PROPOSAL FOR THE USE OF MORINGA OLEIFERA SEED EXTRACT AS A COAGULANT IN THE TREATMENT OF DRINKING WATER

Nicolau Penicela-Chirinza[1], Paulino-Vasco Mariano-Muguirrima[1], Federico León-Zerpa[2]*, Alejandro Ramos-Martín[2], Carlos-Alberto Mendieta-Pino[2]

1 Universidad de Zambeze (UniZambeze), Mozambique.

2 Instituto de Estudios Ambientales y Recursos Naturales (iUNAT), Universidad de Las Palmas de Gran Canaria (ULPGC).

* federico.leon@ulpgc.es

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ABSTRACT:

The aim of this study is to propose the use of Moringa oleifera seed extract as a coagulant in water treatment, with a reference to its efficiency in removing various parameters considered to be the minimum necessary for water potability, compared to the use of aluminium sulphate as a coagulant. The Moringa oleifera seed extract coagulant is easy to acquire and use, and prepared in an optimised way, it complies with the recommended standards for water potability. In environmental terms, its use is recommended because it does not transmit harmful by-products to the environment.

Keywords: Coagulant, Moringa oleifera seed, Aluminium sulphate.

RESUMEN:

El objetivo de este estudio es proponer la utilización del extracto de semillas de Moringa oleifera como coagulante en el tratamiento del agua, haciendo referencia a su eficacia en la eliminación de diversos parámetros considerados como mínimos necesarios para la potabilidad del agua, en comparación con la utilización de sulfato de aluminio como coagulante. El coagulante a base de extracto de semillas de Moringa oleifera es fácil de adquirir y utilizar y, preparado de forma optimizada, cumple las normas recomendadas para la potabilidad del agua. En términos medioambientales, se recomienda su uso porque no transmite subproductos nocivos al medio ambiente.

Palabras clave: Coagulante, semilla de Moringa oleifera, sulfato de aluminio.

1. - INTRODUCTION

Water treatment is a process in which the aim is to remove or eliminate organic matter, sludge, sand and analyse the physico-chemical and microbiological characteristics through regulations to make it ideal for human consumption[1].

The coagulation process is an essential stage in water purification. This depends on converting suspended particles into larger flocs that can settle or be easily filtered out of the water. This process involves the addition of certain chemicals called coagulants, which have the ability to help flocculate suspended particles in water. Moringa is sometimes used in the coagulation process in water treatment, where it is known to have certain proteins that are positively charged in solutions and can bind to negatively charged particles to remove turbidity from water treatment[2,3].

The use of Moringa oleifera seed as a coagulant presents some challenges to overcome, as the unfractionated seed also has other compounds that are released along with the cationic proteins of interest that can cause undesirable results, such as residual organic carbon and cytotoxicity after water treatment[4]. The core of Moringa oleifera seeds contains approximately 36.7% protein, 34.6% lipids and 5.0% carbohydrates (w/w), and as an undesirable consequence, these compounds (organic matter) can facilitate the new growth of microorganisms and lead to the formation of disinfection by-products[2,4]. Natural organic polymers have been used for more than 4,000 years in India, Africa and China as efficient coagulants and as coagulation aids for high turbidity water for domestic use in rural areas. Beginning in the 19th century, chemical coagulants such as iron chloride III ($FeCl_3$) and aluminium sulphate $Al_2(SO_4)_3$ where they came to be used all over the world to treat water for human consumption, which left the use of coagulants in the background, except in rural areas and developing countries that still use them. However, chemical coagulants have an impact on the environment and human health due to their composition and higher cost[1]. It is therefore extremely important to use natural products in order to minimise the environmental impact and unnecessary cost increases in water treatment[5,6].

The general aim of this article is to propose the use of Moringa oleifera seed extract as a coagulant in the treatment of drinking water, comparing its efficiency with aluminium sulphate as a coagulant.

As for the target audience, the proposed innovation is generally aimed at students of process engineering, chemical engineering, higher education courses related to the environment and, lastly, courses aimed at the treatment of wastewater.

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water. It should be noted that in terms of the level of students on the courses mentioned, the innovation covers all levels, from 1st year undergraduates to PhD students.

The previous level of understanding of the subject prior to the application of this work was basic knowledge of coagulants used in water treatment in general, instrumental techniques for extracting chemical compounds from plants and basic chemical engineering operations.

The learning objective is to understand the method of extracting the coagulant from the plant and to understand how to apply the coagulant in drinking water treatment systems and measure its effectiveness.

