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USE OF MORINGA SEED (*Moringa oleifera Lam*.) AS A BIOCOAGULANT TO IMPROVE SURFACE WATER QUALITY

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Abstract

Using Moringa oleifera (Moringa oleifera Lam.) seed as a biocoagulant to enhance surface water's physical and chemical quality was the goal of this study. The methodology applied for the generation of experimental data was through the use of the Jar Test equipment, in a dose of 40 mg/L to 140 mg/L, then a fast mixing of 100 rpm for 1 minute and a slow mixing of 40 rpm for 10 minutes was performed, and sedimentation was left for 5 to 30 minutes, with 5 minutes intervals between each dose. The results show that an optimal biocoagulant dose of 100 mg/L at 20 minutes produced a turbidity reduction effectiveness of 97.06%. Hardness fell by 12% of its starting value, conductivity and total dissolved solids increased dramatically, and there was a 92.3% reduction in perceived colour, which showed that the use of Moringa seeds as a coagulant had a favourable effect on reducing the concentration of turbidity and colour. Because of this, Moringa (Moringa oleifera Lam.) can be used as a natural source to purify drinking water. The Tukey HSD test applied to the turbidity removal percentages, indicates that the means are not significantly different. However, the experimental evaluation indicates that after 20 minutes, the best results are obtained.

Keywords: Bioadsorbent, biocoagulant, Coagulation, Moringa, Turbidity.

1. Introduction

In many regions of the world, water is an increasingly scarce resource due to population growth and the resulting domestic, industrial, agricultural, livestock, mining and other activities. This situation causes a high demand and generates the search for new sources of supply; thus, water becomes a common good that must be preserved to maintain a permanent supply and ensure life in the cities [1]. Certain places are subject to rising demand for drinking water and intricate treatment and supply systems because of the urban sprawl dynamics and population density increase [2]. There is ample evidence that households in developing nations have access to and can use multiple types of water sources, which complicates analyses of water demand because this is not the case in most affluent countries [3].

The community requires water, which is crucial, especially for drinking clean water [4], so water quality for human consumption is essential. According to [5], the assessment and control of water transmitted diseases are vital since the quality of drinking water directly impacts human health.

One of the primary techniques for increasing the general effectiveness of the treatment and the financial viability of water and wastewater treatment is coagulation-flocculation [6]. However, the rural population lives in extreme poverty and consumes untreated water due to the water treatment method and the escalating cost of harmful coagulants [7]. In this regard, one current hot study area is the enhancement of the coagulation process [8].

Due to their advantages over chemical coagulants, natural coagulants have become increasingly popular in the water and wastewater treatment business, and they derive from plants, animals or microorganisms [9]. In the present research, the coagulant property of Moringa (*Moringa oleifera Lam*.), which is a multifunctional tropical tree whose seeds contain premium edible oil (up to 40% by weight) and water-soluble proteins that work as efficient coagulants for water and wastewater treatment, was evaluated [10].

Based on the above, there is a clear trend towards using coagulants of natural origin, which have certain advantages over commercial coagulants commonly used in water treatment, ranging from the high cost of commercial coagulants to the problem of contamination by the sludge generated. In this sense, the objective of this research is to improve the physical and chemical quality of the surface water of the Ahuashiyacu river in the San Martin region of the Peruvian Amazon, using Moringa seed (*Moringa oleifera Lam*.) as a biocoagulant.

2. Material and methods

The research analysed the activity of the biocoagulant obtained from Moringa (*Moringa oleifera Lam*.) seeds using a jar equipment, where the concentrations, speed and mixing time were varied, evaluating its effect on the parameters of turbidity, colour, conductivity and total dissolved solids.

2.1. Materials

The equipment and reagents used in the present investigation are: HACH 2100Q turbidimeter, HACH HQ40 conductivity meter, total dissolved solids were determined with the HACH HQ40 equipment. In addition, a PHIPPS & BIRD 7790-900B Jar Test kit was used and Ethanol (96%) and 1 M NaCl were used as reagents.

