Cr.	$.436^{*}$	$.591^{**}$	$.883^{**}$	0.139	0.096	$.947^{**}$	0.402	-0.002	$.793^{**}$	1	0.251	-0.161	-0.147	-0.139
H_2S	0.303	$.513^{*}$	0.126	0.328	0.071	0.088	0.014	0.009	0.328	0.251	1	-0.18	-0.161	-0.131
E.Coli	0.344	$-.493^{*}$	0.116	0.333	$.528^{*}$	-0.016	0.269	$.653^{**}$	-0.049	-0.161	-0.18	1	$.992^{**}$	-0.283
St.Faec.	0.351	$-.481^{*}$	0.129	0.332	$.530^{*}$	-0.011	0.272	$.692^{**}$	-0.017	-0.147	-0.161	$.992^{**}$	1	-0.288
SVI	0.073	-0.184	-0.221	-0.288	-0.233	-0.232	-0.337	-0.361	-0.225	-0.139	-0.131	-0.283	-0.288	1

**. Correlation is significant at the P = 0.05; (2-tailed).*
***. Correlation is significant at the P = 0.01; (2-tailed).*
n- Number of samples

as Total alkalinity and sulfates(r = 0.726), chromium and TDS, COD respectively with (r = 0.793), (r =0.748), TSS and chlorides with (r =0.767) existed a moderately positive correlation. The rest of the parameters were moderate, weakly, and negatively correlated. The Sludge Volume Index was the only parameter that was weakly negatively correlated with other parameters. This can be explained by the fact that SVI depends on the type and dose of coagulant used for the treatment. The variation in the percentage of pH and Total alkalinity are presented in Fig. 1 and Fig. 2. An increase in pH and Total alkalinity values of tannery effluents after the coagulation process was observed. This may be due to the alkaline nature of tannery wastewaters and the addition of main coagulants such as $FeSO_4$, $FeCl_3$, and lime as coagulant aids. Values of pH and Total alkalinity decreased respectively by 6% and 16.9%; this only happened when $FeCl_3$ was used at a dose at 100 mg/L, while the dose of lime remained constant (1000 mg/L) during all coagulant combinations. This confirmed that the optimum pH of coagulation not only depends on the coagulant types, but also on the nature of the wastewater.

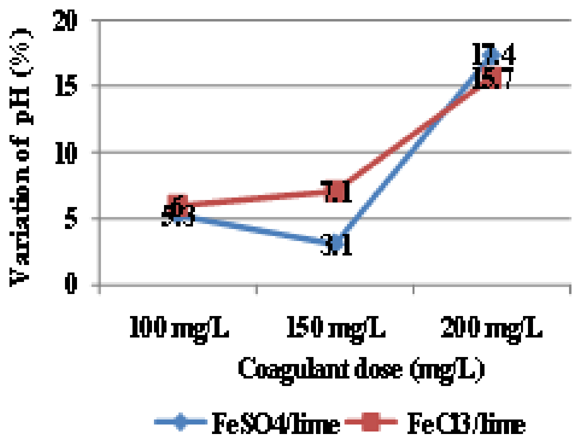

Figure 1: Effect of different doses of $FeSO_4$/lime and $FeCl_3$/lime in the variation of the pH of tannery effluents

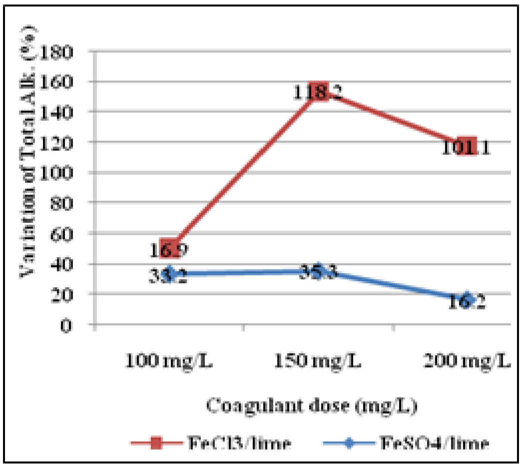

Figure 2: Effect of different doses of $FeSO_4$/lime and $FeCl_3$/lime in the variation of the Total Alkalinity of tannery effluents

According to Fig. 3, the reduction of ammonia after coagulation varied from 50% to 88.6% for the coagulant doses used. The optimum percentage of ammonia reduction, 82.8% with $FeSO_4$ and 88.6% with $FeCl_3$ was achieved using the coagulant dose at 150 mg/L. The lower result of 50% was observed when $FeCl_3$ was used with a dosage of 200 mg/L.

