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# A comparative study on the efficiency of natural and synthetic coagulant for microalgal removal from the Nile water; effect of activated carbon addition

**Reda M. Moghazy**
Water Pollution Research Department, National Research Centre, Dokki, Giza, 12622, Egypt.

**Remog81@gmail.com**

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**ABSTRACT**

A looking for natural coagulants for algal removal is one of the researchers interests due to synthetic coagulants concerning different health problems. So, in this study, a comparative investigation was performed to determine the effect of Alum, FeCl3 as synthetic coagulants, and *Moringa* seed extract as a natural coagulant. The synthetic coagulants were prepared and *Moringa* seed has been watered extracted; all coagulants performed by Jar test at different doses for algal removal, and the effect of adding the powder activated carbon (PAC) derived from cotton stalk was tested as a coagulant aid. The data revealed that all coagulants show good removal but the *Moringa* seed extract in addition to PAC exhibited the excellent result of removal reached 100%.

## INTRODUCTION

Removal of algae from water is an important and costly work in treating plants that produce drinking water. It will be compulsory that algae are wiped out starting with drinking water, preferably, in the early phases to ensure the minimum effect on processes subsequent (Barrado-Moreno et al., 2016).

In general, algae have two reverse roles in water and wastewater, one of them is bioremediation agent for organic and inorganic pollutants (Badr et al., 2016; Doma et al., 2020; El-Kamah et al., 2011; Elkamah et al., 2016; Ellatif et al., 2020; Mansor et al., 2020; Moghazy and Abdo, 2018; Moghazy et al., 2020; Senousy and Ellatif, 2020), and the second one is a hazardous factor on aquatic environments (Badr et al., 2010).

Algae presence in drinking water represents multiple problems including taste and odor, obstruction of filters, growth of biofilm, dangerous toxins, etc. (Chen and Yeh, 2005). This must a chance to be tended to through particular Physico-chemical techniques. These techniques depend on the separation of microorganisms using coagulation (Bratby, 2016), flotation (Chen et al., 1998), filtration (Lee et al., 2012), and many others. Advanced Oxidation Processes (AOPs) are also part of this group of techniques developed recently amongst them one can find ozonation (Miao and Tao, 2009), UV degradation (Sakai et al., 2011), and potassium permanganate oxidation (Wang et al., 2015).

Coagulation–flocculation is the most widely studied and employed in plants producing drinking water using traditional reagents: aluminum or iron salts, etc. The effectiveness of them will be because of the surface characterization of algae, which have an electrical charge in its outer membrane between 10 and 40 mv (zeta potential). This negative change characteristically favors the movement of the cationic coagulant. (Barrado-Moreno et al., 2016).

The aluminum residual in drinking water has a hazardous health effect, where it enters the human body through the gastrointestinal tract. Dissolved aluminum in potable water considers a highly reactive (due to inorganic complexes) to non-reactive (bound to inorganic complexes). Aluminum is more disintegrated in the stomach in a greater amount when the pH is extremely low. The absorption in the stomach may be a risk. Chronic exposure to aluminum. (toxic form: $Al_3$+, $Al(OH)_2$ +, $Al(OH)_{2+}$) is associated with various health problems (Krupińska, 2020).

The *Moringa oleifera* is an important traditional commodity plant that has been used for water treatment in the tropical area of the world. Therefore, *M. oleifera* seeds provide a lot of advantages compared to conventional Coagulants. such as eco-friendly, cost-effective, no necessity for alkalinity addition and reduction in sludge volumes, no pH alteration required. Although many researchers studied the use of *M. oleifera* as bio-coagulants, none had employed the use of its residue for the treatment of water (Zaid et al., 2019).

Activated carbon is one of the promising technique used for water and wastewater treatment, due to its availability naturally source occurring, and its efficiency in terms of treated water turbidity and algal removal. It is found that there is The use of alum as the primary coagulant with increasing powder activated carbon (PAC) dosage as coagulant aid from 5-20 mg/L, there was a systematic decrease in the filtered water turbidity and algal cell concentration (De Julio et al., 2010).

This study, therefore, investigated the use of *M. oleifera* seed extract as a natural coagulant for water treatment in comparison to synthetic coagulants such as aluminum sulfate and ferric chloride and the effect of further addition of activated carbon as a coagulant aid.

## MATERIALS AND METHODS

### 1. Coagulant preparation

#### 1.1. *Moringa* seed extract preparation

After careful removal of seed coats and seed wings, the quality of the kernels was inspected. The seeds weighted and then thoroughly pounded and squeezed in mortar. The powder was transferred to a flask and distilled water was added to the powder to make 3% suspension. The suspension was vigorously shaken for about 5 min. to promote water extraction of the flocculants then filtered through white cotton cloth suspensions can be refrigerated up to two weeks without suffering a reduction in efficiency (Bichi et al., 2012).

#### 1.2. Chemical coagulants preparation

A- Aluminum sulfate solution.

