Evaluation of the coughing power of the *Opuntia ficus indica* for removal of turbidity in waters of the Guatapuri River (Colombian Caribbean)

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Abstract. The purpose of this article is to publicize the evaluation of the effectiveness of *Opuntia ficus indica* as a coagulant during the treatment of raw water from the middle basin of the Guatapuri River, in the Department of Cesar, Colombia. Tuna coagulant is purely organic; it has been shown by phytochemical studies performed on *Opuntia ficus indica* the presence of some minerals among some others; contains glycides or carbohydrates. The evaluation was carried out using the jug test equipment, which operated by varying the revolutions per minute (20, 30 and 40), keeping the mixture fast at 125 rpm and settling for 30 minutes. The samples were physically characterized (Turbidity, Alkalinity, pH and total suspended solids) taking into account the methods specified for parameter in the Standard Methods. With samples of 345.9 NTU and 2799.1 NTU at optimal doses of 658.75 mg/L and 1976.3 mg/L respectively, removals up to 97% and 99.5% were observed in the same order. It was shown that the variation of the slow mixture only influenced with the sample of 2799.1 NTU, being the most effective treatment at 30 RPM.

1. Introduction

Worldwide, the shortage of drinking water and consumption of water of poor quality is one of the main causes of diseases and death especially in the most vulnerable population [1], turbidity is one of the parameters widely applied as a criterion of water quality, both in the sources of supply and in the processes of potabilization and distribution systems [2,3], since it is a rapid and economic measurement. Currently, for the removal of this parameter have been using more coagulants of chemical origin as aluminum salts and iron [4,5], however, by using aluminum salts in the process may be low levels of aluminum in water, between 0.014 and 2.7 mg/l which is associated with diseases such as Alzheimer's disease [6]. On the contrary, the tuna coagulant is purely organic, where it has been demonstrated by phytochemical studies carried out on the *Opuntia ficus indica* the presence of some minerals among some others; also contains, carbohydrates or carbohydrates [7], is also a plant that has become raw material for the food and medicine industries, among the foods based on the plant are cactus fruits, water, sugar, vinegar, juice, oil, soap and finally the seeds, which is rich in carbohydrates, protein, and vitamin E.
on this plant are: pickles, juices, jams and food supplements rich in fiber or for the control of diabetes or obesity, among others [8].

On the other hand, one of the most important negative impacts found in the Guatapurí River basin is the loss of natural cover, which translates into erosion and sedimentation [9], the above generates high levels of turbidity in the receiving waters [10] especially in the winter season, thus making it difficult to treat the water, as water with low turbidity is easier to treat [11]. The objective of this research was to evaluate the effectiveness of an organic coagulant based on prickly pear for the removal of turbidity in raw water from the middle basin of the Guatapurí River.

2. Experimental

For the study, 2 simple samplings were made at the entrance of the water purification treatment plant located in Valledupar, Colombia, during the dry and rainy season, the samples were stored in high density polyethylene (HDPE) containers with a capacity of 20 liters, they were transferred to the fluid mechanics laboratory of the Universidad Popular del Cesar and refrigerated at 4 °C for their preservation.

A completely randomized experimental design with three treatments was used, for this design preliminary tests were made with coagulant solution extracted from the *Opuntia ficus indica* using doses from 1 mL to 300 mL with slow mixing of 20 rpm in order to obtain an optimal range for each turbidity from which the 5 best doses were taken in the turbidity removal and control, this range was performed in triplicate in order to obtain average values to choose the dose of lowest concentration of coagulant that removed the highest value turbidity, obtained the optimal dose treatments were applied varying the revolutions per minute (20, 30 and 40), keeping the mixture fast at 125 rpm and sedimentation for 30 minutes. Each treatment was carried out in triplicate, taking as constant variables the dose of coagulant, temperature (25 °C ± 1 °C), the volume of the sample, the time and speed of the rapid mixture and the time of sedimentation.

To obtain the coagulant, 795 g of *Opuntia ficus indica* buds were used, to which a series of processes ranging from peeled to macerated were applied, where 320 ml of prickly pear extract was obtained, which was used for the preparation of the 10% V/V coagulant solution.

