Coagulation-flocculation technique for domestic wastewater treatment in the city of Ain Aouda, Rabat, Morocco.

Naif Al-Jadabi [1*], *Mohamed* Laaouan[2,3], *Maria* Benbouzid [1], *Jamal* Mabrouki[1] and *Souad* El Hajjaji[1]

[1]Laboratory of Spectroscopy, Molecular Modeling, Materials, Nanomaterials, Water and Environment (LS3MN2E-CERNE2D), Department of Chemistry, Faculty of Sciences, Mohammed V University in Rabat, Avenue IbnBattouta, B.P. 1014, Rabat10000, Morocco

[2]International Institute of Water and Sanitation, National Office of Electricity and Drinking Water (IEA-ONEE), Avenue Mohamed BelHassan El Ouazzani, B.P. Rabat-Chellah 10002/ Rabat, Morocco

[3]Central Laboratory for water quality control, National Office of Electricity and Drinking Water (ONEE), Avenue Mohamed BelHassan El Ouazzani, B.P. Rabat-Chellah 10002/ Rabat, Morocco

Abstract. The goal of this study was to investigate the performance of coagulation-flocculation, and sedimentation tests to reduce contaminant concentrations in domestic wastewater to ecologically acceptable levels. The tests were performed at the (ONEE) laboratory using a jar test apparatus (GPB FLC- Didatec, France) for enhancing the primary treatment of domestic wastewater effluent from the wastewater plant of Ain Aouda City, Rabat, Morocco. Aluminum sulphate $Al_2(SO_4)_3.18H_2O$ (termed alum) was employed as a coagulant in the study. The impact of coagulant doses and pH at optimum dosage on the process of coagulation was studied and conditions were optimized to obtain the best removal of studied pollutants. The evolution of physico-chemical parameters pre-and post-treatment was monitored to determine the efficacy of the process. The turbidity and total suspended solids (TSS) were the best indicators of the treatment's efficacy of coagulant concentration (150mg/L) within the pH optimum of 7. Laboratory tests have shown 98.4% of turbidity, and 97% total suspended solids removal at initial concentrations of 121 NTU, 220 mg/L respectively. Also, it has shown good removal efficiency for COD, BOD5 of the order 83%, 77% at initial concentrations of 340 mg/L, 150 mg/L respectively. Following the coagulation tests, the examination of the main parameters studied revealed that the degree of contamination had decreased. This is confirmed that Aluminium sulphate as a coagulant has proven its effectiveness in the treatment of domestic wastewater in this study.

Keywords: Wastewater; Treatment; Coagulation; Flocculation; Morocco

*Corresponding author: naif.naif.2017@gmail.com

1 Introduction

The obtained of clean and safe drinking water is a great concern around the world [1].

In addition, the increase in urbanization and population growth and have led to freshwater pollution in developing countries due increase in wastewater generation and insufficient wastewater discharge. Therefore, wastewater treatment has become an important issue for the development of communities [2], [3]. Furthermore, often the effluent discharge which is improperly treated from wastewater treatment plants (WWTPs) result in major detrimental effects on the health of these surrounding environments and communities situated near sewage or downstream due to worsening physico-chemical parameters and increased microbial pathogens [4]. In the early 20th century, failure to provide large areas and adequate for untreated wastewater disposal, especially in megacities, led to the application of more efficient wastewater treatment methods [5], which took increasingly important at the beginning of the 1970s [6], [7]. Morocco has a semi-arid climate country in the Mediterranean facing scarcity and deteriorating quality of water. The total annual freshwater resources are estimated to be 22 billion (700 m^3/inhabitant/year) with variations of seasonal and spatial, this disparity becomes a source of concern [8]. As a result, the recourse to sources of non-conventional water has become important. Also, untreated wastewater discharges have contaminated the surface water in some urban areas [9]. Nowadays, reusing treated wastewater is an option solution by the limit of this shortage, preventing pollution, preserving natural resources, particularly, in the sector of agricultural, which consumes 80 to 90 % of Morocco's total water [8], [10]. In response to that, in 2005, Morocco launched a national sanitation program that aims to treat 60% of collected wastewater by 2020 [11]. Furthermore, in the plants of water treatment considered the coagulation-flocculation process is one of the best options, common, extensively applied as primary pretreatment, in particular, wastewater treatment relatively cost-effective, robust, and benign to the environment which removes organic and inorganic pollutants from wastewaters with reducing most of the TSS and COD in this process [6], [12-15]. This process aims to form flocs through destabilization of suspended particles followed by adsorption and aggregation [6]. Among others that influence coagulation-flocculation are the factors (effluent quality, temperature, pH, coagulant type, and dosage) [6]. Polyaluminum chloride, aluminum salts, and ferric salts, are inorganic coagulants used frequently at WWTPs for coagulation [16]. This paper aims to evaluate the coagulation-flocculation process' efficiency with aluminum sulphate ($Al_2(SO_4)_3 \cdot 18H_2O$) commonly called alum as a coagulant for (turbidity), TSS (total suspended solids), COD (chemical oxygen demand), and BOD5 (bio-chemical oxygen demand during 5 days)removal as pre-treatment options for domestic wastewater treatment. Alum is commonly used in wastewater treatment because of its proven performance, availability with cost-effectiveness and also, perform comparatively better in the removal of suspended organic solids than to other substitutes such as metallic salts of iron [17], [18].