The subsequent level of understanding of the subject after applying this work is to gain an understanding of the extraction method and the efficiency of coagulation in drinking water quality. The learning outcomes are an understanding of the use of coagulants as a way of treating drinking water and an understanding of extraction techniques from natural sources.

2.- THEORETICAL BACKGROUND

Water is one of the fundamental components of sustainable development and its conservation is essential for the preservation of biodiversity on our planet. Urbanisation, changes in production and consumption patterns in industrialised and developing nations provide new issues for water cycle management; wastewater sanitation is one of them posing a double threat to public health and environmental protection [7]. However, it is extremely imperative to adopt techniques aimed at treating water in order to meet the quality requirements of potability and environmental standards. The coagulation process is widely used in water and sewage treatment, as it is effective at removing suspended solids, turbidity, organic matter, oil, chemical oxygen demand (COD) and colour. The coagulation process is mainly conducted by adding a coagulant that allows small agglomerated particles (unstable fine particles) to form into larger flocs that can settle. Coagulation and flocculation are interlinked. Coagulation is the process of grouping under high-speed mixing, while flocculation is the process of sedimentation under gentle mixing. Colloidal particles are generally negatively charged particles. Therefore, coagulation is a chemical process involving the neutralisation of these particles in water and wastewater, while flocculation is a physical process involving the formation of flocs from particles neutralised during the coagulation process. Thus, large flocs form during coagulation, and they aggregate and sediment during flocculation [5,6].

Coagulation sedimentation is widely used in water treatment due to its ease of maintenance and low operating cost. Drinking water processing relies heavily on coagulation sedimentation, which accounts for approximately 5% of the total cost of operating water treatment facilities [7-9].

2.1 Moringa oleifera as a coagulant

The coagulation mechanism using Moringa oleifera to remove pollutants from water is due to the combination of the coagulation and charge neutralisation mechanisms. This is similar to the coagulation mechanism of aluminium sulphate[11].M oringa oleifera seeds contain significant amounts of soluble cationic proteins, and when they are ground into powder and added to turbid water, they release positive charges, attracting negatively charged particles such as mud, clay, bacteria and other particulates present in the water. Coagulation occurs when the cationic proteins bind to the negative particles, forming flakes. [10]Moringa oleifera can clarify high, medium and low turbidity water [2,12]. While aluminium-based coagulants are efficient in a restricted range of pH levels in water treatment, the use of Moringa oleifera seeds is independent of the pH of the water to be treated for its efficiency. Another beneficial effect that should be noted when Moringa oleifera is used as a coagulant is the effect of biological water treatment, which occurs concomitantly with coagulation. This effect is due to the fact that Moringa oleifera contains an antimicrobial substance that acts on the microorganisms that are found in the particles suspended in the water and end up being eliminated along with the sludge[7,9,13]. The use of Moringa oleifera seeds and pods together with filtration in water treatment shows good results and reduces the use of non-biodegradable chemical coagulants, as well as having the advantages of less sludge generation, the production of biodegradable sludge, good removal of turbidity and colour, removal of almost 90% of bacteria and maintaining the pH of the water. Other advantages of the moringa seed extract are that it is easy to handle, involves simple technologies that unskilled professionals can operate, and is a biodegradable extract [14,15].

2.2 Quality of drinking water

A significant number of water supply systems that provide drinking water to local people and communities around the world are fed by surface water sources [1,13].

The quality of surface water is important, among other concerns, due to its widespread use as the main source of drinking water for countless communities around the world.

