

Selenium Removal from Naturally Contaminated Groundwater using *Opuntia Ficus Indica* based Coagulants

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Abstract:- This study was conducted on groundwater contaminated by Selenium, for its purification by a cactus-based coagulant, aluminum sulfate, and ferric chloride. The study concerned five parameters: pH, permanganate index, Selenium removal, and settled and colloidal turbidity. The methodology employed was similar to the coagulation process in the drinking water plants. The pH of treatment was the initial water pH, the coagulants doses were in a range of the commonly used. The Ferric Chloride and aluminum sulfate as coagulants for groundwater with low turbidity exceed the WEM10 performances. Taking into account the final settled turbidity value, all the coagulants meet the technical value required in drinking water plants. The final water treated with the WEM10 permanganate index was concernedly high. The WEM10 reduced the Selenium concentration in the groundwater from 0.14 to 0.12 mg.L⁻¹ without modifying the water purification process conditions and the aluminum sulfate and ferric Chloride failed. The exhibit of this work is that the WEM10 is effective for selenium removal, but its turbidity removal yield and permanganate index might be redhibitory for its use in poorly turbid waters.

Keywords: WEM10, Coagulation, Selenium removal, Complete alkalimetric titer, permanganate index, settled turbidity, Colloidal turbidity.

1. INTRODUCTION

The oligo-elements are indispensable to some mechanisms in the human body. Hence their benefits are limited to their presence at certain concentrations the range between their essentiality and toxicity is close. Selenium was reported as anti-carcinogenic and it can prevent heavy metals toxic effects[1]. A higher intake of selenium in humans results in selenosis[2]. Extreme cases of selenosis can result in cirrhosis of the liver, pulmonary edema, and death[2].

The presence of selenium in the hydrosphere, pedosphere, biosphere, and atmosphere, is natural or anthropogenic[3]. The selenium exists naturally in various rocks due to its dispersive nature. In seleniferous soils, Se occurs predominantly in fractions associated with humified organic matter. In saline seleniferous soils with the presence of mirabilite, Se is present mainly as selenate[4]. Mines, coal-fired power plants, oil refineries, and agriculture are important examples of anthropogenic potential sources of Selenium contamination[3].

Selenium attracted tremendous interest especially its removal techniques[1], including reduction techniques[5], phytoremediation[6], bioremediation[7], electrocoagulation[8], electrochemical methods[9], adsorption[10], coprecipitation[11], electrokinetics[12], membrane technology[13], and chemical precipitation[14] and coagulation-flocculation[15].

Drinking water plants follow a common process of treatment based on the coagulation-flocculation process, the reagent commonly used is Ferric Chloride and Aluminum-based coagulants. These coagulants were used to remove Selenium (IV) and Selenium (VI) from drinking water[15].

This work aims to the purification of groundwater contaminated by Selenium by a cactus-based coagulant, aluminum sulfate, and ferric chloride. The study concerned five parameters: pH, permanganate index, Selenium removal, and settled and colloidal turbidity. The methodology employed was similar to the coagulation process in the drinking water plants. The pH of treatment was the initial water pH, the coagulants doses were in a range of the commonly used. The exhibit of this work is that the WEM10 is effective for selenium removal, but its turbidity removal yield and permanganate index might be redhibitory for its use in poorly turbid waters.

2. MATERIALS AND METHODS

2.1. Reagents preparation

10g.L⁻¹ stock solutions of Aluminum Sulfate and Ferric Chloride from their analytical grade were prepared. To Prepare cactus-based coagulant as described by Bouaouine[16]. Cactus cladodes were purchased from Settat-Casablanca region. A 1 mg.L⁻¹ dosage of Sodium Hypochlorite solution was used for the pre-oxidation process. The sample is groundwater with Selenium content higher than the norm.