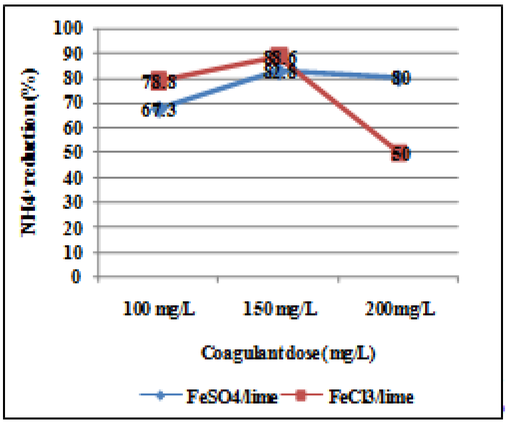

Figure 3: Effect of different doses of $FeSO_4$/lime and $FeCl_3$/lime in the reduction of the ammonia of tannery effluents

Related studies have shown that 9 g/L of chloride could represent a considerable problem for biological plants. Moreover, the impact of curing effluents on terrestrial ecosystems was found to cause aridity on impacted soils [19]. In the current study, the amount of chlorides used in the leather manufacturing process varied from 460.8 mg/L to 30,425 mg/L, and the chloride reduction by the coagulation process varied from 7.7% to 73.5%.The most efficient reduction of chloride (73.5%) during the treatment was achieved at 200 mg/L of $FeSO_4$ and 72.3% was achieved with 150 mg/L $FeSO_4$. The minimum percentage of chloride removal was recorded as 7.7% using $FeCl_3$ at 200 mg/L. Fig. 4 illustrates the results. In Fig. 5 COD removal as a result of the chemical treatment varied from 24% using $FeCl_3$ at 150 mg/L to 73% using $FeSO_4$ at 200 mg/L. The results indicated that $FeSO_4$ and lime were more efficient in COD removal of tannery effluents by the coagulation process.

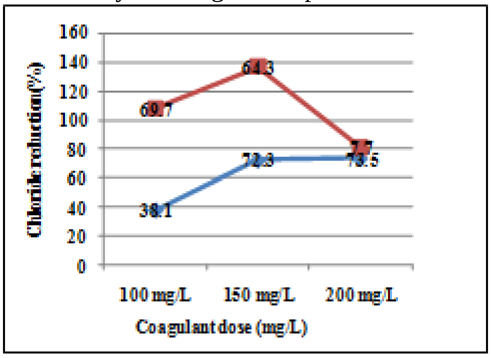

Figure 4: Effect of different doses of $FeSO_4$/lime and $FeCl_3$/lime in the reduction of the chlorides of tannery effluents.

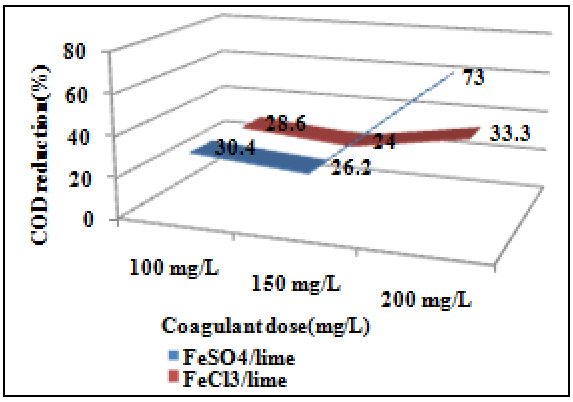

Figure 5: COD reduction with different doses of $FeSO_4$/lime and $FeCl_3$/lime during the treatment of tannery effluents

