# SOCIAL TECHNOLOGY FOR WATER TREATMENT IN A RIVERINE COMMUNITY IN THE LOWER BRANCO RIVER REGION, RORAIMA, EXTREME NORTH OF BRAZIL

TECNOLOGIA SOCIAL PARA TRATAMENTO DE ÁGUA EM UMA COMUNIDADE RIBEIRINHA NA REGIÃO DO BAIXO RIO BRANCO, RORAIMA, EXTREMO NORTE DO BRASIL

TECNOLOGÍA SOCIAL PARA EL TRATAMIENTO DE AGUA EN UNA COMUNIDAD RIBERA DE LA REGIÓN DEL BAJO RÍO BRANCO, RORAIMA, EXTREMO NORTE DE BRASIL

AUTORES

Jordana Souza Paula Riss[1]

Leovergildo Rodrigues Farias[2]

Pedro Aurélio Costa Lima Pequeno[3]

Marcos José Salgado Vital[4]

**ABSTRACT:** Brazil suffers from the problem of lack of basic sanitation, and this fact is intensified in the Amazon region, as a large part of the population lives in areas of vulnerability. The use of chemical coagulants causes harm to the environment and human health. The application of natural coagulants emerges as a promising alternative, as it dispenses with the use of chemicals, presents a simple, low-cost, easy-to-reproduce methodology that is accessible to any community, promoting health and environmental improvements. The objective of this study was to produce a natural coagulant based on Amazonian cacti to treat water intended for human consumption in a riverside community. For the study, about 500 grams of the aerial part of Cereus

1 Doutora em Recursos Naturais pelo Programa de Pós-Graduação em Recursos Naturais-PRONAT da Universidade Federal de Roraima-UFRR. Mestre em Ciência, Inovação e Tecnologia para a Amazônia pela Universidade Federal do Acre-UFAC, Especialista em Metodologia do Ensino da Química, graduação em Farmácia Generalista e Complementação Pedagógica em Química. Servidora Pública Federal, ocupando o cargo de Docente da Educação Básica, Técnica e Tecnológica no Instituto Federal de Educação, Ciência e Tecnologia de Roraima - IFRR. jordana.riss83@gmail.com

2 Graduação em Licenciatura Plena Em Química pela Universidade Federal de Roraima (2006), é mestre em Química, com área de concentração, Química Analítica na linha de pesquisa, análise de traços em matrizes ambientais. Doutor em Recursos Naturais (Ciências Ambientais) pela Universidade Federal de Roraima. Atualmente é professor efetivo do Instituto Federal de Educação, Ciência e Tecnologia de Roraima nos cursos: Superior de Tecnologia em Saneamento Ambiental, Licenciatura em Ciências Biológicas e do Ensino Técnico Integrado ao Ensino Médio. leovergildofarias@yahoo.com.br

3 Graduação em Ciências Biológicas pela Universidade Federal do Amazonas (2008), e mestrado (2011) e doutorado (2017) em Biologia (Ecologia) pelo Instituto Nacional de Pesquisas da Amazônia. pacolipe@gmail.com

4 Bacharel e Licenciado em Ciências Biológicas pela Universidade Federal de Pernambuco, Mestre em Micologia pela Universidade Federal de Pernambuco e doutor em Ciências (Microbiologia Ambiental) pela Universidade Federal do Rio de Janeiro. Atualmente é Professor Titular Livre do Centro de Estudos da Biodiversidade - CBio e atua como Docente Permanente no Programa de Pós-graduação em Recursos Naturais - PRONAT e do Mestrado Profissional em Rede Nacional em Regulação e Gestão de Recursos Hídricos - PROFAGUA e nos cursos de Licenciatura e Bacharelado em Ciências Biológicas da Universidade Federal de Roraima. marcos.vital@ufrr.br

jamacaru was collected in the community of Santa Maria do Boiaçu-RR. The thorns were removed, and the cactus was washed, cut, accommodated in trays and taken to the sun. After drying, the cactus pieces were crushed and sieved. The water samples for the study were collected at 3 points and the treatability test was carried out in the laboratory. Statistical analyzes revealed that the natural cactus-based coagulant is an efficient social technology for the treatment of groundwater and surface water.

