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COMPARATIVE ANALYSIS OF THE REDUCTION OF SUSPENDED SOLIDS USING Opuntia ficus indica AND FERRIC CHLORIDE IN THE WATERS OF THE LURIN RIVER

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Abstract
One of the world's significant concerns lately is the quality of water and its availability over time. Being one of the most critical basic needs for humanity, its care is elementary for the world. In this research, we develop mechanisms for its treatment, the process of coagulation, and flocculation, where synthetic coagulants are added to accelerate the settling of suspended solids. This process was divided into four parts for a better understanding. They are starting with the introduction that provides a broad overview of the research and describes the Lurín area's problem. The methodology indicates the experimental research design where the collected concentrations are measured, going through the two treatments' procedure (*Opuntia ficus indica* and Ferric Chloride) at different doses. The results present initial and final parameters with both *coagulants'* dose tests for determining periods and zones, showing parameters of treatment and removal of the coagulants concerning the Lurín river's water. Finally, the conclusions indicate that the natural coagulant Opuntia ficus Indica obtained the highest percentage of turbidity removal, removal of chemical oxygen demand, reduced biochemical oxygen demand, and generated lower costs than ferric chloride.
Keywords: Water, Lurin River, Oxygen, Natural Coagulation, *Opuntia ficus indica.*

I. Introduction

Water quality and availability is currently a worldwide concern, as it is a vital element for human beings and their development. There are different types of surface water contamination, which have a severe impact on the population. During this process, surface water can be contaminated due to the coagulant used, the most commonly used aluminum sulfate, and ferric chloride, which generate residual sludge (pollutants) in the treatment plants. For this reason, this research work has compared the reduction of suspended solids in surface water from the Lurin River using a

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synthetic coagulant (ferric chloride) and a natural one (*Opuntia ficus indica*), to demonstrate a greater capacity for clean reduction by the natural coagulant. As for the results concerning turbidity reduction, a percentage of 74.14 % removal was obtained for the natural coagulant *Opuntia ficus indica* with a dose of 60 mg/L, reducing the initial turbidity from 100 NTU to 25.85 NTU, while for ferric chloride, a percentage of 73.73 % removal was obtained with a dose of 60 mg/L, achieving final turbidity of 26.26 NTU. Likewise, a portion of displacement concerning COD reduction of 75.69% was obtained for the natural coagulant *Opuntia ficus indica* with a dose of 60 mg/L, reducing the initial COD from 48 mg/L to 11.66 mg/L, while for ferric chloride, a percentage of removal of 72.91% was obtained with a dose of 50 mg/L, achieving a final COD of 13 mg/L. Finally, a portion of displacement concerning BOD_5 reduction of 36.8% was obtained for the natural coagulant *Opuntia ficus indica* with a dose of 40 mg/L, achieving a reduction of the initial BOD5 from 1.08 mg/L to 0.68 mg/L. In comparison, for ferric chloride, a percentage of removal of 21% was obtained with a dose of 40 and 50 mg/L, achieving a final BOD_5 of 0.85 mg/L. *Opuntia ficus indica* has higher turbidity, COD, and BOD_5 removal capacity compared to ferric chloride, which is why this natural coagulant can be used for the treatment of contaminated surface water as in the case of the Lurín River. The waters of the Lurín River's quality and properties are being affected by the constant contamination of the area. This is generated by indiscriminate dumping of domestic and industrial origin. For this reason, the General Directorate of Health (DIGESA) established that the area is unhealthy because two kilometers of fecal coliforms were found in the area. Suspended solids are also present, resulting in a lower concentration of oxygen in the water. The water is used for crop irrigation and consumed by local animals. This is a significant problem not only for the environment but also for the residents.

During the treatment of these waters (flocculation and coagulation) coagulants of artificial origin are used, which when used in large quantities can be harmful to health, which is why it is essential to find an alternative coagulant that is beneficial during the process, and that is not a risk for the local inhabitants.

II. Method

Sampling

Surface water was sampled from the Lurín River at coordinates 12°16'7.49" S, 76°53'56.90" W. The sample volume extracted was 22 liters. These were transported in a thermal box at a temperature of 5 °C to the Chemistry Laboratory of the Environmental Engineering Faculty of the Universidad Nacional Tecnológica de Lima Sur. Also, temperature and pH were measured at the sampling site. Sulfuric acid was also added to one of the samples to preserve the chemical oxygen demand. The procedures applied for surface water sampling of the Lurín River were obtained from the national protocol for monitoring the quality of surface water resources (Resolution No. 010-2016-ANA).