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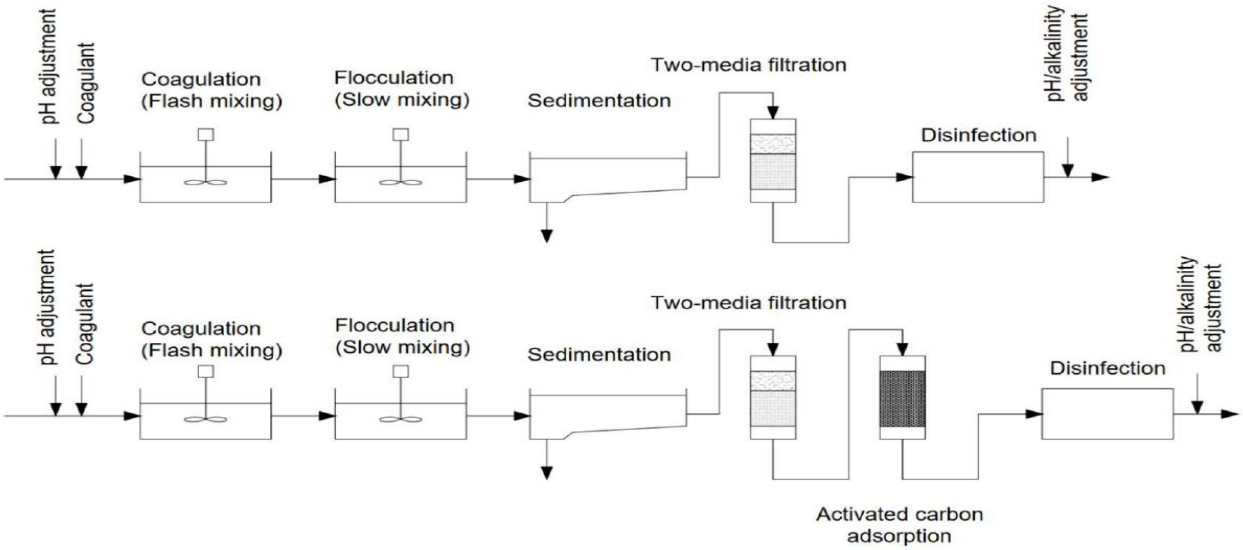

Figure 1: Conventional water treatment system (adapted by Takaara).

Although the specific targets for surface water treatment can vary depending on the source, water quality and regulatory standards, the parameters that usually require reduction are the same for most surface waters and include turbidity, colour and organic matter content. Current surface water purification methods include adsorption, membrane filtration, ion exchange, advanced oxidation processes and biological processes. However, traditional coagulation is still the most prevalent [12].
The conventional water treatment system consists of coagulation followed by sedimentation, filtration and often activated carbon adsorption (Figure 1) [10,12].

3.- MATERIAL & METHODS

Preparation of the coagulating solution from Moringa oleifera seed extract
For the preparation of the bio-coagulant solution, the ideology of the various authors was followed (Alam et al., 2020; Alazaiza et al., 2022a).According to the authors, for an initial turbidity of 50 NTU, the best dosage for the aqueous bio-coagulant would be at a concentration of 2%, with 2 g of the ground sample of Moringa oleifera seeds in 100 ml of distilled water. The procedure used was as follows:

a) Figure 2 shows the Moringa Oleifera seeds in two scenarios: first, the seeds in their shells, and second, the seeds peeled with a knife.

Figure 2: Ground Moringa seed.

In order to improve contact between the particles, it was necessary to reduce the particle size of the seeds using a knife mill.

b) The active compound was extracted as follows:
   I. Using a spatula and an analytical balance, 2 g of Moringa oleifera seed powder was weighed;
   II. A 100 ml beaker was used to measure 100 ml of distilled water;

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III. 2 g of Moringa oleifera seed powder was added to a 600 ml beaker and then 100 ml of distilled water was added to the same beaker.

IV. The mixture was placed on a magnetic stirrer for high agitation for 4 minutes. The solution obtained under these conditions corresponds to a concentration of ground Moringa oleifera seeds of 20 g/l.

The mixture of ground Moringa oleifera seeds and distilled water results in a whitish liquid with an intense odour. Its shelf life is limited due to its biodegradation. For this reason, the Moringa oleifera seed extract solutions were prepared on the days of the Jar Test.

3. - RESULTS AND DISCUSSION

After collecting the samples, it was necessary to carry out an analysis of the different parameters including turbidity, total dissolved solids, temperature, pH, aluminium, iron and manganese before the Jar Test, so that a comparison could then be made of the parameters analysed before and after the treatment of the raw water. It should be noted that Table 1 shows the values for the analyses of the aforementioned raw water parameters.

Table 1: Results of the analyses of the various parameters in the raw water.

Raw water	Turbidity (NTU)	TDS (mg/l)	Temperature (ºC)	pH	Al (mg/l)	Fe (mg/l)	Mn (mg/l)
Sample 1	44	89,9	34,0	7,54	0,095	1,500	0,8
Sample 2	30	84,3	35,6	7,61	0,082	0,101	0,5
Sample 3	57	86,2	33,2	7,43	0,109	1,520	0,3

Evaluation of the efficiency of Moringa Oleifera coagulant Vs Aluminum Sulphate coagulant. In terms of turbidity removal, the following results stood out in three trials analysed separately using the two types of coagulant (Moringa Oil and Aluminum Sulphate). This information is shown in table 2 and table 3.