2.2. Coagulation process

Coagulation was conducted according to the ASTM standards. The pH and the settling water turbidity were measured then the sample was filtered by a 0.45 μ m pore size membrane filter to measure the colloidal turbidity. The pH value is given by a pH-meter (FICHER SCIENTIFIC), the settled and colloidal turbidity by a turbidimeter (HACH 2100N TURBIDIMETER), and expressed in NTU according to the nephelometric standards. The Selenium Concentration was analyzed by inductively coupled plasma coupled to a mass spectrometer in a ICAP/RQ model from THERMO. The permanganate index is described in the Moroccan norms for sweet water[17]. The reagents were of their analytical grade (Sigma-Aldrich, USA).

3. RESULTS AND DISCUSSION

3.1. pH

The Se removal by FC is less dependent on pH. The optimal pH for Se removal by FC was lower than for the Al-based coagulants[15]. The optimal pH values for Se(IV) and Se(VI) removal by FC, AC were about 4, 5 and 6, respectively[15]. The cactus-based coagulants are known for their optimum pH around 10 and the minimum occurs at 6[16], [18], [19]. In the water treatment field, the water is purified under its initial pH condition, those we didn't modify and just measured the pH after the coagulation process. The initial water pH was 6.93 slightly acid. As shown in figure 1, the aluminum sulfate and the Ferric chloride the final pH was higher than the initial for the three first doses then started to decrease to be steady but lower than the initial value. The same mechanism happened for the cactus-based coagulant but the pH stood higher than the initial even after decreasing.

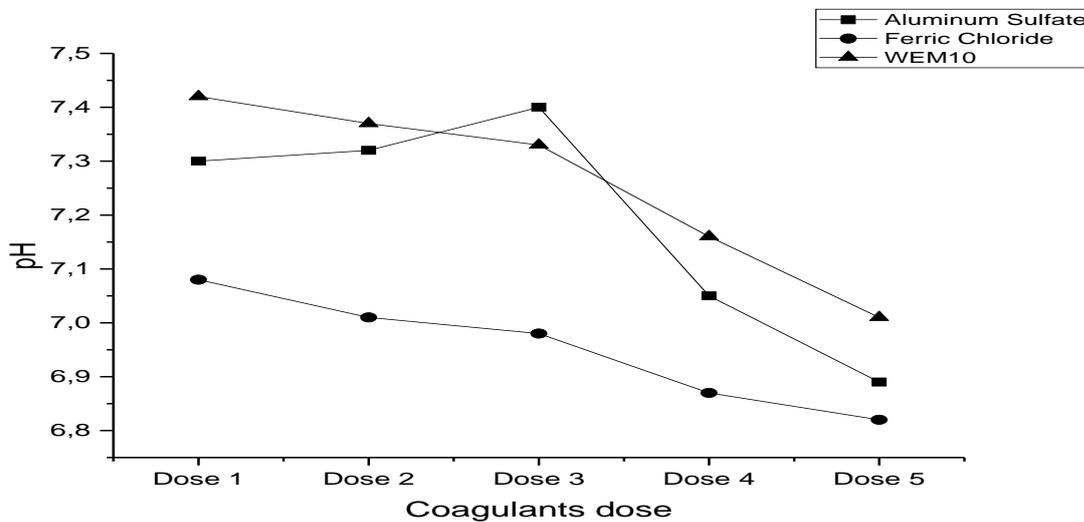


Figure 1: Final pH of the groundwater treated with Aluminum Sulphate, Ferric Chloride, and WEM10; V=1L;

3.2. permanganate index

The initial water permanganate index was 0.288 mg of $O_2 \cdot L^{-1}$. The coagulation by the three first doses of aluminum sulfate increased the value of the permanganate index as shown in figure 2, the fourth and the fifth doses decreased the values of the permanganate index. The same condition happened when the ferric chloride is the coagulant. The final water treated with the WEM10 permanganate index was concernedly high. The high permanganate index is due to the WEM10 nature. The cactus product is known for its content of phosphoryl and phenol groups possibly originating from tannin and lignin especially catechin [20].