**KEYWORDS:** Potability. Amazon. Water quality. Riverine. Cacti.

**RESUMO:** O Brasil sofre com o problema da falta de saneamento básico, e esse fato se intensifica na região Amazônica, pois uma grande parte da população vive em áreas de vulnerabilidade. O uso de coagulantes químicos causa malefícios ao ambiente e à saúde humana. A aplicação de coagulantes naturais surge como uma alternativa promissora, pois dispensa o uso dos químicos, apresenta metodologia simples, de baixo custo, de fácil reprodução e acessível a qualquer comunidade, promovendo saúde e melhorias ambientais. O objetivo deste estudo foi produzir um coagulante natural à base de cactos amazônicos para tratar a água destinada ao consumo humano em uma comunidade ribeirinha. Para o estudo, coletou-se cerca de 500 gramas da parte aérea do Cereus jamacaru na comunidade de Santa Maria do Boiaçu-RR. Os espinhos foram removidos, o cacto foi lavado, cortado, acomodado em bandejas e levado ao sol. Após a secagem, os pedaços de cactos foram triturados e peneirados. As amostras de água para estudo foram coletadas em três pontos e foi realizado o ensaio de tratabilidade em laboratório. As análises estatísticas revelaram que o coagulante natural à base de cacto é uma eficiente tecnologia social para o tratamento de águas subterrâneas e superficiais.

**PALAVRAS-CHAVE:** Potabilidade. Amazônia. Qualidade de água. Ribeirinho. Cactos.

**RESUMEN:** Brasil sufre el problema de la falta de saneamiento básico, y este hecho se intensifica en la región amazónica, ya que gran parte de la población vive en zonas vulnerables. El uso de coagulantes químicos daña el medio ambiente y la salud humana. La aplicación de coagulantes naturales aparece como una alternativa prometedora, ya que elimina el uso de químicos, presenta una metodología simple, de bajo costo, fácil de reproducir y accesible a cualquier comunidad, promoviendo mejoras en la salud y el medio ambiente. El objetivo de este estudio fue producir un coagulante natural a base de cactus amazónicos para tratar el agua destinada al consumo humano en una comunidad ribereña. Para el estudio, se recolectaron alrededor de 500 gramos de la parte aérea de Cereus jamacaru en la comunidad de Santa Maria do Boiaçu-RR. Se quitaron las espinas, se lavó el cactus, se cortó, se colocó en bandejas y se puso al sol. Después del secado, los trozos de nopal se trituraron y tamizaron. Las muestras de agua para el estudio se recolectaron en 3 puntos y se realizó la prueba de tratabilidad en el laboratorio. Los análisis estadísticos revelaron que el coagulante natural a base de cactus es una tecnología social eficiente para el tratamiento de aguas subterráneas y superficiales.

**PALABRAS CLAVE:** Potabilidad. Amazonas. Calidad del agua. Orilla. Cactus.

## INTRODUCTION

Difficulties in accessing water are not always related to water scarcity. The region with the greatest abundance and availability of water resources is the Amazon, especially taking into account the low population density. However, sanitary conditions, drainage of sewage and water treatment are poor, thus aggravating the problem of human health and causing an impact on infant mortality, as pointed out in the report of the "Agenda for Childhood and Adolescence in the Amazon", of the United Nations Children's Fund (UNICEF, 2018). According to the National Information System on Basic Sanitation, one in every 6 Brazilians do not have access to treated water (SNIS, 2019).

The problem of lack of basic sanitation is intensified in the Amazon region when one considers the populations living in areas of difficult access, since the cost and technological complexity of some water treatment methods make implementation in some locations unfeasible (MELLO, 2018) and, thus, a far cry from the reality and local culture of the region. Due to the custom that Amazonian communities have of inhabiting the banks of rivers, or near streams and water sources, this situation of lack of water is alleviated, but low access to good quality water is a reality that is experienced in the region (GOMES et al., 2021).