1% $Al_2 (SO_4)_3$ 16 $H_2O$ solutions in distilled water was prepared.

B- Ferric chloride solution.

1% $FeCl_3$ solution in distilled water was prepared. Both coagulant solutions must be freshly prepared before their use in every experiment.

### 2. Preparation of activated carbon from cotton stalk

The cotton stalk was crashed then dried at 100 °C for 24 hours after washing them with boiling water, the dried biomass then transferred in a stainless steel bowl and placed in Muffle at 200 ° C for 30 min., the temperature then raised to 400 ° C for additional 30 min, the carbonized cotton stalk was mixed with granules of dissolved KOH in an amount of water in the pyrex dishes and the mixing process is done at a ratio of 1: 1 and 1: 4 by weight (KOH: cotton stalk), the mixture is stirred vigorously for an hour and transferred in a stainless bowl Steel and placed in the muffle at a temperature of 800 ° C for 30 minutes and left to cool at room temperature, the produced activated biomass then washed with HCl (0.1 molar) and with boiling water until its pH range reaches 6-7. (Deng et al., 2009; Ekpete and Horsfall, 2011; Youssef et al., 2012).

### 3 Jar Test

A conventional jar test equipment with variable rotational speed was employed (APHA, 2017). The water samples used for this study were collected with a 10 L container from the river Nile at the intake of El-Giza water work. The algal The efficiency of algal removal in the collected water sample were evaluated before and after the treatment by different chemical coagulants and coagulant aids.

# RESULTS AND DISCUSSION

1. **Coagulation by synthetic coagulants**

## 1.1. Aluminum sulfate solution.

The obtained results of using Aluminum sulfate indicated that the optimum dose of alum was 30 mg / l, with the percentage of removing algae 85, 87.5, and 81.9% for green algae, blue-green algae, and diatoms respectively. The overall removal rate was 82.2% (Fig. 1a).

## 1.2. Coagulation by ferric chloride solution.

The results (Fig. 1b ) showed that the optimum dose for ferric chloride was 25 mg / l (sedimentation time 30 minutes), where the percentage of algae removal was 72.2, 90, and 81.9 % for green algae, blue-green algae, and diatoms, respectively. The total algal removal rate was 93.1%.

2. **Coagulation by natural coagulant (*Moringa* seed extract)**

The obtained results (Fig. 1c ) showed that the optimum dose for *Moringa* seed extract was 450 mg / l (sedimentation time 120 minutes) achieve the removal rate of algae 818, 67.2, and 91.8 for each of green algae, blue-green algae, and diatoms respectively.

3. **Effect of activated carbon addition on:**

## 3.1. The efficiency of Aluminum sulfate

The results indicated that the addition of different doses of activated carbon prepared from the cotton stalk ($PAC_1$) using KOH (1: 1) 5, 10, 15, 20, 25, 30 (mg / l), the alum dose (30 mg / l) showed that the optimum dose of $PAC_1$was (5 mg/liter) (Fig. 2), where it achieved a remarkable removal of 95, 93.8, and 96% for green algae, blue-green algae, and diatoms while the total algal removal rate was 96%. As shown in (Fig. 2 ) addition of different doses of alum 5, 10, 15, 20, 25, 30 mg / l) to 5 mg / l of the $PAC_1$ the alum dose decreased from 30 mg / l to 25 mg / l with the removal rate of 95, 93.3, and 96% for green, blue-green algae, and diatoms respectively.