Jar test using coagulant solution from Moringa oleifera seed extract

Table 2: Turbidity results in jar tests using the Moringa oleifera seed extract coagulant solution.

Volume (ml)	4	5	6	7	8
Turbidity after test 1 (NTU)	10,4	8,6	6,8	4,9	6,2
Turbidity after test 2 (NTU)	6,6	6,0	5,9	5,6	4,4
Turbidity after test 3 (NTU)	5,8	5,4	6,1	16,15	15,1

Jar test using aluminium sulphate coagulant solution

Table 3: Results of jar tests using the aluminium sulphate coagulant solution.

Volume (ml)	4	5	6	7	8
Turbidity after test 1 (NTU)	29,0	11,2	9,1	3,9	3,4
Turbidity after test 2 (NTU)	27,6	17,0	5,84	3,9	3,0
Turbidity after test 3 (NTU)	8,81	4,2	4,8	5,9	6,0

After the Jar Tests using the Moringa oleifera seed extract coagulant solution and the aluminium sulphate coagulant solution, the samples with the best turbidity were kept. Then the parameters (turbidity, total dissolved solids, temperature, pH, aluminium, iron and manganese) were analysed. More information is shown in table 4, 5 and 6.

Table 4: Results of the parameter analyses after treating the raw water with the coagulating solution from the Moringa oleifera seed extract.

	Turbidity (NTU)	TDS (mg/l)	Temperature (ºC)	pH	Al (mg/l)	Fe (mg/l)	Mn (mg/l)
Test 1	4,9	89,8	34,0	7,76	0,034	0,23	0,3
Test 2	4,4	89,9	33,3	7,74	0,047	0,10	0,3
Test 3	5,4	80,2	33,8	7,32	0,008	0,15	0,3

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Table 5 Results of the parameter analyses after treating the raw water with the Aluminium Sulphate coagulant solution.

	Turbidity (NTU)	TDS (mg/l)	Temperature (ºC)	pH	Al (mg/l)	Fe (mg/l)	Mn (mg/l)
Test 1	3,4	97,5	34,3	6,51	0,108	0,27	0,5
Test 2	3,0	101,1	32,6	6,73	0,102	0,51	0,5
Test 3	4,2	94,4	32,9	6,70	0,115	0,18	0,7

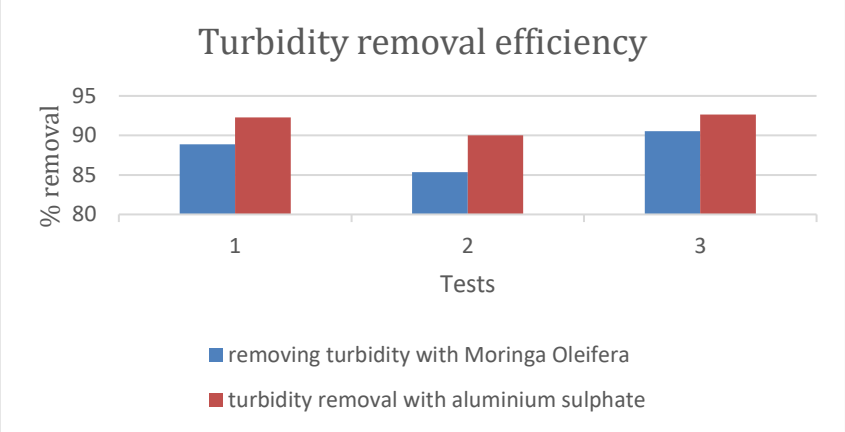
Comparative evaluation of parameter concentration removal efficiency in raw water treatment using Moringa oleifera extract coagulant Vs Aluminium sulphate coagulant.

Turbidity

Table 6: Turbidity removal efficiency at the end of the tests using the Moringa oleifera seed extract coagulant solution and the aluminium sulphate coagulant solution.

	Turbidity removal efficiency with Moringa oleifera (%)	Turbidity removal efficiency with aluminium sulphate (%)
Test 1	88,86364	92,27273
Test 2	85,33333	90
Test 3	90,52632	92,63158

Figure 3. Comparative evaluation of turbidity removal efficiency at the end of the tests using the Moringa oleifera seed extract coagulant solution and the aluminium sulphate coagulant solution.



The use of the Moringa Oleifera extract coagulant obtained inferior results in relation to the removal efficiency using the Aluminium Sulphate coagulant, but according to [16,17]However, at the end of the tests, the use of the Moringa oleifera seed extract coagulant solution achieved up to 90.52632% removal in test 3, and in tests 1 and 2 it removed 88.86364 and 85.33333% respectively.