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Figure 1. Sampling point location

The design for this research is experimental there are two groups to analyzed (control group and experimental group), where we measured the initial concentrations of the control group and the final concentrations of Turbidity, COD, and BOD_5 after the application of the two treatments (T1: *Opuntia Ficus Indica,* T2: Ferric Chloride) at three different doses (40, 50 and 60 mg/L) in the waters of the Lurín river. The simulation of the treatment was carried out using the jar test where the independent variables (natural coagulant: *Opuntia ficus indica* and artificial coagulant: Ferric Chloride) were manipulated to determine the decrease produced in the dependent variable (decrease in Turbidity, COD, and BOD_5).

Phases of the investigation

To obtain the natural coagulant, we considered the methodology carried out by Villabona (2013) in the Colombian Journal of Biotechnology because it received better results in removing turbidity from water compared to other authors.

The *Opuntia ficus indica* stalks were acquired from the San Diego de Nashua community, which is located in the district of Aucara, province of Lucanas, department of Ayacucho.

- The thorns were removed from the stalks and then weighed.

Figure 2: Cleaning of stalks

Figure 3: Weighing of stalks

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- The cuticle was removed from the stalks to separate the pulp, which was then washed and cut into pieces.
- Subsequently, the pulp obtained in pieces was placed in an oven for 72 hours at 60 °C.
- The obtained stalk was crushed with a mortar and pestle's help and then sieved with a sieve No. 18 (1 mm).

Figure 4: Grinding of stalk strips

- The powder obtained was subjected to a Soxhlet extraction process for 4 hours using 96% ethanol as solvent.
- A powder of 13.06 g was obtained, dried at room temperature and stored in the desiccator until use.

III. Results

Parameters obtained before treatment

Turbidity, COD, and BOD_5 of the sample obtained from the Lurín river water before coagulant treatment were determined, obtaining the following results:

Table 1: Initial parameters of Lurín river sample

Sample	Turbidity (NTU)	DQO (O2 mg/L)	DBO_5 (mg/L)	Temperature (°C)	pH (Und.)
Lurín River surface water (2019)	100	48	1.076	25.1	7.49

Also, Table N°6 shows the results of the physical, chemical, and biological parameters of the water quality of the Lurín River, carried out by the National Water Authority. Most of them exceed the environmental quality standards.

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Table 2: Results of water quality monitoring in the Lurín river basin

Sample	Dissolved Oxygen (mg/L)	DQO (O2 mg/L)	DBO (mg/L)	Temp. (°C)	pH (Und.)	Term Coliforms (NMP/100mL)	Escherichia Coli (NMP/100mL)
Lurín River surface water (Rluri8)	6.99	72.5	30.17	27.16	8.24	4900	2300

***Opuntia ficus-indica* and Ferric Chloride coagulant dosage test**

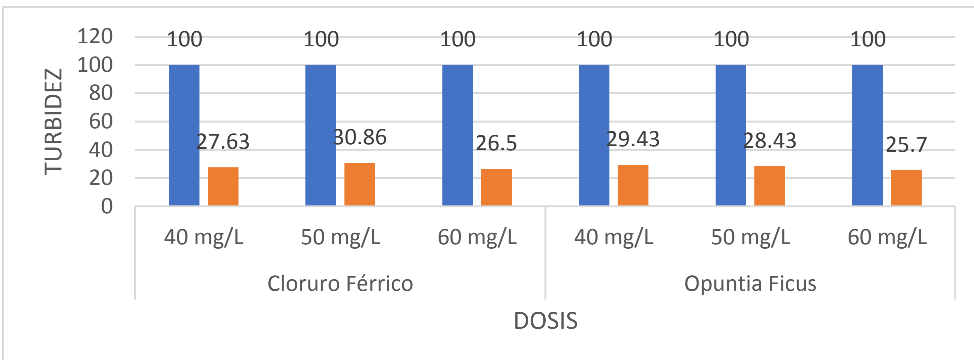

Figure 6: Turbidity results after the third treatment test

The results regarding turbidity for the third treatment test indicate that the natural coagulant *Opuntia ficus indica* has a higher turbidity reduction capacity with a dose of 60 mg/L, generating a decrease from an initial turbidity of 100 NTU to a final turbidity of 25.7 NTU. While the artificial coagulant ferric chloride has a lower turbidity reduction capacity compared to *Opuntia ficus indica*, its dose being 60 mg/L with the highest efficiency, generating a final turbidity of 26.5 NTU.