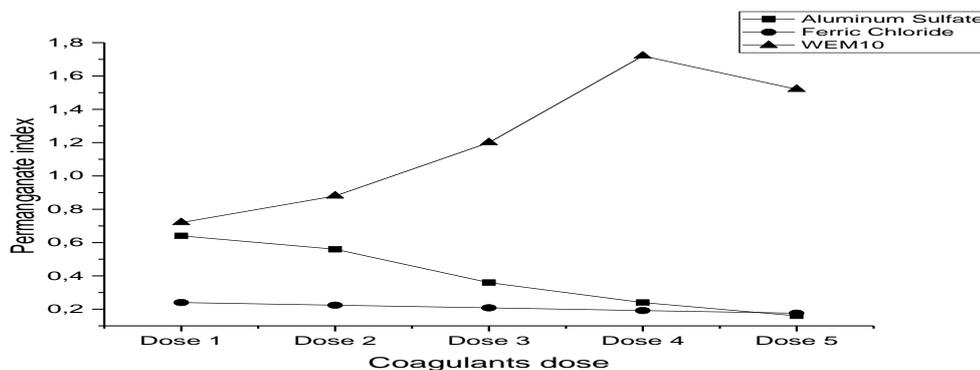


Figure 2: Permanganate index of the groundwater treated with Aluminum Sulphate, Ferric Chloride, and WEM10; V=1L;

3.3. Settled and colloidal turbidity removal yield

As showed in figure 3 the best-settled turbidity removal was reached by the Ferric chloride as a coagulant with a maximum turbidity removal of 83% for 8mg.L⁻¹ against 66% reached by the Aluminum Sulfate. The WEM10 turbidity removal yield was too low with a maximum of 10% at 5mg.L⁻¹. The results obtained by the WEM10 are due to its nature and the initial water turbidity. The initial water turbidity was 2.9 NTU and its initial permanganate index is 0.288 mg of O₂.L⁻¹, which may explain the results obtained by the WEM10, the presence of suspended matter to achieve a good yield. The water extracted material is not soluble in the water and during the process of coagulation, when there isn't good flocs quality, the suspended matter released by the cactus product doesn't settle. The permanganate index of the water treated with the WEM10 also increased and reached 1.72 mg of O₂.L⁻¹ In this case the results given by the turbidimeter are altered by these materials. The colloidal turbidity removal is important to evaluate the coagulation efficiency of the WEM10. The ferric chloride and the Aluminum sulfate best colloidal turbidity removal yield reached is 80% respectively for doses 6 and 20 mg.L⁻¹ against 60% for the WEM10 for doses 5 and 10 mg.L⁻¹. The results of the colloidal turbidity removal may confirm the explanation previously given for the week-settled turbidity removal yield of the WEM10. The small size and small quantity of flocs are an indication of the sweep flocculation mechanism. The results of colloidal turbidity removal yield are given in figure 4.

The Ferric Chloride and aluminum sulfate as coagulants for groundwater with low turbidity exceed the WEM10 performances. Taking into account the final settled turbidity value which is lower than 2.9 NTU for all coagulants doses, all the coagulants meet the technical value required in drinking water plants.