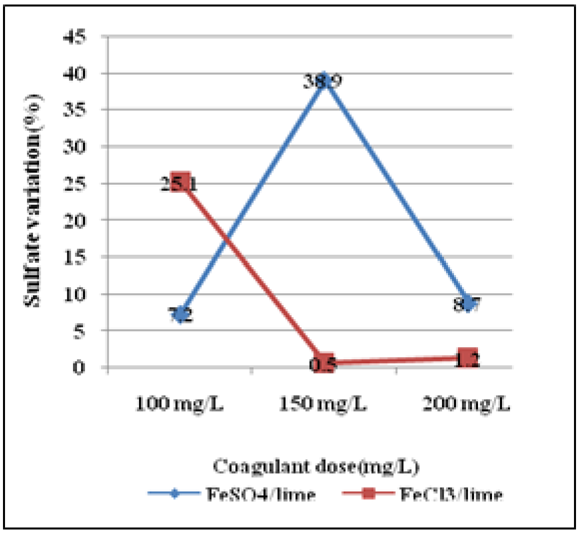

Figure 6: Variation of the sulfates with different doses of $FeSO_4$/lime and $FeCl_3$/lime during the treatment of tannery effluents

Sulfate and sulphide combinations have a variety of potential health (sulphide forming obnoxious and toxic gas H_2S) and environmental impacts [19]. Variation of sulfate content was presented in Fig.6. The percentage of sulfates increased to 7.2% using $FeSO_4$ at 100mg/L and 1.2% using $FeCl_3$ at 200 mg/L. The percentage of sulfate reduction varied from 0.5% to 38.9%. The maximum percentage of sulfate removal (38.9%) was achieved using $FeSO_4$ at 150 mg/L. The minimum value (0.5%) was achieved using $FeCl_3$ at 150 mg/L.

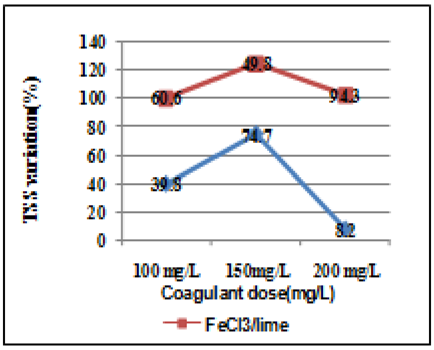

Figure 7: Variation of TSS with different doses of $FeSO_4$/lime and $FeCl_3$/lime during the treatment of tannery effluents

Fig. 7 illustrates the results of TSS variation by chemical treatment. The percentage of TSS was increased to 8.2% using $FeSO_4$ at 200 mg/L, and 94.3% using $FeCl_3$ at 200 mg/L. The percentage of TSS reduction varied from 39.8% to 74.7%. The optimum percentage of TSS removal was recorded at 74.7% using $FeSO_4$ at 150 mg/L.

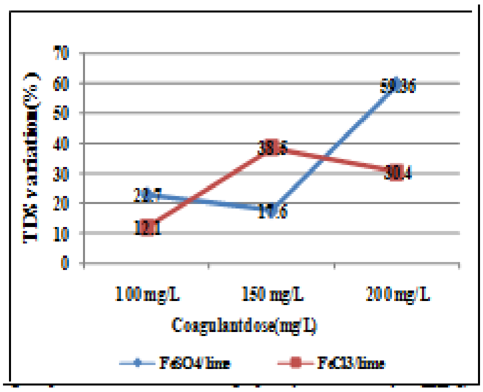

Figure 8: Variation of TDS with different doses of $FeSO_4$/lime and $FeCl_3$/lime during the treatment of tannery effluents

As shown in Fig.8, the percentage of the increase in TDS varied from 12.1% using $FeCl_3$ at 100 mg/L, to 59.3 % using $FeCl_3$ at 200 mg/L. The optimum percentage of TDS reduction was 38.5% using $FeCl_3$ at 150 mg/L.

