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# Alternative water treatment using organic polymers associated with the solar disinfection method

**Danuza das Virgens Lima and Ludmilla Santana Soares e Barros***

Center for Agrarian, Environmental and Biological Sciences, Federal University of Recôncavo da Bahia, Street Rui Barbosa, nº 710 –Cruz das Almas, Bahia, Brazil.

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**The objective of this study was to carry out an alternative treatment of low-cost water using organic polymers, Moringa oleifera seed, Opuntia cochenillifera and Cereus jamacaru, associated with the technique of solar water disinfection. From July to November 2020, the samples were collected within the university campus of the Federal University of Recôncavo from Bahia. The count of total coliforms, Escherichia coli and aerobic mesophilic microorganisms were performed. The physicochemical analysis was also carried out (pH, color, turbidity, Dissolved Oxygen and temperature). Analyzes were performed at time 0 (before exposure to the sun) and time 1 (after exposure to the sun). The microbiological results were compared, based on the quality criteria established by the Consolidation Ordinance n. 5, of September 28, 2017 from the Ministry of Health. For the control of total coliforms, there was no significant interaction between the levels observed, in both treatments and times. In collection 1, the M. oleifera, after being exposed to the sun, proved to be more efficient in controlling mesophilic microorganisms. The C. jamacaru stood out with satisfactory performance in the two collections in the control of E. coli. In the physicochemical parameters, O. cochenillifera was the species that showed the best performance in decreasing the color and turbidity. We concluded that the polymers were efficient in the control of microbiological and physicochemical characteristics of the water, however, the levels reached were not sufficient to meet the quality parameters established by the current legislation. Therefore, further studies are recommended to improve the technique.**

**Key words:** Natural coagulants, natural polymers, water quality, microbiology.

## INTRODUCTION

The ingestion of treated water is one of the most important factors for health conservation; however this resource has been causing concern worldwide, since the water reserves suitable for consumption have been

*Corresponding author. E-mail: barros@ufrb.edu.br. Tel: +55 75 998971234 or +55 75 36219751.

decreasing every year. Several factors have driven the current situation of water scarcity, such as the destruction and contamination of water sources, agriculture, livestock, human consumption and environmental pollution (Amaral et al., 2006).

In several regions of Brazil and the world, problems related to the consumption of contaminated water were found and it is noteworthy that some regions still do not have access to quality water. The lack of access to the water distribution network is inversely related to income, that is, the largest deficits (45%) are associated with the lowest income strata, decreasing as income increases (Viera et al., 2010).

In addition to problems related to failures in the distribution of treated water, the semiarid region of northeastern Brazil faces irregular rainfall, with long periods of drought and high temperatures. Water scarcity represents a chronic problem, generating, as a consequence, several impacts on the region's economic, social and environmental development. Alternative sources of water supply (weirs, dams, wells, among others) play a relevant role in the management of water resources in these locations due to their capacity to store and serve different uses of water for the population. However, water quality becomes a critical factor, since control and monitoring procedures for the quality of drinking water, established in the legislation, are often infeasible and unenforceable (Tomasella at al., 2018).

For water to be considered safe, it must be treated with something that involves several physicochemical processes until the water becomes potable. In the conventional treatment process, the water to be treated at the Water Treatment Station (WTP) goes through the following processes: pre-chlorination, pre-alkalinization, coagulation, flocculation, decantation, filtration, post alkalinization, disinfection, and fluoridation. However, this type of treatment is highly complex and costly (Yongabi, 2015).

Alternative water treatment systems have been the solution to increase access to drinking water, especially in small communities far from large urban centers. The implementation of these systems is cheaper and does not require the operation of large installations, they are easy to implement and can be carried out by the residents of each region (Keogh et al., 2015).

Coagulants or natural polymers represent an innovative, sustainable solution that poses no risk to human health. The sources of natural polymers are diverse and may be obtained mainly from bacteria, fungi, animals and plants and are classified as polysaccharides, amino-polysaccharides, polyphenols and protein-based substances. The use of a natural coagulant can, in a first step, solve the turbidity problems generated by organic and inorganic materials in suspension and assist in the disinfection process (Gunaratna et al., 2007).

*Moringa oleifera* is one of the most studied species and considered one of the potential substitutes for chemical coagulants. Paterniani and Silva (2005), in a work carried out at the Sanitation Laboratory of the Faculty of Agricultural Engineering at UNICAMP, in Campinas, SP, using *M. oleifera* seeds for surface water treatment, obtained medium reductions in turbidity and apparent color of 90% by simple sedimentation and 96% by slow filtration. Amaral et al. (2006) also using *M. oleifera* seed extracts added to water to be disinfected by solar radiation in Polyethylene Terephthalate (PET) bottles and concluded that even for high turbidity values, in the order of 200 to 250 Nephelometric Turbidity Units (NTU), total inactivation of *Escherichia coli* was obtained after 12 h of exposure to the sun.

Other plant species that have recently received great attention are *C. jamacaru* and *O. cochenillifera* popularly known as mandacaru and palm, respectively. Preliminary works indicated the potential of mandacaru and palm as potential natural coagulating agents (Nharingo et al., 2015).

