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Coagulant Activity from *Moringa oleifera* seed for Raw Water Treatment from Reservoirs

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Abstract

This research study aimed at assessing *Moringa oleifera* seeds coagulant activity in raw water turbidity removal from a reservoir; along with its influence on pH, alkalinity and true color. Saline extracts from seeds of *Moringa oleifera* were tested on raw water samples with 3 different turbidities and 3 different coagulant doses in a jar test, according to standardized procedures. Blanks and ANOVAS tables were used to verify if there were statistically significant difference in alkalinity, pH, and color after treatment, with a 95% confidence level. Researches conducted with this coagulant turned out to be very deficient and poor in the turbidity removal of the reservoir raw water, reaching 40% coagulant activity only in high turbidity samples (145 NTU). For raw water samples with low turbidity, coagulant activity was lower, even being null in 52 NTU concentrations. No statistically significant evidence of changes in treated water alkalinity was found, but alterations in pH and color were observed, suggesting a color interference caused by algae in the treatment process. Use of *Moringa oleifera* in the reservoir raw water treatment was proven possible, if there is previous removal of water true color through adsorption with activated carbon or another adsorbing agent.

Keywords: Reservoir, Turbidity, pH, Alcalinity, Color, *Moringa oleifera*, Coagulant Activity

INTRODUCTION

A reservoir is defined as a natural or artificial lake, or a large water tank, which is used for the storage and regulation of water, and as a supply source for irrigation systems or aqueducts [1]. It is one of the most important components of drinking water supply systems and can also act as a defense mechanism in flood or drought conditions [1].

There is a marked tendency of thermal stratification in water reservoirs due to prevailing lentic conditions in the water body. This stratification intensifies with the reservoir depth increase [2], consequently, water physicochemical characteristics remain homogeneous depending on the solar radiation penetration in each stratum, the region rainfall seasonality (dry season and rainy season, for the tropics) and the system anthropic contributions. Nevertheless, in tropical zones it is known that there is thermal stratification when temperature decrease is 0.2 ° C or more for each depth meter. Thus, in tropical warm reservoirs, stratification is less intense than in those located in temperate zones, mainly due to low temperature variation in the environment during the year [3]. A widespread problem in reservoirs is eutrophication phenomenon [4] due to nutrient inputs, caused by surface runoff. Furthermore, many reservoirs present high color concentrations due to algae growth, which can even eutrophicate the reservoir [5].

Broadly, reservoirs, lakes and dams have a lower and more consistent turbidity than rivers. In the same way, pH, color and other physicochemical parameters are more consistent despite passing of time [6]. Turbidity and alkalinity are physicochemical parameters of great interest in water treatment for purification purposes. Typically, raw water turbidity removal is performed using coagulants such as synthetic salts (aluminum sulfate or ferric chloride) in treatment plants. However, large doses of these synthetic coagulants are necessary for an efficient flocculation, which leads to production of large sludge quantities of metal hydroxide [7]. On the other hand, waters with low turbidity (less than 10 NTU), low alkalinity (less than 50 mg L^{-1}) and with color, such as reservoirs raw waters, are the most difficult to coagulate with metallic salts. Therefore, alkalinity or clays must be added during treatment [8].

Natural coagulants from plants, such as saline extracts of *Moringa oleifera* seeds, stand out due to high efficiency in turbidity removal in river waters and for not producing significant changes in pH and alkalinity of the treated water [9,10]. Authors such as [10] and [11] report between 90-98% coagulant activity for *Moringa oleifera* seed in raw water treatment with great turbidity (greater than 90 NTU) from the Sinu River in Colombia, when applying doses between 4.5 and 30.0 mg L^{-1}. For raw water from the Kadahokwa and Rwamamba rivers in Rwanda, reductions of 95%, 99%, and 99.8% were reported for turbidity of 50, 250, and 450 NTU respectively [12]. Similar removals were reported for raw water from a turbid Malaysian stream when *Moringa oleifera* coagulant was used in a pilot treatment plant. 21 and 202 NTU Turbidity reductions were achieved at 1.9 and 4.3 NTU concentrations, respectively [13]. Similarly, turbidity reductions from 270-380 NTU to 4 NTU [14, 15], have been achieved in large-scale treatment trials in treatment plants in Malawi. By and large, technical literature has informed that *Moringa Oleifera* powder has the capacity to reduce low, high and very high values of turbidity in surface water [16, 17]. However, there are few studies on behavior of this natural coagulant in raw water treatment from reservoirs or dams; which physicochemical characteristics are very particular.