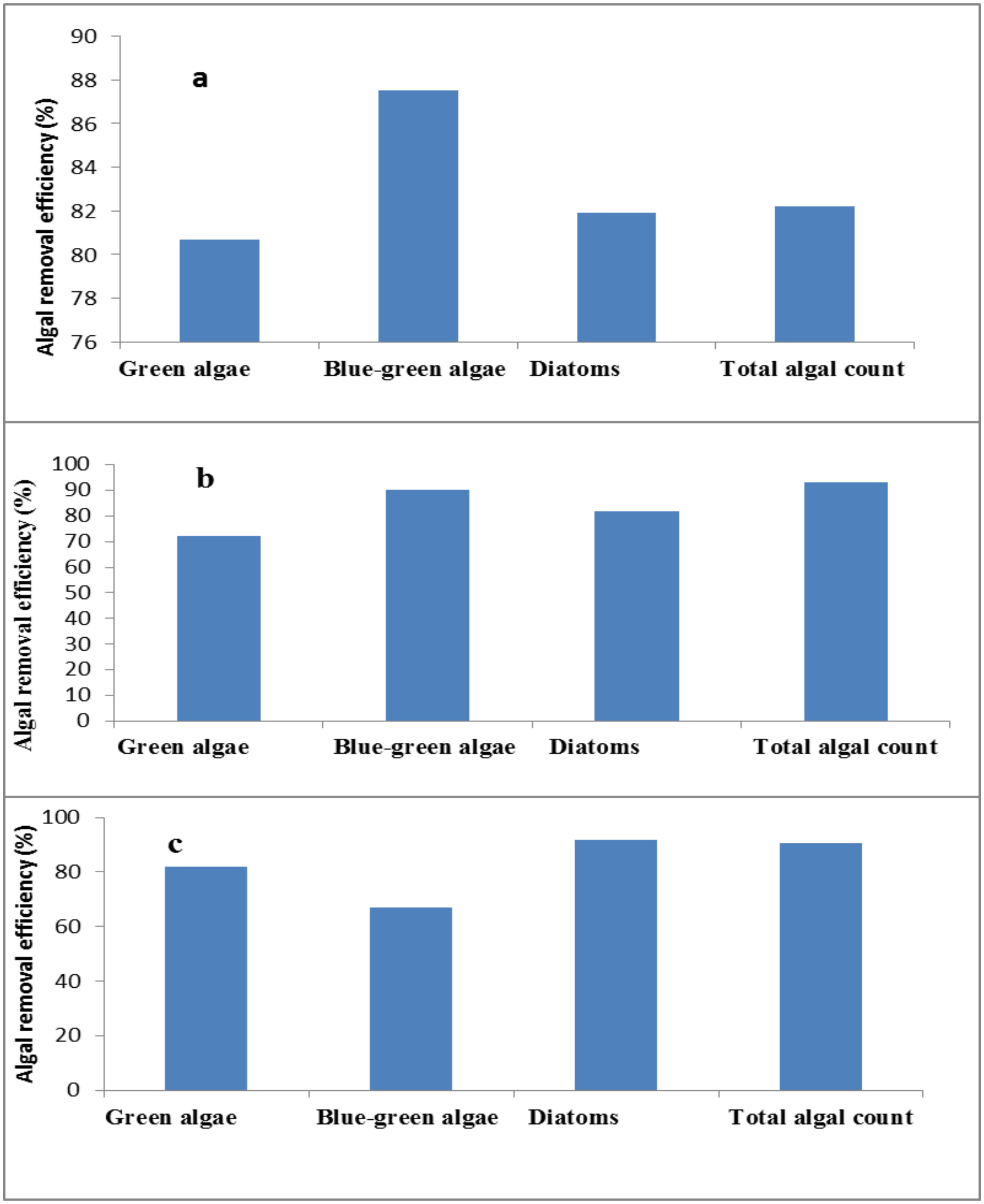


**Figure (1) Efficiency of algal removal of using a- Alum, b- $FeCl_3$, and c- *Moringa* seed extract**

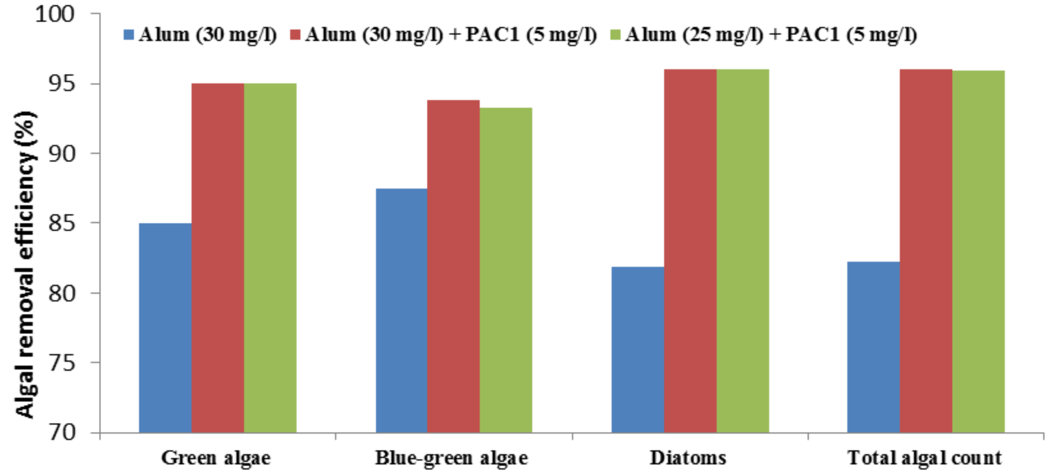


**Figure (2) Comparison of Alum as coagulant before and after the effect of addition of $PAC_1$ as coagulant aid on algal removal**

By using activated carbon prepared from the cotton stalk ($PAC_2$) using KOH (4: 1) as coagulant aid, the optimum dose was 10 mg / l (Fig. 3) and when adding different doses of alum (5, 10, 15, 20, 25, 30 mg / l) to $PAC_2$ dose (10 mg / l) a decrease of the alum dose from 30 mg / l to 25 mg / l occurred with removal rate 95, 93.8, and 95.2% for green algae, blue-green algae, and diatoms respectively.

