Journal of Materials and Environmental Sciences
ISSN : 2028-2508

JMES, 2017 Volume 8, Issue 8, Page 2687-2693

http://www.jmaterenvironsci.com/

2'JP2E, 24-25 Oct. 2016, FP-Taza

Comparative study between Moroccan cactus and chemicals coagulants for textile effluent treatment

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Received 4 Jan 2017,
Revised 21 Mar 2017
Accepted 22 Mar 2017

Keywords

- ✓ Coagulation-flocculation,
- ✓ Moroccan cactus,
- ✓ Water treatment,
- ✓ Effluents,
- ✓ Sludge volume,
- ✓ Heavy metals,
- ✓ Natural coagulant

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Abstract
The present work shows the results obtained during the treatment of a textile effluent by the process of coagulation-flocculation using three coagulants such as: Lime $Ca(OH)_2$, Ferric chloride $FeCl_3$ and Aluminum sulfate $Al_2(SO_4)_3$. This study also concerns the comparison of these chemical coagulants with a natural coagulant (Moroccan cactus). The process efficiency is measured in terms of turbidity, sludge production, heavy metal, absorbance at all wavelengths (200 – 800 nm) and color removal. The treatment with aluminum sulfate has a significant discoloration and turbidity removal of 98% after 2h settling while producing a sludge volume 360 mL/L. Results with $FeCl_3$ showed a 97% removal of turbidity and sludge production similar to aluminum sulfate (380 mL/L), but only after 45 min of settling. Furthermore, lime having a turbidity removal of about 93 % and a sludge volume lower than the product during the treatment with $Al_2(SO_4)_3$ and $FeCl_3$. It is, therefore, clear that the settling time plays an important role in the treatment by coagulation flocculation. Regarding the analysis of metallic elements, the results showed that a substantial removal of the metallic elements in particularly elements as As Cr, Cu, Fe, Mn, Zn and Ni. The use of the new product from the cactus showed a very significant effect on turbidity removal (96%) accompanied by a net decrease of sludge production (3.3 mL/L) compared to previous coagulants. The settling time is however relatively slow (5 h). The elimination of heavy metals exceeds 91% for Cu, Cr and Zn. These results show that the cactus is non-polluting and could be used in small quantities with a minimum of sludge production for the treatment of a textile effluent.

1. Introduction
The treatment of textile effluents has been the subject of several studies [1,2] and has revealed the need to treat or optimize the treatment of wastewater before discharge into the environment. The coagulation-flocculation process has exhibited great efficiency in eliminating pollution during the treatment of textile effluents [3-7]. Most of these studies agree in concluding that the optimization and adjustment of the effluent physicochemical parameters or of the coagulant treatment rate can lead to flocculation and efficient pollutant removal [8-10]. Many studies have been conducted to evaluate the efficiency of several coagulants in water treatment [11,12]. The most commonly used in wastewater treatment are the trivalent salts of iron ($FeCl_3$, $Fe_2(SO_4)_3$) and aluminum ($Al_2(SO_4)_3$) [13-17]. When applying coagulation-flocculation treatment, a large amount of sludge may sometimes be generated. This factor must be taken into consideration when choosing the coagulant [18,19]. Furthermore, in order to minimize the toxic effects of chemical coagulants, more natural coagulants and flocculants have been introduced, such as chitosan [20-23], cactus [24-26], tannin and moringaoleifera[27]. In

this context, a comparative study of the natural coagulant cactus with chemical coagulants such as (Lime, Ferric $chloride_3$ and Aluminum sulfate $Al_2(SO_4)_3$) was conducted. The coagulation-flocculation process efficiency for treating the effluent was evaluated in terms of turbidity, sludge production, metal contamination and color removal.

