CACTUS *OPUNTIA FICUS INDICA* OF MADAGASCAR, AN ALTERNATIVE FOR A MORE EFFICIENT TREATMENT OF WATER

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ABSTRACT

The objective is to reduce the use of synthetic chemicals in the treatment of water with natural flocculants from the cladodes of the Opuntia ficus indica cactus from Madagascar so that they will be valued. The effectiveness of the cactus flocculant was tested on two well waters from the fokontany of Ambodivoanjo in the rural commune of Alasora district of Avaradrano, for this, physico-chemical and bacteriological analyzes before and after treatment were carried out within from the JIRAMA Mandroseza laboratory. Before the coagulation-flocculation treatment process, the analyzes show that the two well waters have a high turbidity, for the water in well 2 in particular, it has a high content of iron and organic matter which greatly exceeds the limit of standards. . Bacteriological analyzes show that the two well waters have a high proportion of germs indicating pollution. After the gel flocculation test of the cactus cladodes, the analyzes show a very large reduction in turbidity by 95%, in iron content by 80.5%, in organic matter content by 87% and 96% germs, and we had found that the natural flocculant from the cactus cladodes does not have much influence on pH and conductivity. The cactus cladodes can be qualified as a natural flocculant in the water treatment process due to its efficiency; moreover, it replaces the use of chemical flocculants without forgetting that this plant is abundant in Madagascar.

Keywords: *well water, cladodes, cacti, flocculation, Madagascar*

1. INTRODUCTION

Water is an essential element in human life and activity. Lack of access to water is the number one killer in the world. By the end of 2000, diarrhea killed 5 million men worldwide, 3.3 million of whom were children under the age of five. The 2015 report of the Joint Monitoring Program mentions that 663 million people worldwide do not have access to drinking water. Sub-Saharan Africa and Asia are the most affected. In sub-Saharan Africa, 319 million people do not have access to drinking water [1; 10]. In Madagascar, access to drinking water is one of the major development challenges. According to data from the African Development Bank, 71% of the Malagasy populations do not have access to drinking water. Madagascar is not immune to problems, so the investigation into the quality of the water consumed seems crucial in order to prevent various forms of contamination. In Madagascar, coagulation-flocculation remains a classic treatment process in drinking water production plants and in treatment plants. This treatment method is known for its effectiveness in removing the finest particles, but also requires the use in large quantities of chemical coagulants and flocculants, which prove to be expensive and dangerous in case of excess. This research work aims to produce drinking water, as well as to reduce the use of synthetic chemicals in water treatment using a natural flocculant contained in the cladodes of the cactus.

1.1. Active agent of cactus

In order to quantify the coagulation efficiency of mucilage, individual components of mucilage (D, L-arabinose,> 99%; D - (+) -galactose,> 99%; L- rhamnose,> 99%, and D- (+) galacturonic acid,> 97%) were purchased from a chemical supplier and have been tested independently or in combination on a batch of turbid water. The coagulation-flocculation activity was calculated using the equation :

$$AC = \frac{Turbi - Turbf}{Turbi} \times 100$$

AC: Coagulation activity expressed as a percentage (%)
Turbi: Initial turbidity expressed in (UTN)
Turbf: Final turbidity expressed in (UTN)

The results show that mucilage, specifically the galacturonic acid component, may explain certain capacities for reducing turbidity by Opuntia ficus indica. Independently, arabinose, galactose, rhamnose does not display any coagulation-flocculation activity; however, added in combination with galacturonic acid, these sugars were able to reduce turbidity between 30% and 50%. The independently added galacturonic acid was able to reduce turbidity by more than 50%. Therefore, the individual components of mucilage in isolation and association with the acid may represent only 50% of the suppression of turbidity observed when the set of cactus blocks was introduced to the solution of turbid water.
It is therefore the action of the polymer constituted by all of its sugars; which is arabinogalactan, fused with the action of galacturonic acid which gives the molecule its flocculating properties [2].

1.2. Structure of arabinogalactan and galacturonic acid

Arabinogalactan consists of a main chain β– (1 → 3) -galactopyranose on which side chains can be grafted in position O-6. These chains are formed by short chains of galactopyranose units linked in β– (1 → 6) and arabinofuranose units linked in α- (1 → 5) [3; 4].

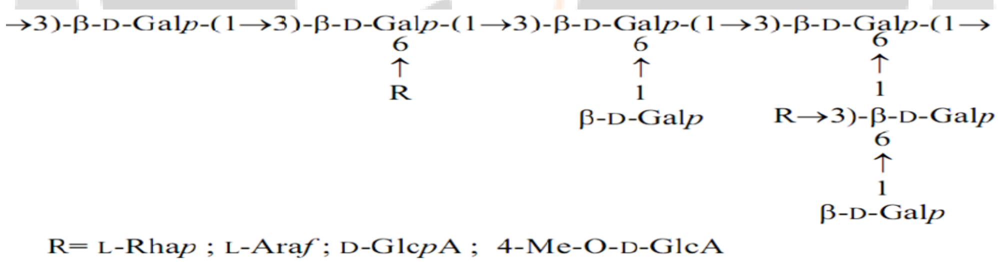

Fig-1: Structure of arabinogalactan.