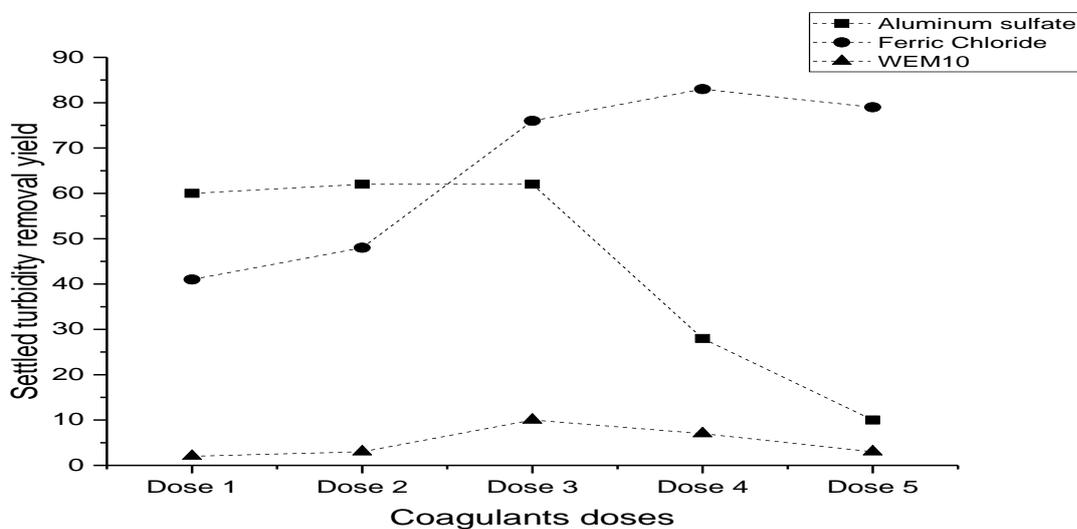


Figure 3: Coagulation with Aluminum Sulfate, Ferric Chloride, and WEM10 settled turbidity removal yield; V=1L;

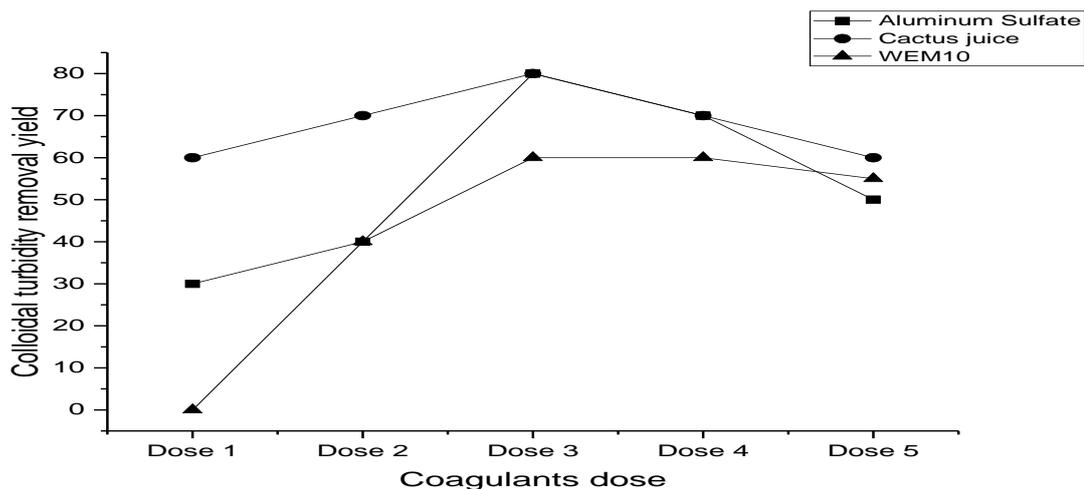


Figure 4: Coagulation with Aluminum Sulfate, Ferric Chloride, and WEM10 colloidal turbidity removal yield; V=1L;