2. Materials and methods

2.1. Characteristics of the effluent

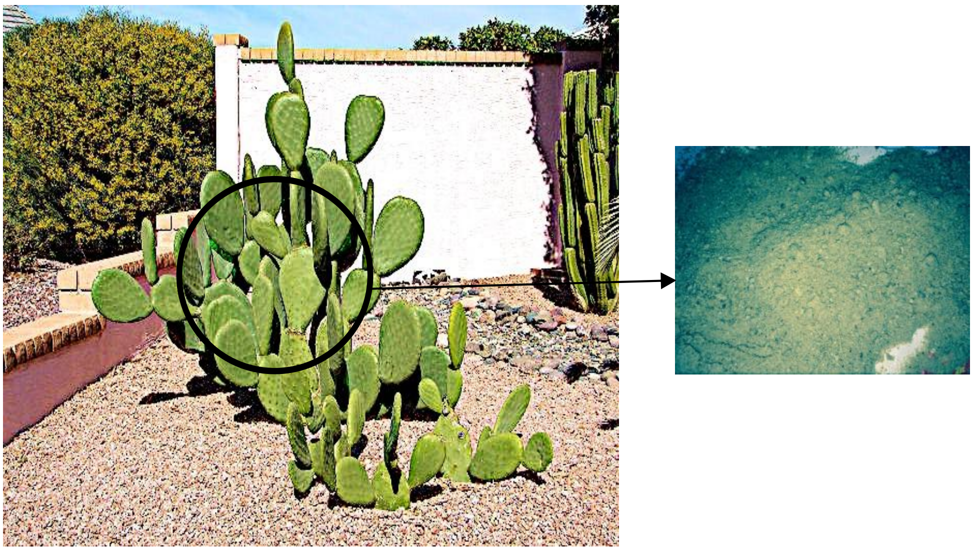
The treatment process was applied to the textile effluent from the MWH Company in Fez (Morocco), whose characteristics are given in table 1.

Table 1. Textile effluent characteristics

pH	Turbidity (NTU)	COD (mg/l)	Conductivity (ms/cm)	Fe (mg/l)	Cr (mg/l)	Zn (mg/l)	Mn (mg/l)	Ni (mg/l)	Cu (mg/l)
6,45	214	1266	2,13	2,61	0,094	0,36	0,15	0,03	0,09

2.2. Natural coagulant

The cactus was harvested at a wild plantation near Fez (picture1). The cactus pads were washed and all thorns were removed and dried at 80°C. The material was ground and sieved to obtain a solid powder with a diameter of 0.5-1.00 mm.



picture1: Moroccan Cactus

2.3. Procedure Jar-Test and analytical techniques

Coagulation-flocculation tests were performed using a jar-test apparatus (FloculateurVelp) equipped with four stirred reactors (Flocculator Fisher 1198). Different concentrations of the selected coagulant were added to the effluent, using the optimal pH of the coagulant. The mixture was then quickly stirred at 200 rpm for 10 min. Thereafter, the speed was reduced to 30 rpm for 30 min to facilitate floc formation. UV-Vis analyses were performed on a UV-visible spectrophotometer (UV 2300), and metal elements in both the raw and treated textile effluent were analyzed by ICP (Inductively Coupled Plasma) after mineralization.

3. Results and discussion

3.1. Coagulation-flocculation results

The study of treating textile effluent by coagulation-flocculation using aluminum sulfate is illustrated in Figure 1a. It shows the evolution of the turbidity and the volume of the sludge produced as a function of the dose of the coagulant. These results show that the turbidity decreases with the increase of the aluminum sulfate. The optimal dose obtained has been estimated at 3 g/l with a turbidity of around 4 NTU and a removal efficiency of approximately 98%. The amount of sludge produced after 2 h of settling was 360 ml/l. The effluent exhibits significant discoloration.