The prime objective of this research is to assess coagulant activity of saline extracts from *Moringa oleifera* seeds in treatment of raw water from a reservoir and its influence on treated water pH, color and alkalinity.

MATERIALS AND METHODS

Samples of Raw Water

Simple samplings were carried out from March to October 2016, at the end of the dry season and the beginning of the rainy season in an artificial reservoir from rural area of Sincelejo city, Colombia, at 9 ° 16'12 "N - 75 ° 20'30" W coordinates [5]. In total, three Raw water samples were taken.

Coagulant extract Preparation

Moringa oleifera seed was extracted from dried pods manually removed from the shell and then dried at room temperature for 1 day [17]. Dry seeds were ground in manual grinder, when a fine powder was obtained, its sieved using a 0.6 mm mesh [7]. Later, 10.0 grams of seed were dissolved up to 1.0 liter - 1.0% (w/v) saline solution [7]. Solutions were mixed and filtered. The filtrate was kept cool at 4°C [7, 18].

Jar Test

An brand EyQ F6-300-T jar test equipment with six rotating blades and with six beakers (1000 mL each) was used [11]. The rotational speed of the rapid mixture was 200 rpm per 1 minute (170 s^{-1} speed gradient), followed by a slow mixture of 40 rpm per 20 minutes (22 s^{-1} speed gradient), and a 30-minute sedimentation time [10, 11, 18]. Dosages of 5, 10 and 15 mg L^{-1} from coagulant extract ware applied to each sample of raw water.

A blank was used to probe the natural coagulants activity and the turbidity removal in all jar tests. This was calculated using the following equation [11, 20-22]:

$$\%\ \text{Coagulant Activity} = \frac{Residual\ Turbidity_{blank} - Residual\ Turbidity_{sample}}{Residual\ Turbidity_{blank}} * 100$$

Equation 1.

Equipment and Physicochemical Parameters

Alkalinity, pH, turbidity and color were calculated for each samples of water before and after the jar tests. The turbidity was measured with a Thermo Orion AQ 3010 turbidimeter and the pH with an Analytics-Lab865 pH meter. Measurement protocols established in the standardized methods for the analysis of drinking and residual water according to the American Public Health Association were followed [23].

Experimental Design

For the experimental design, a 3^2 factorial design was applied: 2 factors in 3 levels. Three control were taken. The initial turbidity of raw water and applied doses of coagulant were the examined factors based on *Moringa oleifera* seeds [10]. The statistical instrument implemented for data analysis was an analysis of variance (ANOVA), using the R program. The level of statistical significance was established at $p<0.05$ for all statistical analyzes [5, 11].

RESULTS AND DISCUSSION

On Table 1, the main physicochemical characteristics from the samples of raw water taken from the reservoir for the treatability tests can be observed

Table 1. Physical-chemical characteristics of the raw water from the reservoir

Parameters	Sample 1	Sample 2	Sample 3
Turbidity (NTU)	52.00	111.00	145.00
pH	6.80	7.01	7.23
Alcalinity (mg L^{-1})	133.20	134.65	138.60
True Color (CU)	50.00	65.00	70.00

Samples turbidity varied according to year season. Sample 1 corresponds to a dry season and samples 2 and 3 correspond to a rainy period. Rainwater runoff drains organic material, silt and clays responsible, along with the reservoir water mixture caused by rainfall, for turbidity increase in in the water body. Likewise, color was a function of turbidity increase and year season. Very different values have been reported in technical literature for turbidity and color in the reservoirs. For the Saralasagar reservoir in Mahabubnagar district, Telangana, India, turbidity values between 1 and 4.8 NTU and color below

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detectable limits were reported [24], in contrast, similar studies in other reservoirs have reported turbidity ranges between 230 and 289 NTU [24, 25].