2 Materials and methods

2.1 Geographic Location of Ain Aouda Wastewater Treatment Plant

The plant of wastewater treatment of Ain Aouda is one of the stations under management of the National Office of Electricity and Drinking Water (ONEE). It depends in treatment on the usage of the activated sludge process with flow reaches 10000 m^3/day. This plant is located about 600 m northeast of the city of Ain Aouda center on the right bank of the thalweg of Wadi Akreuch which is currently serving as a receiver of Ain Aouda discharges While it is bounded from the southwest by the RR401 regional road leading to Rabat [19].

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Fig.1. Geographical location of Ain Aouda [Source Google Maps]

2.2 Wastewater Sampling

The wastewater sample used in this research was brought from treatment plant of domestic wastewater of Ain Aouda city, located in the province of Rabat, Morocco. There are a large number of variables that may change the composition of water are numerous, and they can all be potential pollutant sources. The main measurements, carried out on the studied sample, were (temperature, pH, electrical conductivity, turbidity, TSS, COD, BOD5, total phosphorus, ammonium, nitrates, and nitrites). The samples are taken to the laboratory for analysis and stored at a low temperature (4°C) [20], before use in experimental runs to reduce wastewater decomposition caused by microbial activity [12]. The quality of wastewater

Table 1. Raw domestic wastewater characteristics**,** Moroccan standards for effluent discharge and analytical devices.

Parameters	Unit	Value	Moroccan standards of rejections	Device analysais
pH	-	8.19	6.5-8.5	WTW Multi-parameter Meter, model 3430
Temperature	°C	20.5	<35	
Conductivity	µS/cm	2200	3000	
TSS	mg/L	220	150	3 pos ramp filtration.
Turbidity	NTU	121	<5	Thermo Scientific, Eutech TN-100 Turbidimeter
BOD5	mg/L	150	120	YSI 52 Dissolved Oxygen Meter, american
COD	mg/L	340	250	Hach Company 45600-00 COD Reactor,

				HachDr 2010 Portable Datalogging Spectrophotometer
TP	mg/L	5.35	10	Thermo Scientific iCAP RQ ICP-MS Spectroscopy Analysis
NH_4^+	mg/L	23.5	0.5	Continuous Flow Analyzer (CFA) (reference 475-424)
NO_3^-	mg/L	<1	-	Ion Chromatography Thermo Scientific™ Dionex™ ICS-5000
NO_2^-	mg/L	<0.5	-	

2.3 Coagulant

Aluminum sulphate $(Al_2(SO_4)_3 \cdot 18H_2O)_{(s)}$ with the purity of between 16-17%. was used as coagulant since this is the salt that is most commonly used in practice [14], [21]. 5-g alum was dissolved in 100 ml of distilled water (ultrapure water) to prepare a five percent alum stock solution.

2.4 Coagulation-flocculation Process

The process of coagulation-flocculation was conducted forwastewater treatment from the plant of Ain Aouda (Morocco), using Jar Test Apparatus set-up with 6 pedals (GPB FLC-Didatec, France). The pH adjustment by adding 0.5 N NaOH and 0.1 N H_2SO_4 solutions). Six beakers were used with one-liter capacity. They were filled with 500 mL of the wastewater sample that would be treated. Next, immersed the propellers into the beakers. In order to determine the effect of the doses of alum, increasing doses were introduced into the wastewater samples under study, with various amounts of Aluminium sulphate $(Al_2(SO_4)_3 \cdot 18H_2O)_{(s)}$(50, 100, 150, 200, 250, 300 mg/L),under rapid mixing, with the speed 180 for 2min. Followed by 40 rpm for 20 min. It's important to note that coagulation-flocculation requires the mixing rapid in order to the colloids meet and neutralize each other while relatively slow speed aim to enhance encounter and aggregation of colloidal without breaking already formed flocs [6]. The samples left to settle for a period extending for 30 min. Once finished of coagulation-flocculation process, the blades of the agitator were carefully withdrawn from the treated water. After settling, the supernatant was withdrawn to determine the optimal dosage required to achieve the highest percentage removal of the most important parameters (turbidity, TSS, COD, and BOD5).