The use of *M. oleifera*, *C. jamacaru* and *O. cochenillifera* seeds may be a viable alternative in the simplified treatment of water for the population. However, it is important to emphasize that such agents are used as a pre-treatment that will act in the removal and/or reduction of suspended and dissolved solids in water, where a second stage for the disinfection treatment is needed.

Therefore, the use of sunlight promotes the elimination of pathogenic microorganisms present in water through the synergistic effect of sunlight and temperature (McGuigan et al., 2012). Cavallini et al. (2018) in a study developed in the municipality of Gurupi, obtained satisfactory results in the disinfection of 100% of *E. coli*, in 4 h of sun exposure, and of total coliforms, in 6 h of sun exposure in tests using well water.

Given the aforementioned, the main objective of this work is to carry out an association between alternative methods: organic coagulant (*M. oleifera, C. jamacaru* and *O. cochenillifera*) and use of sunlight, evaluating the greater efficiency in terms of microbiological quality and physicochemical aspects.

## METHODOLOGY

### Study area

The study was conducted in the parasitology and animal microbiology laboratory and in an experimental area of the Agrarian, Environmental and Biological Sciences Center (CCAAB) in the Federal University of Recôncavo from Bahia (UFRB), located in Cruz das Almas, Bahia (12º40' 19"S and 39º06'22'W', altitude 220 m above sea level). The climate is designated as tropical hot and humid, Aw to Am, according to the Köppen classification, with an average annual temperature of 24.5°C, with a relative humidity of 80% and average rainfall of 1,250 mm per year (Agritempo).

**Table 1.** Proportions of *Moringa oleifera* (Moringa), *Cereus jamacaru* (Mandacaru), *Opuntia cochenillifera* (Palma) used in the tests: Seed (S), Grams (g).

| Treatment | Mandacaru (g) | Moringa (S) | Palma (g) |
|---|---|---|---|
| Treatment 1 | 2 | 1 | 2 |
| Treatment 2 | 3 | 2 | 4 |
| Treatment 3 | 4 | 3 | 6 |

### Pre-essay: Dosage test

For the dosage test, a methodology adapted from Ostrowski (2014) was used to elaborate synthetic turbidity water samples. For which a soil sample was collected at a 20 to 40 cm deep horizon and identified as Yellow Latosol (Rodrigues et al., 2009). The collected soil was macerated in a mortar and sieved. Then, 25 g portions were extracted and weighed on a digital scale, to be homogenized in 24 containers of 500 mL of treated water. After stirring clockwise and counter clockwise, it was left to rest for 20 min to decant the excess soil. Then, physicochemical characterization (color, turbidity and pH) was performed.

The different dosages of the respective vegetal species (moringa, palm and mandacaru) were homogenized in the synthetic turbidity water samples. Table 1 shows the proportions used for each plant species. After stabilization of the mixture, they were again evaluated for physicochemical parameters.

### Water collection

Two collections were carried out on different days with microbiological and physicochemical aspects evaluation. The samples were collected superficially in the weir inside the UFRB campus known as “Funil Weir”, where it is used to supply the plant production and experimentation sector of the Experimental Farm of CCAAB/UFRB. All samples were stored in polyethylene containers with a capacity of 25.00 L previously sanitized. Disinfection was carried out using the chemical agent sodium hypochlorite at a concentration of 1%, and exposure to sunlight, where the bottles were immersed for 30 min, and then rinsed with abundant drinking water to remove any traces of the chemical agent used and then exposed to sunlight for disinfection by UV light. The gallons also went through the acclimation procedure (collect a portion of water at the point of collection, shake and discard - Process repeated three times), proceeding the collection (Amaral et al., 2006; Sarpong and Richardson, 2010; Wilson and Andrews, 2011).

In the laboratory, in order to reduce the amount of suspended solids in the collected water, a prior filtration was performed using a 100% cotton fabric, size 40 × 62 cm. The tissue was previously washed with neutral soap and sterilized by humid heat in an autoclave at 121.0°C (1 atm; relative pressure) for 15 min (Penn, 1991).

### Obtaining and preparing Cacti: *O. cochenillifera* and *C. jamacaru*

The methodology used was adapted from the proposal by Zara et al. (2012). Cactaceae popularly known as Palma (*O. cochenillifera*) and Mandacaru (*C. Jamacaru)* were collected on the campus of the UFRB experimental farm. Immediately after collection, washing procedures in running water, removal of thorns and bark, and longitudinal and transversal cuts were carried out, resulting in a viscous complex, then proceeded to measure the masses. The leaves were used. The measure used for Palma was 24 g and for Mandacaru was 48 g. It is important to note that no substances were used to extract the structural components of plant species and there was no dehydration process either.

### Obtaining and preparing of *M. oleifera*

Moringa seeds (*M. oleifera*) were acquired through donations from the university itself and another part through commercial purchase. To prepare the extract, the husks were removed from the seeds and the grinding process was carried out with the aid of a mortar, using 10.0 mL of distilled water for 6.0 g of already peeled seeds (equivalent to 30 seeds) (Amaral et al., 2006; Sarpong and Richardson, 2010; Wilson and Andrews, 2011).