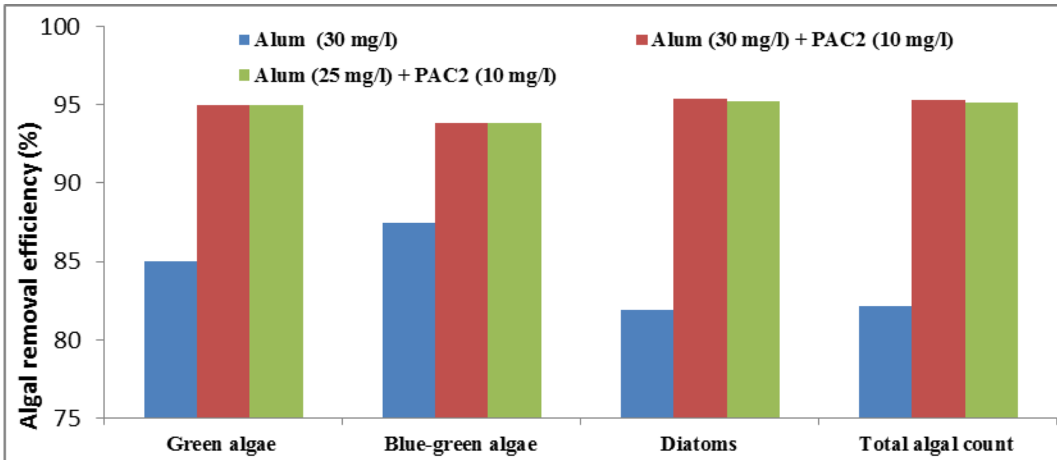


**Figure (3) . Comparison of Alum as coagulant before and after the effect of addition of $PAC_2$ as coagulant aid on algal removal**

These results were compared with the usage of commercial activated carbon by the addition of different doses of commercial activated carbon (5, 10, 15, 20 mg / l) to the alum dose (30 mg / l). The results showed that the commercial activated carbon dose is 5 mg / l (Fig. 4 ), where it achieved a remarkable removal of 94.5, 87.6, and 96% for green algae, blue-green algae, and diatoms respectively, while the total algal removal rate was 95%. by addition of different doses of alum (5, 10, 15, 20, 25, 30 mg / l) to 5 mg / l of the commercial activated carbon dose, the alum dose decreased from 30 mg / l to 25 mg / l where the percentage of removal was 94.6, 96, and 87.6% for green algae, blue-green algae, and diatoms respectively.

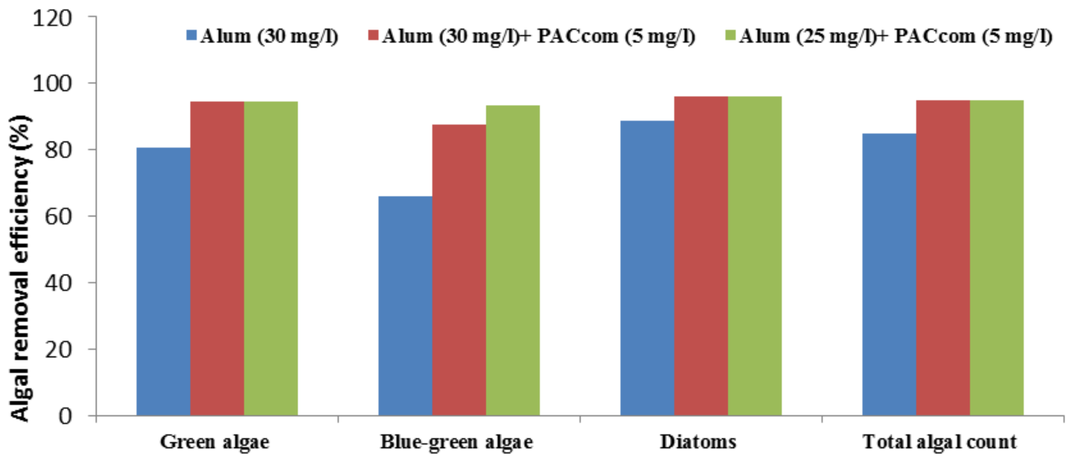


**Figure (4) Comparison of Alum as coagulant before and after the effect of addition of $PAC_{com}$ as coagulant aid on algal…**

The data revealed in fig (5) refer that there is no clear difference between the two types of PAC so that the use of $PAC_1$ with the ratio (1:1) of (KOH: cotton stalk) is more economic than that $PAC_2$ the with ratio (4:1) of (KOH: cotton stalk).

