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Use of the *Moringa oleifera* Seeds Fixed-bed Model and Pernambuco Semi-arid Desalinator Reject

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Authors' contributions

This work was carried out in collaboration among all authors. Author AJGF performed the experiment as a master's thesis, performed the statistical analysis and wrote the first draft of the manuscript. Author HJBLF designed the desalinizer prototype and together with author SCP managed the analysis of the study. Author ASM designed the study and wrote the protocol. All authors have read and approved the final manuscript.

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ABSTRACT

The objective of this research was to use a prototype of fixed-bed columns packed with crushed seeds of *Moringa oleifera* to detect the best adsorption of chemical elements present in the desalinator reject. The column was adapted to the prototype container containing 200 liters of reject.The extract was collected every five minutes until 60 minutes, resulting in 12 samples where pH, EC, Na, K, Ca, Mg and Cl were determined. Statistical analysis was performed by analysis of variance (ANOVA), using the F test, with a 95% confidence interval. It was found through laboratory tests that Moringa seeds were effective in the adsorption of sodium, calcium, magnesium and chloride with five minutes of contact of desalination reject with *Moringa oleifera* crushed seeds with husks.

Keywords: Moringa; fixed-bed column; saline water; adsorption; desalination.

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1. INTRODUCTION

The peculiarities of Pernambuco's semi-arid climate, as well as rainfall rates and drought cycles, have varied greatly in recent years, aggravating a situation that is already drastic in the region:shortage of potable water. This has led the population to use mostly poor-quality brackish water, leading to numerous consequences, including infant mortality and the outbreak of various pathologies [1].

Given this situation, it is essential to treat and reuse this water, the only one available in the region, so that an improvement in the quality of life of this population is promoted [2,3].

Based on this assumption, one of the avenues for access to clean water has been the use of desalination systems in which brackish water is converted to “fresh water” [4,5]. Although great results have already been achieved, water treatment by desalination is costly, mainly due to the type of filter used in this sort of equipment. In addition, this process produces waste that is improperly disposed of in the environment [6,7].

Due, therefore, to the costs of the system and transportation of chemical coagulants, it became unworkable to make room for the use of easily accessible alternative substances called natural coagulants [8,9]. Among these coagulants, *Moringa oleifera* seeds stand out, which can be used in regions that are difficult to access and where water treatment does not reach the general population [10].

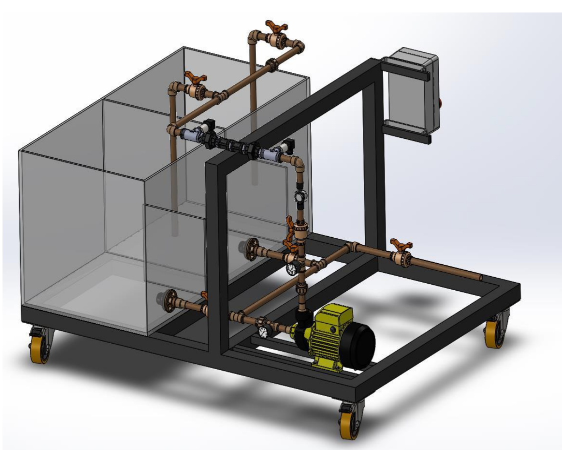
Moringa is a plant with nutritional, medicinal and water coagulant properties, besides being drought tolerant. Its seeds have an active compound that acts on colloidal particle systems, neutralizing charges and forming bridges between these particles, making the process responsible for flake formation. The use of this plant's seed has been a cheap and efficient solution for desalination of semiarid saline waters and has enabled communities in this region to use potable water in their desedentation, which is a relevant aspect in the local quality of life [11].

In an attempt to contribute to solving this problem, an experiment was carried out to test a fixed-bed column prototype packed with *Moringa oleifera* crushed seeds with husks in contact with desalination reject, verifying the best result in the adsorption process of chemicals present in the reject.

2. MATERIALS AND METHODS

In the first stage of the experiment, the best results for adsorption of chemical elements were obtained by *Moringa oleifera* crushed seeds with husks in contact with desalination reject, a treatment used in this stage.