2.2. Procedure

It was carried out in the following stages: Moringa seed collection, drying, defatting, sieving (250 µm), and refrigerating at 4 °C [11]. The biocoagulant was extracted with 1 M NaCl, at 60 rpm for 10 min, filtering on 1.2 µm paper; defatting of the seed was done with ethanol (90%) at 1300 rpm with subsequent drying. For the extraction of the biocoagulant, 50 g of Moringa powder was added to 1 litre of NaCl solution for 10 minutes, mixed in a magnetic stirrer at 60 r.p.m., and the remainder was filtered on 1.2 µm filter paper [12]. At different agitation speeds (100, 150, 200, 250, and 300 rpm), doses of 40, 60, 80, 100, 120, and 140 mg/L were applied for coagulation, flocculation, and sedimentation. The mixing times were 1 minute for fast mixing, 10 minutes for slow mixing, and 5 to 30 minutes for sedimentation. Each Jar test beaker had a different dose of the biocoagulant (1, 2, 3, 4, 5, and 6 ml) before the analyses were conducted.

2.3. Data analysis

Data were processed using SPSS v.25 and Microsoft Excel statistical software. To ascertain whether there are any significant variations between pre-treatment and post-treatment values for each of the parameters assessed, the results were examined using analysis of Tukey HSD at a 95% confidence level and 5% significance.

3. Results

3.1. Surface water characterization

Table 1 shows the physicochemical parameters (turbidity, total dissolved solids, colour and conductivity) of six samples selected from the Ahuashiyacu river in different zones, trying to obtain different and increasing values of turbidity with the aim of carrying out treatments to varying doses of biocoagulant and observing its effect on coagulation activity.

Table 1. Initial physicochemical water parameters.

Sample	Turbidity (NTU)	Total dissolved solids (mg/L)	Colour (PCU)	Conductivity (µS/cm)
M1	30	60.3	10	122.3
M2	128	85.9	30	174.4
M3	135	98.1	45	199.3
M4	385	89.7	53	182.1
M5	471	102	65	207.2
M6	632	136	128	276.6

3.2. Effect of moringa on turbidity, colour, total dissolved solids (TDS) and conductivity

Figure 1 shows the effect of biocoagulant doses on the percentage of turbidity removal with different settling times. Each section of the graph corresponds to samples M1, M2, M3, M4, M5 and M6 treated with initial turbidity data of 30, 128, 235, 385, 471 and 632 NTU. The doses of natural biocoagulant used were 40, 60, 80, 100, 120 and 140 mg/L.

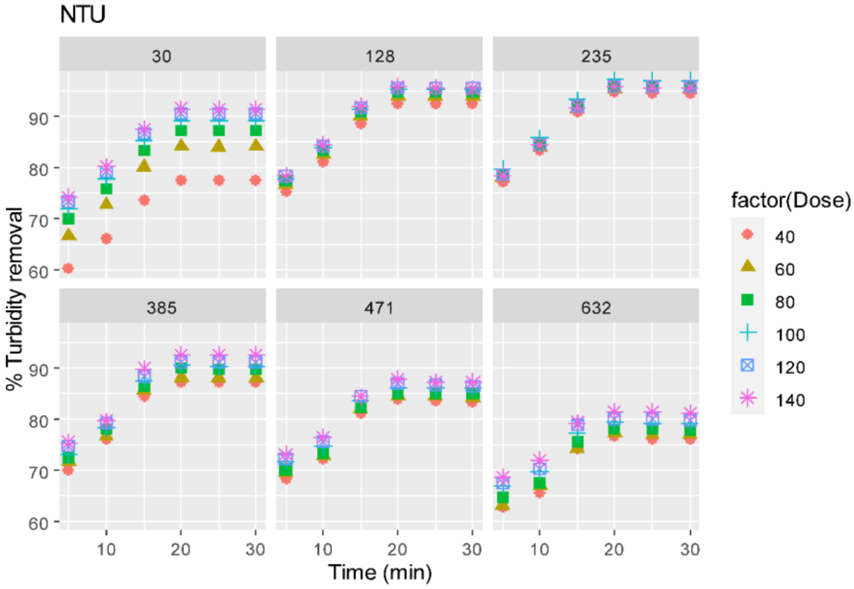

Fig. 1. Effect of biocoagulant and settling time on coagulation activity.