Social technology (ST) emerges as an alternative that is capable of solving essential problems, such as the demand for drinking water, and can promote health and environmental improvements (MENDOLA, 2019). ST is defined as any low-cost product, technique or method that can be easily reproduced and applied, and which presents solutions for social transformation (DOMINGOS; RIBEIRO, 2015; BATISTA et al., 2021).

For the supply of quality water to the population for its daily activities, the water collected for supply goes through a treatment process at water treatment plants (WTP). This process basically consists of the steps of coagulation and flocculation, decantation, filtration and ends with chlorination and fluoridation. Coagulation is a process that involves the application of chemicals that allow an accelerated removal of compounds that are dissolved in water and the destabilization of colloidal suspensions and solids that cannot be removed by sedimentation or filtration. Closely linked to coagulation is flocculation, during which the particles destabilized by the coagulant agglutinate and form flakes that are capable of settling (LIMA JUNIOR, 2018; RICHTER, 2009).

The importance of coagulation in the sanitary context is evidenced by the removal of microscopic particles associated with pathogenic microorganisms, which are usually found in raw water and have a very reduced sedimentation rate (LIBÂNIO, 2010). According to Lima Junior and Abreu (2018), the main coagulants used in the treatment of waters for public use are inorganic salts, such as aluminum sulfate, ferric chloride, ferrous sulfate and aluminum polychloride. Oladoja et al. (2017) affirm that aluminum-based coagulants are more routinely used due to their low cost and efficiency in conventional water treatment. However, there is always a negative effect in the use of these chemical coagulants, for example, the toxicity of aluminum ions to aquatic life when in concentrations greater than 50 µg/L (LIMA; ALMEIDA; VICENTINI, 2020), as well as a possible relationship with pathologies that affect the central nervous system, such as dementia, Alzheimer's and Parkinson's, which are caused by excessive use of aluminum salts (ANG; MOHAMMAD, 2020) The damage done to public health and aquatic life has therefore motivated researchers to explore greener and more sustainable water treatment technologies

(LIMA; ALMEIDA; VICENTINI, 2020).

Natural coagulants achieve a treatment efficiency that is analogous to chemical coagulants (KARANJA; FENGTING; NG'ANG'A, 2017). Multiple studies have sought to establish the effectiveness of cacti as a biocoagulant, and the species Opuntia ficus-indica, Opuntia dillenii and Opuntia stricta are the best known and studied. Cacti are present in all major Brazilian biomes: Amazon, Caatinga, Cerrado, Atlantic Forest, Pampa and Pantanal (ZAPPI; TAYLOR, 2020). They are also abundant in the northeastern region of Brazil (ZARA; THOMAZINI; LENZ, 2012), and in the north in the state of Roraima (OLIVEIRA, 2016; PASSOS, 2019).

According to Karanja et al. (2017), the use of cactus as a coagulant first requires an overview of its efficacy levels and optimal conditions of use, especially with regard to pH, and the research of Beyene et al. (2016) demonstrates the potential of powdered cactus for removing turbidity, a fact that led the authors to suggest its use in water treatment.

This study was developed within the Amazonian context and considers the environmental, spatial, temporal and especially social conjuncture. Therefore, the cactus Cereus jamacaru De Candolle, popularly known in the region as "mandacaru", which makes up the phytophysionomy of the area (OLIVEIRA, 2016; PASSOS, 2019), was used to evaluate its coagulation potential in water treatment. The ST proposal of this research consisted in the production of a natural coagulant based on the mandacaru cactus that was initially bench tested in the laboratory by analyzing the turbidity parameter. Then, the preparation technique was adapted to the material resources available in the riverine community of Santa Maria do Boiaçu, located in the lower Branco River region, Roraima, extreme north of Brazil. This adaptation aimed at simplifying the preparation, and thus enable the production and application of the coagulant by the community. In January 2022, the invitation to the community was made official and a workshop on good practices in the production of natural coagulant was held. The first water collections were carried out in three catchment points by the community; these being two wells and the banks of the river. The physicochemical parameters analyzed were pH, turbidity, and microbiological parameters for total and fecal coliforms.

