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EVALUATION OF THE ASSOCIATION OF COAGULANTS POLYALUMINUM CHLORIDE (PAC) AND MORINGA IN WATER TREATMENT

AVALIAÇÃO DA ASSOCIAÇÃO DOS COAGULANTES POLICLORETO DE ALUMÍNIO (PAC) E MORINGA NO TRATAMENTO DE ÁGUA

EVALUACIÓN DE LA ASOCIACIÓN DE COAGULANTES CLORURO DE POLIALUMINIO (PAC) Y MORINGA EN TRATAMIENTO DE AGUAS

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ABSTRACT
Objective: This study aims to evaluate the efficiency of the combination of PAC and Moringa Oleifera Lam coagulants in removing apparent color and turbidity from water, in order to obtain ideal operating conditions for the coagulation/flocculation and sedimentation process. **Method:** Two stages were performed, each stage having five tests, with analysis of the pH, turbidity, color and alkalinity parameters, performed in the Jar Test. The time and gradient of rapid mixing were, respectively, 60 seconds with a speed of 299 rpm. Slow mixing was divided into two 10-minute periods, with a decreasing gradient of 60 and 50 rpm. After the coagulation and flocculation process, the samples were left to rest for 2 hours so that the particles could sediment. During sedimentation, samples were collected from each jar, with a volume of 20 ml, at the following time intervals: 0, 10, 20, 30, 45, 60, 90 and 120 min. In the analysis of the color and turbidity parameters, there were also two stages. In the first stage, the coagulant aid, Moringa Oleifera Lam, at concentrations of 200, 250, 300, 350 and 400 $mg.L^{-1}$, was associated with 15 $mg.L^{-1}$ of fixed PAC. **Results:** The analyses showed that the concentration of 400 $mg.L^{-1}$ presented the best efficiency, with values of 69% for color and 92% for turbidity. In the second stage, the test ranges of 15, 30, 45 and 60 $mg.L^{-1}$ were used for PAC, and a fixed concentration of Moringa Oleifera Lam of 400 $mg.L^{-1}$. The tests demonstrated the greatest efficiency in the second stage, with the increase in the PAC dosage. **Conclusion:** Therefore, the tests carried out in Jar Test can be considered of great value, since they will guide the procedures applicable on a real scale.
Keywords: *Public Health; Basic sanitation; Drinking water.*

RESUMO
Objetivo: O estudo propõe avaliar a eficiência da associação dos coagulantes PAC e Moringa Oleifera Lam na remoção de cor aparente e turbidez da água, a fim de se obter as condições de operações ideais para o processo de coagulação/floculação e sedimentação. **Método:** Foram realizadas duas etapas, em que cada etapa tinha cinco ensaios, com análise dos parâmetros de pH, turbidez, cor e alcalinidade, realizados no Jar Test. O tempo e o gradiente de mistura rápida foram, respectivamente, de 60 segundos e velocidade de 299 rpm. A mistura lenta dividiu-se em dois tempos de 10 minutos, com gradiente decrescente de 60 e 50 rpm. Depois do processo de coagulação e floculação, as amostras foram mantidas em repouso durante 2 horas, para que as partículas fossem sedimentadas. Durante a sedimentação, foram coletadas amostras de cada jarro, com volume de 20 ml, nos intervalos de tempo: 0, 10, 20, 30, 45, 60, 90 e 120 min. Na análise dos parâmetros de cor e turbidez, também houve duas etapas. Na primeira etapa, foi associado o auxiliar de coagulante, Moringa Oleífera Lam, nas concentrações de 200, 250, 300, 350 e 400 $mg.L^{-1}$, com 15 $mg.L^{-1}$ de PAC fixo. **Resultados:** As análises mostraram que a concentração de 400 $mg.L^{-1}$ apresentou a melhor eficiência, com valores de 69% para a cor e 92% para a turbidez. Na segunda etapa, foram utilizadas as faixas de teste de 15, 30, 45 e 60 $mg.L^{-1}$ para o PAC, e concentração fixa de Moringa Oleifeira Lam de 400 $mg.L^{-1}$. Os ensaios demostraram a maior eficiência na segunda etapa, com o aumento da dosagem do PAC. **Conclusão:** Logo, pode-se considerar de grande valia os ensaios realizados em Jar Test, uma vez que estes guiarão os procedimentos aplicáveis em escala real.
Descritores: *Saúde Pública; Saneamento básico; Água potável.*

RESUMEN
Objetivo: Este estudio tiene como objetivo evaluar la eficiencia de la combinación de los coagulantes PAC y Moringa Oleifera Lam en la remoción de color aparente y turbidez del agua, con el fin de obtener condiciones ideales de operación para el proceso de coagulación/floculación y sedimentación. **Método:** Se

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realizaron dos etapas, cada etapa con cinco pruebas, con análisis de los parámetros pH, turbidez, color y alcalinidad, realizados en el Jar Test. El tiempo y gradiente de mezcla rápida fueron, respectivamente, 60 segundos con una velocidad de 299 rpm. La mezcla lenta se dividió en dos períodos de 10 minutos, con un gradiente decreciente de 60 y 50 rpm. Después del proceso de coagulación y floculación, las muestras se dejaron reposar durante 2 horas para que las partículas sedimentaran. Durante la sedimentación, se recolectaron muestras de cada jarra, con un volumen de 20 ml, en los siguientes intervalos de tiempo: 0, 10, 20, 30, 45, 60, 90 y 120 min. En el análisis de los parámetros de color y turbidez, también se contó con dos etapas. En la primera etapa, el coadyuvante coagulante, Moringa Oleifera Lam, en concentraciones de 200, 250, 300, 350 y 400 mg.L^{-1}, se asoció a 15 mg.L^{-1} de PAC fijado. **Resultados:** Los análisis mostraron que la concentración de 400 mg.L^{-1} presentó la mejor eficiencia, con valores de 69% para color y 92% para turbidez. En la segunda etapa, se utilizaron los rangos de ensayo de 15, 30, 45 y 60 mg.L^{-1} para PAC, y una concentración fija de Moringa Oleifera Lam de 400 mg.L^{-1}. Los ensayos demostraron la mayor eficiencia en la segunda etapa, con el aumento de la dosis de PAC. **Conclusión:** Por tanto, las pruebas realizadas en Jar Test pueden considerarse de gran valor, ya que orientarán los procedimientos aplicables a escala real.
Descriptores: *Salud pública; Saneamiento básico; Agua potable.*

INTRODUCTION

In recent decades, the disorderly occupation of land use, especially in metropolitan regions, has contributed significantly to the reduction of the quality of water resources. According to Tundisi1, the disorderly advance on water sources brings problems that are considered permanent with regard to the availability of drinking water. For this reason, the search for new water treatment technologies is increasingly necessary.

