Use of *Opuntia* sp. mucilage as an alternative for the treatment of wastewater from hemodialysis and dialysis

G. Ochoa[1], G. Fernandez[2] and M.S. Córdova[2]
[1] Faculty of Engineering, [2]Institute of Applied Science and Technology. National Autonomus University of Mexico, University City, 04510, México.
Keywords: dialysis, hemodialysis, mucilage *Opuntia* sp.
Presenting author email: guadalupeochoapastor@outlook.es

Introduction

Hospital effluents can contain hazardous substances, such as pharmaceutical waste, chemicals, toxins, and pathogens; These substances can represent a chemical, biological and physical risk to public and environmental health. The wastewater generated by hemodialysis and dialysis is discharged to the drainage with levels higher than those allowed by those established by Mexican regulations. (Chaguay, 2017; Machado *et al.*, 2014; Carraro *et al.*, 2016).

Figure 1. Dialysis wastewater.

Renal failure is known to affect 10% of the world population (PAHO, 2015), it is estimated that, in 2025, this disease will affect approximately 4 million patients. The annual consumption of drinking water for a healthy person is 1,000 liters per year, while a patient for hemodialysis treatment consumes 37,334 liters and a dialysis patient requires 78,000 liters, so the amount of water consumed for these treatments is greater than that required by a healthy person. One of the alternatives for the treatment of the aforementioned effluents is the pruning nopal mucilage *Opuntia* sp., Which is a polysaccharide that has high coagulation capacity and is a waste in Mexican agricultural practice, in addition its sludge is highly biodegradable and their generation is low.(Urzu *et al.*, 2006; Aliaga, Aceituno & Sa, 2007; Yin, 2010; Rodríguez *et al.*, 2011; Ahuja, 2013; Elena & Gazabón, 2013; Buttice, Alcantar & Florida, 2014; Nawel *et al.*, 2015; Nharingo & Moyo, 2016; Oladoja, 2016).

Figure 2.Milpa Alta Opuntia ficus indica.

Materials and methods

The dialysis and hemodialysis effluent samples come from two different hospitals located in Mexico City and were stored at 4 ° C for study. Table 1 shows the characterization of the effluents used.

Table 1. Characterization of the effluents used

Parameter	Units	Hemodialysis	Dialysis
Turbidity	NTU	76.9	34.6
Oxygen Demand	mg/L	1824	6790
pH	-	7.65	7.45
Temperature	°C	26.5	26.4
Dissolved solids	mg/L	7.85	7
Electrical conductivity	µS/cm	15.73	14.02
Ammoniacal nitrogen	mg/L	113.98	541

Pruning cactus mucilage was obtained from the Institute of Applied Sciences and Technology of the National Autonomous University of Mexico, located in Ciudad Universitaria, according to the procedure applied by Reyes-Ocampo *et al.*, 2019.

Coagulation-flocculation experiments were performed using the Phipps & Bird BP-700 Jar Test Kit. The dose of *Opuntia* sp. mucilage was varied to the hemodialysis effluent samples. and the pH until reaching the optimum values. The pH of the solutions was measured with the HACH Combo Waterproof multiparametric equipment and $Ca(OH)_2$ was used for pH adjustment.

Figure 3. Jar testing in the Sanitary and Environmental Engineering Laboratory.

The samples were shaken at 120 rpm for 1 minute and mixed at 40 rpm for 20 minutes, followed by a 15 minute sedimentation. The effectiveness of *Opuntia* sp. was evaluated by measuring the decrease in turbidity at various pH doses, in both dialysis and hemodialysis effluents. The turbidity of the samples was determined with the HACH 2100 equipment. The tests were carried out in triplicate and the mean values are reported.

Results and Discussion

For the characterization of pruning nopal mucilage, a Shimadzu IRAffinity ATR-FTIR equipment was used in the wavelength range between 4000 to 650 cm-1, the results are shown in Figure 4.