2.5 Analytical Methods

2.5.1 Chemical analysis

Results collection of analysis involved raw and treated samples' initial and final concentrations.The samples were taken from 1 cm below the surface of the supernatant of treated samples using a pipette, and the effectiveness of treatment was based on turbidity, TSS, COD, and BOD5 values. In table 1 shown the characteristics of raw domestic wastewater with the devices used in this analysis according to Moroccan standardized.

2.5.2 Pollutants removal after treatment

The treatment efficiency was calculated based on the percentage removal recorded for the physico-chemical parameters pre-and post-treatment by coagulation process. The removal of each parameter was obtained using the following equation [8]:

$$\textit{Removal rate (\%)} = \frac{C_e - C_s}{C_e} \, x100$$

where, C_e was the concentration before treatment and C_s was the concentration after treatment

3 Results and Discussion

3.1 Sample characterization

The pollution degree of domestic wastewater is based on the assessment of a number of physicochemical characteristics of this wastewater. Table. 1 shown important information regarding the values of the effluent parameters before the treatment with comparison to the limits of the values fixed by Moroccan standards.

The temperature and Conductivity recorded were 20.5°C and 2200µS/cm below 35 °C, 3000 µS/cm, as limit values of water designated for irrigation according to the Moroccan norms [22]. The pH of this wastewater was 8.19 and usually is pH of wastewater slightly alkaline. Also, this value is within the Moroccan standards range from 6.5 to 8.5 [8], which can be linked to the presence of compounds used in detergents which include a wide range of amphoteric, cationic, and anionic compounds [23]. The turbidity (121 NTU) of this wastewater (Table 1) is very important in this treatment process because it sensitive. This high of this parameter is due to the presence of solid matter, in particular, suspended solids [6]. The COD/BOD5 ratio gives (2.27) that indicates satisfactory biodegradability of this effluent [8]. The suspended solids, COD and BOD5 are the most important parameters because of their high impact generated on the environment when they are released into bodies of water [6].

3.2 Coagulant dose effect

One of the most significant factors to consider when defining the optimal condition of coagulant performance in coagulation-flocculation process is the dose of the coagulant. which is influenced by the TSS or colloid content of the wastewater [7], [18]. Essentially, inadequate dose or overdosing would result in low flocculation results. As a result, determining the optimal dose is significant to reduce cost of dosing, sludge formation, and also, simultaneously achieving the best treatment results [24].

The experiments of coagulation were carried out without prior adjustment of pH with varying the dose range of coagulant between 50–300 mg/L. Fig.2 shows the progression of coagulant dosages from underdosing to optimum dosage and then overdoing.The optimum alum dose was 150 mg/L, which was the lowest needed dosage that resulted in the highest removal. The maximum removal efficiencies of turbidity, TSS, COD, BOD5 were 98.3%, 96.8%, 81.8%, 75% at the optimum dose of 150 mg/L.

3.3 pH variation according to the dose of coagulant $Al_2(SO_4)_3.18\ H_2O$

The pH decreases when the alum dose is increased, as seen in Fig. 3. We note that the progressive addition of this coagulant to wastewater resulted in a pH decrease from 8.19 to 7.6.at optimum dose 150mg/L. This decrease of pH explained due able of alum in released of H^+ ions when dissolution in water [25], and can be interpret the decrease in pH result the reaction of natural alkalinity found in water in water with aluminum [24].

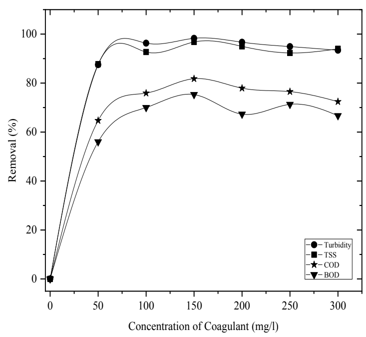

Fig.2. Effect of alum dose on (turbidity, TSS, COD, and BOD5) removal.

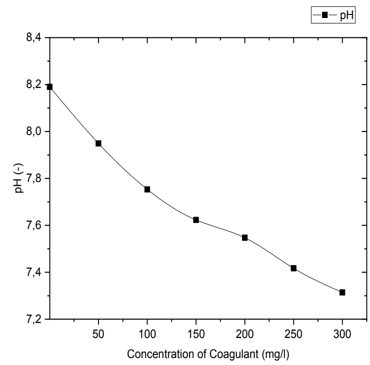

Fig.3. Evolution of pH according to the dose of alum

3.4 Effect of pH

The experiments were performed again with prior adjustment of pH at various values (6-9) for fixed optimal dosage (150 mg Al^{3+}/L to determine the optimum pH. The results are shown in Fig. 4, which plots removals of turbidity, TSS, COD, and BOD5 against pH. The removal efficiency rate of all studied parameters initially increased up to pH 7, where the removal performance was at the maximum 98.4%, 97%, 83%, and 77%, for turbidity, TSS, COD, and BOD5 respectively. Then after this point (pH 7) the rate of removal started to decrease with the pH value increased.At optimal dosage and after 30 min of settling was the amount of produced sludge 26 ml/L with initial turbidity of 121 NTU.