Figure 2 shows the effect of biocoagulant doses on the percentage of colour removal at different initial apparent colours. The rate of colour removal is determined from the biocoagulant treatment of samples (M1 to M6) with initial colour data, as indicated in Table 1. The dosages of biocoagulants are the same for the evaluation of all physicochemical parameters as shown in the procedure.

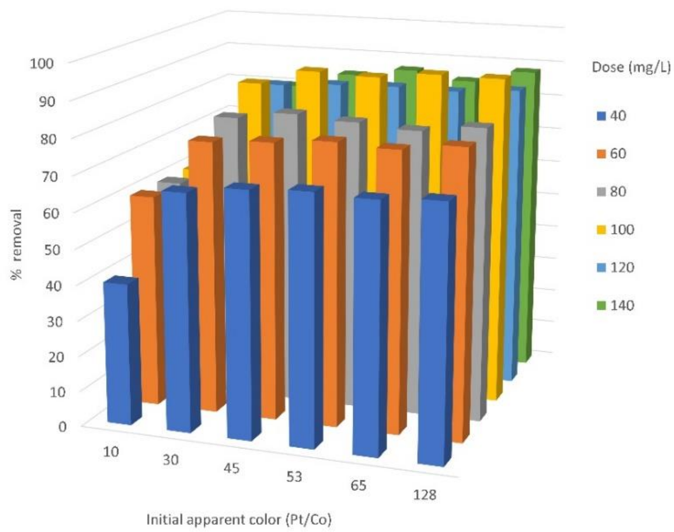

Fig. 2. Effect of biocoagulant on apparent water colour.

Figure 3 shows the effect of moringa on total dissolved solids. The biocoagulant doses are the same, and the initial TDS concentrations correspond to samples M1 to M6, whose values are also given in Table 1.

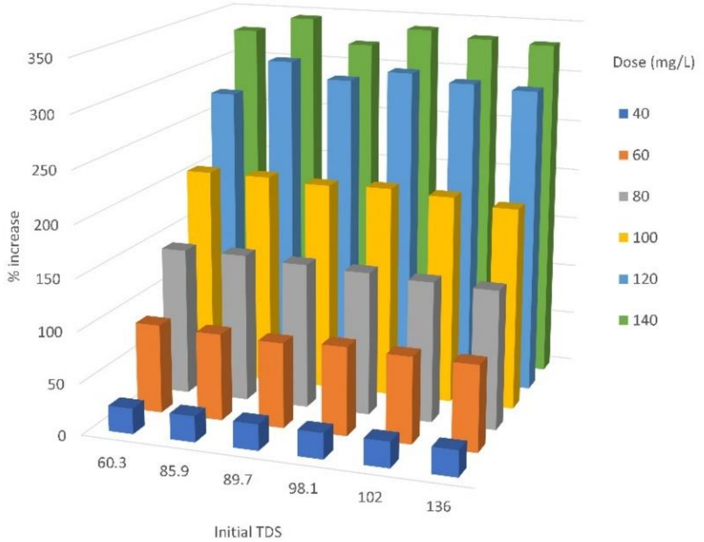

Fig. 3. Effect of biocoagulant on total dissolved solids (TDS).

Figure 4 shows the effect of moringa on conductivity. The biocoagulant doses are the same, and the initial TDS concentrations correspond to samples M1 to M6, whose values are also in Table 1.