Total dissolved solids

Table 6 shows the total dissolved solids removal efficiency values after the tests using the Moringa oleifera seed extract coagulant solution and the aluminium sulphate coagulant solution.

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Table 6: Comparative evaluation of total dissolved solids removal efficiency at the end of the tests using the Moringa oleifera seed extract coagulant solution and the aluminium sulphate coagulant solution.

	TDS removal efficiency with Moringa oleifera (%)	**TDS removal efficiency with aluminium sulphate (%)**
Test 1	0,11123	-8,4538
Test 2	-6,6429	-19,929
Test 3	6,96056	-9,5128

The results for total dissolved solids removal efficiency showed low removal efficiency for both the treatment with the Moringa oleifera seed extract coagulant solution and the aluminium sulphate coagulant solution, but the use of the Moringa oleifera seed extract coagulant solution proved to be more efficient at removing total dissolved solids, with up to 6.96056% removal for trial 3. For the treatment with aluminium sulphate, the results were not satisfactory, obtaining negative values, i.e. increasing the concentration of total dissolved solids in all tests.

Temperature

Table 7 shows the temperature variation values after the tests using the Moringa oleifera seed extract coagulant solution and the aluminium sulphate coagulant solution.

Table 7. 1Temperature variation at the end of the tests using the Moringa oleifera coagulant solution and the aluminium sulphate coagulant solution.

	Temperature variation with Moringa oleifera	**Temperature variation with aluminium sulphate**
Test 1	0	0,3
Test 2	-2,3	-3
Test 3	0,6	-0,3

Table 7 shows that there were small variations in temperature at the end of the tests. The temperature values at the end of the tests remained close to the raw water value for each sample, with a maximum variation of 3 °C more for test 2 using the aluminium sulphate coagulant solution and a minimum variation of 0 °C for test 1 using the Moringa oleifera seed extract coagulant solution.

Hydrogen potential

Table 8 and Graph 4 show the pH variation values after the tests using the Moringa oleifera seed extract coagulant solution and the aluminium sulphate coagulant solution.

Table 8: pH variation at the end of the tests using the Moringa oleifera seed extract coagulant solution and the aluminium sulphate coagulant solution

	pH variation with Moringa oleifera	**pH variation with aluminium sulphate**
Test 1	0,22	-1,03
Test 2	0,13	-0,88
Test 3	-0,11	-0,73

Several studies that have used aluminium sulphate to treat water point to a decrease in pH in relation to its initial value [18–20]. During the coagulation/flocculation and sedimentation tests, this drop was seen in the pH values of the tests using the aluminium sulphate coagulant solution, and when using the Moringa oleifera seed extract coagulant solution, there was a slight increase in values in tests 1 and 2, and a slight drop in test 3 in relation to the initial values. Table 8 and Graph 4 show that there were greater variations in pH in the tests using the aluminium sulphate coagulant solution. The pH values at the end of the tests showed that the use of the Moringa oleifera seed extract coagulant solution was more satisfactory than those obtained using the aluminium sulphate coagulant solution, with the smallest variation being 0.11 units less in test 3 using the Moringa oleifera seed extract coagulant solution and the largest variation being 1.03 units less in test 1 using the aluminium sulphate coagulant solution.

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Aluminium

Table 9 shows the aluminium removal efficiency values after the tests using the Moringa oleifera seed extract coagulant solution and the aluminium sulphate coagulant solution.

Table 9: Aluminium removal efficiency at the end of the tests using the Moringa oleifera seed extract coagulant solution and the aluminium sulphate coagulant solution

	Aluminium removal efficiency with Moringa oleifera (%)	Aluminium removal efficiency with aluminium sulphate (%)
Test 1	64,21053	-13,6842
Test 2	42,68293	-24,3902
Test 3	92,66055	-5,50459

Aluminium removal in the treatment with the Moringa oleifera seed extract coagulant solution showed better efficiency, reaching up to 92.66055% in trial 3, and was more efficient in all trials, with trials 1 and 2 removing up to 64.21053 and 42.68293%. With the use of the aluminium sulphate coagulant solution, the results were negative in terms of removal, with an increase in the concentration of aluminium of up to 24.3902% in the treatment of sample 2, with samples 1 and 3 having an increase of 13.6842% and 5.50459% in relation to the raw water for both samples.

Iron

Table 10 shows the iron removal efficiency values after the tests using the Moringa oleifera seed extract coagulant solution and the aluminium sulphate coagulant solution.