### Decantation and flocculation test

Three containers with a capacity of 20 L were used, for each container 12 L of raw water sample were added. The decantation test consisted of mixing the respective treatments (24.0 g of *O. cochenillifera*, 48.0 g of *C. Jamacaru* and 6.0 g of *M. olifera* seeds) with the raw water samples. The homogenization process was performed manually using a sterilized polyethylene stick. Initially, two speeds were used, one fast and constant and the other slow for 5 min (Muyibi and Okuofu, 1995; Amaral et al., 2006).

The samples were left to rest for 24 h in the animal parasitology and microbiology laboratory at a temperature of 21°C, for particle sedimentation. After this period, samples of the supernatant were again characterized for microbiological and physicochemical characteristics in the laboratory (zero time).

### Disinfection process by exposure to solar radiation (SODIS)

To minimize the turbidity and color parameters of raw water, pre-treatment of coagulation and flocculation with extracts from mandacaru, palma and moringa were performed.

The treated water samples were placed in transparent polyethylene terephthalate (PET) bottles, with a capacity of 2,000 mL, where they were previously disinfected with 1% sodium hypochlorite and solar disinfection. In the SODIS process, the bottles were exposed to the sun for two consecutive days, this period was recommended by the SODIS Application Guide - Solar Water Disinfection (2002), due to weather conditions (75% of cloudy sky). In order to increase the efficiency of SODIS, the bottles were placed on a glossy reflective surface (EAWAG / SANDEC, 2006).

At the end of the period of sun exposure, the samples were evaluated for the action of radiation, with microbiological and physicochemical analyses.

**Table 2.** Mean test and coefficient of variation (CV) for microbiological analysis of water under alternative treatment with Mandacaru, Moringa, Palma, Control treatment- (AB paste), raw water, at two different times (T0- before exposure to the sun and T1- after sun exposure) for collection 1.

| Treatment | Mesophiles (NMP/100 mL) | | Coliforms (NMP/100 mL) | | *E. coli* (NMP/100 mL) | |
|---|---|---|---|---|---|---|
| | T0 | T1 | T0 | T1 | T0 | T1 |
| Mandacaru | $941.19^{bA}$ | $1489.67^{bB}$ | $2033.71^{aA}$ | $2419.20^{aA}$ | $21.36^{aA}$ | $8.00^{aA}$ |
| Moringa | $1620.00^{cB}$ | $241.66^{aA}$ | $2419.20^{aA}$ | $2419.20^{aA}$ | $2419.20^{cA}$ | $2419.20^{bA}$ |
| Palma | $1467.91^{cA}$ | $1640.33^{bB}$ | $1915.46^{aA}$ | $2419.20^{aA}$ | $214.50^{bA}$ | $2419.20^{bB}$ |
| ABcole | $129.50^{aA}$ | $129.50^{aA}$ | $2419.20^{aA}$ | $2419.20^{aA}$ | $13.76^{aA}$ | $13.76^{aA}$ |
| Mean | 1039.65 | 875.29 | 1974.59 | 2419.2 | 667.18 | 1215.04 |
| CV (%) | 7.02 | | 26.43 | | 2.15 | |

Means followed by the same lower case letter in the columns and upper case in the rows do not differ statistically from each other by the Tukey test at 5% probability.

#### Parameter analysis

To determine the microbiological parameters, the chromogenic substrate method (Colilert®) was used to quantify total coliforms and *E. coli*. This method consists of using β-galactosity to metabolize ONPG and as most non-coliforms do not have these enzymes, they cannot grow and interfere in the reaction, minimizing the incidence of false positives and false negatives, obtaining the results expressed in Most Probable Numbers (MPN) in 100 mL of the sample. For the counting of mesophilic microorganisms, the deep plating technique was used, with the Merck® Plate Count Agar (PCA) culture medium (Barros, 2016).

#### Experimental design and statistical analysis

A completely randomized experimental design was used, in a 4×2 factorial scheme, with 4 treatments (Mandacaru, Moringa, Palma, Control-ABcole treatment) in two stages (Time 0 and Time 1), with three replications.

Data were subjected to analysis of variance (ANOVA) and Tukey's test at 5% probability to analyze the difference between treatments. The statistical software R version 3.6.1 was used.

## RESULTS

### Microbiological parameters in collection 1

ANOVA was performed, where the results obtained in the present study had a significant difference between treatments, with significant interaction between them.

According to the mean test, the time 0 that provided the lowest growth of mesophilic microorganisms was Mandacaru with 941.19 NMP, with a higher value only than the control (129.5 NMP). The treatments with Moringa and Palma did not differ according to the Tukey test, with the highest mesophilic values. For time 1, the best treatment was with Moringa, followed by the other two treatments that had no statistical difference between them (Table 2).

When comparing the two times (T0 and T1), it appears that the treatment before exposure to the sun (T0) has better results for Mandacaru and Palma. However, for the treatment using Moringa after being exposed to the sun (T1), it was more efficient in controlling mesophiles. Regardless of the type of treatment, the coefficient of variation was satisfactory.

For the control of total coliforms, there was no significant interaction between the levels observed, both in treatments and in times.