The characterization of the raw water was determined by means of turbidity, total suspended solids, pH, temperature and alkalinity. For which the average values that corresponded to the initial physicochemical characteristics of the two samples studied were calculated. These parameters were measured before and after the coagulation treatment to evaluate the effectiveness of the coagulant. The parameters taken into account are:

- **Turbidity**: measured by the nephelometer method. 25 mL of the sample was taken after agitation and taken to the Hatch 2100AN turbidimeter, selecting the 750 method, at a wavelength of 450 nm, calibrated with the target (distilled water), throwing the measure of turbidity.
- **pH**: It was determined through the potentiometric method, using a pH meter, in which the electrode was introduced in the sample until obtaining the constant reading.
- **Total Suspended Solids (SST)**: The gravimetric method was used, using an analytical balance, filter paper with fiberglass and aluminum capsules. Suction filter in a vacuum pump 25 ml of sample through the pre-weighed filter paper which was the constant weight (P1), this was deposited in an aluminum capsule, then the capsules were introduced in an oven with a temperature range between 103 and 105ºC for one hour. After this time, they were left to cool in a desiccator and weighed to obtain the weight (P2). The calculation of the Total Suspended Solids was made by means of the following formula:

\[
SST \left( \frac{mg}{L} \right) = \frac{(P_2 - P_1) \times 10^6}{VM}
\]

Where:
- **P1**: Weight of the capsule, at room temperature, (g).
- **P2**: Weight of the residue + capsule, at 103-105ºC, (g).
- **VM**: Sample Volume (mL).
3. Results and discussion

3.1 Characterization of raw water samples

Table 1 presents the results obtained from the characterization of raw water from the middle basin of the Guatapurí River in dry and rainy season, according to the Regulation of the Drinking Water and Basic Sanitation Sector (RAS), the turbidity of both samples allows to categorize to the source as very deficient because it is higher than 150 NTU, and recommends a conventional treatment with coagulation, sedimentation, filtration and disinfection.

| Physical-chemical parameter | Standard Method          | Units     | Results Summer | Results Winter | Maximum acceptable values Resolution 2115 of 2007 |
|-----------------------------|--------------------------|-----------|----------------|----------------|---------------------------------------------------|
| Turbidity                  | Nephelometric            | NTU       | 345,9          | 2799,1         | 2                                                  |
| Total suspended solids     | Gravimetric              | mg/L      | 400            | 1890           | No register                                       |
| pH                         | Potentiometer            | pH        | 8,1            | 8,2            | 6,5-9,0                                           |
| Total Alkalinity           | Laboratory method        | mg/L      | 110            | 97,5           | 200                                               |
| Alkalinity method          | CaCO₃                    | ºC        | 26             | 26             | No register                                       |

3.2 Results of the turbidity parameter in treatments 20, 30 and 40 RPM for the turbidity of 345.9 NTU

In Figure 1, the results of each of the treatments are presented, which consisted of using a slow mixture of 20, 30 and 40 RPM, using the optimum dose for a turbidity of 345.9 NTU, which was 658.8 mg / l of tuna. According to Figure 1, with each of the treatments (20, 30 and 40 rpm) the turbidity decreases significantly, obtaining removal percentages of 97.1, 97.4 and 97.4% respectively, indicating that the coagulant of tuna is effective for the removal of turbidity, however the maximum acceptable value stipulated by resolution 2115 of 2007 is not reached, so a filtering process was carried out that managed to comply with the Colombian regulations.

On the other hand, the variation of the speed of agitation in the slow mixture during the coagulation process affected little the decrease of this parameter, where it is evident that the treatment that decreased more the turbidity was using the slow mixture at 40 RPM observing that the difference between this and the other treatments is minimal.
Figure 1. Turbidity results in each treatment.

Comparing these results with those obtained by Parra et al. (2011) [12] which worked with Opuntia goiana for the removal of turbidity in raw waters presenting removal percentages between 85.25 - 94.84% said percentage is high, however better results are presented with the Tuna Opuntia cochenillifera, on the contrary Lameda et al. (2014) [13] used the Tuna Opuntia ficus-indica for the removal of turbidity in synthetic waters obtained lower percentages between 17.22-82.37%.

3.3 Results of the pH parameter in treatments 20, 30 and 40 RPM for the turbidity of 345.9 NTU

In Figure 2, the pH results of each of the treatments are presented.

Figure 2. pH results in each treatment.
As it is observed, the pH does not present variations in each of the treatments, in addition it is evident that in none of the treatments the pH parameter exceeds the range established by Resolution 2115 of 2007. Comparing these results with those obtained by Villabona et al. (2013) [14] which used Opuntia ficus-indica in the removal of turbidity in raw waters, obtained a pH range between 7.5 - 7.9 which did not have a significant variation and also these values are within the limits established by the regulations Colombian, likewise Lameda et al (2014) [13] who worked with Opuntia ficus-indica in the removal of turbidity with synthetic water obtaining a range of 6.90 - 7.82 which presented greater variation however does not exceed the stipulated range by the norm mentioned above.