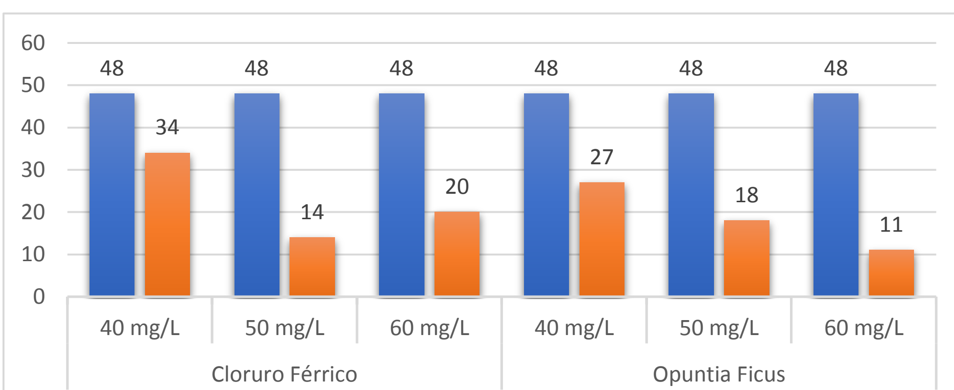

Figure 7: Resultados de DQO después del tratamiento tercera prueba

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The results regarding the chemical oxygen demand for the third treatment test indicate that the natural coagulant *Opuntia ficus indica* has a higher COD reduction capacity at a dose of 60 mg/L, generating a decrease from the initial COD of 48 mg/L to a final COD of 11 mg/L, while the artificial coagulant Ferric Chloride has a lower COD reduction capacity compared to *Opuntia ficus indica*, while the artificial coagulant ferric chloride has a lower COD reduction capacity compared to *Opuntia ficus indica*, with a dose of 50 mg/L being the most efficient, generating a final COD of 14 mg/L.

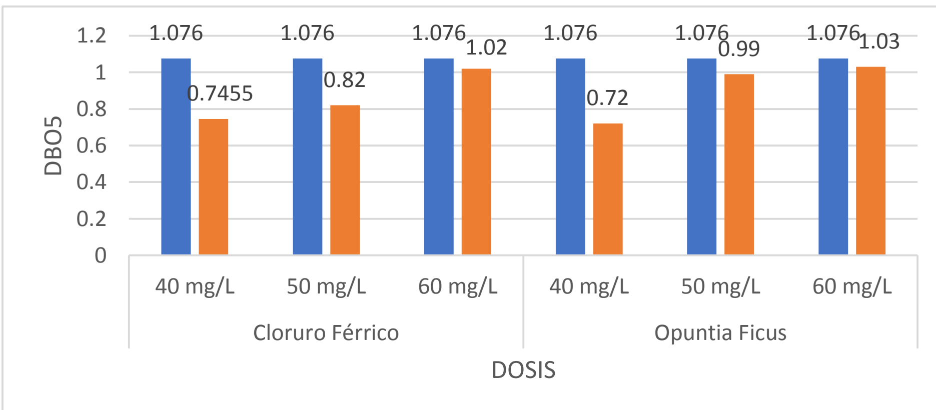

Figure 8: BOD_5 results after the third treatment test

The results with respect to the biochemical oxygen demand for the third treatment test indicate that the natural coagulant *Opuntia ficus indica* has a higher BOD_5 reduction capacity with a dose of 40 mg/L, generating a reduction of the initial BOD_5 of 1.076 mg/L to a final BOD_5 of 0.72 mg/L, while the artificial coagulant Ferric Chloride has a lower BOD_5 reduction capacity. 076 mg/L to a final BOD_5 of 0.72 mg/L, while the artificial coagulant Ferric Chloride has a lower BOD_5 reduction capacity compared to *Opuntia ficus indica*, with a dose of 40 mg/L being the most efficient, generating a final BOD_5 of 0.74 mg/L.