The guiding questions of this research are i) Does the coagulant based on the mandacaru cactus produced by the community have sufficient coagulant action for the treatment of water intended for human consumption? (ii) Is there a difference in efficiency between the concentrations of the coagulant and the source of the water to be treated? and iii) Does seasonality affect the performance of mandacaru-based natural coagulant?

In order to obtain an easily replicated social technology, the objective of this research was to produce a coagulant based on cacti from Roraima to treat water destined for human consumption in a riverine community of the Branco River basin in Roraima.

## MATERIALS AND METHODS

### Study area

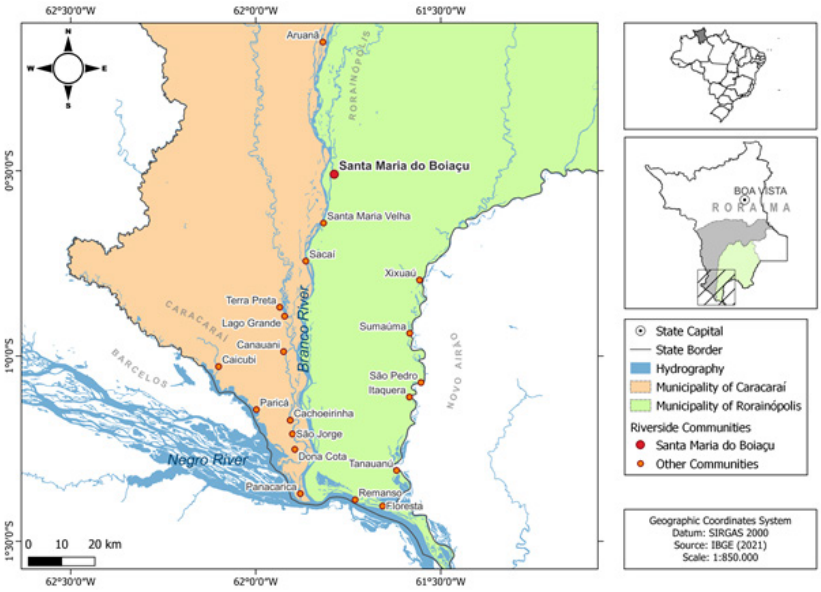
The study was developed in the riverine community of Santa Maria do Boiaçu, which is located in the lower Branco River region, on the left margin of the Branco River, in the municipality of Rorainópolis, state of Roraima (00° 30′ 33″ N, 61° 47′ 19″ W) (RORAIMA, 2010). The lower Branco River region, located

on the southern borders of the state of Roraima with the northwest of the state of Amazonas, is a region of difficult access, as there are no roads, and boats are the most used means of transport to reach the riverine community of Santa Maria do Boiaçu (CAVALCANTE et al., 2020). The region is composed of 20 communities that are part of the municipalities of Rorainópolis and Caracaraí (Figure 1).

The communities that are located on the right margin of the river belong to the municipality of Caracaraí and those located on the left margin belong to the municipality of Rorainópolis. In December 2021, the first telephone contact was made with the president of the Community Fund of the District of Santa Maria do Boiaçu in order to present the research proposal to the entire community. In January 2022, a letter was sent to the leadership officializing the invitation to the community to participate in the workshop on the production of a natural coagulant based on cacti for water treatment, with the inclusion of 15 participants. The workshop conducted, had the active participation of local members. Throughout the event, we discussed and implemented best practices in the manufacturing of natural coagulants, with a focus on the sustainable development of the communities.

There are three main water sources that supply the community of Santa Maria do Boiaçu; two artesian wells and the Branco River itself. The community does not have a water treatment plant, i.e., there is no quality control system for the water consumed by the people who live there.