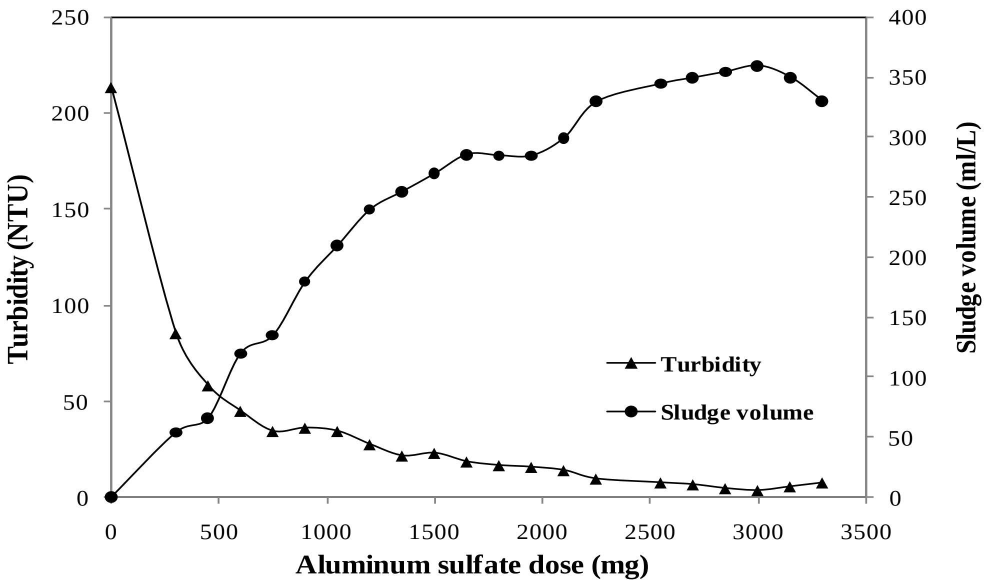


Figure1a: Evolution of turbidity and sludge volume depending on the dose of $Al_2(SO_4)_3$

The study of treating effluent using a Ferric chloride is illustrated in Figure 1b. The optimal dose obtained has been estimated at 3,2 g/l with a turbidity of around 5 NTU and a removal efficiency of approximately 97%. The amount of sludge produced after 45 mn of settling was 380 ml/l.

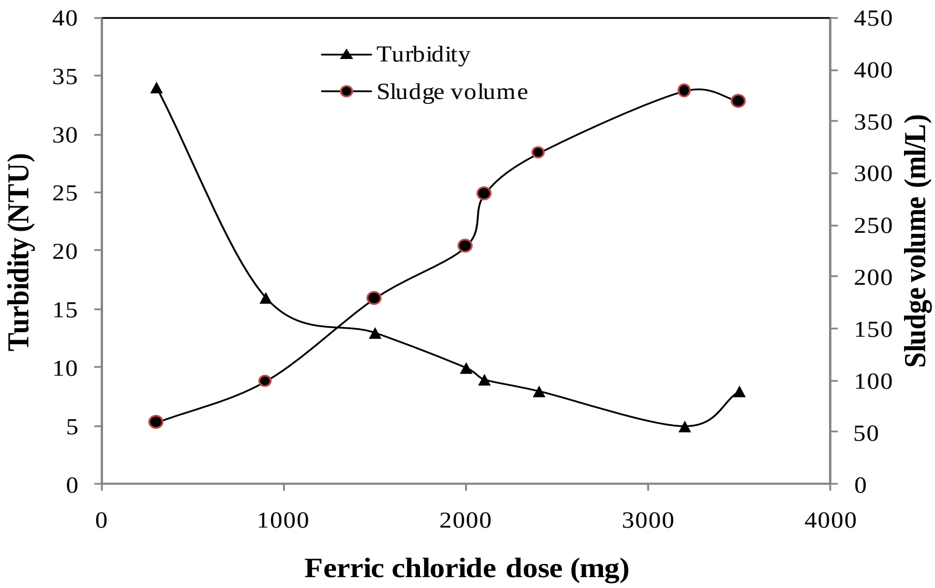


Figure 1b: Evolution of turbidity and sludge volume depending on the dose of $FeCl_3$

The study of treating effluent using a lime is illustrated in Figure 1c. The optimal dose obtained has been estimated at 1,3 g/l with a turbidity of around 17 NTU and a removal efficiency of approximately 93%. This efficiency of removal of the turbidity remains lower than that obtained with ferric chloride and aluminum sulfate. On the other hand, decanting is done much faster in the case of lime. The amount of sludge produced after 30 min of settling was 70 ml/l.

