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"Gheorghe Asachi" Technical University of Iasi, Romania

PREPARATION OF *Moringa oleifera* SEEDS AS COAGULANT IN WATER TREATMENT

Karina Cardoso Valverde[1*], Priscila Ferri Coldebella[1], Angélica Marquetotti Salcedo Vieira[2], Letícia Nishi[1], Milene Carvalho Bongiovani[1], Aline Takaoka Alves Baptista[2], Márcia Regina Fagundes-Klen[3], Onélia Aparecida Andreo dos Santos[1], Rosângela Bergamasco[1]

[1]Engineering Chemical Department, State University of Maringá, Av. Colombo 5790, Block D-90, 87020-900, Maringá, Paraná, Brazil
[2]Engineering Food Department, State University of Maringá, Maringá, Paraná, Brazil
[3]Engineering Chemical Department, State University of West Paraná, Toledo, Paraná, Brazil

Abstract

The influence of the active compound of *Moringa oleifera* Lam (MO) seeds was evaluated by different methods for the preparation of the natural coagulant in the treatment of surface water. Nine methods were analyzed, comprising samples of seed powder with different granulometry, aqueous and saline solutions, evaluated before and after oil extraction from MO seeds. Tests of coagulation/flocculation and sedimentation were accomplished using simple Jar Test. Natural coagulant dose of 50 $mg \cdot L^{-1}$ identified the best preparation methods in terms of removal efficiency of the quality parameters. Doses of whole powder coagulant, whole and defatted solution (saline) in concentrations between 10 $mg \cdot L^{-1}$ and 200 $mg \cdot L^{-1}$ were then added for the treatment of water turbidity to 70 NTU. The whole powder coagulant constituted a good preparation of the natural coagulant with a high potentiality for the treatment of water and may be used by populations in developing countries in which facilities for the treatment of drinking water are lacking.

Key words: Moringa oleifera seed preparations, natural coagulant, water treatment

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1. Introduction

Access to clean and safe water is a major problem in several developing countries. More than 780 million people still use untreated surface or well water at the beginning of the 21st century (UNICEF/WHO, 2012). According to Ali et al. (2010), more than 6 million children die of diarrhea annually in developing countries. Since several places lack adequate water sources, it is highly relevant to have at one´s disposal technical alternatives for water treatment so that the above health issue could be attenuated (Valverde et al., 2013). Research on low-cost interventions is necessary to identify sustainable interventions for reducing risks in communities that use low quality water, including for consumption. Probably a more effective conventional water treatment may be expensive to install and maintain in these communities. The tested methods include slow sand filters, disinfection by solar energy and others. These low-cost measures have shown great potential but locally adapted low-cost technologies to treat water are still required.

Several coagulants of plant origin have been traditionally used to clean water, such as the kernels from the genus *Prunus* (almond, apricot, peach) and

*Author to whom all correspondence should be addressed: e-mail: karinacvalverde@gmail.com

the seeds from the family *Papilionaceae* (beans, peas, lentils) (Jahn, 1988). *Moringa oleifera* Lam (MO) seeds are being recognized as a substitute in wastewater treatment due to their effectiveness as a water purifier (Sengupta et al., 2012).

Since the plant MO may be produced locally, its use as a coagulant in water cleansing should be encouraged (Amagloh and Benang, 2009; Jafari and Mahvi, 2015). According to Joshua and Vasu (2013) and Mangale et al. (2012b), MO seeds may be used as a natural coagulant in water treatment in rural areas. In fact, MO functions within a wide pH range (Sánchez-Martín et al., 2012) and does not alter significantly the pH of water (Yarahmadi et al., 2009) and its alkalinity after treatment (Pise and Halkude, 2012), neither does it cause corrosion (Ndabigengesere and Narasiah, 1998). The sludge produced during the coagulation process is harmless (Ndabigengesere et al., 1995). Furthermore, MO seeds also have antimicrobial activity (Amagloh and Benang, 2009; Joshua and Vasu, 2013; Mangale et al., 2012b; Nwaiwu et al., 2012).