Figure 1 - Map of the lower Branco River region, showing the community of Santa Maria do Boiaçu, Roraima




Source: Adapted IBGE (2021)

**Preparation of the social technology together with the community**

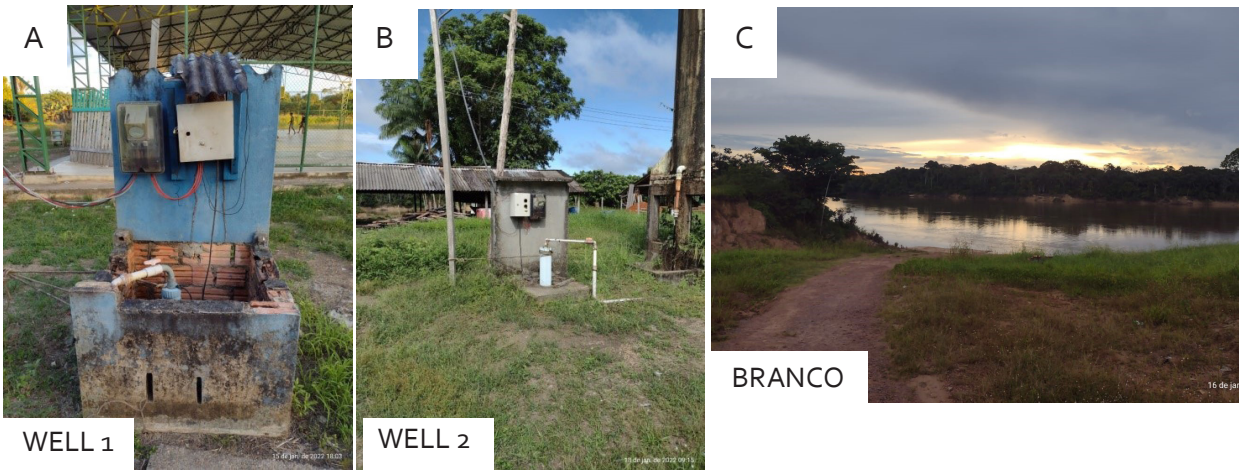
To obtain the powdered cacti that was used as a natural coagulant, we used the methodology adapted from that proposed by Miller et al. (2008) and by Othmani et al. (2020). The natural coagulant was prepared with 500 g of the aerial part of the mandacaru cactus collected in the community of Santa Maria do Boiaçu. The thorns of the plant material were removed with a knife and discarded. Then, the

cactus was washed under running water, cut into pieces of about 1 cm, placed on trays and left in the sun for three days. After drying, the cactus pieces were ground in a household blender and/or mills and sieved with the help of sieves. This powder was stored in a clean, hermetic container, dated and identified, until the completion of the laboratory treatability tests using the jar test.

**Assessment of water quality in the community**

The initial assessments of water quality were carried out by the team of researchers at the three water collection points for consumption used by the community, in two underground wells which are here called Well 1 and Well 2, and on the banks of the Rio Branco (surface water) (Figure 2). Two collections were carried out, in the dry and rainy periods, to assess whether seasonality influences the coagulation process. The first collection was carried out on January 19, 2022 after the production of the natural coagulant by the community; the second on June 16, 2022.

Figure 2 – Water supply sources and sample collection sites in the community of Santa Maria do Boiaçu.




Source: Riss

The surface and groundwater were characterized by measuring turbidity using a portable turbidimeter (Hanna, Hi93703c), pH, with pH meter (Del Lab DLA-PH) and total and fecal coliforms (COLIFORMESBAC). For all collections, the Standard Methods for the Examination of Water and Wastewater (APHA, 2017) were used as a basis.

**Sample collection**

A total of twelve liters of water samples were collected from each of the three points. These were stored in amber bottles, packed in a thermal box containing ice for refrigeration and then transported to the laboratory at the Federal Institute of Roraima, for testing.