Table 10. Iron removal efficiency at the end of the tests using the Moringa oleifera seed extract coagulant solution and the aluminium sulphate coagulant solution

	Iron removal efficiency with Moringa oleifera (%)	Iron removal efficiency with aluminium sulphate (%)
Test 1	84,6667	82
Test 2	90,099	49,505
Test 3	90,1316	88,1579

For iron removal, the treatment with the Moringa oleifera seed extract coagulant solution showed better efficiency, reaching up to 90.1316% in trial 3, and was more efficient in all trials, with trials 1 and 2 removing up to 84.6667 and 90.099%.With the use of the aluminium sulphate coagulant solution, the results were lower than those obtained with the use of the Moringa oleifera seed extract coagulant solution, but satisfactory, achieving a maximum removal efficiency of 88.1579% in test 3, with tests 1 and 2 having reduced it by 82 and 49.505% compared to the raw water for both samples.

Manganese

Table 11 shows the manganese removal efficiency values after the tests using the Moringa oleifera seed extract coagulant solution and the aluminium sulphate coagulant solution.

Table 11: Manganese removal efficiency at the end of the tests using the Moringa oleifera seed extract coagulant solution and the aluminium sulphate coagulant solution

	Manganese removal efficiency with Moringa Oleifera (%)	Emotional manganese removal efficiency with aluminium sulphate (%)
Test 1	62,5	37,5
Test 2	40	0
Test 3	0	-133,333

For manganese removal, treatment with the Moringa oleifera seed extract coagulant solution showed better efficiency, reaching up to 62.5% in trial 1, and was more efficient in all trials, with trials 2 and 3 reducing 40 and 0% of manganese. With the use of the aluminium sulphate coagulant solution, results were lower than those obtained with the use of the Moringa oleifera seed extract coagulant solution, achieving a maximum removal efficiency of 37.5% in trial 1, with trial 2 maintaining the same concentration in relation to the raw water and trial 1 increasing 133.333% in relation to the raw water.

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The article has focused on test 2, seeking the most appropriate data to reduce coagulation and improve cleaning. Regarding turbidity removal, the use of the aluminum sulphate coagulant solution proved to be more efficient, achieving 92.63158 % removal in test 3, with better results for tests 1 and 2, with 92.27273 and 90%, respectively.

The coagulant extracted from Moringa oleifera seeds usually gives satisfactory results in terms of turbidity removal, achieving reductions of 80 to 99% for this parameter6,11. At the end of the trials, the use of the Moringa oleifera seed extract coagulant solution achieved up to 90.52632% removal in trial 3, with trials 1 and 2 having removed 88.86 and 85.33% respectively.

Although the removal efficiency when using the Moringa oleifera seed extract coagulant solution is lower than the removal efficiency when using the aluminium sulphate coagulant solution, the results achieved in tests 1 and 2 meet the limits set by the Regulations on the Quality of Water for Human Consumption. In view of the results obtained, the use of Moringa oleifera coagulant is highly recommended in terms of environmental quality and human health.

The advantages of using Moringa oleifera as a coagulant compared to aluminium sulphate coagulant are extremely visible, from the low cost of acquisition to the ease of handling without the possibility of contaminating by-products in the environment. In the specific case of a Mozambican drinking water treatment plant, obtaining aluminium sulphate is very expensive because it depends on the international market. It is also easy to prepare this organic material as a coagulant, without the need for cutting-edge technology. Its observation has been taken into account and experiments are carried out with several different quantities of water in order to rule out the hypothesis that the results may vary in other conditions. A study has been conducted on the prices of moringa internationally. It can be found in different forms, with varying prices. In Spain, for instance, moringa powder costs approximately €65 per kilo, while the whole dried leaves can cost up to €118 per kilo in the European Union. It is evident that these prices are considerably lower in countries of origin, such as Mozambique, where prices can be as low as half of the European Union average. Furthermore, prices in the rest of the African continent and South America are also similar.

4. - CONCLUSIONS

The use of Moringa oleifera coagulant is highly recommended because it is optimally prepared and meets the required standard for water potability. In terms of economic evaluation and environmental quality, the use of Moringa oleifera coagulant is also very valuable, as its acquisition and preparation does not require a great deal of technology or energy. The results obtained in the laboratory analyses of the various parameters in three tests showed satisfactory results and perfect removal efficiency, although the use of the coagulant in the proposal is recommended. With regard to environmental quality, it does not contribute contaminating by-products to the environment or the possibility of contaminating the treated water.

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