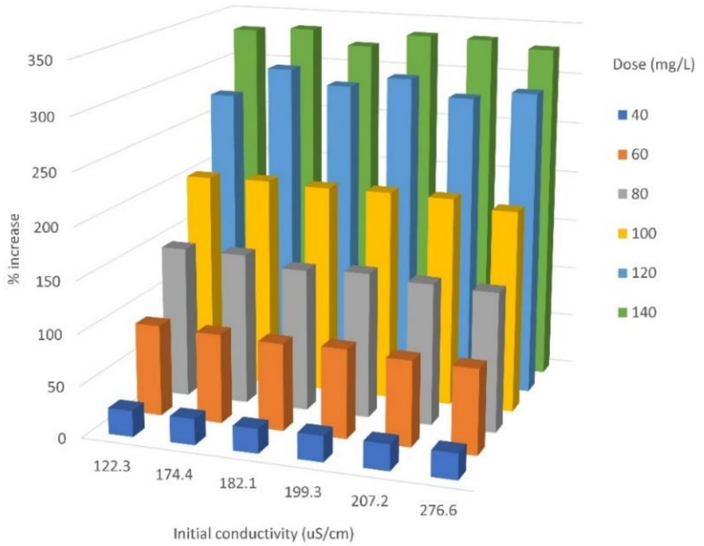

Fig. 4. Effect of biocoagulant on water conductivity.

3.3. Statistical tests

Table 2 shows the means of the turbidity removal percentages as a function of the biocoagulant doses analysed with the Tukey HSD test.

Table 2. Testing of homogeneous subsets for biocoagulant doses.

HSD Tukey			
Biocoagulant dose mg/L	**N**	**Media**	**Group**
140	36	85.55	A
120	36	84.90	A
100	36	84.43	A
80	36	83.22	A
60	36	82.02	A
40	36	80.07	A
p value	0.074		

Table 3 shows the means of the turbidity removal percentages as a function of settling times analysed with the Tukey HSD test.

Table 3. Homogeneous subset test for settling time.

HSD Tukey					
Settling time min	**N**	**Media**	**Group**		
5	36	72.32			C
10	36	77.24		B	
15	36	85.25	A		
30	36	88.39	A		
25	36	88.43	A		
20	36	88.56	A		
p value		0.000			

4. Discussion

4.1. Turbidity, colour, total dissolved solids and conductivity

Moringa is proteinaceous and soluble in nature [13], also containing glutamine, arginine, proline and other residues. The protein has eight positively charged amino acids and 15 glutamine residues [14]. Sodium chloride, in low concentration, improves the activity of the biocoagulant as it increases the solvating power or solubility of the protein (explained by the Debye Huckel Theory). At high salt concentrations, the solubility of the protein in water decreases because the solvating power also decreases, which is explained by John Gamble's Principle [15].

In the case of dose, treatments with a biocoagulant dose of 40 mg/L had the lowest turbidity removal activity. The highest turbidity removal effectiveness was 97.06%, using a dose of 100 mg/L for an initial turbidity of 235 NTU and a settling time of 20 minutes (Table 1, Fig. 1). Moringa seed validates its potential to act as a natural coagulant in water treatment, as its dimeric cationic proteins neutralize and adsorb particles present in water [16]. Due to electrostatic interactions, the negatively charged particles of the contaminants are attracted by the cationic charges of the Moringa oleifera protein, leading to the accumulation of the particles, elevation of their molecular weight and subsequent sedimentation [14]. However, it was found that removal decreases with turbidities of 385 NTU, 471 NTU and 632 NTU. A charge imbalance or concentration gradient between adsorbent and adsorbate will result in particle stabilisation [17]; in this case, it is observed that if the starting turbidity increases from a certain point, the removal starts to decrease despite working with the same doses of biocoagulant and settling times; in light of these results, an unbalance of loads is present here and higher amounts of biocoagulant will be required to destabilise the loads present.