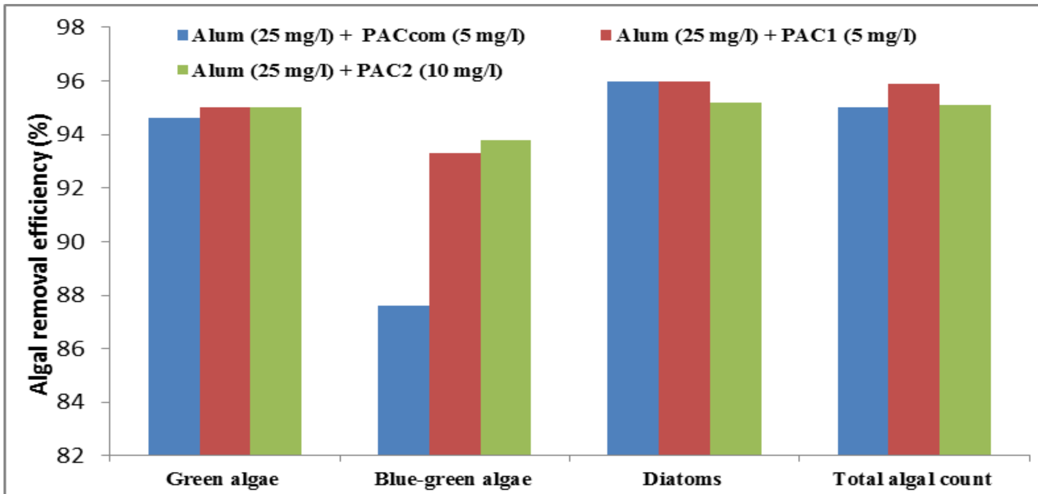


**Figure (5) comparison between Efficiency of activated carbon PAC $_{com}$, $PAC_1$ and $PAC_2$ as coagulant aid with alum**

### 3.2. The efficiency of ferric chloride

The addition of different doses of ferric chloride (5, 10, 15, 20, 25 mg / l) to the activated carbon $PAC_1$ dose (5 mg / l) decreased the optimum dose of ferric chloride dose from 25 mg / l to 20 mg / l, where the removal rate was 90.1, 90, and 96% for green algae, blue-green algae, and diatoms respectively (Fig. 6).

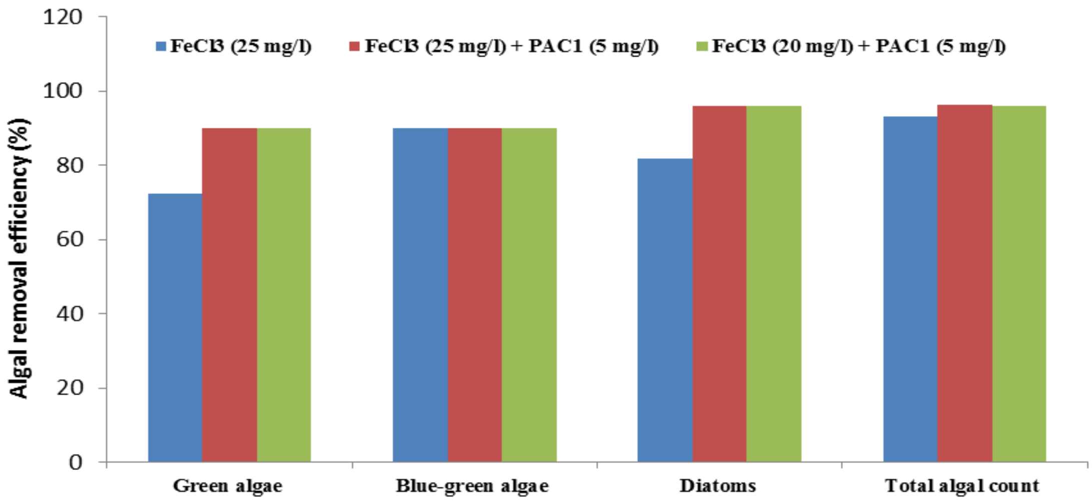


**Figure (6) Comparison of $FeCl_3$ as coagulant before and after the effect of addition of $PAC_1$ as coagulant aid on algal removal**

As compared by commercial activated carbon of dose (5 mg / l) with additive doses to different ferric chloride doses (5, 10, 15, 20, 25 mg / l) also decreased it from 25 mg / l to 20 mg / l removal rate 94, 93, and 97% for green algae, blue-green algae, and diatoms respectively (Fig. 7).

(Younker and Walsh, 2016) investigate the potential impact of adding powdered activated carbon or organo clay (OC) adsorbent and ferric chloride ($FeCl_3$) coagulant together on the coagulation, and the results showed that the turbidity of the clarified water sample was lower when OC was added during the coagulation process and powdered activated carbon removed.