In Brazil, the ordinance that regulates the treatment of water for supply purposes, in different processes and operations, to adapt the water from the springs to the potability standards required by the Ministry of Health, is Consolidation Ordinance No. 20/2017, which "provides for the control and surveillance procedures of the quality of water for human consumption and its potability standard"[2].

In the processes involved in water treatment, one of the main steps in the search for good quality consists of the addition of synthetic or natural coagulants, such as Polyaluminum Chloride (PAC) and Moringa Oleifera Lam, respectively.

According to Moreti *et al*[3], the use of natural products, such as moringa in water treatment, proves to be a form that is not harmful to the environment and consumers, as well as involving low production costs. Moringa Oleifera Lam stands out as a coagulant in water clarification, mainly due to the presence of a soluble cationic coagulant protein capable of reducing the turbidity of treated water[4].

On the other hand, the synthetic coagulants most used in Water Treatment Plants (WTPs) are inorganic coagulants, usually trivalent salts of Iron (Fe) and Aluminum (Al), mainly because they have low cost and the ability to efficiently coagulate water. An example of a synthetic coagulant is Polyaluminum Chloride (PAC), widely used due to its efficiency and low toxicity, and is generally effective in a pH range between 6 and 9[4.5].

Although chemical coagulants are the most widely used, they are not always available at affordable prices for low-income populations or rural communities. To overcome this difficulty, natural coagulants have been tested/used, as they have low costs, such as Moringa Oleifera Lam6. Moringa is a plant belonging to the Moringaceae family, which is composed of only 1 genus (Moringa) and 14 species. However, the mechanism of action is not yet well defined. In the characterization of the Moringa Oleifera Lam seed, there is a high content of proteins and lipids[7]. Gidde, Bhalerao and Malusare[8]

observed 37% protein, 37% lipid and 16% carbohydrate in the composition of the moringa seed.

In the studies by Muthuraman, Sasikala and Prakash[9] and Pritchard et al[10], the existence of risks related to the use of moringa seeds in water treatment was not proven, as well as there was no evidence that the seeds could cause side effects, such as toxicity to humans, at the dosages practiced in the coagulation stage.

Within this context, this study proposes to evaluate the efficiency of the association of PAC and Moringa Oleifera Lam coagulants in the removal of apparent color and turbidity from water, in order to obtain the ideal operating conditions for the coagulation/flocculation and sedimentation process.

METHODS

COLLECTION AND CHARACTERIZATION OF RAW WATER

Samples of raw water were collected from the Maranguapinho River dam, located in the city of Maranguape in the state of Ceará (CE), specifically in the Novo Maranguape II neighborhood. The dam is located between the limits of the cities of Maracanaú and Maranguape and is located approximately 18 km from the municipality of Fortaleza, as can be seen in Figure 1.

Figure 1 - Maranguapinho River Dam, between the cities of Maracanaú and Maranguape.

Source: Google Earth Pro

For the collection, three containers were used, with a unit capacity of 20 L. The parameters analyzed for the raw water were: pH, Alkalinity, Turbidity (NTU) and Color (uH). The analyses were carried out at the Integrated Laboratory of Water from Springs and Wastewater (LIAMAR) at the Federal Institute of Ceará (IFCE) – Fortaleza Campus.

Table 1 contains the methods used to determine these parameters, according to Silva's Manual of Physicochemical Analysis of Supply and Wastewater[11].

Table 1 - Parameters analyzed of the raw water of the Maranguapinho River, Maranguape, Ceará (CE), Brazil, 2019.

Parameter	Method and Equipament
pH	Electrometric and pH meter
Alkalinity	Potentiometric
Colour	Spectrophotometric and HACH/DR 2800
Turbidity	Nephelometric and Turbidymeter

Source: Silva[11]

PREPARATION OF THE LAM OLEIFERA MORINGA SOLUTION

The dry pods were harvested on the campus of the Federal University of Ceará (UFC); Then, the seeds were removed from the pods, peeled and macerated in the mortar, to obtain the fine powder. After this step, the standard 1% (w/v) solution was prepared, in which: 1000 mg of seed powder was added to the 100 ml volumetric flask and completed with distilled water.

PREPARATION OF THE LAM OLEIFERA MORINGA SOLUTION

The solution of Aluminum Sulfate $Al_2(SO_4)_3$ was prepared from a standard 1%(w/v) solution, with the addition of 10 g of PAC 23 Suall to 1 L of distilled water.