This corroborates the assumption of [18] that maximum efficiency can be achieved when coagulant dose and turbidities are at optimum levels. The turbidity removal effectiveness of this study is similar with achieving a reduction efficiency of 88.75%, applying coagulant from Moringa [19]; while 100% removal was conducted using a dose of 0.34 mg/L of Moringa saline solution [20].

Regarding the settling time, a maximum turbidity removal (97.06%) was obtained after 20 minutes, a value higher than that studied by [21], who mentions having achieved a turbidity removal of 94% after 60 minutes, using a dose of 70 mg/L of Moringa seed solution as a biocoagulant for initial turbidity levels of 438, 486 and 499 NTU.

The apparent colour of the water, as well as the turbidity, has a similar behaviour concerning an optimal dose of Moringa biocoagulant (Fig. 2). With an initial apparent colour of 65 PCU scale, a maximum reduction of 92.3% was achieved with a dose of 100 mg/L biocoagulant. The evident colour reduction of this study is lower than that acquired by [20], who using 0.34 mg/L of biocoagulant based on Moringa seed, achieved 100% reduction; in contrast, [22] had favourable results, reducing the colour by 86.23% of the initial colouration greater than 100 PCU of water samples, using a dose of 275 mg/L of Moringa seed extract extracted in saline solution.

TDS have a directly proportional relationship with the natural Moringa biocoagulant; the more biocoagulant added, the higher the total solids obtained (Fig. 3). At the optimum achieved dose of 100 mg/L to remove the initial turbidity of the water, the TDS increases by 202.3%. A removal of 25% was also reported [23], which increased TDS in treatments where they used 40 mg/L Moringa seeds in saline solution (NaCl) as a biocoagulant. The results are in agreement with those obtained in this research, where using the same dose of Moringa biocoagulant in saline solution, the TDS increases on average by 25.1%.

Conductivity is related to TDS. In Fig. 4, it can be seen that the conductivity of the water after the addition of the Moringa solution increases on average by 202.6 % of its initial value, using doses of 100 mg/L biocoagulant. This behaviour was also reported by [23], who using a saline solution of Moringa at a concentration of 40 mg/L, reported an increase of 39.3%; Sodium chloride ions in the solution are the cause of this. It is further stated that using a coagulant based on Moringa seed does not affect the conductivity, which remains at its initial value [16].

4.2. Statistical tests

The Tukey HSD test applied to the turbidity removal percentages as a function of biocoagulant doses, as reported in Table 2, indicates that the means are not significantly different due to the parameter $p > 0.05$; however, the same test applied to the settling time, Table 3, reports that the means for the times of 5 and 10 minutes are significantly different. The interpretation according to these data is that the treatment with the biocoagulant becomes relevant after 5 minutes, and after 15 minutes, the results can be similar; the experimental evaluation indicates that after 20 minutes, the best results are obtained.

5. Conclusions

The optimum dose of the natural moringa biocoagulant is 100 mg/L as maximum removals of 97.06% turbidity and 92.03% apparent colour were achieved under a settling time of 20 minutes for both; however, total dissolved solids increased to 202.3% and conductivity to 202.6% at the same dose and settling time. TDS and conductivity are connected; the latter values rise sharply due to the sodium chloride ions in the biocoagulant. The action of the biocoagulant studied lies in the presence of dimeric cationic proteins. This biocoagulant can be applied as a natural source of water treatment for human consumption due to its low toxicity. It is recommended to investigate the quantity, treatment and usefulness of the sludge generated when using the natural biocoagulant based on Moringa seeds. The Tukey HSD test indicates that the means of the turbidity removal percentages are not significantly different and for the settling time indicates that the means are significant for 5 and 10 minutes. Experimentally the best results were observed after 20 minutes.

Nomenclatures

HSD	Honestly-significant-difference
N	Number of samples
NTU	Nephelometric Turbidity Units
PCU	Platinum-Cobalt Units
TDS	Total dissolved solids

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