**Coagulation test**

The coagulation test was performed in triplicate for the three collection points using jar test equi-

pment (Alfakit, AT-700) comprising six jars with the paddle speed regulated in two mixing gradients: fast (150 rpm for three minutes); slow (60 rpm for 17 minutes). The sedimentation time was 30 minutes with the equipment turned off, and used 400 milliliters (mL) of raw water, according to methodology adapted from Zara et al. (2012).

The dosages of the cactus-based natural coagulant were determined according to values obtained in the literature and in pre-assays of this study. Concentrations of 0.01, 0.02, 0.04, 0.05, 0.1, 0.2, 0.3, 0.4 and 0.5 g of natural cactus coagulant (VILLABONA ORTIZ; ASTUDILLO; MARTÍNEZ, 2013; FEDALA et al., 2015) applied directly to the 400 mL of water contained in individual jars. At the end of the coagulation test, samples of the treated water were collected from each of the jars with the aid of a 20 mL graduated pipette and a new turbidity and pH measurement was performed to verify the effect of the natural coagulant on the samples.

## RESULTS AND DISCUSSION

Brazilian Ordinance No. 888/2021 defines water for human consumption as drinking water intended for ingestion, preparation and production of food and personal hygiene, regardless of its origin (BRASIL, 2021). Therefore, it must meet the minimum potability standards and be within physicochemical and microbiological parameters presented in Table 1.

Table 1 - Parameter values established by Ordinance No. 888/2021 regarding the quality of water intended for human consumption

| Parameter | Maximum values permitted (MVP) | Unit |
|---|---|---|
| **Turbidity (surface water)** | Up to 5.0 | uT |
| **Turbidity (groundwater)** | Up to 1.0 | uT |
| **pH** | 6-9 | - |
| **Thermotolerant coliforms** | Absent in 100 mL | - |

Source: Adapted from Brasil (2021).

The raw water samples from the Branco River, and from well 1 and well 2 showed different values of initial pH and initial turbidity for the different collection seasons and the absence of coliforms, as shown in Table 2. During the dry and rainy season, the water from the Branco River and from one of the wells (Point 1) that supplies the community did not meet the minimum standard for the turbidity parameter established by Ordinance No. 888/2021, though they did present initial pH within the standards.

Table 2 – Values of initial turbidity, initial pH and coliforms during different seasons in the riverine community of Santa Maria do Boiaçu, Roraima.

| Sample | Season | Initial tubidity (uT) | Initial pH | Coliforms |
|---|---|---|---|---|
| **Branco River** | dry | 26.17 | 7.3 | Absent |
| **Point 1 (well)** | | 5.99 | 6.57 | Absent |
| **Point 2 (well)** | | 0.39 | 7.3 | Absent |
| **Branco River** | rainy | 7.18 | 6.87 | Absent |
| **Point 1 (well)** | | 0.67 | 6.86 | Absent |
| **Point 2 (well)** | | 0.41 | 6.88 | Absent |

Source: Riss

**Coagulation test**

Figure 3a shows the efficiency of turbidity removal according to the coagulation test using different concentrations of the cactus-based coagulant. It is noted that by increasing the concentration of the natural coagulant the turbidity increases. This behavior of a decrease in turbidity removal efficacy with the increasing dosage of the natural coagulant demonstrated in this study corroborates the results of Pichler et al. (2012), who used cactus mucilage in water treatment and observed that when they increased the dose of mucilage, the turbidity of the supernatant after sedimentation of the flakes also increased. Although the use of natural coagulants is a sustainable alternative for treating water for human consumption, the application of forms, such as powders, mucilage or unpurified extracts, directly in the water to be treated leads to an increase in organic matter, which leaves the water more cloudy.

Choy et al. (2014) attribute the increase in organic matter to the presence of lipids, which are biomolecules that do not participate in the coagulation process. Although it was not possible to perform organic matter quantification tests, this effect can be observed in the initial turbidity of 26.17 uT of the water from the Branco River. This used the highest coagulant dosage of 0.5 g of the cactus powder and presented the lowest removal efficiency and left the water with a greenish appearance. However, it is possible to improve the quality of treated water using filters, since the flakes formed by the biomolecules are usually large and easily retained, and do not require more advanced filtration systems (PICHLER et al., 2012).