Jahn (1989) and Ndabigengesere et al. (1995) reported that the active protein of MO is a soluble protein which functions as a natural cationic polyelectrolyte during treatment and causes the coagulation of turbid water. Amagloh and Benang (2009) and Joshua and Vasu (2013) registered that when powder from the seeds is added to muddy water, the proteins release positive charges which attract negative ones such as mud, clay, bacteria and toxic particles in the water. Flocculation occurs when proteins bind themselves to the negative charges and produce flocs by aggregating the particles in the water. Consequently, the use of the MO seeds may be a feasible alternative to metal salts used in water treatment around the world (Ndabingegesere and Narasiah, 1996; Sánchez-Martín et al., 2012).

Specific literature recommends the extraction of the active components of the MO seeds powder by oil extraction, salt extraction, microfiltration and ultrafiltration techniques to improve its removal efficiency in low turbid water (Ravikumar and Sheeja, 2012). For Al-Anizzi et al. (2014) the normal dose of MO used to treat water with turbidity lower than 100 NTU is in the range 100–200 $mg \cdot L^{-1}$ (Nkurunziza et al., 2009; Sutherland et al., 1990).

For highly colored water, doses of up to 250 $mg \cdot L^{-1}$ may be required, which could place the supernatant in the toxicity range. Yet, toxicity studies on MO are scarce (Asare et al., 2012). Rolim et al. (2011) claim that the use of high doses of the extract may pose a risk to human health and the safe use of MO seed powder to treat water for human consumption requires more study. However, the dose 200 $mg \cdot L^{-1}$ of MO seed extract recommended to treat water for humans did not pose a risk to human health.

Fine powder from MO was prepared by grinding with mortar and pestle and directly used as a coagulant, following Mangale et al. (2012a). Preparation methods for the MO solution have been widely studied, featuring aqueous (Amagloh and Benang, 2009; Katayon et al., 2006; Muyibi and Evison, 1995; Pise and Halkude, 2012; Valverde et al., 2013) and saline extractions (Madrona et al., 2012; Okuda et al., 2001; Yarahmadi et al., 2009). Procedures for the use of defatted MO were evaluated by Ali et al. (2010) and Nwaiwu et al. (2012) since an edible oil may be obtained as a byproduct.

Although literature reported the production of a coagulant based on MO seeds, no thorough analysis has been provided that compares the different methods for the preparation of this natural coagulant. The current paper evaluates the removal efficiency of surface water quality parameters with different preparation methods of MO seeds as a natural coagulant.

2. Experimental

Surface water for the tests was collected by the Paraná Sanitation Company (Sanepar), from the Pirapó River basin, state of Paraná, Brazil. MO seeds from Aracaju, Sergipe, Brazil, were first selected and had their husks removed for the tests.

Current research was divided into two stages. First, efficiency in the removal of apparent color, turbidity and compounds with absorption at UV_{254nm} was verified for the nine preparation methods of the coagulant from MO seeds by adding a 50 $mg \cdot L^{-1}$ dose to the coagulation/ flocculation and sedimentation process. Afterwards, tests performed only for the most efficient preparation methods of the natural coagulant with doses ranging from 10 $mg \cdot L^{-1}$ to 200 $mg \cdot L^{-1}$ were carried out. The procedure allowed demonstrating which coagulant dose was best indicated for water treatment. Fig. 1 shows the nine preparation methods of the natural coagulant of MO seeds. Procedures for obtaining natural coagulants from the MO seeds will be given below.

2.1. Preparation of coagulants from MO seeds

- *Whole powder coagulant (Po_{who})*: 15 g of seeds were dried in a forced air buffer (Digital Timer SX CR/42) at 40°C till constant weight (Amagloh and Benang, 2009). Sample was ground in a common processor to obtain whole powder coagulant (Po_{who}). Powder granulometry was not assessed.
- *Whole powder coagulant – Tyler 32 and Tyler 48 ($Po_{who\text{-}32}$ and $Po_{who\text{-}48}$)*: 10 g of previously dried and ground seeds were homogenized in a series of sieves (Bertel) for 1 hour. Fractions from granulometry with meshes 0.500 mm and 0.300 mm were labeled $Po_{who\text{-}32}$ and $Po_{who\text{-}48}$, respectively.
- *Defatted powder coagulant (Po_{def})*: 10 g of whole powder coagulant were placed in a Soxhlet continuous extractor and 170 mL of hexane were added.