Mandacaru stood out among all treatments when submitted to time 0 and time 1 for *E. coli*, shown in Table 2. Moringa presented a value much higher than the others, being considered, according to the data, the least indicated and with less efficiency for the treatment of *E. coli* regardless of the time evaluated (with or without exposure to the sun). The average presented was 667.18 NMP for T0 (before exposure to the sun). The treatment using the palm showed the best result at time 0.

The coefficient of variation (CV), which seeks the smallest dispersion among the data, indicated the homogeneity of the results, where mesophiles obtained a CV of 7.02%, *E. coli*, a CV of 2.15%. The results for total coliforms showed a greater degree of dispersion (26.43%); however, a value within the mean.

### Microbiological parameters in collection 2

In collection 2, all treatments differed from each other, the treatment that had the lowest growth of mesophiles at time 0, being considered the best, was Mandacaru, followed by Palma and Moringa. Treatment with moringa had the greatest growth of mesophiles for time 0, 1665 NMP. All treatments (Mandacaru, Palm and Moringa)

**Table 3.** Mean test and coefficient of variation (CV) for microbiological analysis of water under alternative treatment with Mandacaru, Moringa, Palma, Control treatment- (ABcole), raw water, at two different times (T0- before exposure to the sun and T1- after sun exposure) for collection 2.

| Treatment | Mesophiles (NMP/100 mL) | | Coliforms (NMP/100 mL) | | *E. coli* (NMP/100 mL) | |
|---|---|---|---|---|---|---|
| | T0 | T1 | T0 | T1 | T0 | T1 |
| Mandacaru | 759.33$^{bA}$ | 929.33$^{bB}$ | 2419.2$^{aB}$ | 1095.4$^{aA}$ | 9.33$^{aA}$ | 10.35$^{aA}$ |
| Moringa | 1665.00$^{dB}$ | 1478.50$^{cA}$ | 2419.2$^{aA}$ | 2419.2$^{bA}$ | 2419.20$^{cA}$ | 2419.20$^{bA}$ |
| Palma | 1072.00$^{cA}$ | 1351.66$^{cB}$ | 2419.2$^{aA}$ | 2419.2$^{bA}$ | 65.43$^{bA}$ | 2419.20$^{bB}$ |
| ABcole | 131.00$^{aA}$ | 131.00$^{aA}$ | 2419.2$^{aA}$ | 2419.2$^{bA}$ | 22.70$^{aA}$ | 22.70$^{aA}$ |
| Mean | 906.83 | 972.62 | 2419.2 | 2088.25 | 629.17 | 1217.86 |
| CV (%) | 7.81 | | 18.25 | | 0.77 | |

Means followed by the same lower case letter in the columns and upper case in the rows do not differ statistically from each other by the Tukey test at 5% probability.

**Table 4.** Mean test and coefficient of variation (CV) for physicochemical analysis of water under alternative treatment with Mandacaru, Moringa, Palma, Control treatment-(ABcole), raw water, at two different times (T0-before exposing in the sun and T1- after exposure to the sun) for collection 1.

| Treatment | Turbidity(UNT) | | Temperature (ºC) | | Color (uC) | | DO (mg/L) | | pH | |
|---|---|---|---|---|---|---|---|---|---|---|
| | T0 | T1 | T0 | T1 | T0 | T1 | T0 | T1 | T0 | T1 |
| Mandacaru | 37.50$^{bB}$ | 10.23$^{aA}$ | 23.70$^{aB}$ | 37.33$^{aA}$ | 400.00$^{bA}$ | 400.00$^{cA}$ | 10.80$^{aB}$ | 8.96$^{aA}$ | 6.92$^{aA}$ | 6.60$^{bB}$ |
| Moringa | 50.11$^{cB}$ | 19.10$^{bA}$ | 23.60$^{aB}$ | 37.66$^{aA}$ | 300.00$^{aB}$ | 250.00$^{aA}$ | 9.10$^{aA}$ | 16.20$^{bB}$ | 7.00$^{aA}$ | 6.38$^{cB}$ |
| Palma | 14.16$^{aA}$ | 8.80$^{aA}$ | 23.60$^{aB}$ | 38.50$^{aA}$ | 400.00$^{bB}$ | 300.00$^{bA}$ | 10.90$^{aB}$ | 8.33$^{aA}$ | 6.65$^{bA}$ | 6.76$^{bA}$ |
| ABcole | 60.05$^{dA}$ | 60.05$^{cA}$ | 23.60$^{aA}$ | 23.60$^{bA}$ | 400.00$^{bA}$ | 400.00$^{cA}$ | 9.43$^{aA}$ | 9.43$^{aA}$ | 7.07$^{aA}$ | 7.07$^{aA}$ |
| Average | 40.46 | 24.55 | 23.63 | 34.27 | 375.00 | 337.5 | 10.05 | 10.73 | 6.91 | 6.70 |
| CV (%) | 4.40 | | 2.27 | | 0.00 | | 9.25 | | 1.01 | |

Means followed by the same lower case letter in the columns and upper case in the rows do not differ statistically from each other by the Tukey test at 5% probability.

showed a higher growth rate of mesophilic micro-organisms than the control sample.

In time 1, the Mandacaru treatment also showed the best result for the control of mesophiles, with a growth of 929.33 NMP. The treatments with Moringa and Palma had no significant difference between them. The overall mean for treatment 0 and treatment 1 were not very discrepant between them for mesophilic growth, 906.83 and 972.62 NMP, respectively.