A low-cost-material (acrylic), fixed-bed model was constructed with the following column dimensions: 42.5 cm long and 2 inches thick, which were packed with 50.0 g of *Moringa oleifera* crushed seeds with husks (Fig. 1).



(a) Isometric view of the prototype

(b) View of the packed filter

Fig. 1. Prototype of the fixed-bed column packed with *Moringa oleifera* crushed seeds

This column was then coupled to the desalination prototype that operated with volume (V) = 200 L and flow (Q) = 35.04 mL / s. in an average time of 28.53 minutes.After contact of the seeds with the reject, 12 samples were collected at intervals of 5 minutes, totaling 60 minutes, in order to investigate the best adsorption time of the chemical elements present in the desalination reject.

In the samples collected it was determined: pH through pHmetry, electrical conductivity (EC) through conductometry, sodium (Na) by flame emission spectrophotometry, chloride (Cl) by precipitation titrimetry, and calcium (Ca) and magnesium (Mg) by complexation titrimetry. Reagents used: (a) pH = water 1:2, 5; (b) CE = direct reading; (c) Na = Direct reading; (d) Cl = $AgNO_3$, K_2CrO_4; (e) Ca = EDTA, NaOH, murexide; (f) Mg = EDTA, buffer solution, Eriocromo-black.

Statistical analysis was performed using SigmaPlot 11.0 software (Systat Software, 2008, USA), with a significance level of 5% for all determinations.Prior to performing ANOVA, data normality was tested using the Kolmogorov-Smirnov test and homogeneity of variances by Barlett's test.One-way ANOVA was used for data with normal distribution or homogeneity of variance.When the tests showed significant differences ($p<0.05$), the comparison of the means of the treatments was performed, and in relation to the control, by the Dunnett test. The Kruskal-Wallis test was used when therequirements for ANOVA were not achieved.

3. RESULTS AND DISCUSSION

The pH behavior of the control was unchanged within 60 minutes; pH of samples showed oscillations within 10 minutes (6.78 - slightly acidic); it then matched the pH of the control (7.48 - basic) and from 25 minutes it rose to 8 and remained up to 60 minutes.Thus, it was found that the treatment significantly changed the reject's pH, as shown in Fig. 2.

It is important to point out that studies already carried out by Araújo [12] indicated that *Moringa oleifera* seed was efficient in removing water turbidity and removing metals, without causing changes in pH; it is a viable and significant alternative in the treatment of water in places where salt concentrations are present. A possible assumption for these different results may be the fact that, in the present research, the substance tested was the reject, which has high salt contents.

There was no significant difference in electrical conductivity: the control maintained its value (19.3 dS / cm).The reduction in EC ranged from 47.7 to 47.9%, according to Fig. 3. As shown in research by Amagloh and Benang [13], *Moringa oleifera* seed has a low molecular weight protein and when crushed acquires positive charges that attract negatively charged particles, which corroborates the results present in this study.

Regarding sodium, the control presented a concentration around 1900 mg / L, and in the samples with moringaaround 600 mg / L. Regarding the reduction of Na, the variation was 70%. From this percentage, Moringa's effectiveness in reducing Na is evident, according to Fig. 4. This result was also obtained by Menezes, Campos and Costa [11], in researches made with ground seeds of Vegetable Loofah, Pumpkin, Almond, Moringa, Algaroba, Umbu, Umburana and Mulungu, in