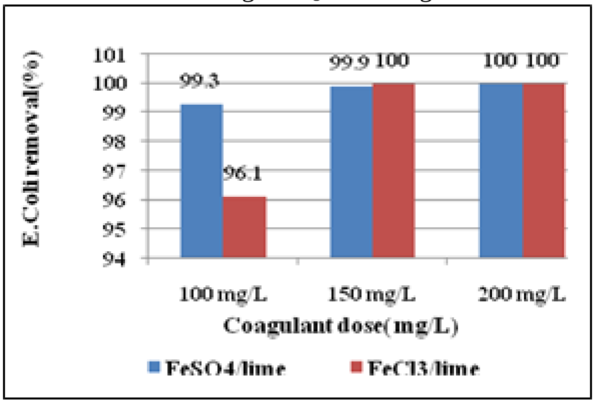

Figure 9: Removal efficiency of total chromium with different doses of $FeSO_4$/lime and $FeCl_3$/lime for the treatment of tannery effluents

Fig. 9 shows the percentage of chromium removal that varied from 60% using $FeSO_4$ at 150 mg/L to 100% using $FeCl_3$ at 150 mg/L and 200 mg/L, and $FeSO_4$ at 150 mg/L. The obtained results determined that both coagulants were very efficient at removing chromium in the conditions of the coagulation with alkaline pH. This may be explained by the association of coagulants and pH effects.

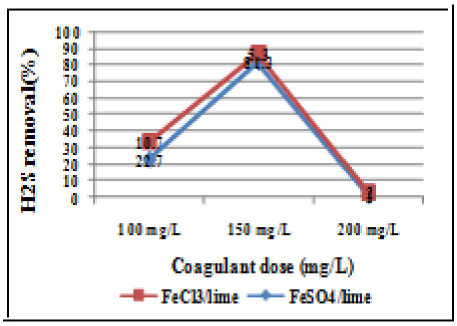

Figure 10: Removal efficiency of H_2S with different doses of $FeSO_4$/lime and $FeCl_3$/lime for the treatment of tannery effluents

Fig. 10 shows that the optimum dose of $FeSO_4$ for H_2S removal was 150 mg/L. Values of the percentage of H_2S varied from the lower 1% using $FeSO_4$ at 200 mg/L to 81.3% using $FeSO_4$ at 150 mg/L. Coagulation using $FeSO_4$ appeared to be more effective than $FeCl_3$ in the removal of H_2S. The results in Fig.11 and Fig. 12 indicate that the maximum reduction of E.Coli and St. Faecalis was achieved using both chemical coagulants $FeSO_4$, $FeCl_3$ and lime at different doses (100mg/L, 150mg/L, 200 mg/L). The percentage of E.Coli and St. Faecalis reduction varied from 99.3% and 99.4% using $FeSO_4$ and $FeCl_3$ at 100mg/L to 100% using $FeSO_4$ and $FeCl_3$ at 150mg/L and 200 mg/L. This can be explained by the fact that coagulants are effective in removing fecal pollution because they are known for producing a large volume of flocks – entities known for their ability to entrap bacteria as they settle [20].

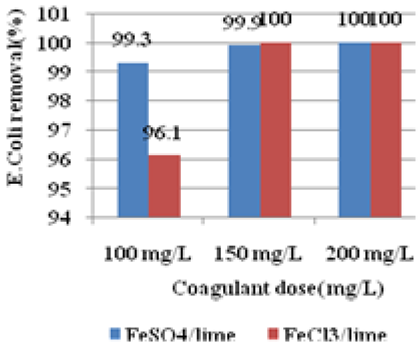

Figure 11: Effect of different doses of $FeSO_4$/lime and $FeCl_3$/lime in removal efficiency of E.Coli during the treatment of tannery effluents