Table 3: Treatment with average dose, initial BOD5, final BOD_5 and removal percentage

N° of jar	**Coagulant**	**Dosage**	**DBO_5 Initial**	**DBO_5 Final**	**% reduction**
1	*Opuntia ficus indica*	40 mg/L	1.08	0.68	36.80
2	*Opuntia ficus indica*	50 mg/L	1.08	1	7.06
3	*Opuntia ficus indica*	60 mg/L	1.08	1.02	5.20
4	Ferric Chloride	40 mg/L	1.08	0.85	21
5	Ferric Chloride	50 mg/L	1.08	0.85	21
6	Ferric Chloride	60 mg/L	1.08	1	7.06

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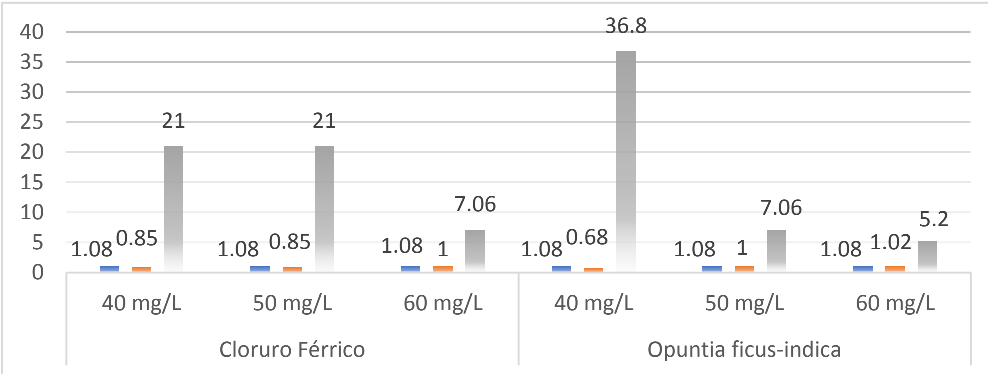

Figure 9: Average BOD5 results and percent removal after treatment third test

The average results obtained indicate that the highest percentage of removal of biochemical oxygen demand is 36.8% corresponding to the natural coagulant *Opuntia ficus indica* with a dose of 40 mg/L and a final BOD_5 of 0.68 mg/L, while Ferric Chloride indicates that its highest percentage of removal is 21% with a dose of 40 and 50 mg/L and a final BOD_5 of 0.85 mg/L.

IV. Conclusion

The natural coagulant *Opuntia ficus indica* obtained the highest percentage of turbidity removal being 74.14 % with a dose of 60 mg/L and a final turbidity of 25.85 NTU, while the Ferric Chloride indicates that its highest percentage of removal is 73.73 % with a dose of 60 mg/L and a final turbidity of 26.26 NTU, that is why we can indicate that the natural coagulant is more efficient than the artificial coagulant with respect to turbidity removal.

The natural coagulant *Opuntia ficus indica* obtained the highest percentage of chemical oxygen demand removal being this 75.69 % with a dose of 60 mg/L and a final COD of 11.66 mg/L, while the Ferric Chloride indicates that its highest percentage of removal is 72. 91 % with a dose of 50 mg/L and a final COD of 13 mg/L, which is why we can indicate that the natural coagulant is more efficient than the artificial coagulant with respect to the removal of chemical oxygen demand.

The natural coagulant *Opuntia ficus indica* obtained the highest percentage of removal of the biochemical oxygen demand being 36.8 % with a dose of 40 mg/L and a final BOD_5 of 0. 68 mg/L, while the Ferric Chloride indicates that its highest percentage of removal is 21% with a dose of 40 and 50 mg/L and a final BOD_5 of 0.85 mg/L, which is why we can indicate that the natural coagulant is more efficient than the artificial coagulant with respect to the removal of the biochemical oxygen demand.

Regarding the cost of the treatment for the purification of the samples obtained from the Lurin River, the cost generated for *Opuntia ficus indica* was lower compared to that of ferric chloride, since we must take into account that during water treatment, the artificial coagulant generates sludge, which makes the process more difficult and generates a higher budget.

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We used 10 grams of *Opuntia ficus indica* and 10.10 grams of Ferric Chloride for the treatment of 18 liters of contaminated water from the Lurín River, investing 5 and 8 soles approximately, it should be noted that for the *Opuntia ficus indica* we had to wash, peel and dry obtaining the natural coagulant powder while for the Ferric Chloride we obtained directly.