Evaporation of the solvent occurred within a three-hour cycle (Ali et al., 2010; Nwaiwu et al., 2012). Extract was washed in 500 mL of distilled water at 40°C and dried in an air buffer (Digital Timer SX CR/42) at 40°C till constant weight (Amagloh and Benang, 2009).

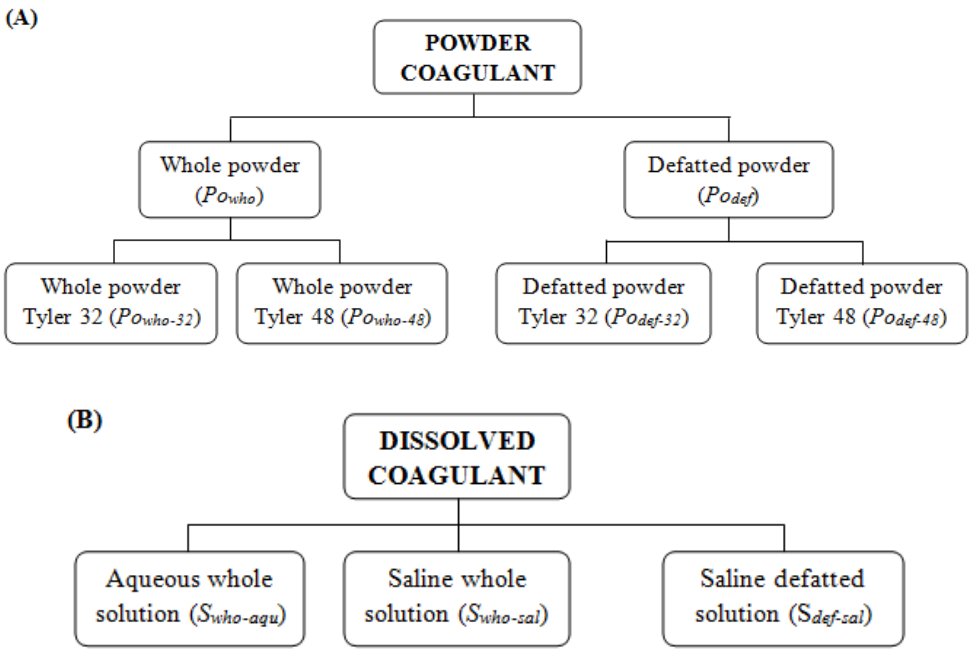

Fig. 1. Flowchart of different types of natural coagulants (A) powder coagulant, (B) dissolved coagulant

- *Defatted powder coagulant – Tyler 32 and Tyler 48 (Po_{def-32} and Po_{def-48}):* Pre-determined granulometry of defatted powder was obtained by sieve shaker after procedures for the chemical extraction of oil from MO seeds.
- *Coagulant in whole aqueous ($S_{who-aqu}$) and saline ($S_{who-sal}$) solution:* Solutions were prepared at 1% m/v concentration. After that, 100 mL distilled water ($S_{who-aqu}$) were added for water extraction and 100 mL 1mol·L^{-1} NaCl ($S_{who-sal}$) were added for saline extraction. Extractions were performed by turbolysis in a blender for 3 min; they were shaken in a magnetic shaker for 30 min to have better results in extraction and then vacuum filtered (Madrona et al., 2010).
- *Coagulant in defatted saline solution ($S_{def-sal}$):* 1 g of deffated powder coagulant was used to prepare a saline solution at 1% m·v^{-1} concentration. Subsequently, 100 mL of 1 mol·L^{-1} NaCl ($S_{who-sal}$) were added for saline extraction. Extractions were performed by turbolysis in a blender for 3 min; they were shaken in a magnetic shaker for 30 min to have better results in extraction and then vacuum filtered (Madrona et al., 2010).