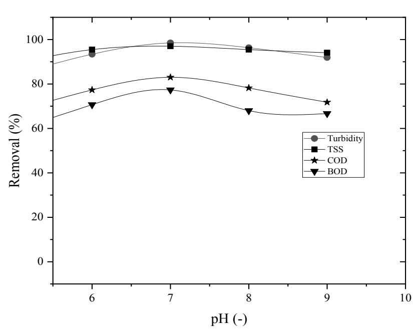

Fig.4. Effect of initial pH on elimination of (turbidity ,TSS, COD, and BOD5) at dose of alum 150 mg/L.

3.5 Effectiveness of the Coagulation Process in Eliminating

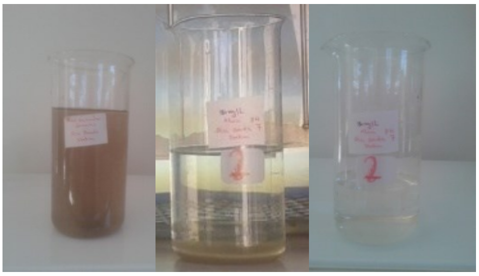

Fig.5. Depicts the effects of (alum coagulant dose :150 mg/L and pH at 7) on domestic wastewater effluent (before and after

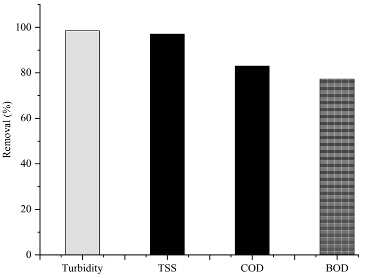

Fig.6. Elimination efficiency of the coagulation process at pH 7 and dose of alum 150 mg/L.

Fig.6 illustrates the results of removal efficiency of the coagulation process for studied pollutants under optimal conditions (optimal dosage 150mg/L, pH=7). The Turbidity and TSS(total suspended solids) were of the best removal in this process that the maximum removalratesreached 98.4%, and 97% respectively. On the other hand, (COD) chemical oxygen demand, and (BOD5) biochemical oxygen demand content removal reach 83% and 77% respectively.

3.6 Comparison of current study with literature

The comparison of results obtained from this study with literature is presented in Table 2. The table isshown various doses of coagulant in determining the effectiveness in pollutants reduction of wastewater.

In our study, it can be described that pollutants reduction using 150 mg/L was best comparable to hight doses with others literature. This study demonstrated good results with 150 mg/L.

Table 2. Comparison of results obtained from current study with literature.

Locality of use	Wastewater Type/ Pollutant	Dose of alum	Removal efficiencies (%)	Reference
Algeria	domestic wastewater 350 NTU (Turbidity)	600 mg/L	Turbidity 99.7%	[15]
Brazil	domestic wastewater 41.1 NTU(Turbidity) 54.2 mg/L (BOD) 223 mg/L (COD)	200 mg/L	Turbidity 93%, BOD 58%, COD 70%	[16]
Algeria	domestic wastewater 90.5mg/L(BOD5)	400 mg/L	BOD5 78.74%	[26]
Iraq	domestic wastewater 834mg/L(COD)	6g	COD 84.41%	[27]

Morocco	domestic wastewater 136 NTU (Turbidity) 220 mg/L (TSS) 340 mg/L (COD) 150 mg/L(BOD)	150 mg/L	Turbidity 98.4%, TSS 97%, COD 83%, BOD 77%	This study

4 Conclusion

This study showed that the performance of the coagulation-flocculation process was efficient in the treatment of domestic wastewater of the city of Ain Aouda plant using aluminum sulfate $Al_2(SO_4)_3 \cdot 18H_2O$ (alum). The experiments of Jar-test were performed to determine the optimum conditions to remove pollution. Turbidity and TSS are considered the best efficiency indicators in wastewater treatment [5]. The efficiency of this process was assessed in terms of its ability to remove in terms of the removal of (turbidity), (TSS), (COD), and (BOD). At an optimum experiment condition (coagulant dose: 150 mg/L, pH: 7 showed 98.4% removal for turbidity, 97% of TSS while having reached 83% removal for COD, and 77% of BOD5. The coagulation-flocculation process has proven it effectiveness using Aluminum sulphate to treat the domestic effluent of Ain Aouda city and adjust to the limits established in Moroccan state regulations and national legislation for the effluents discharge into the aquatic environment.

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