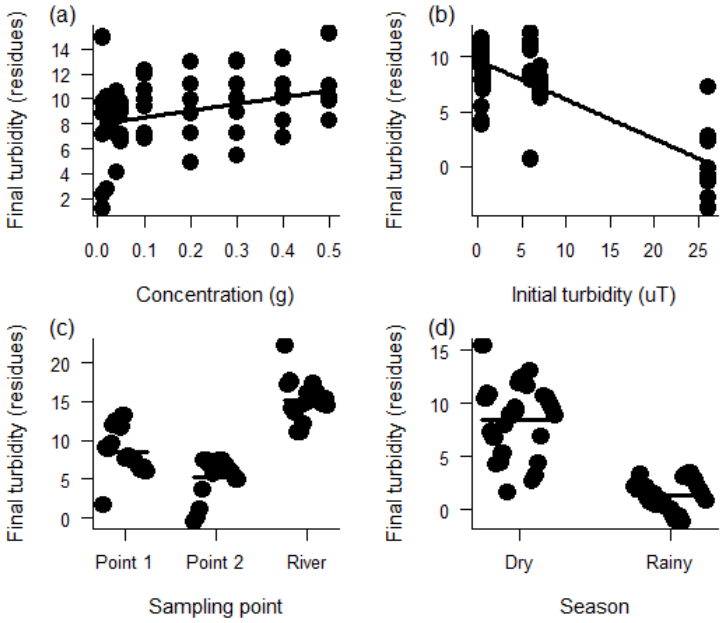
Figure 3 presents the results of the parameter turbidity after the application of the natural coagulant in the water samples collected in the community of Santa Maria do Boiaçu. Branco, Roraima. The action of the natural coagulant in the removal of turbidity of water from the different points and collection season is evidenced in Figure 3b, when comparing the initial turbidity and the final turbidity, corroborating the results of Karanja et al. (2017) who obtained a satisfactory reduction between the initial and final turbidity when using Opuntia ficus-indica mucilage. Such results led the researchers to infer that cactus mucilage is efficient as a natural agent for water treatment.

Unlike some studies that have shown that the higher the turbidity of the water to be treated, the better the efficiency of natural coagulants, the effect observed in the present study was satisfactory (Figure 3c) for samples of surface and groundwater with low turbidity (Table 2). Pritchard et al. (2010)

used a natural coagulant based on Moringa oleifera seed in the treatment of water with a turbidity of 40 uT and 200 uT, and the removal efficiencies at the end of the treatment were 50% and 90% respectively. Nishi et al. (2011) observed that there was a better removal efficiency in water samples with a turbidity of 350 and 450 uT. A possible justification for this behavior lies in the fact that both M. oleifera and cacti are considered polyelectrolytes, in other words, they are flocculating polymers with different ionic charges that act on the formation of flakes and assist in coagulation.

For Baghvand et al. (2010), low turbidity waters have a small amount of colloidal matter, i.e., this lower concentration of suspended colloids in the water limits the contact rate between the particles and the flocculating polymers, thus hindering the coagulation process and, consequently, the performance of the coagulant. An alternative to treating low turbidity waters consists in adding synthetic turbidity to provide the formation of heavier flakes, which makes them more likely to settle. In the present study, no addition of synthetic turbidity was required. The crude water samples collected in the rainy season presented the lowest initial turbidity values (7.18 uT, 0.67 uT and 0.41 uT), when compared to the dry season (26.17 uT, 5.99 uT and 0.39 uT) for the Branco River, Point 1 and Point 2, respectively; and, after the coagulation test, the turbidity levels remained the lowest, as shown in Figure 3d.