3.4. Results in the parameter of total suspended solids (TSS) in the treatments at 20, 30 and 40 RPM
In Figure 3, the results of the concentration of total suspended solids in the treatments at 20, 30 and 40 RPM are presented applying the optimal dose which was 658.75 mg / L of coagulant of prickly pear.

It can be evidenced that the treatment with the best behavior in the removal of the total suspended solids was the 20 RPM, with a remnant of 30 mg / L with a removal percentage of 92.5%, which is well below the maximum acceptable value by the Colombian technical standard 813, on the other hand the results of treatments at 30 and 40 RPM (35 and 40 mg / L respectively) also showed good results with percentages of removal greater than 90% and that are also found by below the maximum acceptable value stipulated for this parameter in said standard.

![Figure 3. Results of the treatments in the parameter of Total Suspended Solids (SST).](image)

3.5. Results in the turbidity parameter in treatments 20, 30 and 40 RPM for turbidity of 2799.1 NTU
In Figure 4, the results are presented with each of the treatments, with a coagulant dose of 1976.3 mg/L of Tuna, which turned out to be the optimal dose for this turbidity.
As seen in Figure 4, with each of the treatments (20.30 and 40 RPM) the turbidity is significantly reduced, obtaining removal percentages of 99.5%, 99.5% and 99.3% respectively, indicating that the coagulant of Tuna is effective for the removal of waters with high turbidity, however the maximum acceptable value stipulated by Resolution 2115 of 2007 for this parameter is not reached, therefore a filtering process was carried out that did not comply with this norm, now it is necessary to take into account that the filtration carried out in the drinking water treatment plant that supplies the city of Valledupar carries out the process by means of mixed sand and anthracite filters, which suggests that with this Adequate filtration could reach the maximum acceptable value by Colombian regulations.

On the other hand, the stirring speed of the slow mixture influences the removal of turbidity, where it is evident that using the slow mix at 20 and 30 RPM, better removals were obtained, however the difference between these and the treatment at 40 RPM is minimal , the above can be explained that with high velocity gradients there is a greater probability of flocculation, while with very high gradients it generates the rupture of flocs already formed by the action of liquid cutting forces, that is to say, a shearing effect occurs. it produces the mechanical breakage of the flocules [15].

3.6. Results in the pH parameter in treatments 20, 30 and 40 RPM for turbidity of 2799.1 NTU
According to Figure 5, the pH results show that the coagulant of prickly pear does not alter this parameter in each of the treatments, also it is observed that none of the treatments exceeds the range established by Resolution 2115 of 2007. In addition, it can be affirmed that the natural coagulant based on Tuna has the property of not significantly altering the pH of the water when it is applied in high doses.
3.7. Results in the parameter of total suspended solids (SST) in the treatments at 20, 30 and 40 RPM

In Figure 6, we present the results of the concentration of total suspended solids in the treatments at 20, 30 and 40 RPM applying the optimum dose which was 1976.3 mg / L of coagulant of prickly pear.

As shown in Figure 6, there was a significant decrease in each of the treatments, decreasing from 1890 mg / L to 20 mg / L at 20 RPM with a removal percentage of 98.9%, while for treatments of 30 and 40 RPM showed a residual of 40 mg / L with a removal percentage of 97.9%, which indicates that the treatment at 20 RPM fuel is the most effective for the removal of SST, in addition with the three treatments a concentration is obtained well below the stipulated in the Colombian technical standard 813 that is 200 mg/ L, it should be noted that for resolution 2115 which indicates the characteristics for water for human consumption this parameter is not contemplated, so it is not possible to make a comparison with this parameter physical.
4. Conclusions

This study showed that the coagulant of Opuntia ficus indica is effective in the removal of turbidity, reaching percentages of removal between 97.1% to 99.5%, without affecting the pH greatly. The optimal doses obtained in the coagulation process using samples of raw water from the Guatapurí River with initial turbidities of 345.9 and 2799.1 NTU, under the conditions of rapid mixing with a speed of 125 rpm and a time of 1 minute, slow mixing with a speed of 20 rpm and time of 20 minutes and a sedimentation time of 30 minutes, were 658.75 and 1976.3 mg / liter respectively. Based on the above, the coagulant of tuna is considered as an alternative for the treatment of raw water of low and high turbidity, being more effective when it is high.

Conflict of Interest.

The authors report there are no conflicts of interest.

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