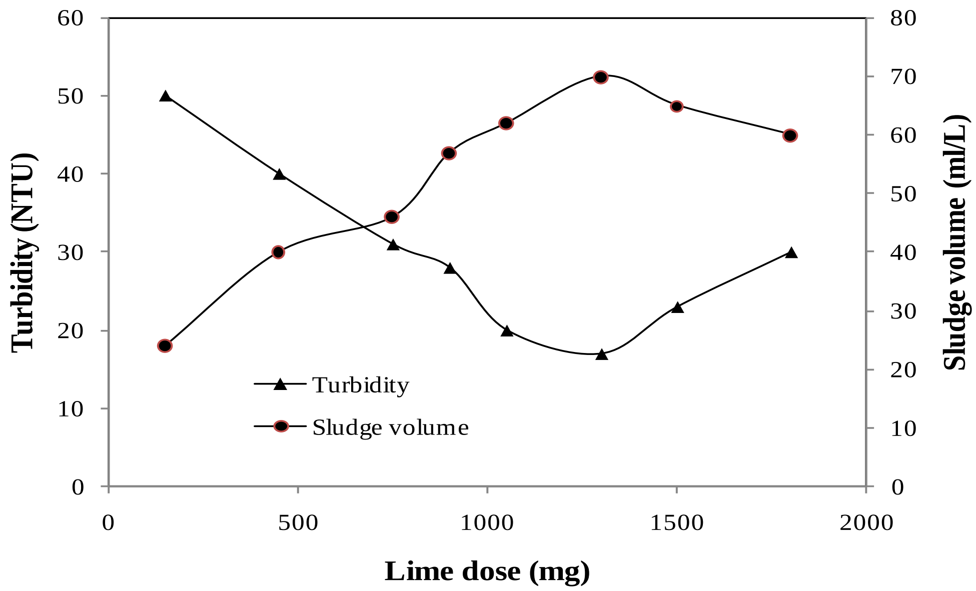


Figure 1c: Evolution of turbidity and sludge volume depending on the dose of $Ca(OH)_2$

The study of treating textile effluent by coagulation-flocculation using a cactus-based product is illustrated in Figure 1d. The optimal dose obtained (with an optimal pH of 10) has been estimated at 33 mg/L with a turbidity of around 4 NTU and a removal efficiency of approximately 96%. The amount of sludge produced after five hours of settling was 3.3 ml/L. The sludge volume remained very low with significant discoloration of the effluent.