D-Galp: D-galactopyranose
L-Araf: L-Arabinofuranose
L-Rhap: L-Rhamnofuranosis
D-Glcp: D-Glucopyranose
4-Me-O-D-GlcA: 4-Methyl-O-Glucose

Galacturonic acid is a uronic acid and a constituent of pectin. The latter is responsible for the rigidity of the walls of plant cells. Galacturonic acid is a chemical compound obtained by oxidation of the last carbon in galactose.

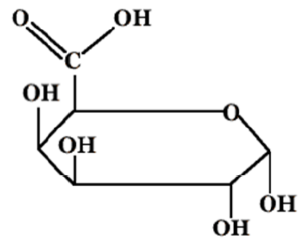

Fig-2: Semi-developed formula of galacturonic acid

1.3. Coagulation-flocculation mechanism by Opuntia ficus indica

The optimal dose of cactus for a given water increases with the initial turbidity. This behavior is incompatible with a flocculation scanning mechanism. Since Opuntia ficus indica is capable of performing up to 98% coagulation activities at pH 10, it can be concluded that electrostatic repulsion between negatively charged particles is not enough to prevent successful coagulation by Opuntia ficus indica . The mechanism is therefore not a neutralization of the charge.

Experimental analysis of the conductivity measurements of water treated with Opuntia ficus indica indicates that the ionic strength provided by Opuntia ficus indica is not high enough to cause coagulation due to the double layer compression [9 ; 11].

These results show that the predominant coagulation mechanism for Opuntia ficus indica is therefore adsorption and bypass. Indeed, the particles in suspension are not directly communicated with each other but are linked to a polymer which is arabinogalactan. Adsorption can occur through the hydrogen bond or dipole interaction. It is likely that natural electrolytes within Opuntia ficus indica in particular bivalent cations, which are known to be important for coagulation-flocculation with anionic polymers, can facilitate adsorption [5 ; 7].

2. METHODOLOGY

2.1. Study zone

The cactus sample, as well as the two water wells: P1 and P2, are found in the fokontany of Ambodivoanjo Ambohidrazaka, Alasora commune, Avaradrano district and Analamanga region.

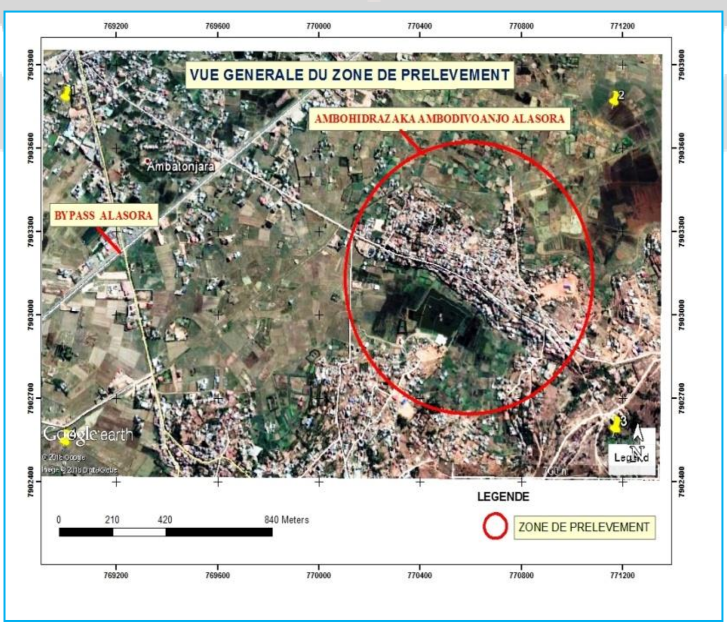

Fig-3: General view of the study area

And table 1 shows the characteristics of the two noted wells: P1 and P2

Table-1: Characteristic and environment of P1 and P2

Characters	P1	PII
Types	drilled	drilled
Depth	4.5m	5m
Diametre	0.58m	0.57m
Height	3.5m	3.75m
Volume	0.92m 3	0.94m 3
Lid	yes	yes
Nombre of families	12	7
Distance from pit to latrine	8m	9m
Presence of coping	yes	yes
Distance between pit and discharge	8m	9m

2.2. Method of preparing the cactus flocculant

The raw materials used are freshly picked cladodes, and do not require any special conditions during transport and storage. The cladodes are first cleaned with water, peeled, cut with a knife, crushed with a mixer, then filtered with a sieve, part of the filtrate is then diluted to 20% by distilled water using a flask 100 mL volumetric, the mixture is homogenized by stirring using a magnetic stirrer for 15 minutes.