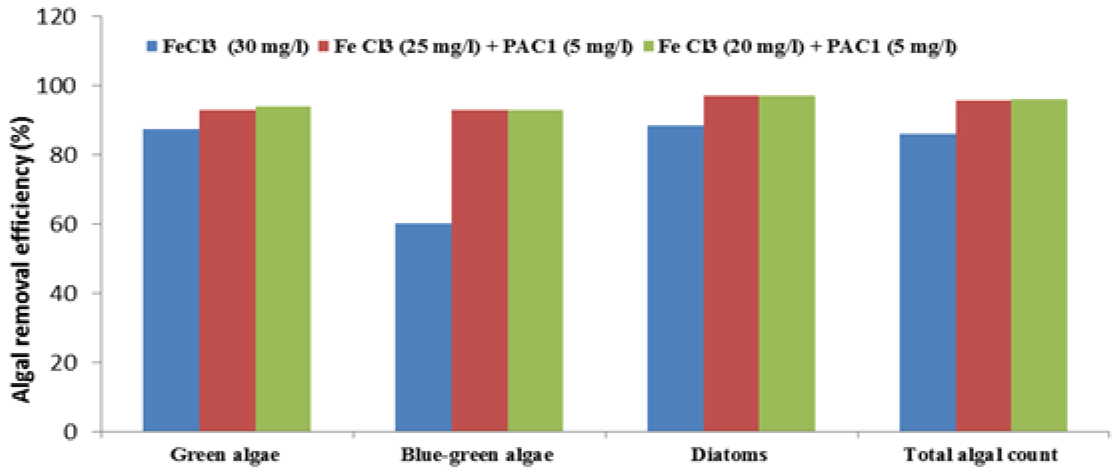


**Figure (7) Comparison of Fe $Cl_3$ as coagulant before and after the effect of addition of PACcom as coagulant aid on algal removal**

### 3.3. The efficiency of *Moringa* seed extract

When different doses of *Moringa* seed extract (250, 300, 350, 400, 450 mg / l) were added to (5 mg / l) activated carbon $PAC_1$ dose, it reduced *Moringa* seed extract dose from 450 mg / l to 350 mg / l achieving removal rate 100, 100, and 97.2% of green algae, blue-green algae, and diatoms respectively (Fig. 8).

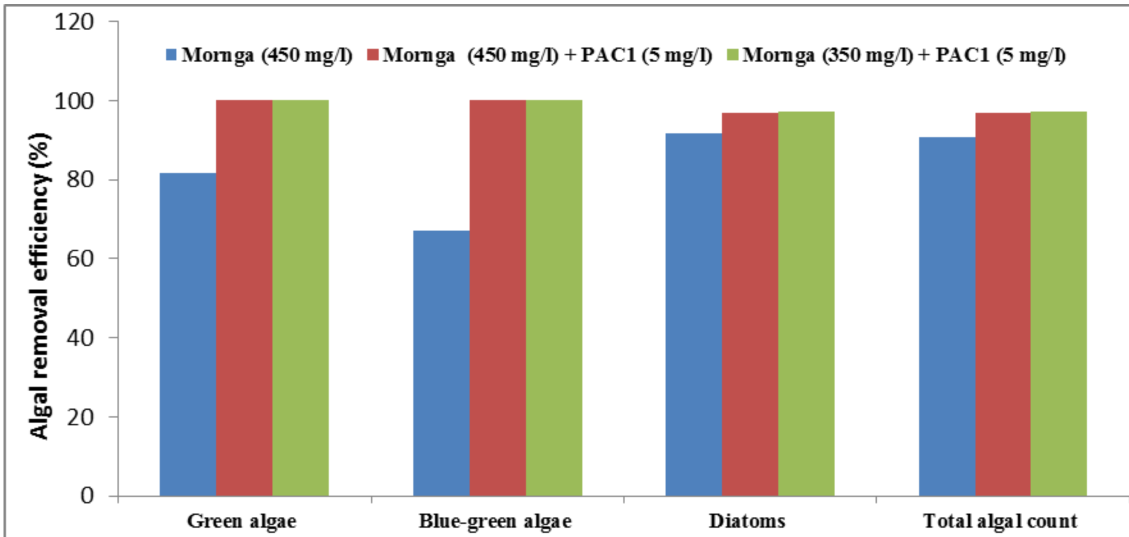


**Figure (8) Comparison of *Moringa* as coagulant before and after the effect of addition of $PAC_1$ as coagulant aid on algal removal**

Also, the result revealed that with the addition of different doses of *Moringa* seed extract (450, 400, 350, 300, 250 mg / l) to the commercial activated carbon dose (5 mg / l), the

*Moringa* seed extract dose decreased from 450 mg / l to 400 mg / l to give removal rate of 100%, 100%, 96.8% for green algae, blue-green algae, and diatoms respectively (Fig. 9). (Sánchez-Martín et al., 2014) Found that algal removal by *Moringa* extract alone from aqueous solutions through the coagulation/flocculation process was up to 98%.