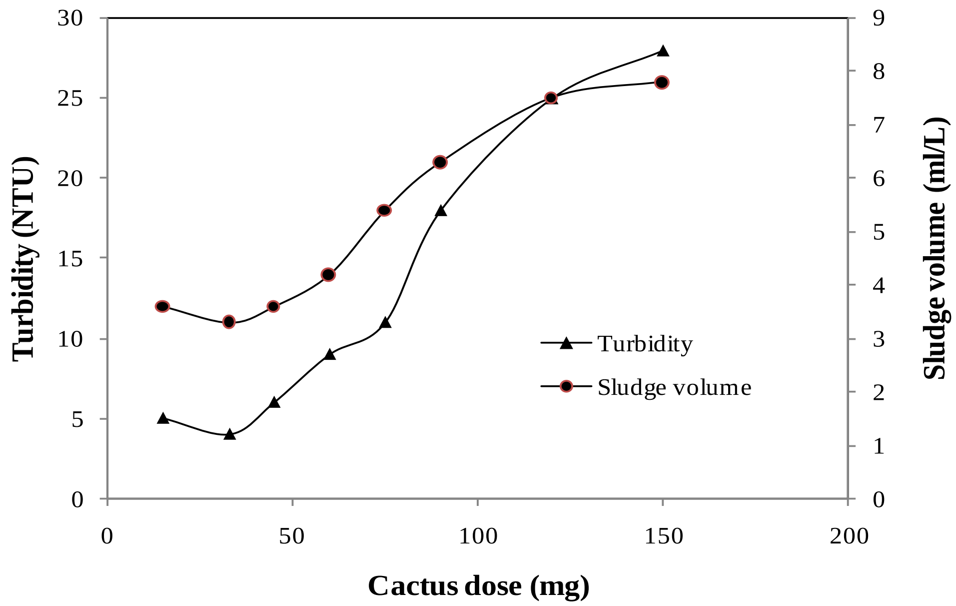


Figure1d: Evolution of turbidity and sludge volume depending on the dose of Cactus

The cactus was compared with three chemical coagulants, including aluminum sulfate, ferric chloride and lime. Figure 2 shows the evolution of the parameters (turbidity, sludge volume production and settling time) of the treated effluent depending on coagulant type. These results demonstrate that the ratio between the amount of sludge produced and the removal of turbidity is basically the same for both the ferric chloride and aluminum sulfate coagulants. As regards the lime coagulant, the sludge volume decreases yet it exerts less of an effect on turbidity than $FeCl_3$ and $Al_2(SO_4)_3$.

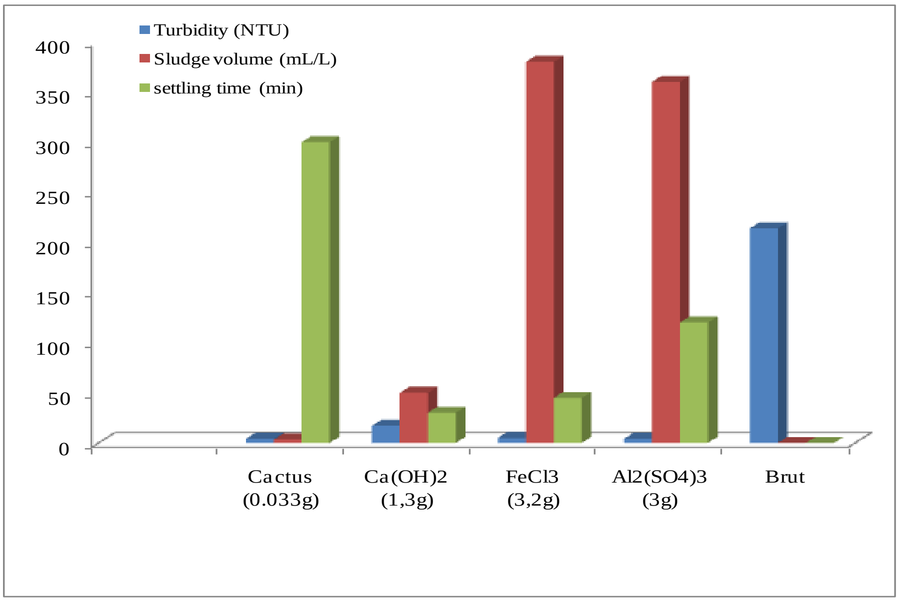


Figure 2: Evolution of the turbidity, the volume of sludge and the settling time according to the type of coagulants

Use of the new cactus product has eliminated turbidity to a similar extent as the ferric chloride and aluminum sulfate. The main difference between the two classes of coagulant (chemical and natural) is more distinct in the difference of both the amount of added coagulant and sludge production. We actually observed that in the case of cactus, the optimal dose and sludge volume are very small compared to what is associated with other chemical coagulants. The settling velocity, however, is much faster in the case of lime, followed by ferric chloride, aluminum sulfate and lastly the cactus.

3.2. UV-visible absorption spectrophotometer (case of the cactus)

Figure 3 displays UV-vis spectra in a wavelength range between 200 and 800 nm for of the effluent before and after coagulation treatment process in the presence of various coagulant cactus doses.