For the analysis of total coliforms, the treatments did not differ from each other, except for the treatment with Mandacaru, which at time 1 had the lowest number of FC, 1095 NPM, differing from all other treatments.

For *E. coli*, within time 0, the best treatment was the use of Mandacaru, followed by Palma and in last place was Moringa as the worst expected result, shown in Table 3. At time 1, the treatment with Mandacaru continued as the best result. Treatments with Moringa and Palma did not differ according to Tukey's statistical test, showing the highest growth.

## Physicochemical parameters collection 1

Some attributes related to physicochemical characteristics were also analyzed (Table 4). For the variable turbidity at time 0, the best treatment was Palma with the lowest value of 14.16 UNT, followed by Mandacaru with a value of 37.50 UNITS. Moringa did not present satisfactory results, as it presented values above the total average. For the time with sun exposure (T1), the treatments with Mandacaru and Palma provided less turbidity, not differing statistically from each other. Moringa treatment showed more satisfactory results than the control treatment (Table 4). When analyzing all treatments, regardless of time, Palma was more efficient for the turbidity variable.

The temperature variable both at time 0 and at time 1 did not present significant differences between them, only the control differing when exposed to the sun.

In relation to color at time 0, the treatment that provided the lowest color was Moringa, with 300 uC, differing from

**Table 5.** Mean test and coefficient of variation (CV) for physical-chemical analysis of water under alternative treatment with Mandacaru, Moringa, Palma, Control treatment-(ABcole), raw water, at two different times (T0-before exposing in the sun and T1-after exposure to the sun) for collection 2.

| Treatment | Turbidity (UNT) | | Temperature (ºC) | | Color (uC) | | DO (mg/L) | | pH | |
|---|---|---|---|---|---|---|---|---|---|---|
| | T0 | T1 | T0 | T0 | T1 | T0 | T0 | T1 | T0 | T1 |
| Mandacaru | 42.86bB | 28.00cA | 21.83aB | 12.86bB | 6.96aA | 6.73ab | 12.86bB | 6.96aA | 6.73ab | 6.45bB |
| Moringa | 55.63cB | 18.90bA | 21.66aB | 12.83bA | 17.66cB | 6.63bA | 12.83bA | 17.66cB | 6.63bA | 6.44bB |
| Palma | 22.16aB | 14.10aA | 22.33aB | 20.53cB | 13.56bA | 6.89ab | 20.53cB | 13.56bA | 6.89ab | 6.61aB |
| ABcole | 69.04dA | 69.04dA | 22.16aA | 8.66aA | 8.66aA | 6.34cA | 8.66aA | 8.66aA | 6.34cA | 6.34bA |
| Mean | 47.42 | 32.51 | 21.99 | 13.72 | 11.71 | 6.65 | 13.72 | 11.71 | 6.65 | 6.46 |
| CV (%) | 1.36 | | 4.64 | | 3.98 | | 10.72 | | 1.10 | |

Means followed by the same lower case letter in the columns and upper case in the rows do not differ statistically from each other by the Tukey test at 5% probability.

all other treatments, which had values of 400 uC. At time 1, all treatments differed, with Moringa being the best treatment, followed by Palma, Mandacaru and control, with values of 250, 300, 400, and 400 uC, respectively.

The treatments did not differ from each other when evaluated for dissolved oxygen (DO) at time 0. At time 1, the treatments with Mandacaru, Palma did not differ from each other. Moringa had a DO rate of 16.2 mg/L (Table 4).

Within time 0, the best pH values were with the treatments with Mandacaru and Moringa that did not differ from each other, as well as they did not differ from the control treatment, keeping the pH close to neutrality. In time 1, the treatments that had the best pH values were Palma and Mandacaru, providing the best pH values.

Analyzing the treatments in relation to time, Mandacaru and Palma had similar effects in relation to the DO rate. Time 1 had better DO values compared to time 0. For Moringa the DO rate increases over time, where at time 0 it has a value of 9.10 mg/L and at time 1 it has a value of 16.20 mg/L. For pH, the treatments behaved in the same way, being better at time 0, except for the palm treatment, which had no significant difference in relation to the times tested.

## Physicochemical parameters collection 2

All treatments differed in terms of turbidity, with a better result for Palma when evaluated at time 0 (Table 5). The treatment with Moringa did not present satisfactory values, where it obtained a value more than twice of Palma (55.63 UNT), whereas Mandacaru (22.16 UNT) was characterized with intermediate values, where the control treatment presented a turbidity of 69.04 UNT. At time 1, all treatments differed, with the best treatment being Palma, with 14.1 UNT, followed by treatment with Moringa and Mandacaru.

Regarding temperature, at time 0, the treatments did not differ from each other. At time 1, the palm, moringa and mandacaru presented approximate values, with no significant differences. However, when compared in terms of times, the values differed, with an increase in temperature at time 1 compared to time 0 for the expected result, since they were stored under the same temperature conditions.

