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Safety in Wastewater Treatment Plants and the use of Natural Coagulants as an Alternative for Turbidity

Mayra A. Vargas[a], Alex S. Armas[b], Zanhy L. Valencia[b,*], Elmer Benites[c]

[a]Universidad Nacional Tecnológica de Lima Sur, Sector 3 Grupo 1A 03, Av. Central, Villa EL Salvador, Lima 15834, Perú
[b]Universidad Nacional Mayor de San Marcos, Ciudad Universitaria , Lima 15081, Perú
[c]Universidad César Vallejo, Av. Alfredo Mendiola 6232 Los Olivos Lima 15314, Perú
zvalenciar@unmsm.edu.pe

It is important to update work procedures in the preventive aspects and occupational diseases of wastewater treatment plants. The objective of the research was to identify levels of exposure to hazardous products by the tasks performed in wastewater treatment plants in order to update work procedures in the preventive aspects and occupational diseases of wastewater treatment plants, and reduce health risks and negative impacts on the environment. One of the operating processes in the treatment of domestic wastewater is coagulation, where aluminum sulfate is generally used with very efficient results, but it generates health and environmental risks; Therefore, the coagulating power of *Opuntia ficus-indica* clouded and *Caesalpinia spinosa* gum was evaluated against the conventional coagulant Aluminum Sulfate to remove turbidity from water samples of the UASB effluent from the Septic Tank of the Wastewater Research Center (CITRAR) - UNI. The tests were done by jar test for the coagulation, flocculation and sedimentation process, in six equal doses for each coagulant. The results of coagulant removal efficiency were 59.42 % when using a dose of 40 mg/L of Opuntia ficus-indica, 55.78 % with a dose of 110 mg/L of *Caesalpinia spinosa* and 91.60 % with a dose of 70 mg/L of Aluminum Sulfate. The results indicate that natural coagulants offer considerable percentages of turbidity improvement in the treatment of urban effluents; therefore, replacing the use of aluminum sulfate with natural coagulants reduces negative impacts and prevents damage to health, providing safety to workers and the environment.

1. Introduction

The wastewater discharged into aquatic environments is a threat to human health, emerging pollutants are known as new chemicals or substances present for a long time, but only recently examined, may not be commonly controlled in the environment, causing adverse effects on ecology and human health. (Xue et al., 2021), aluminum sulfate is widely used to reduce the turbidity of water, if the optimal dose, intensity, agitation speed, flocculation and sedimentation times outside the optimal range are not used, they could remain in the water with high levels representing a risk to health. (Ospina Zúñiga & Cardona García, 2020).
Having quality water is essential for human health, environmental protection and economic development. In industrialized countries, wastewater treatment has become an indispensable requirement to maintain water quality optimal conditions. Therefore, the treatment of wastewater becomes an unavoidable necessity, water treatment refers to the treatment or adequacy of wastewater prior to discharge. Wastewater is a product of human activity. It is collected by a sewage network and transported to a wastewater treatment plant, where it is treated according to the plant's capacity and then discharged into a receiving medium. There are different systems for wastewater treatment, although they can be classified according to two main treatment strategies: Industrial wastewater is usually treated by physicochemical methods, while domestic or urban wastewater by biological processes. These biological processes are a technological version of the self-purification processes that occur naturally in watercourses, when substances are released into the water below certain limit concentrations, some microorganisms initiate the self-purification process. They also break down waste, metabolizing it and transforming it into simple substances such as carbon dioxide, nitrogen. These wastes have a high concentration of toxic substances. The interesting component of this technological version is that it allows an acceleration of these natural processes (Vilanova et al., 2017).

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In recent years, interest in the operation and control of water treatment plants has increased due to increasingly stringent water quality regulations. Also, in order that the treated water can be used in other activities, such as irrigation of green areas, washing of yards and industrial buildings, etc., without presenting any risk to public health and, on the other hand, that it does not degrade the natural state of the receiving ecosystems. Occupational diseases are those produced directly by the exercise of the profession, the work history is essential, it is important to know both your current job and the work you have done before, asking specifically about the work you did, the time of exposure, the use of protective equipment (Salinas & Del Solar, 2015).
One of the most common problems in wastewater treatment plants is the odor generated, which can affect employees. This leads to trying to control the impact of air pollutants in the affected areas, with volatile sulfur compounds being the most worrying, since their exposure can cause health problems for workers (Li et al., 2021).
Industrial wastewater contains volatile organic compounds, releasing high amounts of benzene, toluene, and xylenes during the wastewater treatment process. Volatile organic compounds can cause negative environmental effects. (Zhang et al., 2019).