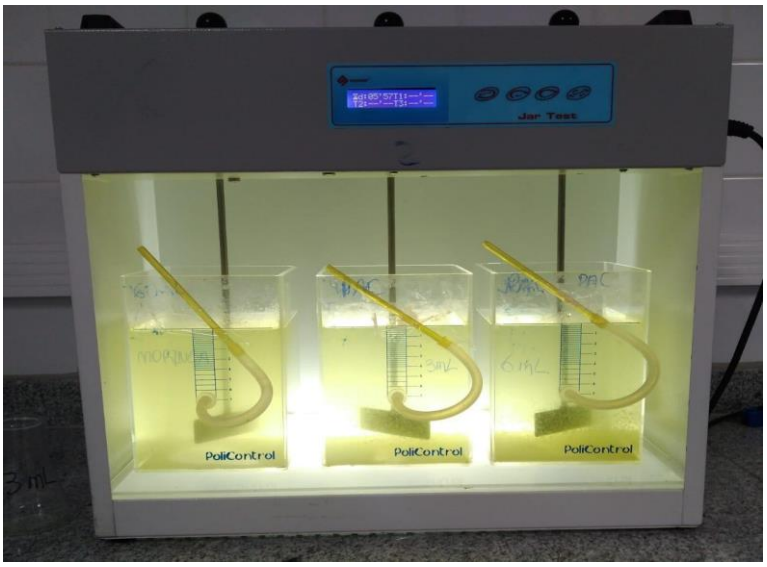
COAGULATION AND FLOCCULATION ASSAY

The tests were carried out at the Integrated Laboratory of Water Springs and Wastewater (LIAMAR), at the Federal Institute of Ceará (IFCE) – Fortaleza Campus, using the *Jar Test*, according to Figure 2.

It should be noted that the collection was carried out in November 2019, a period of little rain, which contributes to lower values of turbidity and color, unlike the rainy season, in which color and turbidity can have a significant increase.

2 stages were performed: the first with five trials to determine the optimal conditions of Moringa Oleifera Lam, and the second, subdivided into two stages: one trial to determine the efficiency of Moringa without association and the second with four trials to determine the optimal conditions of PAC, associated with moringa as a coagulation aid. The *Jar Test* used contains three jars, with a capacity of 2L each, so that all were filled with the water collected from the dam of the Maranguapinho River.

Figure 2 - Trials using the Jar Test.



Fonte: Author (2019)

According to Veras, Mendonça and Ferreira[12], the Maranguapinho River dam receives contributions from open sewage, cattle pastures and burnt garbage in the dam area. Such scenarios cause an increase in nutrients and, consequently, increase the apparent color of the water. In this context, it was necessary to apply an oxidant to reduce the organic matter present in the collected water samples, in order to facilitate the coagulation, flocculation and sedimentation stages. For the oxidation stage, 20 mg was used. L^{-1} of Calcium Hypochlorite [$Ca(ClO)_2$], based on the methodology adopted by Veronezi-Viana et al[13], with a velocity gradient of 100 s-1 and a detention time of 20 minutes.

TEST TO DETERMINE THE OPTMAL AMOUNT OF MORINGA OLEIFERA LAM SOLUTION

After the coagulation, flocculation and sedimentation assays, the concentrations of the coagulant auxiliary were defined for the performance of five assays with different concentrations for the jars: 200; 250; 300; 350 and 400 ($mg.L^{-1}$). These concentrations were used based on the methodology adopted by Rorato[14], in which the author adopted the range with the highest treatment efficiency. Then, for the PAC coagulant, a single value of 15 mg was defined. L^{-1} for each test, which allowed obtaining the highest efficiency value of the adopted range for the treated water. The fast-mixing time was set at 60s, with a gradient velocity of 6 13.2 s^{-1}. The slow mixture was divided into two 10-minute times, with a decreasing speed gradient of 52.12 and 40.88 s^{-1}. After the coagulation and flocculation process, in order for the particles to be sedimented, the samples were kept at rest for 2 hours.

During sedimentation, for the analysis of color and turbidity parameters, samples were collected from each jar, with an approximate volume of 20 ml, at the following time intervals: 0, 10, 20, 30, 45, 60, 90 and 120 min.

With the end of the sedimentation process, it was possible to obtain the interval in which the moringa solution proved to be more effective, and this value was then adopted

as the single value for the subsequent step. The pH and Alkalinity parameters of the post-treated water were also analyzed for each assay.

TEST TO DETERMINE THE OPTMAL AMOUNT OF CHLORIDE (PAC) SOLUTION

In this stage, the interval of the moringa solution, which proved to be more efficient, was adopted to perform the five assays. It is noteworthy that, for the first assay, only the $Ca(ClO)_2$ oxidant and the moringa solution were used, which aimed to show the efficiency of the natural coagulant in the removal of colloidal and suspended particles in the water. Therefore, 400 mg was used.L^{-1} of moringa, the most efficient concentration.

The amount of PAC set in the step of determining the optimal amount of moringa was 20 mg. L^{-1}, and to obtain a test interval that can observe the efficiency of the coagulant with lower and higher concentrations, than the one that has already been used, the following amounts were used in the four assays: 15, 30, 45 and 60 mg. L^{-1}. The values of slow mixing time, fast mixing, sedimentation, and velocity gradient, as well as the determination of pH and alkalinity parameters, were the same used in the step of determining the optimal amount of moringa, described in the previous item.

RESULTS

RAW WATER CHARACTERIZATION

The results obtained in the characterization of the raw water for the CAP tests associated with moringa are shown in Table 2, with the parameters analyzed and their respective results.

Table 2 - Characterization of the raw water of the Maranguapinho River, Maranguape, Ceará (CE), Brazil, 2019.

Parameters Analyzed	Results
Apparent colour (uH)	155
Turbidity (NTU)	42
pH	8,25
Alkalinity	88,08

Source: Author (2019)

It is observed that the turbidity and color, in the first analysis, were relatively high. It should be noted that, next to the Maranguapinho River, there is a sanitary landfill that receives domestic and industrial waste from Maracanaú and Maranguape, which, according to technical standards, is an inadequate procedure in the packaging of industrial waste. The effluents from the leachate treatment plant of the Maracanaú landfill are sent to an open-air channel, which flows into a tributary of the Maranguapinho River, directly influencing the color and turbidity of the water.