3.4. Selenium removal

As shown in figure 5, the aluminum sulfate and the ferric Chloride failed to reduce the amount of Selenium in the water sample using the doses and reproducing the conditions commonly used in the drinking water treatment field. The WEM10 reduced the Selenium concentration in the groundwater from 0.14 to 0.12 mg.L⁻¹ without modifying the water purification process conditions. The maximum amount of Selenium admissible in drinking water is 0.1 mg.L⁻¹ this value wasn't reached but the water at the exit of the settling reactor is injected in a sand or gravel filter that may improve the elimination of selenium results. Cactus products are known for their positively charged molecules. The WEM10 mechanism of coagulation-flocculation is adsorption bridging. The surface potential of flocs might play an important role in coagulation to remove Se[15]. In the pH conditions typically found in natural waters, selenium species will be predominantly HSeO₃⁻ or SeO₄²⁻[3]. Under oxidizing environment selenium predominantly species is SeO₄²⁻[21]. The water sample was oxidized before the coagulation experiment, in these conditions the most plausible theory is that the Selenium was adsorbed in the positively charged surface of the WEM10 molecules. The WEM10 yield on Selenium removal is outstanding regarding the permanganate index and turbidity removal results, which might be redhibitory for its potential use in common drinking water plants. The selenium anion has a weak interaction with the metal anion[21] which explains the result obtained with the aluminum sulfate and the ferric chloride.

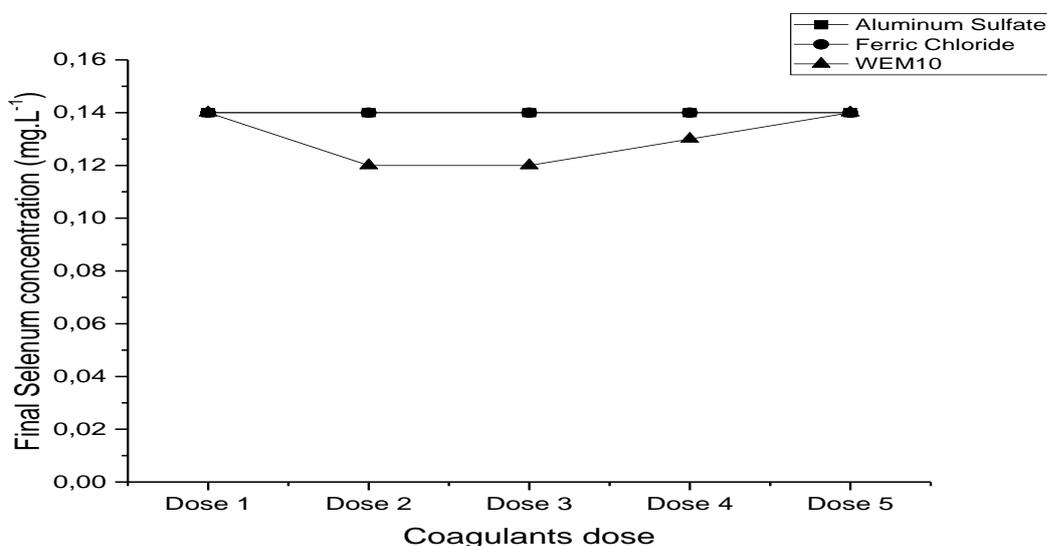


Figure 5:: Final Selenium concentration in the water treated with Aluminum Sulfate, Ferric Chloride, and WEM10 colloidal turbidity removal yield; V=1L;

4. CONCLUSION

This study was conducted on groundwater contaminated by Selenium, for its purification by a cactus-based coagulant, aluminum sulfate, and ferric chloride. The study concerned five parameters: pH, permanganate index, Selenium removal, and settled and colloidal turbidity. The methodology employed was similar to the coagulation process in the drinking water plants. The pH of treatment was the initial water pH, the coagulants doses were in a range of the commonly used. The Ferric Chloride and aluminum sulfate as coagulants for groundwater with low turbidity exceed the WEM10 performances. Taking into account the final settled turbidity value which is lower than 2.9 NTU for all coagulants doses, all the coagulants meets the technical value required in drinking water plants. The final water treated with the WEM10 permanganate index was concernedly high. The WEM10 reduced the Selenium concentration in the groundwater from 0.14 to 0.12 mg.L⁻¹ without modifying the water purification process conditions and the aluminum sulfate and ferric Chloride failed. The exhibit of this work is that the WEM10 is effective for selenium removal, but its turbidity removal yield and permanganate index might be redhibitory for its use in poorly turbid waters.

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