For the color variable, when treatments were tested at time 0, there was a significant difference between treatments, with values of 400 uC for Mandacaru and Moringa and 500 uC for Palma. At time 1, all treatments differed, with the best results being obtained with Palma (266.66 uC), followed by Moringa and Mandacaru (366.66 and 416.66 uC, respectively). When compared with the control treatment, there was a significant difference in the decrease of the color samples at both time 0 and time 1.

The coefficient of variation for the color variable was 3.98 uC, even with a higher value than the first treatment; it is still considered an excellent result, given the importance of a low coefficient of variation.

Analyzing the treatments in relation to time, all treatments had different results in the times tested for turbidity. The treatments with Moringa, Mandacaru and Palma had the best results at time 1. Taking into account the temperature, all treatments differed from each other, showing better results when exposed to the sun (T1). For color, the treatments using Moringa and Palma stood out at time 1, while the treatment with Mandacaru had no difference between the times tested.

Evaluating the treatments in relation to dissolved oxygen at time 0, there were no significant differences between the treatment using Mandacaru and Moringa, with these showing the best results (Table 5). In time 1, the Mandacaru treatment stood out with a value above 7.0 mg/L, surpassing even the control treatment (ABcole).

Regarding pH, at time 0 the best treatment was Mandacaru, with a value of 6.73, the other treatments did not differ from each other in relation to the control treatment. However, at time 1, the best pH value was obtained with the treatment with Palma, followed by the treatment with Mandacaru and the other treatments did not differ from each other.

## DISCUSSION

*Mandacaru* was the polymer that showed better results in the control of *E. coli* when compared with control samples. *M. oleifera*, on the other hand, was efficient in controlling the growth of aerobic mesophilic microorganisms, when time 0 and time 1 were compared (Tables 2 and 3). According to Davet et al. (2009), the crude extract of the cortex and wood of *C. jamacaru* has antibacterial potential and inhibits the growth of *Streptococcus epidermidis*, *Staphylococcus aureus*, *Pseudomonas aeruginosa* and *E. coli* colonies. In this way, its extract is a promising source for obtaining natural antibiotics.

Cacti are promising coagulants and this effect may be associated with the presence of various pectins, a complex family of heterogeneous polysaccharides present in plant cell walls (Lima and Abreu, 2018).

*M. oleifera* has been acting as a clarifying agent due to the presence of a cationic protein that destabilizes the particles contained in the water in liquid form. Moringa also has constituents such as pterygospermine and rhamnosyl-oxybenzyl-isothiocyanate that have antimycobrian actions (Cardoso et al., 2008; Batista et al., 2013; Franco et al., 2017).

Palm was the most efficient agent in reducing turbidity when compared with mandacaru and moringa. Moringa, on the other hand, was the agent with the best performance for decreasing apparent color. The samples collected from a natural source had very high turbidity and color contents, where the polymers used were not sufficient to the point of decreasing these parameters in order to allow an efficient solar sterilization. According to Di Bernardo (2004), the lower the turbidity resulting after decantation, the more efficient the subsequent processes such as filtration and disinfection will be.

By adding more organic matter (Mandacaru, Moringa and Palm treatments), there was a reverse effect, which behaved as a growth and development medium for the microorganisms present there. The presence of dissolved matter in the water characterizes an increase in the apparent color, which hinders the penetration of light rays, consequently interfering with solar disinfection (Amaral et al., 2006).

The climatic characteristics of the weather during the study also influenced the microbial growth of the samples, shown in Tables 4 and 5, the average maximum temperatures reached in the collections were 34.27° and 34.46°, respectively, not being sufficient for disinfection of the samples. Paterniani and Silva (2005) affirmed that water heating and bacterial inactivation are influenced by weather conditions during the time of exposure to the sun, where infrared radiation is responsible for the rise in water temperature, such an increase that after 50°C it helps in disinfecting water and preventing bacterial regrowth.

The solar water disinfection technique has no residual effect, which favors microbial regrowth 24 h after the end of the disinfection process when the water temperature was below 50°C (Paterniani and Silva, 2005).

The polymers tested had little effect on the pH of the samples, as shown in Tables 4 and 5. Also according to the current ordinance, this parameter must be in the range of 6.0 to 9.5. The pH value influences the distribution of free and ionized forms of various chemical compounds, in addition to contributing to a greater or lesser degree of solubility of substances and defining the toxicity potential of various elements (BRASIL, 2014). Jacob (2018), when testing the application of organic coagulants extracted from cactus (*O. cochenillifera*) and *M. oleifera* in water treatment, found that the pH of the samples did not change during the processes using *M. oleifera* and the coagulants in combination, but for the *O. cochenillifera* cactus, the pH of all assays increased during the processes.

Sousa (2019) when evaluating the coagulation capacity of *C. jamacaru, Opuntia ficus-indica* and *Pilosocereus gounellei* cacti as pre-treatment for disinfection by solar radiation, obtained satisfactory results, which obtained inactivation of total coliforms present in their samples. The author asserts that cacti are great potential natural coagulants to be used as occasional pre-treatment of real turbid water for subsequent solar disinfection, since after treatment all parameters evaluated met the requirements established by Brazilian legislation for drinking water.

According to Manoj and Vara (2021), coagulants showed their effectiveness in comparison with the available literature. However, the use or acceptance of these coagulants in industrial wastewater treatment is very low. The use of coagulants can be improved, showing their efficiency compared to the advanced treatment technologies available in the current scenario.