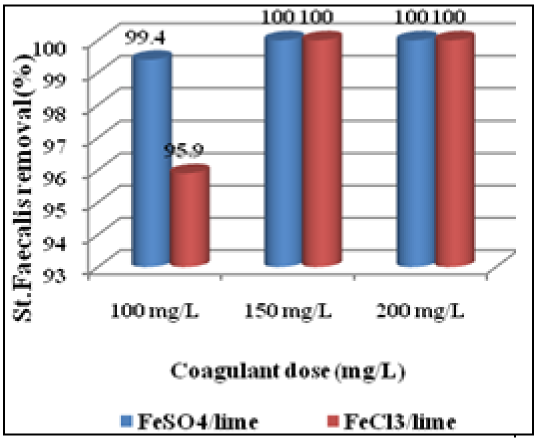

Figure 12: Effect of different doses of $FeSO_4$/lime and $FeCl_3$/lime in removal efficiency of St. Faecalis during the treatment of tannery effluents

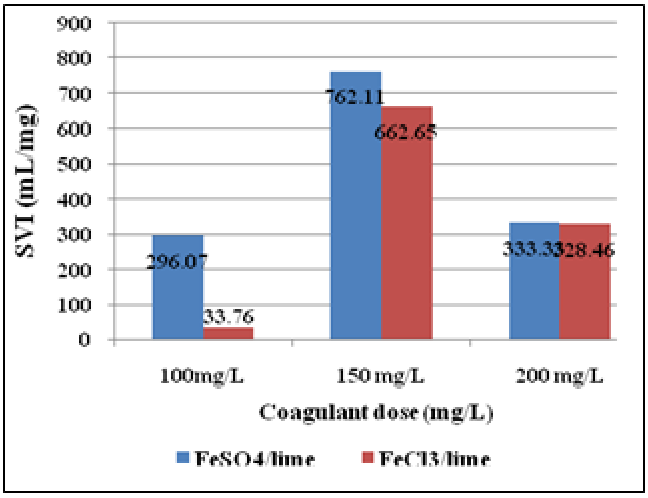

Figure 13: Effect of different coagulant doses of $FeSO_4$/lime and $FeCl_3$/lime in the variation of SVI during the treatment of tannery effluents

In Fig. 13, the relation between the Sludge Volume Index and the coagulant doses used in the treatment of tannery effluents is shown. The amount and characteristics of the sludge produced during coagulation/flocculation depends on the type of coagulant used and the operating conditions [21]. Sludge production may affect the economic feasibility of the proposed method [9]. The proper determination of coagulant and flocculants types and dosages will not only improve the water characteristics, but will also decrease the cost of treatment [9]. SVI is a very important indicator that determines the control of how much sludge is to be returned to the aeration basin and how much should be taken out of it from the system [18]. SVI was calculated from the formula that was given in the correspondent reference [18]. SVI varied from 33.76 mL/mg to 762.11 mL/mg. The best result of SVI was achieved using $FeCl_3$ at 100mg/L. $FeSO_4$ seemed to be less effective than $FeCl_3$, with regard to the SVI. Furthermore, the experimental observations indicated that coagulation and flocculation process using $FeCl_3$ had lower efficiency than $FeSO_4$ in removing the color. It was also efficient in all doses in odor decrease. In this study, $FeSO_4$ and lime can be recommended as the best coagulant combination to decolorize the tannery wastewater at 100 mg/L and 150mg/L, while it was not effective at 200 mg/L in the color reduction.

4. Conclusion

This study concluded that the chemical combination of $FeSO_4$ and $Ca(OH)_2$ at 150 mg/L and 1000mg/L was more effective than $FeCl_3$ and $Ca(OH)_2$ for the treatment of the tannery effluents with a high efficiency in the removal of chromium, E.Coli and St. Faecalis, ammonia ions, chloride, H_2S, TSS, COD and sulfate. A small disadvantage was observed with regard to the COD and TDS – tannery effluents remained very alkaline after coagulation. Therefore, the pH of the raw and treated tannery wastewaters should be adjusted to be neutral before they are discharged into a natural body of water, otherwise biological treatment will be required to meet safe environmental standards.

Acknowledgements

I′m grateful to the Directorate of Public Health (Berat, Albania), as well as my colleague biologist, V. Tapia and chemist E. Quku, for their help and support in performing this study. I also thank D.Turkel for his English assistance.

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