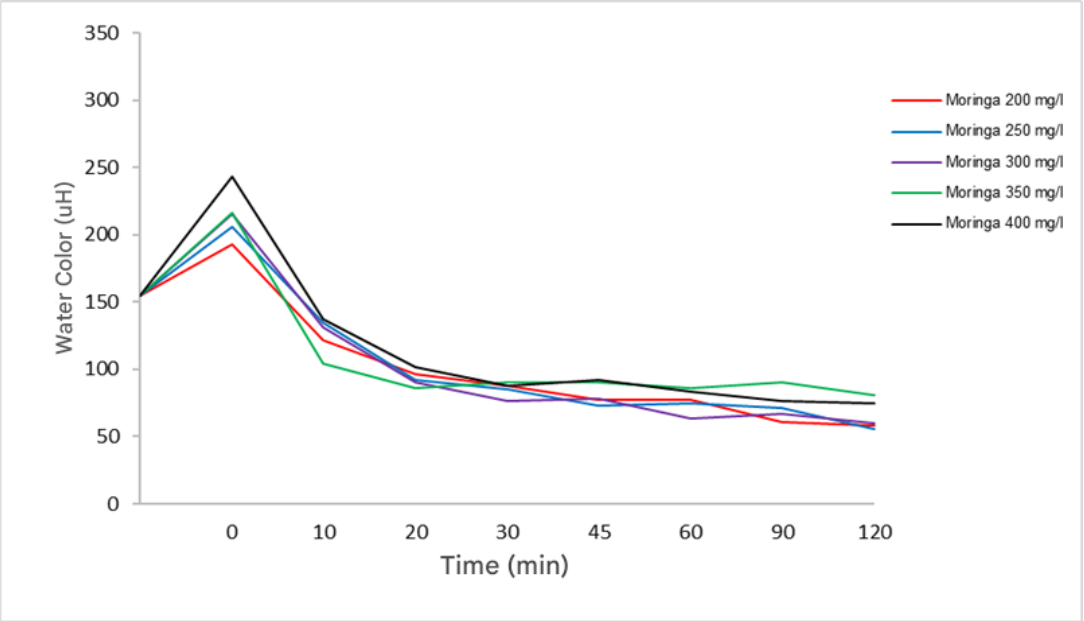
In addition, near the dam, there is no basic sanitation, and the more distant areas pollute the urban stretches of the tributary rivers with clandestine sewage, which leads to an increase in the eutrophication process, as well as a decrease in water quality, leading to the presence of microalgae and cyanobacteria and pathogenic microorganisms, also causing difficulties in water treatment and diseases for the population. Hence the

importance of the pre-oxidation process for the removal of such organisms. In view of this, it is possible to note the efficiency of the use of oxidants in the treatment of water with cyanobacteria, such as the water studied in the Maranguapinho River dam.

RESULT OF THE OPTIMAL AMOUNT OF MORINGA OLEIFERA LAM

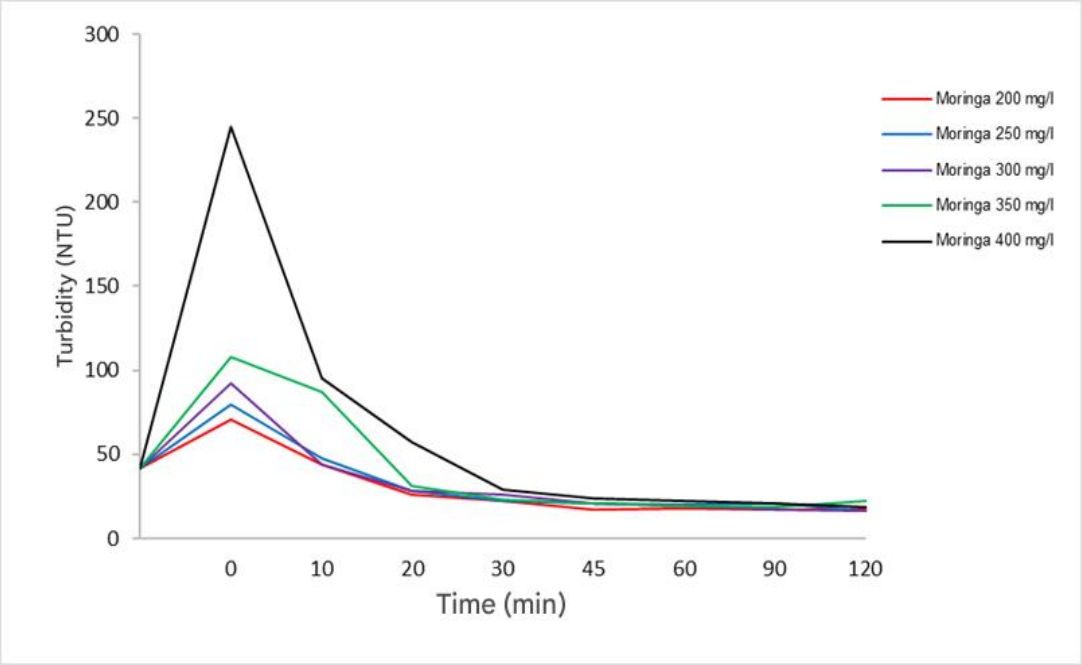
The action of coagulants essential for the destabilization of colloidal and suspended particles carried out by the conjunction of physical actions and chemical reactions is emphasized**.** And through the analysis of the results obtained, in the association of the coagulant auxiliary Moringa Oleifera Lam, with the concentrations of 200, 250, 300, 350 and 400 ($mg.L^{-1}$) and 20 $mg.L^{-1}$ of PAC, to identify the most efficient amount of moringa, the one that showed the best result was the concentration of 400 mg. L-1, with an efficiency of 69% in color reduction and 92% in turbidity removal. The other concentrations of 200, 250, 300 and 350 (mg. L-1) had efficiencies of: 70% (color) and 76% (turbidity); 73% (color) and 79% (turbidity); 72% (color) and 82% (turbidity); 63% (color) and 83% (turbidity). In figures 3 and 4, it is possible to observe how color and turbidity, respectively, behaved over the 120 min of sedimentation.