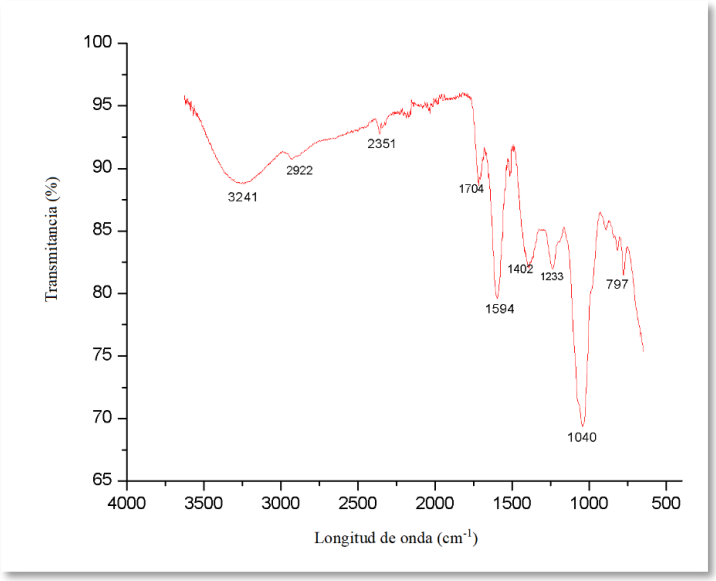

Figure 4. IR mucilage Opuntia sp.

in accordance with Delgado *et al.*(2018); Fox (2011);Ibarra-Rodríguez *et al.*(2017);Nharingo, Zivurawa y Guyo(2015), the functional groups that are present in this type of mucilage are: O-H, C-H and C = O mainly. In figure 4, the band displayed at 3241cm-1 corresponding to the O-H stretch; the band at 2922 cm-1 is due to the C-H bond of the alkane groups; whereas, the band at 1704 cm-1 is assigned to C = O stretching vibrations associated with carboxylic acid and, at 1594 cm-1, it is associated with COO groups and finally, at 1233 and 1040 cm-1, they correspond to asymmetric C-O tension vibrations. Among the most prominent groups observed are phosphates, phenolics, hydroxyl, carboxylates, carbonyl, amides and amines, among others, which lead to coagulation in dialysis and hemodialysis effluents.

Figure 5 shows the average of the treatments which were repeated 3 times where a change in the graph for the 25 mg / L dose can be seen.

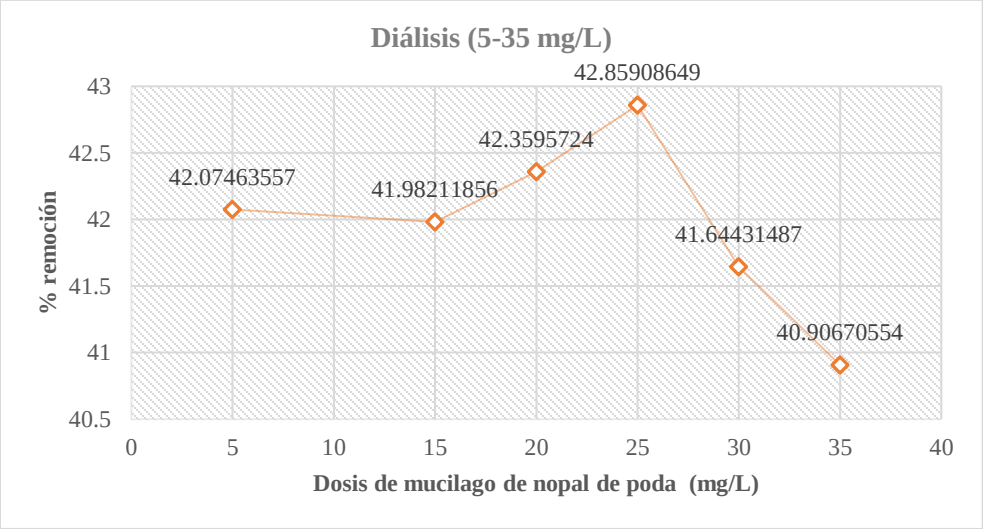

Figure 5. Removal results of dialysis effluent Jar Test (5-35 mg / L)

According to research by Choque *et al.*, 2018 reports that optimal doses of *Opuntia* are in the range of 10 to 20 mg / L and remove between 80 to 90% of the solids; In the case of dialysis effluent, it is observed that the optimal dose is 25 mg / L and its percentage of turbidity removal is 42.85%, which indicates that there is removal, but the properties of the effluent as it contains particles smaller than those of domestic wastewater make the treatment not so effective, but giving favorable results for its discharge.