References

1. Amaya Robles, Julio (2009). “El cultivo de Tuna” Opuntia ficus índica. Trujillo, Perú.
2. Autoridad Nacional del Agua, Marzo (2014). “Segundo monitoreo de calidad de agua superficial en la cuenca del río Lurín- Lima”. Lima, Perú
3. Andía Cárdenas Yolanda. (05 abril de 2000). Tratamiento de agua Coagulación y floculación. Lima: Sedapal. Recuperado de http://www.sedapal.com.pe/c/document_library/get_file?uuid=2792d3e3-59b7-4b9e-ae55-56209841d9b8&groupId=10154
4. Bayro Javier Morejón Díaz. (2017), Utilización del mucílago de Tuna (opuntia ficus-indica) en el mejoramiento de la calidad del agua de consumo humano, en la comunidad de Pusir Grande, provincia del Carchi, (tesis de pregrado) Universidad Técnica del Norte.
5. Carpio M, Ruiz C, Esenarro D, Rodriguez C, Garcia Godolia & Breña J. (2020). Natural Coagulan ton Mango Seeds (*Mangifera indica L*) in Removal of Turbidity of Domestic Wastewater. International Journal of Advanced Science and Technology Vol.29, N° 7 pp. 2276-2734.
6. Candelario Mondragon, J. (2018, 01 de mayo). Ecología del cultivo, manejo y usos del nopal. Icarda. Recuperado de http://www.fao.org/3/i7628es/I7628ES.pdf
7. Cepes (04 de marzo de 2017). Diagnostico calidad de agua cuenca río Lurín. Perú: Cepes. Recuperado de http://www.cepes.org.pe/pdf/OCR/Partidos/diagnostico_calidad_aguatomo2/diagnostico_calidad_agua_cuenca_rio_lurin.pdf/
8. Christina Elizabeth Montoya Arias y Kimberly Alexandra Silencio Acuña, (2017), titulado: “Evaluación de pH, concentración de FeSO4 y FeCl3, en la remoción de sólidos suspendidos y sulfuros en efluentes de pelambre en curtiembres”, (tesis para optar el grado académico de ingeniero químico) Universidad Nacional de Trujillo.
9. Godoy Briones, V. M. (2018). Análisis comparativo de la disminución de la turbidez en el proceso de floculación utilizando un floculante comercial y la paleta de Tuna, (tesis de pregrado) Universidad Privada del Norte, Cajamarca-Perú
10. Hernández Ana María (02 agosto de 2007). Sólidos suspendidos totales en agua secados a 103 – 105 ºC. Colombia: Ideam. Recuperado de http://www.ideam.gov.co/documents/14691/38155/S%C3%B3lidos+Suspendidos+Totales+en+aguas.pdf/f02b4c7f-5b8b-4b0a-803a-1958aac1179c