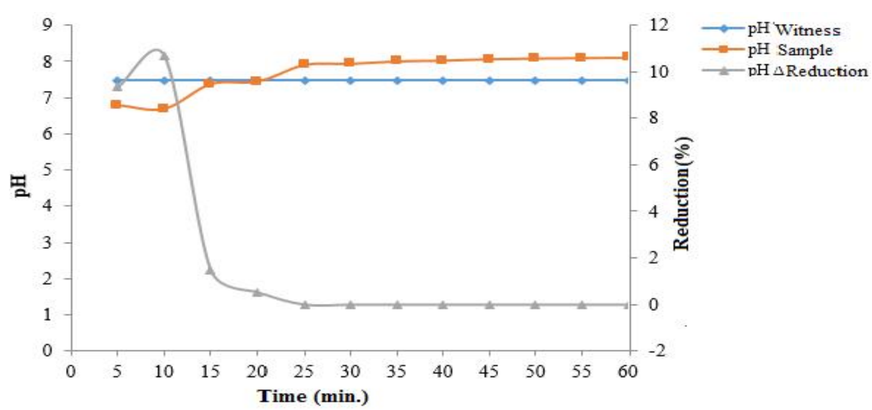


Fig. 2. pH in samples and control

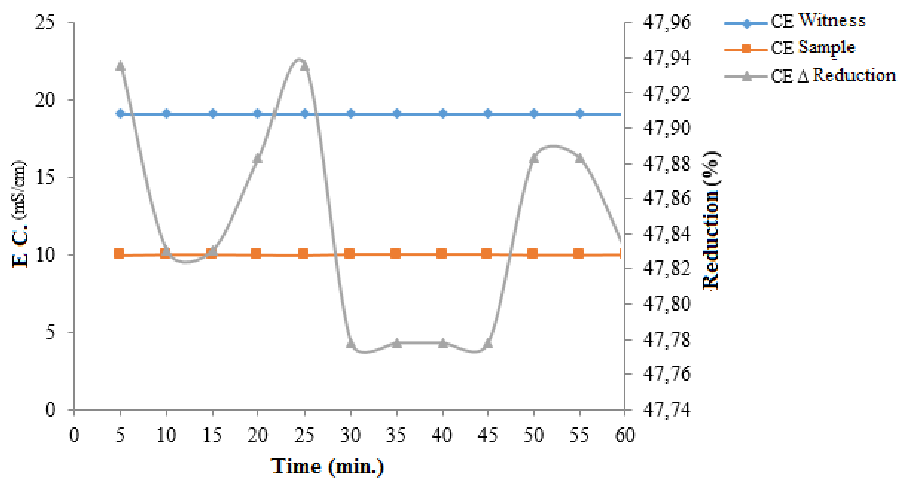


Fig. 3. Electrical conductivity in samples and control

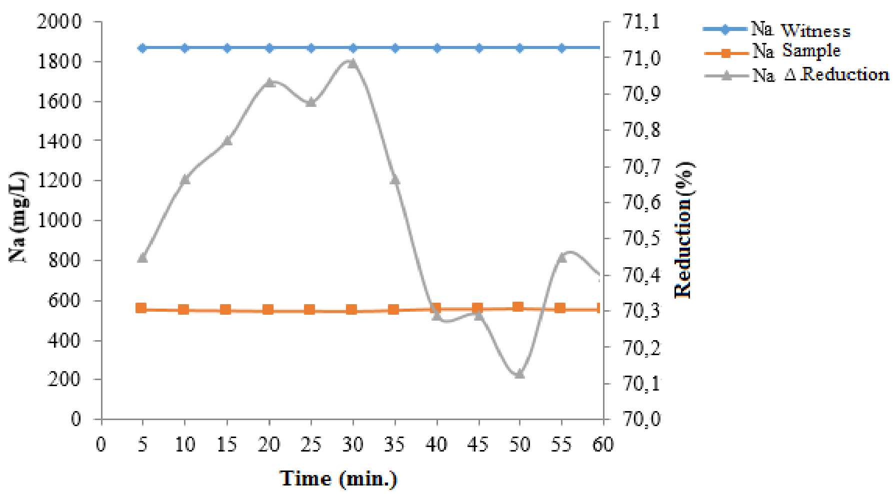


Fig. 4. Amount of sodium (Na) in samples and control

order to verify which of these seeds would present the highest sodium adsorption. Among the seeds tested, Moringa seeds reached adsorption percentage of 12%; however, only within one hour of contact with brackish water.

Regarding calcium, the control maintained its concentration of 1000 mg / L for 60 minutes, while in the 5-minute collection it was reduced to 400 mg / L.The percentage of Ca reduction ranged from 55 to 63%, according to Fig. 5.

Regarding magnesium, the control maintained the value of 740.9 mg / L and in the other samples the concentration was around 174 mg / L, indicating a reduction of 75.6 to 77.2%, as shown in Fig. 6.