The results are in figure 6, for this treatment the best dose was 15 mg / L with 21.9% removal of turbidity.

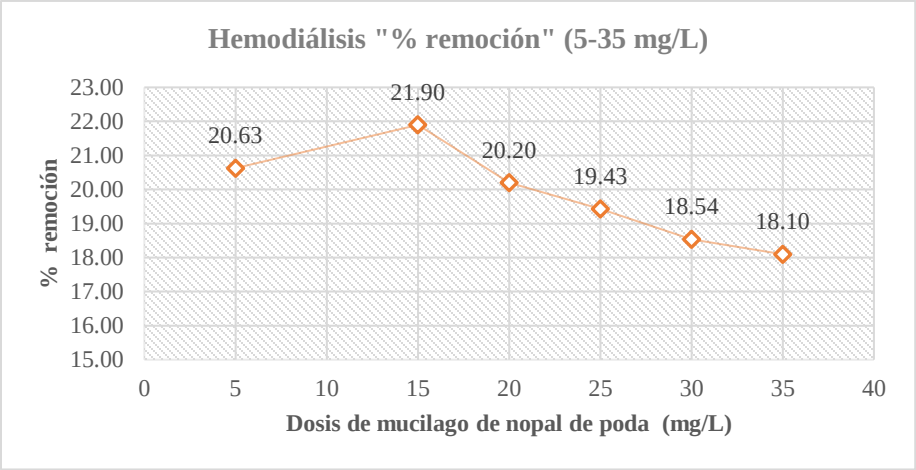

Figure 6. Removal results of hemodialysis effluent Jar Test (5-35 mg / L)

Miller (2008) y Manunza (1997) they report that *Opuntia* sp. It offers the ability to clot, that is, its active ingredient "galacturonic acid" which is a main component of pectin in plants, which is presented in polymeric form. The mechanism by which it works is through "bridge" coagulation where the particles in solution do not directly contact each other, but are attached to a polymer-like material that causes them to adsorb. Galacturonic acid evidently indicates that it is anionic due to the partial deprotonation of the functional group and the existence of functional groups along the chain, implies the chemisorption that can occur in charged particles and -COO-.

For the dialysis effluent, the optimal dose of *Opuntia* sp. mucilage is 25 mg / L and the optimum pH is 9, obtaining a turbidity removal of 53%, as observed in figure 7.

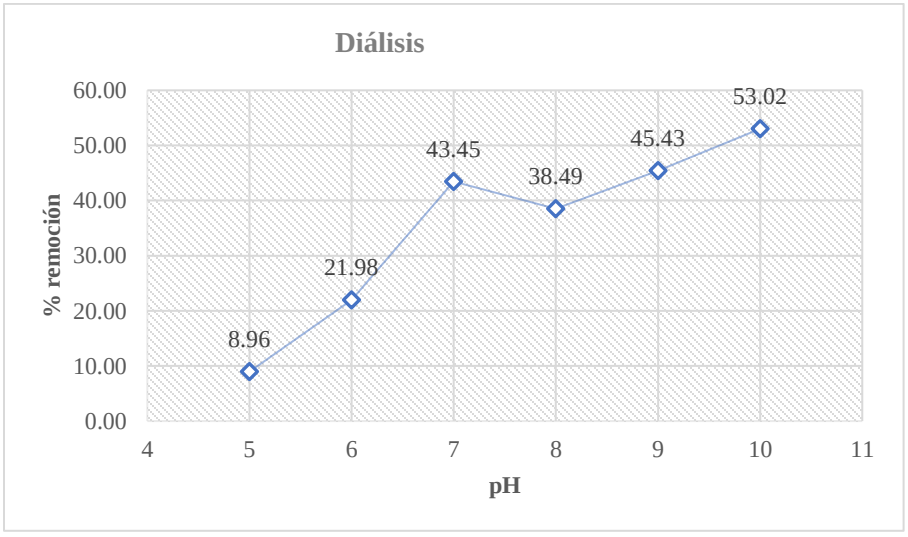

Figure 7. Dialysis effluent "pH vs% turbidity removal"

Figure 8 shows the case of the hemodialysis effluent, the optimal dose of *Opuntia* sp. is 15 mg / L, the best pH value is 9, achieving a removal of 31.99%.