2.2. Coagulation/flocculation process

Tests of coagulation/flocculation were accomplished using simple Jar Test, Milan – Model JT101/6 of six proofs with rotation regulator of the mixing rods, in 400 mL vessels of raw water. Speed was fixed at 100 rpm (129.8 s^{-1}) for 3 min and at 15 rpm (7.5 s^{-1}) for 15 min respectively for fast and slow mixture respectively. The 60 min sedimentation stage was observed and water temperature was kept at 25.0 ± 3.0ºC in all tests, following Madrona et al. (2012) and Valverde et al. (2013).

According to Joshua and Vasu (2013), doses between 25 and 75 mg·L^{-1} of MO aqueous coagulant were enough for raw water with turbidity rates between 50 and 150 NTU, whereas, according to Muyibi and Evison (1995), 50 mg·L^{-1} was the best dose for synthetic water with initial 50 NTU turbidity. Based on these studies, the 50 mg·L^{-1} dose was selected to define the most efficient preparation methods of MO seeds out of nine natural coagulants under analysis.

Tests with 10 mg·L^{-1}, 25 mg·L^{-1}, 50 mg·L^{-1}, 100 mg·L^{-1}, 150 mg·L^{-1} and 200 mg·L^{-1} doses of the natural coagulant were then performed only for the preparation methods of the natural coagulant, featuring the removal efficiency for apparent color, turbidity and compounds with absorption at UV_{254nm} in order to select the most adequate dose of the natural coagulant to be used in the treatment of water with turbidity close to 70 NTU.

Raw water was characterized by the following quality parameters: apparent color, compounds with absorption at UV_{254nm} (spectrophotometer DR 5000 Hach), turbidity (turbidity meter 2100P Hach), total dissolved solids (APHA, 2005) and pH (pH meter Thermo-Scientific VSTAR92 Orion Versastar). Coagulation/flocculation and sedimentation process was evaluated by decrease percentage of the parameters color, turbidity and compounds with absorption at UV_{254nm}.

2.3. Statistical analysis

Statistical analysis was divided into two parts. The first part identified the most efficient types of natural coagulants for the removal of quality parameters; the second part estimated the best

coagulant dose for water treatment. A totally randomized experimental design with nine preparation methods of natural coagulants with 50 mg·L^{-1} dose was employed to evaluate the preparation methods of MO seeds for the removal of water quality parameters apparent color, turbidity and compounds with absorption at UV_{254nm} after the coagulation/flocculation and sedimentation processes.

Factorial design 3 x 6, with factors methods (the three best natural coagulants) and doses (six doses of natural coagulant), evaluated the natural coagulant dose. Analysis of variance (ANOVA) and Tukey´s test for mean comparison at 95% reliability ($p< 0.05$) were performed to verify significant differences in removal efficiency of the parameters under analysis by Statsoft Statistica 8.0.

3. Results and discussion

3.1. Characterization of initial raw water

Table 1 shows results for raw water in all the coagulation/flocculation and sedimentation tests.

Table 1. Characterization of raw water

Quality parameter	*Unit*	*Raw water*
Apparent color	uH(1)	357
Turbidity	NTU(2)	69.4
Compounds with absorption at UV_{254nm}	cm^{-1}	0.296
Total dissolved solids	mg·L^{-1}	107.67
pH	-	8.12

(1) uH: Hazen unit (mg Pt–Co L^{-1})
(2) NTU: nephelometric turbidity units

3.2. First stage: Evaluation of nine different preparation methods of MO seeds (50 mg·L^{-1} dose of MO)

Table 2 shows general means of removal efficiency of parameters evaluated for each method of preparation of natural coagulant with 50 mg·L^{-1} dose. Evaluation of the three types of whole powder coagulant (Po_{who}, Po_{who-32} and Po_{who-48}) revealed removal variations between 76.0% and 80.0% for apparent color; between 83.0% and 85.0% for turbidity; between 61.0% and 67.0% for compounds with absorption at UV_{254nm}. Statistical analysis showed that there was no difference in quality parameters. Whole powder with specific granulometry could be employed, although the former one (Po_{who}) was more advantageous due to the easier preparation of natural coagulant.