Figure 3 - Optimal amount of Moringa Oleifera Lam in relation to apparent color.



Fonte: Author (2019)

Figure 4 - Optimal amount of Moringa Oleifera Lam in relation to turbidity.



Fonte: Author (2019)

At the beginning of the experiment, after the addition of the oxidant (Ca(ClO)2), the coagulant auxiliary (Moringa Oleifeira Lam) and the coagulant (PAC), there was a considerable increase in the time 0 (zero) of turbidity and apparent color, in which these parameters started in the graph with raw water values. And as the experiment went on, there was a decrease, as seen in Figures 03 and 04.

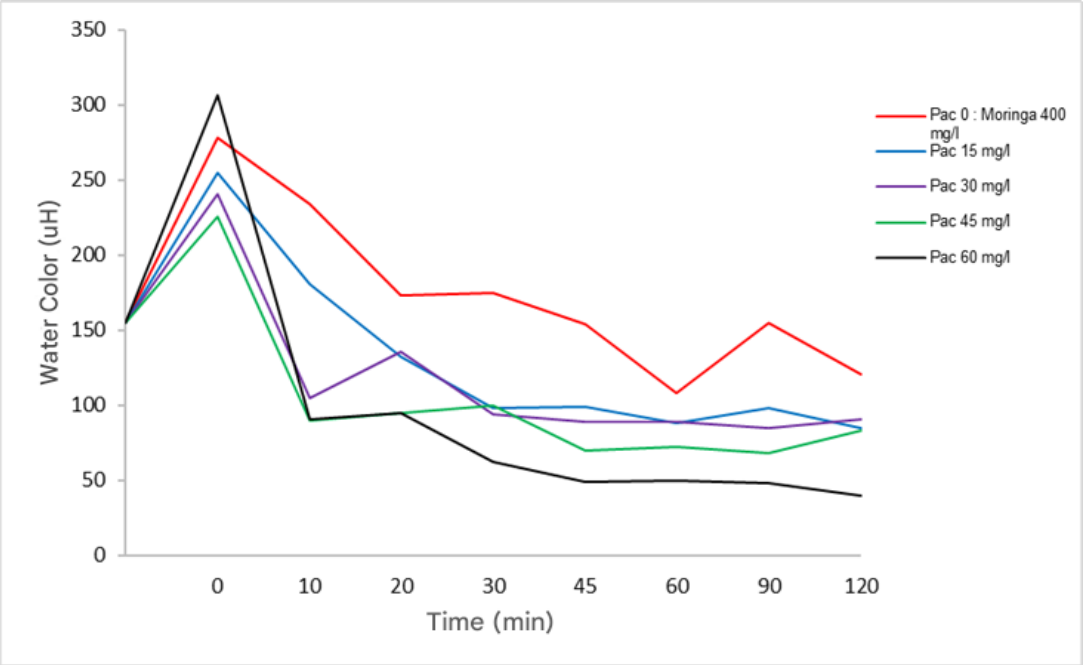
After determining the most efficient amount of moringa, it was necessary to use it without association with PAC, to observe its effect on the water of the dam, which is a natural coagulant, thus more accessible to communities, as well as more sustainable.

The concentration is 400 mg. L^{-1} of moringa showed the following efficiency: 61% (color) and 72% (turbidity), as shown in Figures 5 and 6. The result demonstrates that its use, without the association, does not have an optimal efficiency.

RESULT OF THE OPTIMAL AMOUNT OF ALUMINUM POLYCHLORIDE (PAC)

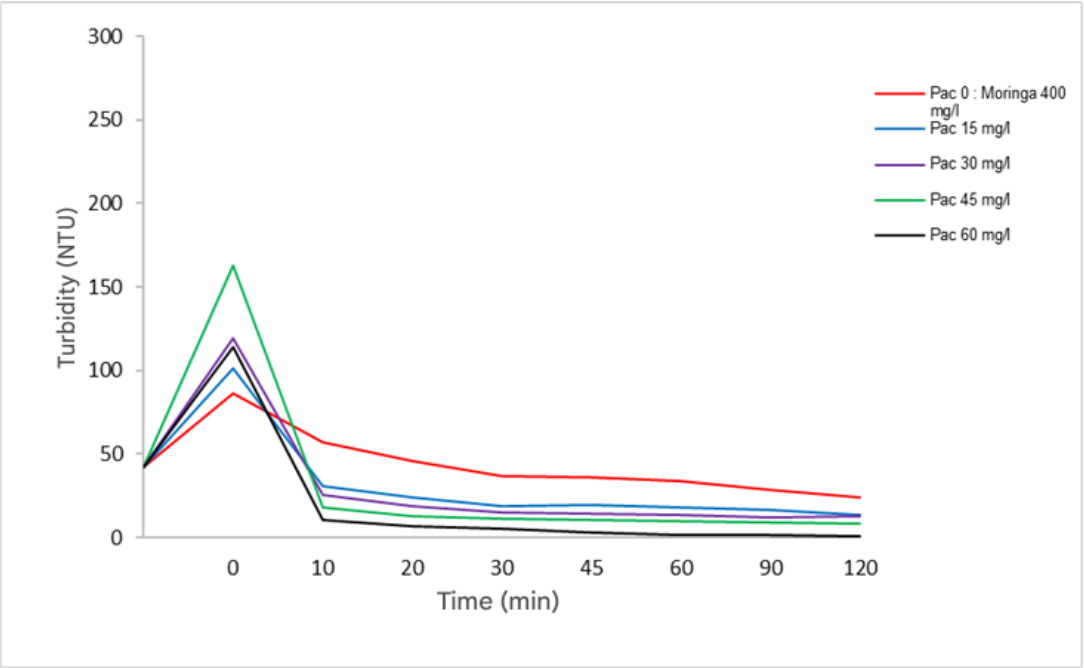
Soon after fixing the amount of Moringa Oleifera Lam concentration of 400 mg. L-1, the test range used from 15, 30, 45 and 60 mg. L^{-1} had, respectively, the following efficiency: 67% (color) and 86% (turbidity); 63% (color) and 90% (turbidity); 70% (color) and 95% (turbidity); 87% (color) and 99% (turbidity). The concentration that had the best efficiency was 60 mg. L^{-1}, which can be observed in the test range better results when the coagulant dose was increased. Figures 5 and 6 show the values of the parameters, color and turbidity, along the sedimentation.