P-ISSN: 2204-1990; E-ISSN: 1323-6903
DOI: 10.47750/cibg.2021.27.02.486

11. Igreda, Manuel. (21 de enero de 2012). Denuncian a sedapal por contaminar playa de Lurín. Perú 21. Recuperado de https://peru21.pe/lima/denuncian-sedapal-contaminar-playa-lurin-12729
12. Karina Urquía Collantes. (2017), Eficiencia de la Opuntia Ficus-Indica frente a la Moringa Oleífera, en el tratamiento de aguas del Río Huaycoloro, SJL-2017, (tesis de pregrado) Universidad César Vallejo. Lima-Perú.
13. Kriss Estefany Razuri Malqui. (2017), Disminución del contenido de la DBO y la DQO mediante coagulantes naturales (Aloe Vera L. y Opuntia ficus indica) en las aguas del canal de regadío E-8 Chuquitanta – San Martín de Porres, (tesis de pregrado) Universidad César Vallejo. Lima-Perú.
14. Lozano Florián, L. L. (2018). Efecto en la disminución de la turbidez en el agua por floculantes de *Opuntia ficus-indica* (Tuna) con diferentes procesos de extracción en el río Chonta de Cajamarca, 2018, (tesis de pregrado) Universidad Privada Antonio Guillermo Urrelo, Cajamarca-Perú
15. Malena, L. P. (2018). Evaluación del uso de la cactácea opuntia ficus-indica como coagulante natural para el tratamiento de aguas, (tesis de pregrado) Universidad Nacional Agraria la Molina, Lima-Perú.
16. Medizzine (09 de junio de 2010). Nopal (*Opuntia ficus indica*) información para usuarios y pacientes. México: Medizzine. Recuperado de http://www.medizzine.com/plantas2/nopal.php
17. Nihonkasetsu (23 de junio de 2015). DBO y DQO para caracterizar aguas residuales. Chile: Nihonkasetsu. Recuperado de http://nihonkasetsu.com/es/dbo-y-dqo-para-caracterizar-aguas-residuales/
18. Oxiquim (20 de marzo de 2007). Oxiquim. México: Oxiquim. Recuperado de http://www.asiquim.com/nwebq/download/HDS/Cloruro_Ferrico.pdf
19. Oxychile (10 de mayo de 2015). Oxychile. Chile: Oxychile. Recuperado de http://www.oxychile.cl/opensite_20073.aspx
20. Pastor Torín José (30 de octubre de 2016). Prueba de jarras. México: sistemajpi. Recuperado de http://sistemajpii.blogspot.com/2016/10/prueba-de-jarras.html
21. Químico Global (11 de abril de 2011). Químico Global. México: Químico Global. Recuperado de https://quimicoglobal.mx/cloruro-ferrico/
22. Rocío Lizeth Gabino Curiñahui. (2018), *Opuntia ficus-indica* como coagulante para remoción de sólidos suspendidos totales del efluente de beneficio en avícola la chacra, (tesis de pregrado) Universidad Continental. Huancayo-Perú.
23. Ruiz C, Esenarro D, Valderrama K, Alfaro T & Baroza G. (2021). Enviromental Bioindicator of Quality of the Biological Aquatic Enviroment in the Lurín River, Antioquia- Huarochirí, Peru. Journal of Green Engineering (JGE) Vol. 11 N° 2. Pp. 1142-1152.
24. Sal y Rosas M, Esenarro D, Garcoa G, Ruiz C & Breña J. (2020). A Mathemathical Model to determine Mass and Energy Transfer in the Palm Oil Production Process. Journal of Green Engineering (JGE). Vol. 10 N° 9 pp. 4800-4813.

P-ISSN: 2204-1990; E-ISSN: 1323-6903
DOI: 10.47750/cibg.2021.27.02.486

25. Sonia Milagros Jara Vásquez. (2018). Uso del coagulante natural extraído de la semilla de tamarindo "*Tamarindus indica L*." para reducir sólidos coloidales en laboratorio de las aguas del río Lurín, Lima - 2018, (tesis de pregrado) Universidad César Vallejo, Lima-Perú
26. Sosa Rogelio. (24 de abril de 2018). Mexicanos producen con nopal biogás único en el mundo como alternativa limpia de combustible. América Economía. Recuperado de https://www.americaeconomia.com/negocios-industrias/mexicanos-producen-con-nopal-biogas-unico-en-el-mundo-como-alternativa-limpia-de
27. Sucso Ruth (17 de febrero de 2011). Externalidades en cuenca del rio Lurín. Perú: Rsucso. Recuperado de http://rsucso.blogspot.com/
28. Velandia Barrera Yeniffer Shirley. (18 enero de 2013). Turbiedad del agua. Lima: Blogspot. Recuperado de http://turbiedaddelagua.blogspot.com/p/bibliografia.html
29. Vico Torres Contreras. (2017), Análisis del coagulante natural opuntia ficus con fines de implementación de una planta potabilizadora de agua en Chalhuanca, Apurímac, 2016, (tesis de pregrado) Universidad César Vallejo. Lima-Perú
30. Villabona Ortiz, Ángel, Paz Astudillo, Isabel Cristina y Martínez García, Jasser. (2013). Caracterización de la Opuntia ficus-indica para su uso como coagulante natural. Revista Colombiana de Biotecnología, Volumen (15) ,137-144
31. Zanabria Jose García (2019). Estadísticas Ambientales. Perú: Instituto Nacional de Estadística e Informática. Recuperado de https://www.inei.gob.pe/media/MenuRecursivo/boletines/informe-estadisticas-ambientales-marzo2019.pdf

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