Conditions should be provided so that the flocs formed in the coagulation/flocculation processes be deposited by gravity during the sedimentation period. The clarification of the supernatant ensued. However, the above was not reported in samples of defatted powder (Po_{def}, Po_{def-32} and Po_{def-48}) since they had removal rates which were lower than those of the other types of natural coagulant from MO seeds for the three quality parameters under analysis. Since the suspension of a great part of the defatted powder occurred during the tests, a great number of suspended particles was collected during sampling and interfered significantly in the removal efficiency. The above may be due to the oil extraction from the MO seeds.

Po_{def} had the lowest removal efficiency rate within the context of all preparation methods proposed in the current research. The above suggests that defatted powder had several particle diameters including fractions with less than 0.300 mm apertures which affected results negatively.As a rule, small particles have low organic matter and also low turbidity removal efficiency in the coagulation/flocculation process.

Small particles generally decant at a slower rate than bigger particles (Zhao et al., 2012). In fact, tests with Po_{def-32} had higher removal rates than those with Po_{def-48}. The smaller the size of the defatted particles of MO seeds in the coagulation/flocculation process, the lower is the process efficiency. Dense flocs cannot be formed and, therefore, subsequent difficulties in the sedimentation process exist. In the case of the coagulant in aqueous whole solution ($S_{who-aqu}$), removal efficiency reached 35.5% for apparent color; 60.5% for turbidity; 14.2% for compounds with absorption at UV_{254nm}. Madrona et al. (2010) showed that results from the aqueous solution of MO seeds were not representative for the removal efficiency of apparent color and turbidity, as demonstrated by the results obtained.

Table 2. Parameters removal efficiency for different preparation methods of MO seeds for 50 mg·L^{-1} dose of natural coagulant

Natural coagulant	*Removal efficiency (%) (1)*		
	Apparent color	*Turbidity*	*UV_{254nm}*
Po_{who}	79.8 ± 1.21 ^{d}	84.0 ± 0.50 ^{de}	66.8 ± 0.58 ^{c}
Po_{who-32}	78.8 ± 0.93 ^{d}	84.9 ± 1.19 ^{de}	61.2 ± 1.02 ^{c}
Po_{who-48}	76.8 ± 3.22 ^{d}	82.9 ± 2.57 ^{d}	64.4 ± 3.35 ^{c}
Po_{def}	2.2 ± 0.00 ^{a}	35.00 ± 0.90 ^{a}	8.7 ± 0.00 ^{b}
Po_{def-32}	43.2 ± 0.19 ^{c}	60.6 ± 0.21 ^{c}	13.8 ± 1.02 ^{b}
Po_{def-48}	30.4 ± 2.07 ^{b}	44.4 ± 2.72 ^{b}	0.00 ± 0.02 ^{a}
$S_{who-aqu}$	35.5 ± 0.37 ^{b}	60.5 ± 0.00 ^{c}	14.2 ± 0.25 ^{b}
$S_{who-sal}$	82.9 ± 0.37 ^{d}	89.3 ± 0.47 ^{e}	66.2 ± 0.00 ^{c}
$S_{def-sal}$	77.9 ± 3.52 ^{d}	84.0 ± 1.76 ^{de}	62.0 ± 2.32 ^{c}

(1) Results given in mean rates ± standard deviation. Means followed by the same letter in the same column do not differ statistically from one another using Tukey´s test at 5% significance level

Since this type of coagulant proved to be inefficient in the removal of these water quality parameters, tests with defatted aqueous solutions were discarded. Removal efficiency for saline solution ($S_{who\text{-}sal}$ and $S_{def\text{-}sal}$) was close to 80.0% for apparent color; 85.0% for turbidity; 63.0% for compounds with absorption at UV_{254nm}. It was thus verified that the coagulating capacity of the coagulant in MO saline solution ($S_{who\text{-}sal}$ and $S_{des\text{-}sal}$) provided removal rates which were higher than those of aqueous solution ($S_{who\text{-}aqu}$). The above was corroborated by Madrona et al. (2012) and Okuda et al. (2001). In fact, the active principle obtained from the saline solution had a different composition than that extracted in water (Okuda et al., 2001).