Figure 5 - Optimal amount of PAC in relation to apparent color.



Fonte: Author (2019)

Figure 6 - Optimal amount of PAC in relation to turbidity.



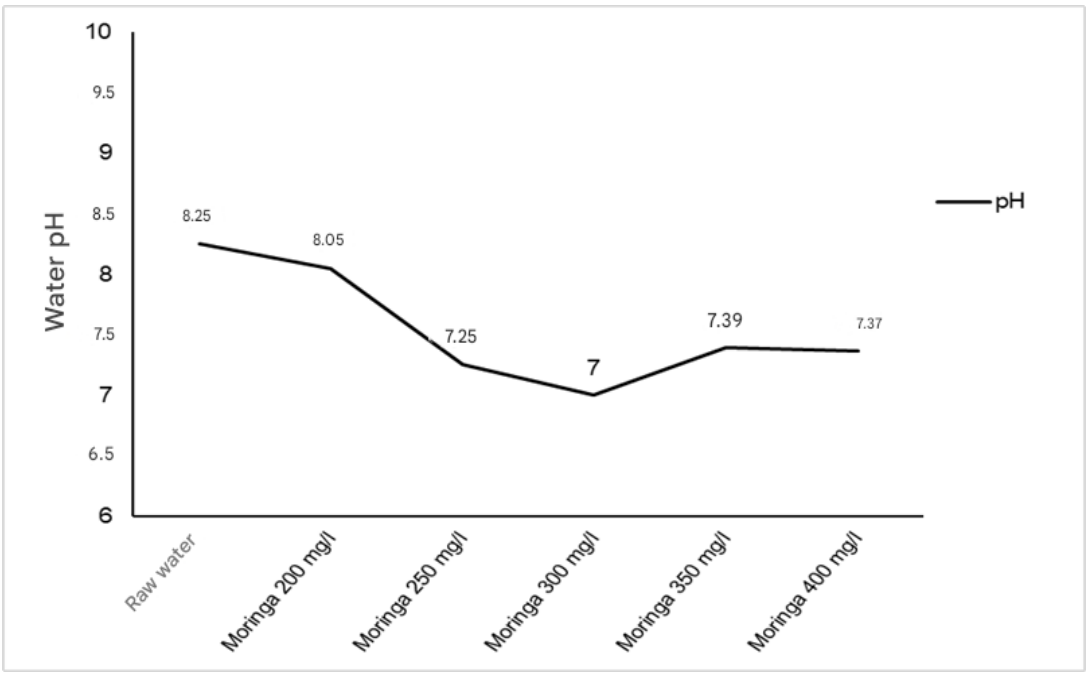
Fonte: Author (2019)

It is possible to analyze that the efficiency of the reduction of turbidity and apparent color is related to the increase in the concentration of the coagulant solution. That is, the more concentrated the PAC coagulant solution, the better the removal. These values indicate that the concentration of coagulant should be proportional to the turbidity of the raw water to be treated, i.e., the higher the turbidity, the more concentrated the coagulant solution to be applied should be.

pH AND ALKALINITY

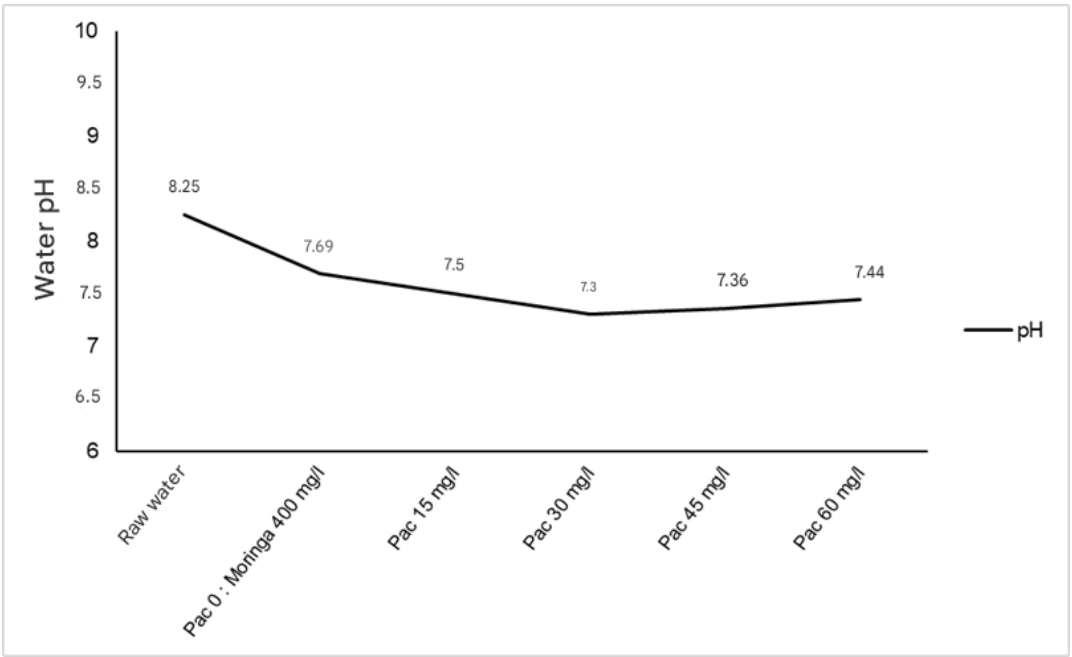
And through the analysis of the results obtained in the association of Moringa Oleifera Lam coagulants with CAP and $Ca(ClO)_2$, similar pH variations between 7 and 8 were observed, as seen in Figures 7 and 8.