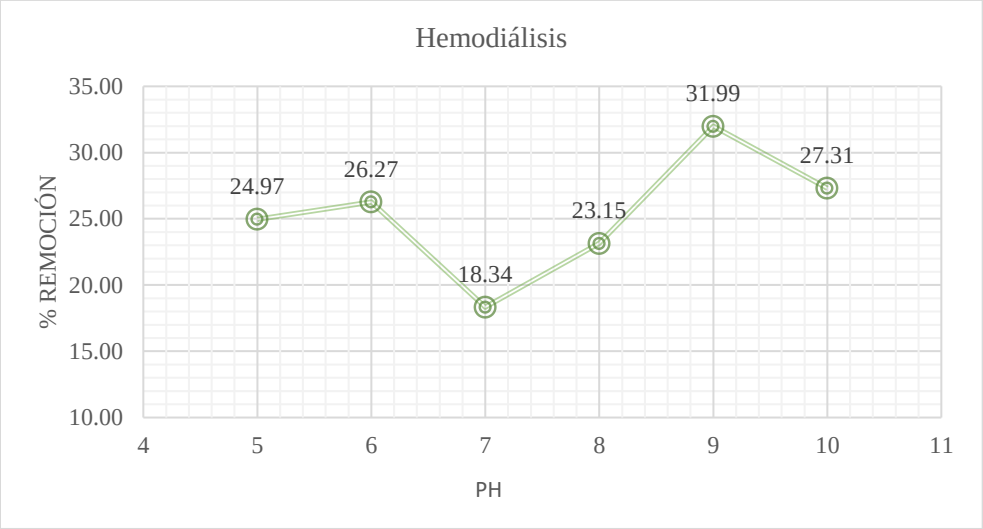

Figure 8. Hemodialysis effluent "pH vs% turbidity removal"

Conclusions

As for the extraction of nopal mucilage with the use of solvents is the most used procedure so far and it is expensive to carry out, since the yields are approximately 1%, in addition to the use of substances such as alcohol or ether, no it is an environmentally friendly procedure. On the other hand, if the extraction by the simple filtering method by Reyes-Ocampo *et al*., 2019, the yields found are similar and have the advantage of using only water, using the mechanical process, so the liquid discharge can go directly to the drain without contaminating.

The extraction of prickly pear mucilage Opuntia sp. It is cheap, abundant, renewable, fast growing, low cost, and due to its high coagulation capacity, it was useful as a coagulant in the treatment of hospital effluents since it allowed to treat biological-infectious waste, very little amount of sludge was generated (which which constitutes a disadvantage of physicochemical treatments), in addition to their plant origin, they are highly biodegradable, the most important thing is that good removals were obtained, a low-cost flocculant such as calcium hydroxide was used. These coagulants from non-toxic natural resources and considered a waste, should be encouraged to develop on a large scale.

The use of nopal mucilage for the treatment of hospital effluents, it can be concluded that it is a good alternative for the treatment not only of wastewater as previously treated, but also for hemodialysis and dialysis effluents. It is important to mention that you are using a waste that can be revalued, instead of discarding it and not giving

it any application. In addition, chemical coagulants that negatively impact due to the abundant formation of toxic sludge could be substituted.