The coagulation mechanism in the aqueous solution seemed to be adsorption and neutralization of charges (Mangale et al., 2012b). On the other hand, Okuda et al. (2001) suggested that adsorption and bridge-making mechanism was improbable for saline extraction owing to its low molecular weight. Adsorption mechanism and the neutralization of charges failed to cause coagulation with saline solution. Consequently, the activation mechanism of MO as a coagulant requires a better explanation, as it's still undefined. According to Ndabigengesere et al. (1995), higher solubility of coagulants is reached by increasing salinity rate during the extraction process. Due to its dissociation from salt, increase in charge density contributes towards higher rates within the coagulation/flocculation process (Madrona et al., 2010). The above may explain why whole solution and saline defatting ($S_{who\text{-}sal}$ and $S_{def\text{-}sal}$) produced good removals in contrast to the powder coagulant with the best removals without soil extraction (Po_{who}, $Po_{who\text{-}32}$ and $Po_{who\text{-}48}$). When the different coagulant preparation methods were investigated (Table 2), preparation types of the natural coagulants Po_{who}, $S_{who\text{-}sal}$ and $S_{def\text{-}sal}$ were recommended for the removal of quality parameters evaluated. Consequently, other tests were performed with three preparation methods in natural coagulant doses between 10 $mg{\cdot}L^{-1}$ and 200 $mg{\cdot}L^{-1}$.

3.3. Second stage: Evaluation of three preparation methods: Po_{who}, $S_{who\text{-}sal}$ and $S_{def\text{-}sal}$ (10 $mg{\cdot}L^{-1}$ and 200 $mg{\cdot}L^{-1}$ doses)

Fig. 2 shows mean results for the removal efficiency of apparent color for preparation types of the natural coagulant from MO seeds, Po_{who}, $S_{who\text{-}sal}$ and $S_{def\text{-}sal}$ with doses 10 $mg{\cdot}L^{-1}$, 25 $mg{\cdot}L^{-1}$, 50 $mg{\cdot}L^{-1}$, 100 $mg{\cdot}L^{-1}$, 150 $mg{\cdot}L^{-1}$ and 200 $mg{\cdot}L^{-1}$.

Fig. 2 shows that 10 $mg{\cdot}L^{-1}$ and 25 $mg{\cdot}L^{-1}$ doses had removal rates for apparent color lower than others. The above revealed that the amount of coagulant added to the coagulation/flocculation process was insufficient. In fact, best apparent color removal rates were 79.8%, 82.9% and 77.9% for 50 $mg.L^{-1}$ dose and 83.0%, 84.7% and 81.6% for 100 $mg.L^{-1}$ dose, for the natural coagulants Po_{who}, $S_{who\text{-}sal}$ and $S_{def\text{-}sal}$ respectively. In addition, 77.6% removal was obtained by 150 $mg{\cdot}L^{-1}$ dose of the natural coagulant Po_{who}, whereas 77.8% and 83.5% removals were obtained respectively for 150 $mg{\cdot}L^{-1}$ and 200 $mg{\cdot}L^{-1}$ doses of $S_{def\text{-}sal}$, with no significant statistical difference. Mangale et al. (2012b) reported that apparent color was totally removed when the coagulation/flocculation and sedimentation processes were applied with whole powder of the MO seeds at doses between 50 $mg{\cdot}L^{-1}$ and 150 $mg{\cdot}L^{-1}$. Removals close to 80.0% were achieved for apparent color in the current research. The above showed that the seeds had absorbent qualities. There was a decrease in the removal of apparent color at the 200 $mg{\cdot}L^{-1}$ dose used in the preparation of the natural coagulants Po_{who} and $S_{who\text{-}sal}$. According to Mangale et al. (2012a) and Muyibi and Evison (1995), excess of coagulant may cause polymer sites saturation along with particle destabilization.