Figure 7 - pH in relation to Moringa Oleifera Lam dosages.



Fonte: Author (2019)

Figure 8 - pH in relation to PAC dosages.

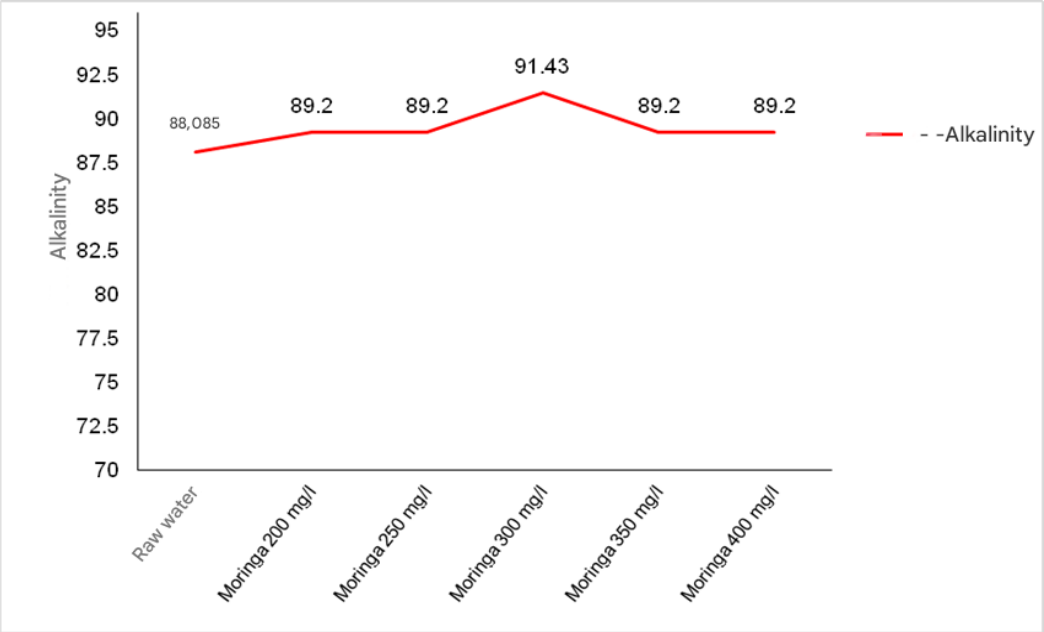


Fonte: Author (2019)

Figures 7 and 8 show that the coagulants Moringa Oleifera Lam and PAC ranged from basic to neutral pH and, despite the variation, it is emphasized that they are in accordance with Ordinance No. 2914.

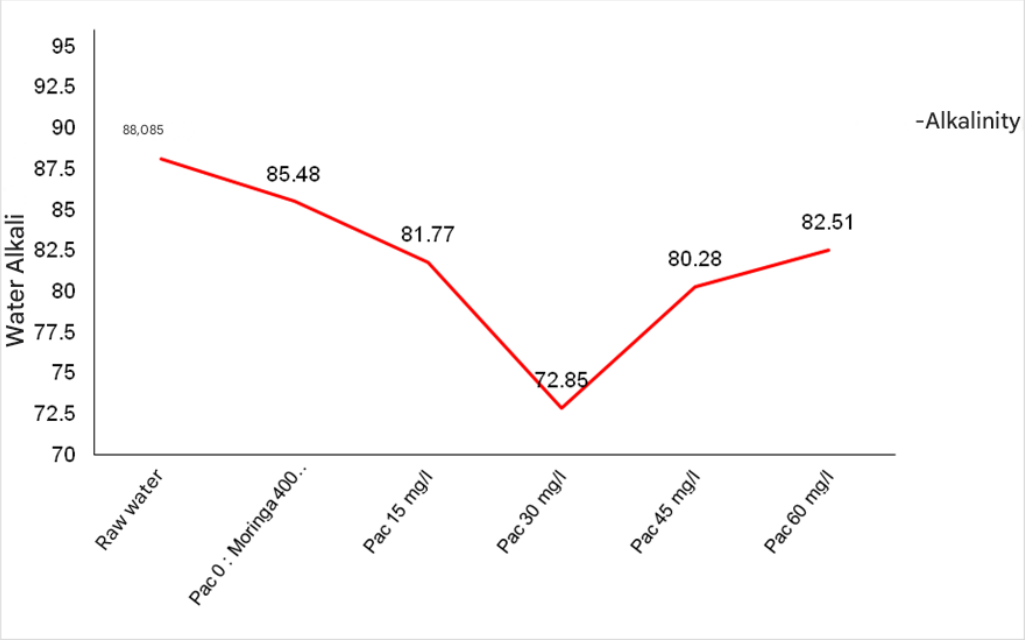
In relation to alkalinity, it is seen that the alkalinity parameter did not suffer significant variations in the five assays with varying concentrations of M. oliferia, as can be seen in Figure 09. In relation to PAC, Figure 10, there was a significant variation of 72.85 in the dosage of 30mg.L.

Figure 9 - Alkalinity in relation to Moringa dosages.



Fonte: Author (2019)

Figure 10 - Alkalinity in relation to Moringa dosages.



Fonte: Author (2019)

It is possible to observe that the alkalinity of the raw water is high, with 88.08mg/L $CaCO_3$, necessary in the coagulation stage since the reaction of neutralization of the impurities significantly alters the pH of the water. Therefore, alkalinity helps maintain this pH, helping to maintain the range of action of the coagulant agent used.

Coagulants commonly act with acids in solution, reducing alkalinity and lowering the pH value. If the alkalinity decreases, coagulation may require the addition of alkalizing agent to adjust the pH and balance it.