References

1. Ahuja, S. S. (2013) Chapter 1 - Monitoring Water Quality, Pollution Assessment, and Remediation to Assure Sustainability, Monitoring Water Quality. Elsevier B.V. doi: 10.1016/B978-0-444-59395-5.00001-7.
2. Aliaga, E., Aceituno, C. and Sa, C. (2007) 'Extraction and characterization of mucilage in', 68, pp. 534–545. doi: 10.1016/j.jaridenv.2006.08.001.
3. Buttice, A. L., Alcantar, N. A. and Florida, S. (2014) 1 . 7 Sediment Removal with the *Opuntia ficus-indica* Cactus : A Water Purification Method for Communities in Latin America, Comprehensive Water Quality and Purification. Elsevier Ltd. doi: 10.1016/B978-0-12-382182-9.00007-4.
4. Carraro, E. et al. (2016) 'Hospital effluents management: Chemical, physical, microbiological risks and legislation in different countries', Journal of Environmental Management. Elsevier Ltd, 168, pp. 185–199. doi: 10.1016/j.jenvman.2015.11.021.
5. Chaguay (2017). Propuesta de tratamiento del manejo de aguas residuales generadas en una unidad diálisis. Ecuador: Universidad de Guayaquil
6. Choque-Quispe, D. et al. (2018) 'Capacidad floculante de coagulantes naturales en el tratamiento de agua', Tecnología Química, 38(2), pp. 298–309. doi: 10.1590/2224-6185.2018.2.
7. Elena, L. and Gazabón, M. (2013) 'Remoción de la turbidez del agua del río Magdalena usando el mucílago', 8(1), pp. 19–27.
8. Fox, D. I. (2011) 'Cactus Mucilage-Assisted Heavy Metal Separation: Design and Implementation', p. 148. Available at: http://libproxy.lib.unc.edu/login?url=http://search.proquest.com/docview/1171873535?accountid=14244.
9. Ibarra-Rodríguez, D. et al. (2017) 'Capacity of "nopal" pectin as a dual coagulant-flocculant agent for heavy metals removal', Chemical Engineering Journal, 323, pp. 19–28. doi: 10.1016/j.cej.2017.04.087.
10. Machado, C. K. et al. (2014) 'Potential environmental toxicity from hemodialysis effluent', Ecotoxicology and Environmental Safety. Elsevier, 102(1), pp. 42–47. doi: 10.1016/j.ecoenv.2014.01.009.
11. Nawel, A. et al. (2015) 'Improvement of electrocoagulation – electroflotation treatment of effluent by addition of *Opuntia* ficus indica pad juice', SEPARATION AND PURIFICATION TECHNOLOGY. Elsevier B.V., 144, pp. 168–176. doi: 10.1016/j.seppur.2015.02.018.
12. Nharingo, T. and Moyo, M. (2016) 'Application of *Opuntia ficus-indica* in bioremediation of wastewaters . A critical review', Journal of Environmental Management. Elsevier Ltd, 166, pp. 55–72. doi: 10.1016/j.jenvman.2015.10.005.
13. Nharingo, T., Zivurawa, M. T. and 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. Springer Berlin Heidelberg, 12(12), pp. 3791–3802. doi: 10.1007/s13762-015-0815-0.
14. Oladoja, N. A. (2016) 'Advances in the quest for substitute for synthetic organic polyelectrolytes as coagulant aid in water and wastewater treatment operations', Sustainable Chemistry and Pharmacy. Elsevier, 3, pp. 47–58. doi: 10.1016/j.scp.2016.04.001.
15. Reyes-Ocampo, I. et al. (2019) 'Solvent-free mechanical extraction of *Opuntia ficus-indica* mucilage', Journal of Food Process Engineering, 42(1), pp. 1–9. doi: 10.1111/jfpe.12954.
16. Rodríguez-González, S. et al. (2011) 'Optimización de la extracción del mucílago de nopal (*Opuntia ficus-indica*)', XIV Congreso Nacional de Biotecnologia y Bioingenieria , (2004), p. 58240.
17. Torres, L. G., Carpinteyro-urban, S. L. and Vaca, M. (2012) 'Use of Prosopis laevigata Seed Gum and *Opuntia ficus-indica* Mucilage for the Treatment of Municipal Wastewaters by Coagulation-Flocculation', 2012, pp. 35–41.

18. Urzu, C. C. et al. (2006) ‘Chemical characterization of the mucilage from fruits of Opuntia ficus indica’, 63, pp. 263–267. doi: 10.1016/j.carbpol.2005.08.062.
19. Yin, C. (2010) ‘Emerging usage of plant-based coagulants for water and wastewater treatment’, Process Biochemistry. Elsevier Ltd, 45(9), pp. 1437–1444. doi: 10.1016/j.procbio.2010.05.030.