The result obtained in this experiment regarding the hardness of the reject (Ca and Mg) in contact with *Moringa oleifera* showed a reduction in concentrations when compared to the control. A study by Caldeira [14] reached the same result: the researcher proved that Moringa seed powder in contact with the organic material from the well water reduces the hardness value within 24 hours.

Regarding chloride, the control maintained the value of 6,997.6 mg / L, while in the other samples a variation of 1,736 to 4,462.9 mg / L was observed over a period of 60 minutes.The range of reduction was between 75 and 37% in the experimental period. The highest chloride adsorption occurred at 5 minutes of contact, as shown in Fig. 7.

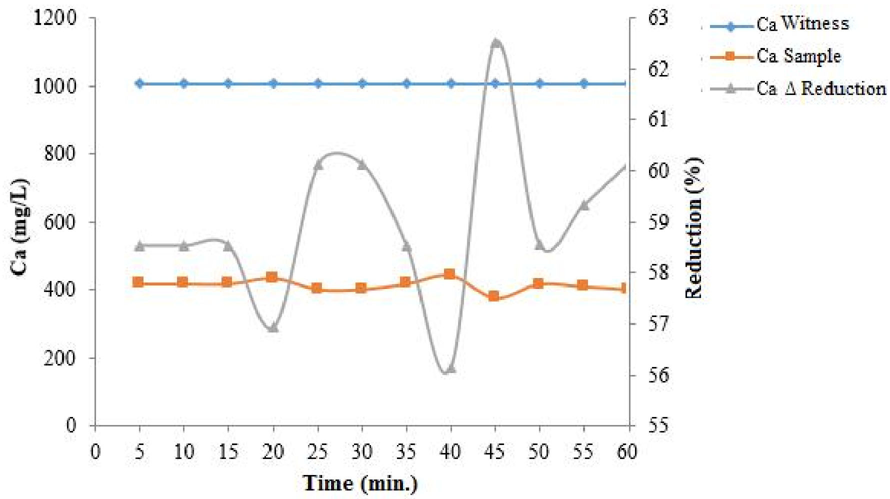


Fig. 5. Amount of calcium (Ca) in samples and control

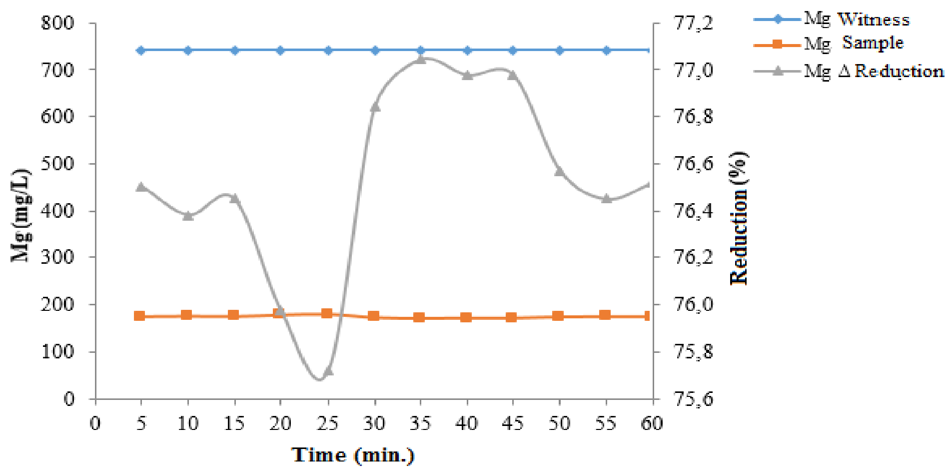


Fig. 6. Amount of magnesium (Mg) in samples and control

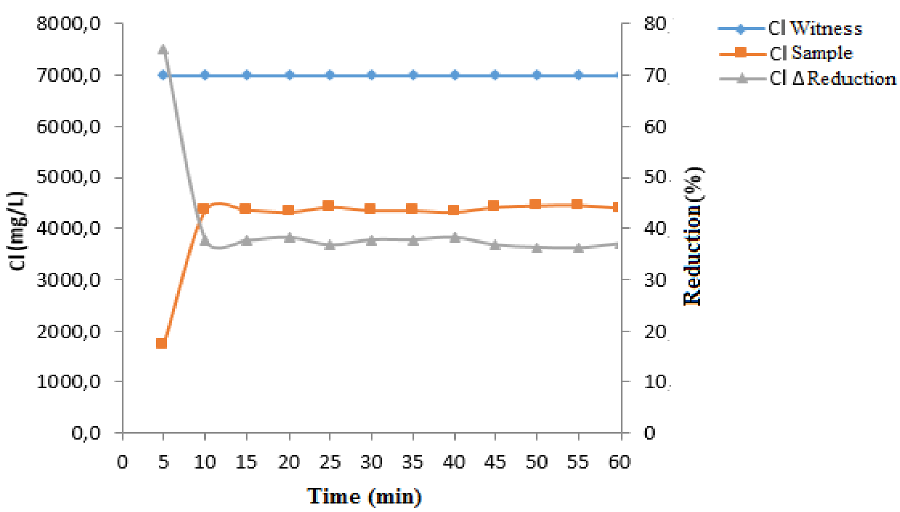


Fig. 7. Chloride (Cl) amount in samples and control

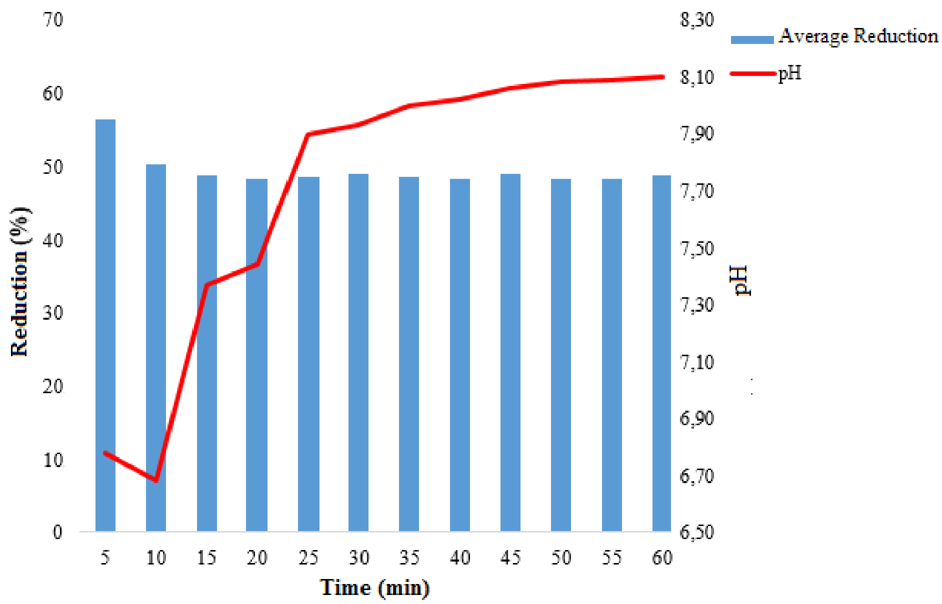


Fig. 8. Average reduction for all parameters studied

This same phenomenon was observed in research by Mangale, Chonde and Raut [15] with well water in contact with Moringa seeds in Kolhapur (India). The result showed a reduction in chloride ions from 12 to 5 mg / L due to the chemical attraction of the cationic substance present in the seed with anionic ions of the chlorides present in the water.

Fig. 8 shows the average reduction of all parameters determined in their respective times.As an example, the best contact time between the crushed moringa seed and the reject (5 minutes) is: pH 9%, EC 47%, Na 70%, Ca 58%, Mg 76% and Cl 75%, resulting in a mean of 56%.

4. CONCLUSION

Of the 12 samples collected every 5 minutes and for 60 minutes, from the contact between crushed *Moringa oleifera* with husk and the desalination reject, the sample that had the best adsorption in relation to time was the 5-minute one, with the highest reduction mean (56%), that is, with the highest adsorption by *Moringa oleifera* of the salts present in the reject. It is worth mentioning that this occurred in the slightly acidic environment (pH = 6.7) and that during the collections up to 60 minutes the pH became alkaline and the adsorption gradually decreased.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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