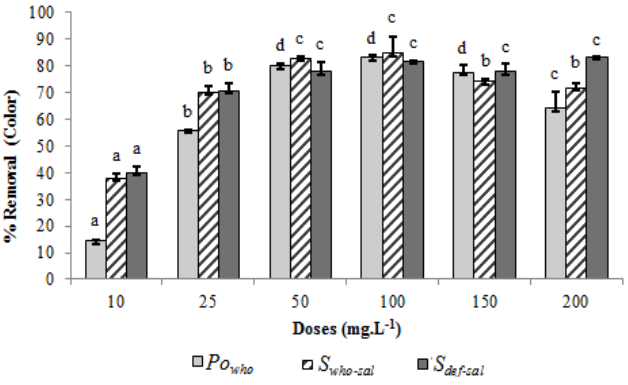

Fig. 2. Removal efficiency of the parameter apparent color for preparation types (Po_{who}, $S_{who\text{-}sal}$ and $S_{def\text{-}sal}$) of the natural coagulant

*Taking each coagulant individually, means followed by the same letter do not differ statistically with regard to natural coagulant dose using Tukey´s test at 5% significance level

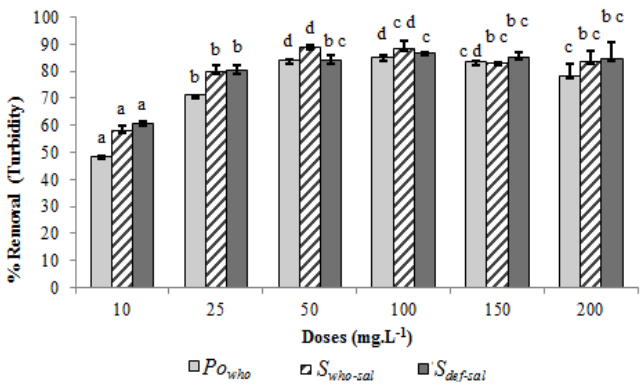

Fig. 3. Removal efficiency of the parameter turbidity for the preparation types of natural coagulants Po_{who}, $S_{who\text{-}sal}$ and $S_{def\text{-}sal}$

*Taking each coagulant individually, means followed by the same letter do not differ statistically with regard to natural coagulant dose using Tukey´s test at 5% significance level

This can be a reasonable explanation for our findings. Fig. 3 shows mean results for the removal efficiency of turbidity concerning preparation types of the natural coagulant from MO seeds, Po_{who}, $S_{who\text{-}sal}$ and $S_{def\text{-}sal}$ with 10 mg·L^{-1}, 25 mg·L^{-1}, 50 mg·L^{-1}, 100 mg·L^{-1}, 150 mg·L^{-1} and 200 mg·L^{-1} doses. Fig. 3 shows that the best turbidity removals for the natural coagulant Po_{who} were 84.0%, 85.0% and 83.4% for doses between 50 mg·L^{-1} and 150 mg·L^{-1}. In the case of $S_{who\text{-}sal}$, 89.3% and 88.39% removals were obtained respectively for doses 50 mg·L^{-1} and 100 mg.L^{-1}. $S_{def\text{-}sal}$ failed to have any statistical difference for doses between 25 mg·L^{-1} and 200 mg·L^{-1}, with removals between 80.2% and 86.7%.

A similar trend may be observed with regard to the removal of parameters apparent color and turbidity, which may be due to the fact that both water quality parameters are related to the concentration of solids, whilst apparent color mainly refers to organic materials dissolved or to colloidal materials, besides suspended particles. Turbidity refers to suspended particle material in the water.

Fig. 4 shows mean results for the removal efficiency of compounds with absorption at UV_{254nm} of the natural coagulant from MO seeds, Po_{who}, $S_{who\text{-}sal}$ and $S_{def\text{-}sal}$ using 10 mg·L^{-1}, 25 mg·L^{-1}, 50 mg·L^{-1}, 100 mg·L^{-1}, 150 mg·L^{-1} and 200 mg·L^{-1} doses. Fig. 4 demonstrates that the best removals of compounds with absorption at UV_{254nm} for Po_{who} were 66.8%, 66.9% and 63.5% for doses between 50 and 150 mg·L^{-1}. In the case of $S_{who\text{-}sal}$, a 66.2% removal was obtained for 50 mg.L^{-1} dose, whilst 68.4% and 65.1% removals, thus considered statistically equivalent, were obtained for 100 mg·L^{-1} and 200 mg·L^{-1} doses, in the case of $S_{def\text{-}sal}$.