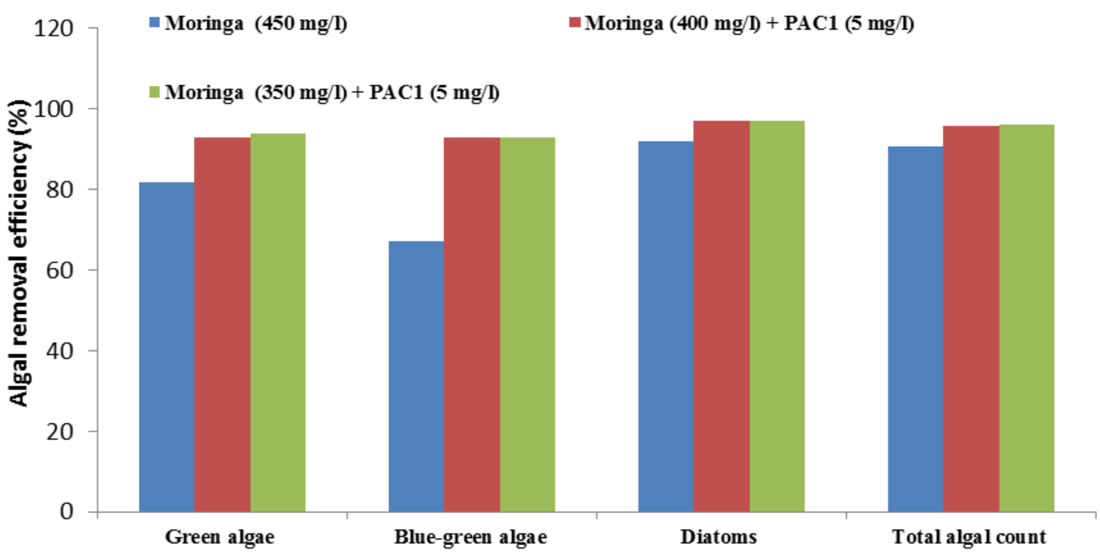


**Figure (9) Comparison of *Moringa* as coagulant before and after the effect of addition of PACcom as coagulant aid on algal removal**

There is a triple effect of activated carbon addition, first, one is to minimize the coagulant dose, increase the efficiency of coagulation, and reduce disinfection by-products. (Kristiana et al., 2011) found that the removal of natural organic material improved by 70%, which led to a significant reduction (80-95%) in the formation of disinfection by-products.

## 4. Comparison of the efficiency of different coagulants and the effect of coagulant aid additives

It is clear from the previous data that there is a difference between the efficiency of alum and ferric chloride as a synthetic coagulant and *Moringa* seed extract as a natural coagulant and there is an obvious effect of the addition of activated carbons as coagulant aids these effects have a dual function, the first one is reducing of the coagulant dose by about 16, 20, and 22% for alum, ferric chloride, and *Moringa* seed extract, and the second effect is increasing the removal efficiency of algae (Fig. 10 ).

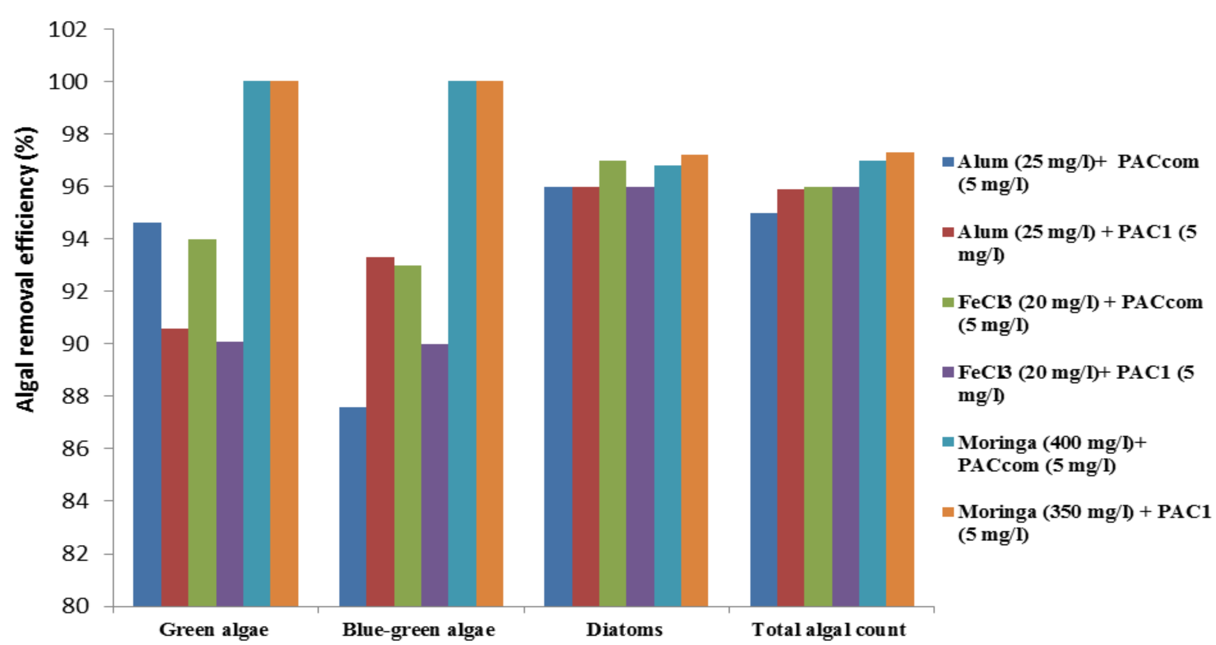


**Figure (10) Comparison of the efficiency for Powder activated carbon ($PAC_{com}$ and $PAC_1$) as coagulant aid with Alum, $FeCl_3$ ( as synthetic coagulants) and *Moringa* extract (as natutural coagulant)**