In view of the results, it is seen that the use of M. oliferia, associated with PAC, has satisfactory results, since the use of moringa, as a coagulation aid, reduces the consumption of synthetic coagulants by up to 50%, and can bring improvements in water sanitation in a practical and sustainable way, because moringa can be cultivated locally.

DISCUSSION

According to Silva et al[15], the presence of phytoplankton organisms (microalgae and cyanobacteria) and pathogenic microorganisms, when present in water sources intended for supply, cause difficulties in treatment, which compromises the efficiency of WTPs. In view of this, the pre-oxidation process represents a very important step for the removal of such organisms. Results obtained by Veronezi-Viana et al[13] confirm what was previously said, in which pre-oxidation, using a dosage of 1.2 mg. L^{-1}, of $Ca(ClO)_2$, with a contact time of 30 min, showed an efficiency of 80% in the removal of organisms.

It is noteworthy that the study used the coagulant aid (Moringa Oleifeira Lam) and the coagulant (PAC). This scenario can be justified by the research by Alves[17], who reports that the coagulant extracted from Moringa Oleifera Lam releases a lot of organic matter, which makes the water more turbid.

Moreti et al[3], in their study, mention the low efficiency of Moringa Oleifera Lam for waters with low initial turbidity, verifying difficulty in reducing color and turbidity. However, for families who do not have drinking water, Moringa Oleifera Lam is a great low-cost alternative to obtain better quality water.

In the study conducted by Resende et al[16], moringa showed better results for the removal of turbidity with higher concentrations, ranging from 500 to 1000 mg. L-1, which corroborates the results of this research.

A study by Casagrande[18] corroborates the results of this study, since the best results were obtained with the use of PAC coagulant, with removal efficiencies of 98% for residual turbidity, 97% for apparent color, and 90%.

The use of PAC can be explained by the fact that this synthetic coagulant is generally effective in a pH range between 6 and 9, also acting at pH 10[19]. Therefore, pH is an important parameter in the coagulation/flocculation process since each coagulant has an optimal operating range[20]. In addition, the use of M. oliferia did not significantly alter the pH parameter, possibly indicating that the extract does not contribute to changes in the H+/OH- ratio in solution[21].

PAC coagulant is a cationic polymer widely accepted in the market for its efficiency and ability to act in a wider pH range, highly recommended for use in water treatment plants, in order to replace the conventional coagulants used (aluminum salts and iron salts), since PAC has a better clarification efficiency[19].

It is noteworthy that the pH, both in the first and second stages, are in accordance with Ordinance No. 291401 of the Ministry of Health, which recommends a range of 6.0 to 9.0 in the distribution system.

According to Awad et al[22], pH has a great influence on the water treatment process, as it is directly related to the efficiency of the coagulant and, if necessary, can be adjusted with alkalizing products to flocculate.

Several factors interfere in the coagulation process, especially the pH and alkalinity of the raw water and the type and dosage of the chemicals applied[23]. According to Di Bernardo and Dantas[24], alkalinity influences chemical coagulation when metal salts are used as coagulating agents, since they are donors of protons in solution.

Valverde et al recommend, in cases of low efficiency in removing quality parameters, the association of moringa with another coagulant, so that there are more promising results, as in the case of PAC. Abaliwano et al [26] also emphasized the use of moringa as a coagulation aid, which can reduce the consumption of synthetic coagulants by up to 50%. Dalen et al [27] highlight that the combination of coagulants can effectively improve water sanitation in underdeveloped countries, mainly because Moringa Oleifera Lam can be cultivated locally.

The use of coagulants in water treatment is a common practice to remove impurities from drinking water. PAC and Moringa oleifera extracts have stood out, especially in contexts of underserved populations that face difficulties in accessing adequate water treatment. The implementation of accessible treatment techniques, using CAP and/or Moringa, contributes to improving the quality of life and public health in communities with few resources, offering a viable and sustainable solution for access to drinking water[25-27].

Thus, the creation of strategies so that moringa and other associations with local raw material that can be used is essential, in addition to being more compatible with current environmental issues. Therefore, it is necessary to take collective actions and strategies in an integrated manner and articulated with environmental public policies[28].

FINAL CONSIDERATIONS

The tests showed the highest efficiency in the second stage, in which, with the increase in PAC dosage, there was an efficiency of 87 and 99% in the removal of color and turbidity, respectively. When compared to the first stage, the concentration that had the most efficiency was 60 mg. L^{-1} PAC.

It is noteworthy that the research faces some limitations, especially when evaluating the association between these two coagulants, as well as the existence of few studies and the correlation with the health area, as well as the interference of raw water parameters: The coagulation efficiency depends on the initial quality of the water (pH, turbidity, organic matter, etc.). Differences in these parameters can impact the performance of coagulants and make it difficult to standardize the results.

But it is possible to observe the potential of the study, since Moringa Oleifera Lam, being a natural coagulant, is considered sustainable and low cost, which makes its study important for water treatment. During the research, M. oleifera proved to be

efficient when associated with another coagulant, in a different way when used alone. The most efficient concentration was 400 mg.L^{-1}. In addition, the pre-oxidation step was extremely important to assist in the removal of suspended and colloidal particles in the water.

After analyzing the result of the experiment with Ordinance No. 2914/2011, it was observed that the concentrations of 60 mg.L^{-1} PAC and 400 mg.L^{-1}, of Moringa Oleifeira Lam, obtained results within the standard for human consumption established by Ordinance No. 2914/2011 for the turbidity parameter, as well as the time 120 min presented turbidity of 0.7 NUT.

Therefore, the tests performed in Jar Test can be considered of great value, since they will guide the procedures applicable on a real scale. In addition, all the factors that influence the coagulation, flocculation and sedimentation processes must be taken into account, since these will translate the efficiency of the entire water treatment.

Thus, it was evidenced that the tests with different types of coagulants help in the best choice of products used in the treatment of water for supply, based on the available parameters and the characteristics of each source.

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