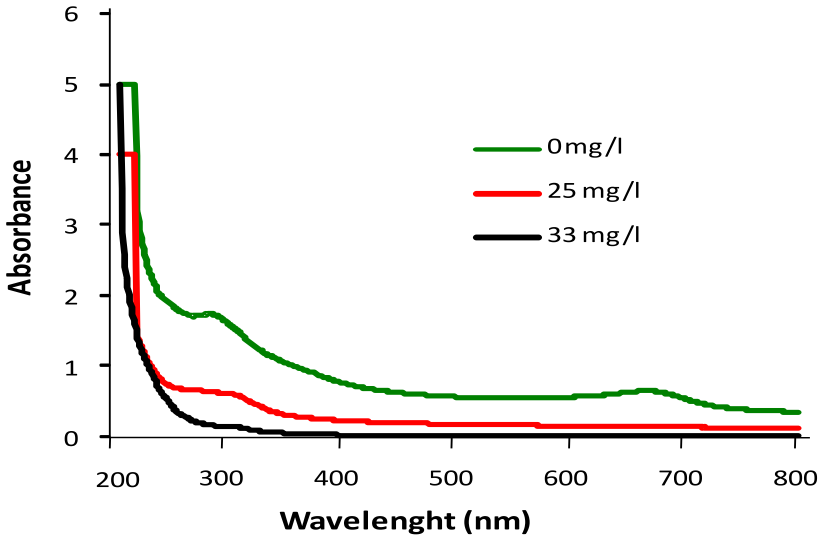


Figure 3: UV-vis absorbance spectra of the raw effluent and treated with cactus

The raw effluent spectrum shows two broad bands located at wavelengths 290 nm and 675 nm; these absorbance bands decrease with the amount of coagulant. They disappear altogether in the presence of the optimal cactus concentration.

3.3. Heavy metals analysis

The results of heavy metals analysis in both raw effluent and effluent treated with cactus flocculants and aluminum sulfate are displayed in Table 2.

Table 2: Concentrations of metallic elements in the raw effluent and treated

Metals mg/L	Fe	Cr	Zn	Mn	Ni	Cu
Raw effluent	2,61	0,094	0,36	0,15	0,03	0,09
Effluent treated with $Al_2(SO_4)_3$	0,53	0,017	0,13	0,07	0,02	0,02
Effluent treated with Cactus	0,32	0,008	0,03	0,06	0,02	0,009

Several metallic elements were present in the effluent. Fe being the most prevalent, followed by Zn, Mn and Cr. Treatment of the effluent by coagulation showed that aluminum Sulfate is most suitable for the elimination of Cr with an elimination rate of 83%. Fe and Zn are eliminated with percentages of 72% and 63%.Furthermore,cactus is in particular very suitable for removing copper, chromium and zinc. The metal reduction percentage actually exceeded 92%.

Conclusion

In this study, the treatment of a textile effluent by a coagulation-flocculation process has been evaluated. The present work concerns a comparative study of the cactus with chemical coagulants. The coagulation-flocculation process efficiency was assessed in terms of turbidity, sludge production, metal pollution, absorbance and color removal. Results obtained show that the optimal dose for aluminum sulfate is estimated at 3 g/l with a removal rate of 98% in turbidity. The lime allows a turbidity elimination of 93% for an optimal dose of 1.3 g / l and seems to be more suitable for the treatment of the effluent studied with a low sludge production (70 mL/L for 30 min of settling). Ferric chloride gives 97% turbidity elimination and produces slightly the same amount of settled sludge as aluminum sulfate (380m L/L). Use of the cactus exhibited a very significant effect on turbidity removal (96%) and reduced sludge production (3.3 ml/l) compared to previous coagulants.

Analysis of the heavy metals showed that aluminum sulfate is particularly suitable for the removal of Cr, Fe and Zn respectively, while for the cactus, the metal reduction percentage exceeded 92%, especially as regards copper, chromium and zinc.

A comparative study of the cactus with chemical coagulants indicates that the cactus may be used in small quantities with low sludge production. In addition, cactus is non-polluting and biodegradable flocculant.

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(2017) ; http://www.jmaterenvironsci.com