Raw water samples pH was kept in a very narrow neutrality range, between 6.8 and 7.23. These values indicate that there is a carbonates and bicarbonates balance in the reservoir [26]. This is highly important in water treatment and conservation of aquatic biota since pH affects metabolic activities of some living beings sensitive to sudden variations in pH [27]. The ideal pH range for life of many aquatic living beings is 6.5 to 8.2 [28].

Samples alkalinity were very similar to each other, with values lower than those found in the water quality standards from Colombia (200 mg L-1) [29]. There was no evidence of influence from turbidity and year season in alkalinity of samples taken from the reservoir. Alkalinity is significant in treatments of water because it reacts with coagulants of iron and aluminum salts in the flocculation process [22]. Therefore, waters with an alkalinity less than 15 mgCaCO3 L^{-1} will hardly form precipitable flocs with these coagulating salts [30]. Alkalinity values between 62 and 702 mg L^{-1} have been reported for the Guajáro reservoir [31], in northern Colombia. The samples alkalinity of the reservoir used in this study are found in this range.

True color of samples was high (between 50 and 70 CU) and much higher than the maximum value found in Colombian standards (15 CU) [29]. Obtained values may be due to algae presence in the reservoir, with a pale green color prevailing in the water body. Generally, color has a directly proportional relationship to pH and has great significance in treatment of drinking. Organic color of humic acids or algae after chlorine disinfection makes highly colored water and this can lead to chlorination byproducts occurrence such as trihalomethanes and haloacetic acids, which are carcinogenic compounds [30].

On figure 1, the results of the *Moringa oleifera* seed coagulating activity in the treatment of samples of raw water from the reservoir, are shown.

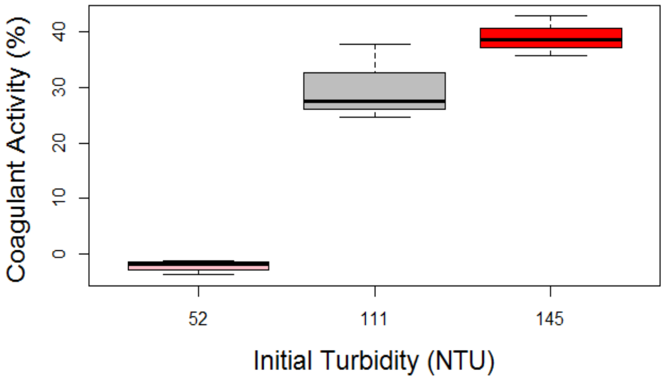

Figure 1. Coagulating activity (CA%) of *Moringa oleifera* for raw water from the reservoir

In water samples with low turbidity, the coagulant extract of *Moringa oleifera* did not have any coagulant effect, however, for 111 NTU and 145 NTU turbidities, 30% and 40% coagulant activity averages were obtained respectively. For crude shallow waters of rivers, with turbidity and pH alike, coagulant activity between 90% and 98% has been reached by using *Moringa oleifera* seeds as coagulant [10, 18]. Namely, the researches made with this coagulant for reservoirs water treatment, resulted in very low efficiencies and deficient performance.

Figure 2 shows the physicochemical parameters behavior after applying natural coagulant.