The dramatical reduction of coagulant consumption with activated carbon addition could be due to the presence of very active surface of powdered carbon and its high absorption capability (Afshin and Azadeh, 2013), this is demonstrated by Physico-chemical properties (Table 1), also the investigation by SEM (Fig. 11) shows the presence of an adequate morphological profile represented by an irregular surface with micropores and microparticles. Or this efficient removal may be due to activated carbon microparticles provide a more surface area and more positively charged (Mopoung et al., 2015) flocculants for enhancement of the more negatively charged microalgae (Branyikova et al., 2018).

**Table (1) Physico-chemical properties of activated carbons prepared from cotton stalks**

| PAC type | Physico-chemical properties | | | | | |
|---|---|---|---|---|---|---|
| | **KOH/CCS (w/w)** | **Surface area** $m^2/g$ | **Total pore volume** $cm^3/g$ | **Pore diameter** Å | **Methylene blue number mg/g** | **Carbon yield** ٪ |
| **$PAC_1$** | 1:1 | 950 | 0.423 | 17.8 | 222 | 23 |
| **$PAC_2$** | 4:1 | 551 | 0.123 | 8.9 | 166 | 12 |

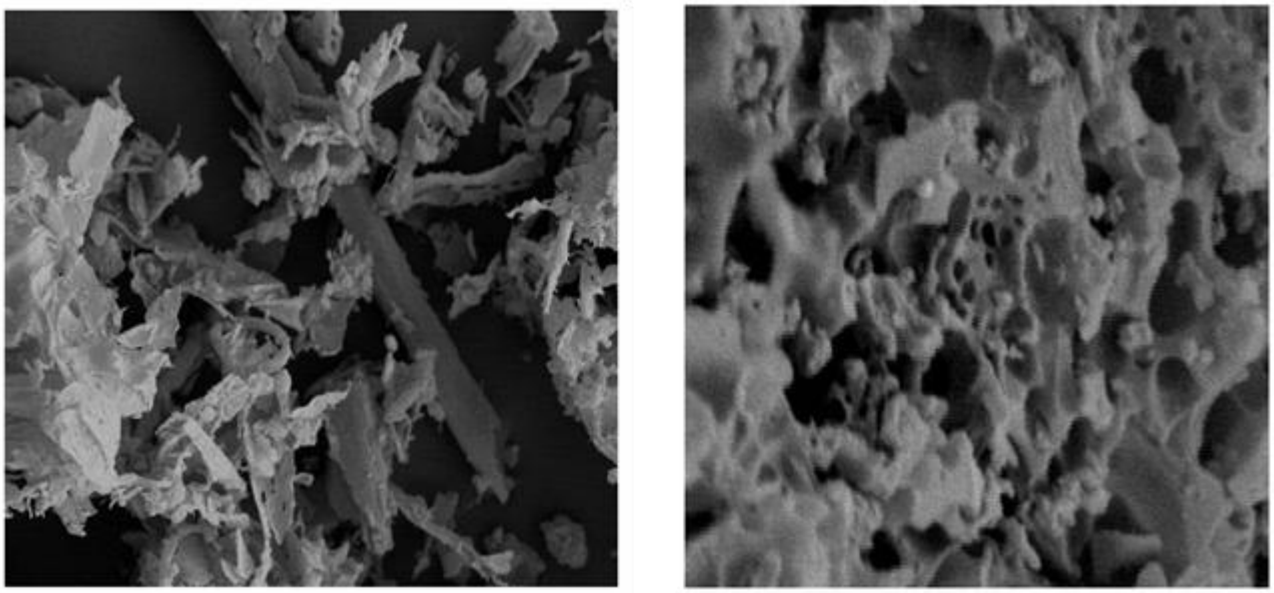

**Figure (11)** SEM micrographs of cotton stalks (left) and activated carbon produced from the activation of cotton stalks with KOH at 800$^oC$ (right).

## CONCLUSION

Synthetic coagulants represented by Alum and $FeCl_3$ and natural coagulant represented by *Moringa* seed extract were tested for algal removal and exposed to the effect of PAC as a coagulant aid. The Obtained results prove that the PAC has a dual effect on the coagulants, the first one is reducing the coagulant dose, the second one is increasing algal removal efficiency, this efficiency exhibited in *Moringa* seed extract by removal rate 100% in the case of green and blue-green.

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