Fig-4: Cactus flocculant

The flocculant obtained is stored at a temperature of approximately 10 ° C.
According to the study, 100 mL of concentrated cactus juice can be obtained from 1 kilogram of rackets, a yield of 10 to 15%.

2.3. Flocculation test

Flocculation is a process of agglomeration of the particles between them using a physical bond made up of long chains of polymers of great molecular weight forming as a result flakes or flocs which can settle
Two transport phenomena govern flocculation, pericinetic flocculation linked to Brownian diffusion (thermal agitation) and orthokinetic flocculation linked to dissipated energy [6; 8].
The tests consist in assessing the quality of the flocculation as well as the minimum turbidity after introduction of an increasing quantity of ingredients in solution in 1-liter beakers.
The materials used are: a flocculator with adjustable speed between 0 to 150 rpm-1, five to six 1-liter vases, a siphon, a chrono or a watch Materials to measure pH, iron and organic matter, a turbidimeter, and an agitator. The reagents used during the study are:
Alumina sulphate : 1%, lime : 1%, cactus flocculant : 20%.

Volumes of P1 and P2 are taken from a 10-liter bucket. Its aspects are noted, then some parameters are measured: turbidity, pH, iron content and possibly organic matter . The beakers are filled to the mark of 1000 ml with agitated raw water, then the flocculator is connected. Using a pipette, increasing amounts of reagents are introduced into each beaker, then the beakers are placed on the flocculator and the propellers are lowered into the water. Afterwards, rapid agitation will be carried out at 100 rpm for 1

2 min, then slow agitation at 40 rpm for 20 min, and the time of appearance of the first flocs is noted. After 15 min of slow agitation, the quality of the flocculation (appearance of the flocs) is evaluated. Then the mixture is decanted for 10 to 15 min, and the speed of cohesion of the sludge is noted. And finally half the height of each beaker is siphoned and the pH, turbidity, iron, organic matter. on siphoned water are controlled, noting each beaker according to the quality of the flocculation. The photos in Figure 25 show the different stages of the flocculation tests.
The table 2 shows the flocculation test determining the optimal dose in cactus flocculant of P1

Table-2 : Determination of the optimal cactus flocculant. rate of P1

N° Beaker	B1	B2	**B3**	B4
Alumina sulphate (mL)	0.4	0.4	**0.4**	0.4
Lime. (mL)	0.1	0.1	**0.1**	0.1
Cactus flocculant (mL)	1.5	2	**2.5**	3
Turbidity (UTN)	5	2	**0.58**	1.5
Flocs aspect	Small	averrage	**Very big**	big

And the table 3 shows the flocculation test determining the optimal dose by flocculating P2 cacti.

Table-3.: Determination of the optimal rate for flocculating P2 cacti

N° Beaker	B1	B2	**B3**	B4
Alumina sulphate (mL)	2.5	2.5	**2.5**	2.5
Lime. (mL)	0.4	0.4	**0.4**	0.4
Cactus flocculant (mL)	2	2.5	**3**	4
Turbidity (UTN)	6	7	**1.89**	4
Flocs aspect	small	small	**Very big**	big

3. RESULTS AND DISCUSSIONS

3.1. Results of physico-chemical and bacteriological analyzes of P1 and P2 before treatment

Table-4: Results of the physical analysis of P1 and P2

Physical parameters	P1	P2	Malagasy standards
pH	6.2	6.42	6.5-9.0
Temperature (°C)	23.5	24	‹25
Conductivity (µS.cm^{-1})	113.3	174.3	‹3000
Turbidity(UTN)	18.5	34.7	‹5
Mineralization (mg.L^{-1})	110	145	‹2 in acid ‹5 in alkali

Table-5: Results of chemical analyzes of P1 and P2

Chemical parameters	P1	P2	Malagasy standards
Total hardness (°F)	3.04	5	50
Calcium hardness (°F)	1.4	2.2	-
Chlorides (mg.L^{-1})	37.63	35.5	250
Alkalinity (°F)	0	0	-
Full alkalinity (°F)	1	2.9	-
Organic matter (mg.L^{-1})	0.9	1.9	‹2
Nitrites (mg.L^{-1})	0	0	0.1
Nitrates (mg.L^{-1})	5.58	2.03	50
Sulphates (mg.L^{-1})	4.87	9.31	250
Ammonium (mg.L^{-1})	0.1	0.38	0.5
Total Iron (mg.L^{-1})	0.2	0.55	‹0.5