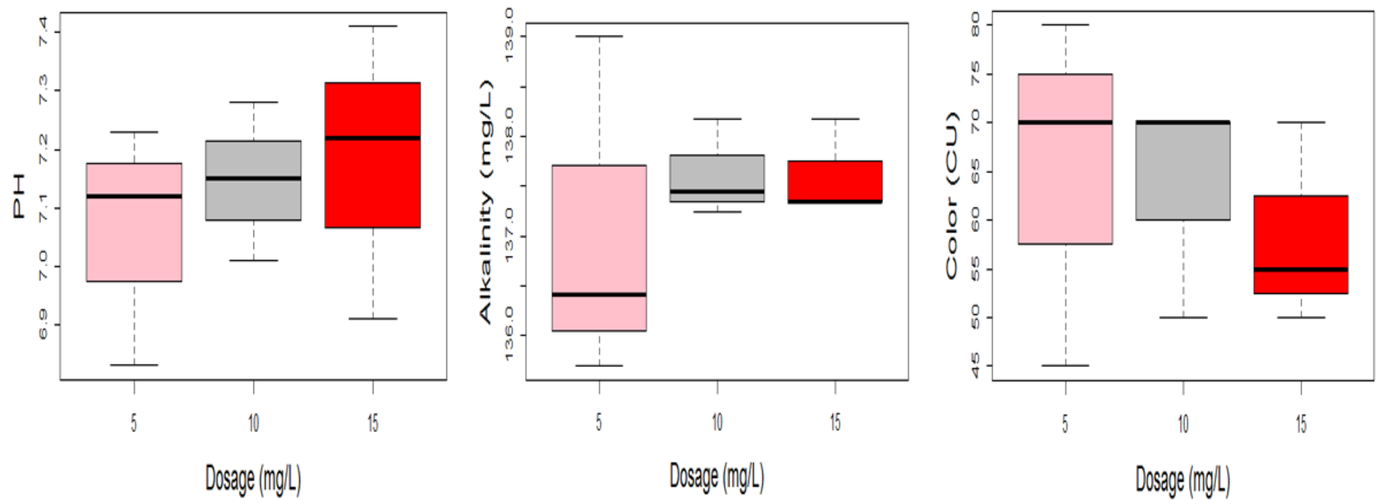

Figure 2. Behavior of pH, Alkalinity and true color in the water samples

Alkalinity, pH variability, and color concentration in each coagulant dose applied to the water samples were found through variability coefficient (VC), so that, with lower VC, greater homogeneity in the variable values [32]. For pH, VCs were between 1.9% and 3.5%, meaning that pH values of water samples were homogeneous in each applied dose. The same behavior had the sample alkalinity, with VC between 0.3% and 1.3%. Nonetheless, the color did show great variability in each of the applied coagulant doses, with VC values between 17.8% and 27.7%. To check if there was influence of statistically significant coagulant doses on the behavior of physicochemical parameters (alkalinity, pH, and color), an analysis of variance was performed in the treated samples. P values were found once normality assumptions, variances homogeneity and independence of ANOVA residues were demonstrated. In table 2, the ANOVA result is shown.

Table 2. ANOVA P Values for pH, Alkalinity and True Color

Parameters	P Values
pH	0.00048
Alkalinity (mg$CaCO_3$ L^{-1})	0.230
True Color (CU)	0.023

It was demonstrated that there were no statistically significant differences in the alkalinity of samples (P-value> 0.05), with a 95% confidence level [32], but it was observed that there were statistically significant differences in the pH and true color of the samples (P-value <0.05). These results show the possible interference of the samples high color in the coagulation process, due to algae presence in the reservoir. Functional groups and concentration of aromatic chains in water can influence coagulation efficiency, as well as variation of their molecular masses [34]. The humic substances seem to interact with the positively charged aluminum compounds to form a heavy precipitate formed by fulvic acid and aluminum depending on the raw water pH (low pH of 6 to 7) [35]. However, they did not seem to interact significantly with the protein agents from the *Moringa oleifera* seed and its coagulating activity.

CONCLUSIONS

Researches carried out for the natural seed coagulant of *Moringa oleifera* demonstrated to be very deficient and with a deficient performance in the treatment of raw water from reservoirs, even with high turbidity concentrations, regardless of applied dose. There were no statistically significant changes in alkalinity of treated samples but in pH concentrations and true color, suggesting that the color caused by algae presence in the water body, could have caused interference in the coagulation-flocculation process. Before using this natural coagulant for raw water treatment from a reservoir, it is necessary to remove true color by adsorption processes with activated carbon or another adsorbing agent.

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