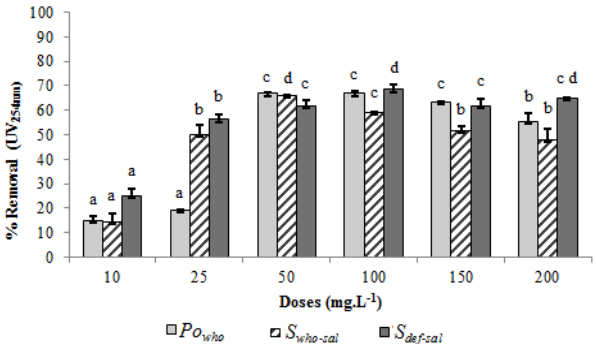

Fig. 4. Removal efficiency of parameter compounds with absorption at UV_{254nm} for preparation types of the natural coagulants Po_{who}, $S_{who\text{-}sal}$ and $S_{def\text{-}sal}$
*Taking each coagulant individually, means followed by the same letter do not differ statistically with regard to natural coagulant dose using Tukey´s test at 5% significance level

Since natural coagulants are made up of organic matter, it seems that the low efficiency removal of compounds with absorption at UV_{254nm} using 200 mg·L^{-1} doses for the natural coagulant Po_{who} and 150 mg·L^{-1} and 200 mg·L^{-1} for $S_{who\text{-}sal}$ is due to an increase in the concentration of organic matter in water because of the composition of MO.

Statistical analysis among the three preparation methods of MO seeds (Po_{who}, $S_{who\text{-}sal}$ and $S_{def\text{-}sal}$) demonstrated that 50 mg·L^{-1} dose did not statistically differ regarding the parameters apparent color, turbidity and compounds with absorption at UV_{254nm}. The dose may be said to be the most advantageous one to the removal of these quality parameters for the type of water under analysis, with initial turbidity close to 70 NTU. Mangale et al. (2012a) studied the coagulation/flocculation process for raw water with initial turbidity 15.4 NTU and pH 8. Turbidity removal at 69.5% and 77.7% were reported for doses of MO coagulant in whole powder at 50 mg·L^{-1} and 100 mg·L^{-1} respectively.

Fig. 3 indicates that higher removals, 84.0% and 85.0%, were reported for the same coagulant (Po_{who}), the same pH band and the same doses, when raw water had an initial turbidity rate of 69.4 NTU. Katayon et al. (2006) stated that coagulation efficiency depended on the initial turbidity of raw water since more efficient removals of this parameter were obtained for water with high initial turbidity employed in the current experiment.

Yarahmadi et al. (2009) obtained a turbidity removal percentage close to 70.0% with a 50 mg·L^{-1} dose of whole saline solution of MO for synthetic raw water prepared with kaolin and with 50 NTU initial turbidity and pH 8.1. In the present study, it was observed an 89.3% removal for the same dose of coagulant used. Consequently, the characteristics of the water under analysis may affect the coagulation/flocculation process due to the particles characteristics.

It should be underscored that, in the case of drinkable water, the filtration and disinfection stage should be taken into account so that quality parameters comply with the highest rates legally permitted. This is due to the fact that the coagulation/flocculation and sedimentation process does not eliminate completely the flocs.

4. Conclusions

Whole powder from MO seeds at 50 mg·L^{-1} dose showed, in the case of raw water with 70 NTU turbidity, efficiency removals of 80.0%, 85.0%, 65.0% for color, turbidity and compounds with absorption at UV_{254nm}, respectively and this coagulant preparation may be highlighted due to its easy preparation and application in coagulation/flocculation of water. In addition, it may be used by populations in developing countries in which structures for the treatment of drinkable water are lacking. Besides, the suggested methods for the preparation of the coagulant from MO seeds both defatted and whole solutions (saline) are potentially good forms of coagulant in water treatment. However, it is necessary to have an appropriate structure for the preparation of the coagulant.

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