Table-6: Results of bacteriological analyzes of P1 and P2

Germs	P1	P2	standards
Total Coliformes	$1.6\ 10^3$	$1.5\ 10^3$	0/100mL
Escherichia Coli	$8\ 10^1$	$3\ 10^1$	0/100mL
Fecal Streptococci	$1.6\ 10^2$	$2.8\ 10^3$	0/100mL
Sulphite-reducing anaerobes	in	in	0/20mL

3.2. Results of physico-chemical and bacteriological analyzes of P1 and P2 after addition of flocculant

Comparison of P1A; P1B and P1C after flocculation

Table-7: Comparison of P1A; P1B and P_1C

BEAKER	**P_1A**	**P_1B**	**P_1C**
Alumina sulphate (mL)	0.4	0.65	**0.4**
Lime (mL)	0.1	0.3	**0.1**
Cactus flocculant (mL)	0	0	**2.5**
Flocs Appearance time	10^{th} min	15^{th} min	**19^{th} min**
Flocs aspect	small	average	**Very big**
Settling Speed	slow	average	**Very fast**
Turbidity (UTN)	7	4.5	**0.58**
pH	6.49	6.51	**6.75**
Iron	0.1	0.05	**0.01**
Organic matter	055	0.4	**0.1**

P1A: P1 treated with alumina sulfate and lime
P1B: P1 treated with the optimal dose of alumina sulfate and lime
P1C: P1 treated with the dose of alumina sulfate and lime of P1A, but added with a quantity of cactus flocculant

Comparison of P2A, P2B, P2C and P2D

Table-8: Comparison of P2A, P2B, P2C and P2D

BEAKER	**P_2A**	**P_2B**	**P_2C**	**P_2D**
Alumina sulphate (mL)	2.5	2.75	3	**2.5**
Lime (mL)	0.4	0.5	0.6	**0.4**
Cactus flocculant (mL)	0	0	0	**3**
Flocs appearance time	10^{th} min	14^{th} min	15^{th} min	**19^{th} min**
Flocs aspect	average	average	big	**Very big**
Settling Speed	slow	average	Very fast	**Very fast**
Turbidity (UTN)	16	12.4	5.5	**1.89**
pH	6.25	6.5	6.57	**6.89**
Iron	0.4	0.35	0.29	**0.2**
Organic matter	0.95	0.75	0.5	**0.25**

P2A: P2 treated with alumina sulfate and lime
P2B: P2 treated with alumina sulfate and lime but at a different dose
P2C: P2 treated with the optimal level of alumina sulfate and lime
P2D: P2 treated with the dose of alumina sulfate and lime of P2A added with a quantity of cactus flocculant.

Results of bacteriological analyzes of P1C and P2D after flocculation

Table 25: Results of the bacteriological analysis of P1C and P2D

	P1C (S.A + chaux + cactus juice)	P2D (S.A + chaux + cactus juice)	Standards
Total Coliforms	0	0	0/100mL
Fecal Streptococci	0	0	0/100mL
Thermotolérant Coliforms (E-Coli)	0	4	0/100mL
Clostridium sulphito-reductor	$2.0\ 10^1$	$1.0\ 10^1$	0/20mL

3.3. Discussions

The results of the physico-chemical analyzes show that the two well waters have a high turbidity, for the water of well 2 in particular, it has a high iron content and the organic matter content is at the limit of the standard. Bacteriological analyzes show that they have a high proportion of pollution-indicating germs.
After the flocculation tests, the analyzes show a large reduction in turbidity by 95%, in the iron content of 80.5%, in the organic content of 87% and in the germs of 96%, and the natural flocculant n has not too much influence on pH and conductivity.
There is a strong decrease in germs, this is due to the action of polymers of the natural flocculant, which by bridging forms large flocs eliminating germs. Treatment with alumina sulfate, lime and the cactus flocculant eliminates germs by approximately 90%.
The cladodes of the cactus can be qualified as natural flocculant in water treatment due to its effectiveness, moreover it minimizes the use of chemical flocculants.

4. CONCLUSIONS

Fresh water is a very rare natural resource. In Madagascar, access to drinking water is still a major problem. In addition, water treatment products prove to be expensive and have drawbacks in case of excess. This fact led to the use of the cladode gel of the Opuntia ficus indica cactus in water treatment as a natural flocculant.
Sampling of the two well waters and the collection of cladodes from the Opuntia ficus indica tree at Ambodivoanjo Ambohidrazaka, are followed by laboratory studies including: physico-chemical and bacteriological analysis of the two well waters, preparation of the natural flocculant (cactus juice), the treatment test using the natural flocculant and finally the analyzes after the flocculation test.
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According to the properties it has, this bio-flocculant is recommended for wastewater treatment plants or drinking water production. As a yield, 100 g of concentrated gel are obtained per kilogram of cladode. This cactus is easy to grow, the great south of Madagascar also has hectares of cacti. Why not use them in water treatment?

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