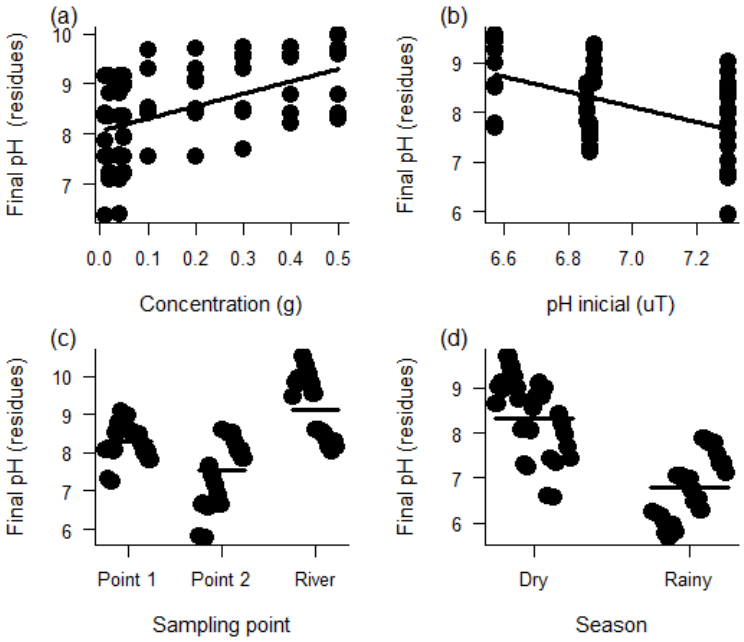
Figure 3 - Results of the turbidity parameter after the application of the natural coagulant in the water samples collected in the community of Santa Maria do Boiaçu, Roraima.




The study by Beyene, Hailegebrial and Direrssa (2016) makes a comparison between cactus powder and aluminum sulfate, and reveals that cactus powder is more efficient in maintaining pH. In the present study, there was no comparison between the natural coagulant and the chemical coagulant, and all samples collected had the pH within the expected limit of 6-9. What can be observed is that as the dose of the natural coagulant increased, the pH also increased (Figure 4a); and the doses of coagulant used maintained the pH levels within the desirable limits (Figure 4b). The lowest pH values with the application

of the natural coagulant were maintained at Point 2 (Figure 4c). In the rainy season, the lowest pH values were obtained when compared to the dry season (Figure 4d). Karanja et al. (2017) emphasize the importance of studies that present efficacy levels and optimal pH conditions when using cacti as a coagulant. In studies using Opuntia cactus powder, the authors found no significant effects for the pH parameter.

Figure 4 - Results of the pH parameter after the application of the natural coagulant in the water samples collected in the community of Santa Maria do Boiaçu. Branco, Roraima.




## CONCLUSION

The social technology produced together with the riverine community of Santa Maria do Boiaçu demonstrated effectiveness in coagulation through the analysis of turbidity and pH parameters, thus allowing their consumption. Replacing polluting chemicals with natural coagulants in the treatment of water for human consumption will contribute to quality of life, and enables any community in a vulnerable condition to produce the natural coagulant and obtain quality water, in addition to protecting the environment and contemplating two important sustainable development goals proposed by the United Nations - health and well-being and drinking water and sanitation. Therefore, it is possible to suggest the execution of new works that seek to perform other tests of physicochemical parameters, coliforms, characterization of natural coagulants obtained from Amazonian cacti, and toxicity and oxidation tests in order to ensure an effective application of cactus coagulants in the treatment of water for human consumption.

The engagement with the riverside community of Santa Maria do Boiaçu has been truly enriching. Witnessing the active participation and enthusiasm of the community members during the workshop was inspiring. Post-event, we observed a tangible impact on the community's awareness and knowledge regarding sustainable practices in natural coagulant production. There is a growing sense of empower-

ment and self-sufficiency as community members have incorporated these newfound practices into their daily lives. Additionally, the shared knowledge has sparked ongoing conversations about environmental stewardship, fostering a stronger sense of community cohesion. The experience with Santa Maria do Boiaçu has not only been a momentary interaction but has sown seeds for long-term positive change within the local community

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