## Conclusions

The polymers used in this research were efficient in controlling microbiological and physicochemical characteristics of water. However, the levels reached were not sufficient to meet the quality parameters established by current legislation.

The climatic conditions of the region where the study took place had an influence on the result obtained in this study. It is also inferred that the microbiological composition of the plant species used also influenced the result of this work. Thus, it is important to carry out other studies in order to quantify the influence of such variables.

Developing the use of natural polymers is very relevant as it can bring advances in social, economic and environmental aspects for the population.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

## REFERENCES


Agritempo: Sistema De Monitoramento Agrometeorológico. http://www.agritempo.gov. br/agroclima/sumario.

Amaral LA, Rossi Júnior O, Soares e Barros LS, Lorezon CS, Nunes AP (2006). Tratamento alternativo da água utilizando extrato de semente de Moringa oleifera e radiação solar. Arquivos do Instituto Biológico 73(3):287-293. . http://www.biologico.sp.gov.br/uploads/docs/arq/v73_3/amaral.pdf

Barros LSS (2016). Rural health mapping the Recôncavo from Bahia. Revista Brasileira De Higiene E Sanidade Animal 10:604-652. http://www.higieneanimal.ufc.br/seer/index.php/higieneanimal/article/view/350

Batista RF, Filho LCAL, Silva JBA, Dutra I, Santos DB (2013). Tecnologias limpas aplicadas ao tratamento de água superficial no semiárido brasileiro. Enciclopédia Biosfera 9(16):186-198. http://www.conhecer.org.br/enciclop/2013c/tecnologias.pdf

BRASIL (2014). Ministério da Saúde. Fundação Nacional de Saúde. Manual de controle da qualidade da água para técnicos que trabalham em ETAS / Ministério da Saúde, Fundação Nacional de Saúde. – Brasília: Funasa. http://www.funasa.gov.br/documents/20182/38937/Manual+de+controle+da+qualidade+da+%C3%A1gua+para+t%C3%A9cnicos+que+trabalham+em+ETAS+2014.pdf/85bbdcbc-8cd2-4157-940b-90b5c5bcfc87

Cardoso KC, Bergamasco R, Sala CE, Konradt Moraes LC (2008). Otimização dos tempos de mistura e decantação no processo de coagulação/floculação da água bruta por meio da Moringa oleifera Lam. Acta Scientiarum. Technology 30(2):193-198. https://www.redalyc.org/pdf/3032/303226522010.pdf

Cavallini GS, Araújo DLB, Da S, Lima JGF (2018). Desinfecção de água de poço por radiação solar (SODIS). Desafios - Revista Interdisciplinar Da Universidade Federal Do Tocantins 5:66-73. https://doi.org/10.20873/uft.2359-3652.2018v5nEspecialp66

Davet A, Virtuoso S, Dias JFG, Miguel MD, Oliveira AB, Miguel OG (2009).Atividade antibacteriana de *Cereus jamacaru* DC, Cactaceae. Revista Brasileira de Farmacognosia [online] 19:561-564. https://doi.org/10.1590/S0102-695X2009000400009

Di Bernardo AS (2004). Desempenho de sistemas de dupla filtração no tratamento de água com turbidez elevada/ Tese (doutorado), Escola de Engenharia de São Carlos- Universidade de São Paulo, https://www.teses.usp.br/teses/disponiveis/18/18138/tde-24112015-111804/pt-br.php

EAWAG/SANDEC (2006). Training manual for SODIS promotion, Dübendorf, Suíça pp. 1-88.

Franco CS, Batista MDA, Oliveira LFCD, Kohn GP, Fia R (2017). Coagulação com semente de moringa oleifera preparada por diferentes métodos em águas com turbidez de 20 a 100 UNT. Engenharia Sanitária e Ambiental 22:781-788. https://doi.org/10.1590/S1413-41522017145729

Gunaratna K, Garcia B, Andersson S, Dalhammar G (2007). Screening and evaluation of natural coagulants for water treatment. Water Science and Technology: Water Supply 7(6):19-25. https://doi.org/10.2166/ws.2007.147

Jacob AC (2018). Aplicação de coagulantes orgânicos extraídos do cacto (*Opuntia cochenillifera*) e da *Moringa oleifera* no tratamento de água. Trabalho de Conclusão de Curso apresentado à Universidade Tecnológica Federal do Paraná, Londrina. http://repositorio.roca.utfpr.edu.br/jspui/handle/1/10256

Keogh MB, Castro-Alférez M, Polo-López MI, Fernández Calderero I, Al-Eryani YA, Joseph-Titus C, Sawant B, Dhodapkar R, Mathur, C, McGuigan KG, Fernández-Ibáñez P (2015). Capability of 19-L polycarbonate plastic water cooler containers for efficient solar water disinfection (SODIS): field case studies in India, Bahrain and Spain. Solar Energy 116:1-11. https://doi.org/10.1016/j.solener.2015.03.035.

Lima JRN, Abreu FOMS (2018). Produtos Naturais Utilizados como Coagulantes e Floculantes para Tratamento de Águas: Uma Revisão sobre Benefícios e Potencialidades. Revista Virtual de Química 10(3):709-735. http://static.sites.sbq.org.br/rvq.sbq.org.br/pdf/v10n3a20.pdf

Manoj KS, Vara S (2021). Natural Coagulants for the Treatment of Water and Wastewater: A Futuristic Option for Sustainable Water Clarification. Recent Innovations in Chemical Engineering 14(2):120-147. https://doi.org/10.2174/2405520413999201110094015

McGuigan KG, Conroy RM, Mosler HJ, du Preez M, Ubomba-Jaswa E, Fernandez-Ibanez P (2012). Solar water disinfection (SODIS): a review from bench-top to rooftop. Journal of Hazardous Materials 235:29-46. https://pubmed.ncbi.nlm.nih.gov/22906844/

Muyibi AS, Okuofu CA (1995). Coagulation of low turbity surface waters with *Moringa oleifera* seeds. International Journal of Environmental Studies, 48:263-273. https://www.tandfonline.com/doi/abs/10.1080/00207239508710996

Nharingo T, Zivura MT, Guyo U (2015). Exploring the use of cactus *Opuntia ficus* indica in the biocoagulation–flocculation of Pb(II) ions from wastewaters. International Journal of Environmental Science and Technology 12(12):3791-3802. http://www.bioline.org.br/pdf?st15355

Ostrowski J (2014). Utilização de extrato de cacto *Cereus jamacaru* como coagulantes auxiliares para a diminuição de turbidez da água de turbidez sintética. Trabalho de Conclusão de Curso. Universidade Tecnológica Federal do Paraná – UTFPR Campus Toledo. http://repositorio.roca.utfpr.edu.br/jspui/handle/1/6229

Paterniani JES, Silva MJM (2005). Desinfecção de efluentes com tratamento terciário utilizando energia solar (SODIS): Avaliação do uso do dispositivo para concentração dos raios solares. Engenharia Sanitária e Ambiental 10:09-13. https://www.scielo.br/j/esa/a/kmB3BwQqmtnVMDrGmWj5mks/?lang=pt&format=pdf

Penn C (1991). Chapter 1. Equipment and materials; Chapter 5. Sterility and aseptic technique. In: "Handling Laboratory Microorganisms", Open University Press, Philadelphia 5(25):41-48. https://fdocumentos.tips/document/tcnicas-de-esterilizao-e-desinfeco-esterilizao-de-esterilizao-de-cerca-de-15.html

Rodrigues MDGF, Nacif PGS, Costa OV, Olszevski N (2009). Solos e suas relações com as paisagens naturais no município de Cruz das Almas – BA. Revista de Biologia e Ciências da Terra 9(2):193-205. https://www.redalyc.org/pdf/500/50016937017.pdf

Sarpong G, Richardson CP (2010). Coagulation efficiency of *Moringa oleifera* for removal of turbidity and reduction of total coliform as compared to aluminum sulfate. African Journal of Agricultural Research 5(21):2939-2944 https://academicjournals.org/journal/AJAR/article-full-text-pdf/F9E4AC134122

Sousa KML (2019). Estudo dos coagulantes naturais *Cereus jamacaru, Opuntia ficus-indica* e *Pilosocereus gounellei* como pré-tratamento para desinfecção solar. 44 f. Trabalho de Conclusão de Curso (Licenciatura em Química) – Unidade Acadêmica de Serra Talhada, Universidade Federal Rural de Pernambuco, Serra Talhada. http://hdl.handle.net/123456789/1315

Tomasella J, Silva Pinto Vieira RM, Barbosa AA, Rodriguez DA, de Oliveira Santana M, Sestini MF (2018). Desertification trends in the Northeast of Brazil over the period 2000–2016. International Journal of Applied Earth Observation and Geoinformation 73:197-206 https://doi.org/ 10.1016/j.jag.2018.06.012

Viera GHF, Mourão JA, Ângelo ÂM, Costa RA, Vieira RHSDF (2010). Antibacterial effect (in vitro) of Moringa oleifera and Annona muricata against Gram positive and Gram negative bacteria. Revista do Instituto de Medicina Tropical de São Paulo 52:129-132 https://doi.org/10.1590/S0036-46652010000300003.

Wilson SA, Andrews SA (2011). Impact of a natural coagulant pretreatment for colour removal on solar water disinfection (SODIS). Journal of Water, Sanitation and hygiene for development 1(1):57-67 https://www.ircwash.org/sites/default/files/Wilson-2011-Impact.pdf

Yongabi K (2015). Biocoagulants for Water and Waste Water Purification: a Review. International review of chemical engineering 2(3):444-458. Retrieved from https://www.praiseworthyprize.org/jsm/index.php?journal=irebic&page=article&op=view&path%5B%5D=2386

Zara RF, Thomazini MH, LENZ GF (2012). Estudo da eficiência de polímero natural extraído do cacto Mandacaru (*Cereus jamacaru*) como auxiliar nos processos de coagulação e floculação no tratamento de água. REA – Revista de estudos ambientais. Revista de Estudos Ambientais 14(2):75-83. (Online). http://www.abq.org.br/entequi/2011/trabalhos/1/1-20-10458.htm