2. Methodology

The research aims to update the working procedures in the preventive aspects and occupational diseases of the new wastewater treatment plants, in order to reduce health risks and negative impacts on the environment, in addition to providing an overview of the most studied vegetable coagulants compared to the conventional coagulant Aluminum Sulfate, as well as analyzing turbidity. The characterization and effects of the operating parameters used, such as the optimal dose of coagulants used, temperature, pH, BOD5 and turbidity, were investigated, in addition to examining the effectiveness of the coagulants. Finally, the studies found show that natural coagulants are efficient in removing turbidity from water, with some coagulants being more efficient than others.

Identification of exposure levels for tasks performed at Wastewater Treatment Plants

Aluminum is considered one of the most abundant metals on earth, as well as a toxic metal for health, and can affect the central nervous system, the bone system, brain tissue and blood cells. Its most common exposure is through an aluminum-based foods and food additives. It is widely used in the treatment of drinking water, aluminum salts are widely used as flocculants since it reduces organic matter, turbidity and microorganisms, which leads to a higher intake of aluminum, it is estimated that the average total dietary exposure of an adult is between 14 and 280 mg of aluminum per week. After ingestion, aluminum absorbed into the blood is removed by the kidneys and excreted in the urine (Yassa et al., 2017).

Water samples from the Septic Tank of the Wastewater Research Center (CITRAR) – UNI

A sample was taken from the effluent of an upflow anaerobic sludge blanket reactor (UASB) of the Septic Tank type, as shown in Figure 1, which operated with an approximate flow of 3600 L/day. At each sampling point, single samples were taken in duplicate, the volume of each sample was one liter, although smaller volumes were used in the laboratory. The sampling procedure was carried out according to USEPA method 525.2 (1995) (Peña-Álvarez & Castillo-Alanís, 2015). The analysis was performed the same day the sample was taken.

Figure 1: Sampling of effluent from an upflow anaerobic sludge blanket sludge reactor (UASB) of the septic tank type

The concentrations (mg/L) were 40, 70, 90, 110, 130, 150 for the treatment with natural coagulants: Opuntia ficus-indica, *Caesalpinia spinosa* and for the conventional coagulant aluminum sulfate. Then it was subjected to rapid agitation at 120 revolutions per minute (rpm) for 1 min until coagulation. Slow agitation of 30 rpm was carried out for 20 min for flocculation to occur. During the jar test, floc formation and the Willcomb index, which allows a qualitative evaluation of floc formation, were taken into account. After flocculation, the floc formation times were recorded, using the Wilcomb index. The paddles were then carefully removed so as not to disturb the water, leaving the vessels at rest for 15 min. All experiments were carried out in duplicate daily in February. The response variable analyzed was turbidity, for which a pipette was used to extract treated water for each beaker, 100 ml of the sample was extracted, taking care to perform this operation at the same suction speed and at the same depth from the surface of the liquid (5 cm).
The main parameters such as temperature, conductivity and turbidity were determined according to the methodology of the 21st edition Standard Methods for the Examination of Water and Wastewater (APHA, 2005), the pH was measured with an Orion potentiometer (model 310), and the multiparameter Hanna HI 9828. The results of these analyzes were compared with the upper limits established for water bodies Maximum Permissible Limits (LMP) (Ministerio del Ambiente (Perú) 2010)).

3. Results and Discussion

3.1 Physic-chemical parameters

For the physicochemical parameters using Opuntia ficus - BOD5 was obtained from 62.1 to 122.3 mg/L, pH from 7.75 to 7.78, electrical conductivity from 703.7 to 942.6 µS/cm, temperature from 27.87 to 28.50 °C; when using *Caesalpinia spinosa* BOD5 was obtained from 142.4 to 167. 9 mg/L, pH from 7.32 to 7.46, electrical conductivity from 645.2 to 952.4 µS/cm, temperature from 27.68 to 27.91°C; and by using aluminum sulfate, BOD5 was obtained from 49.2 to 81.7 mg/L, pH from 7.26 to 7.44, electrical conductivity from 724.5 to 940.8 µS/cm, temperature from 27.75 to 28 °C. From the review of the scientific literature, it was determined that aluminum salts (aluminum sulfate) are widely used in the wastewater treatment process in the clarification part; at the same time, when not used at the optimum dose, its excess constitutes a health risk to people and the environment.

3.2 Turbidity monitoring using natural coagulants and aluminium sulphate

The values of the turbidity of the effluent at the time of treatment with the coagulants are presented in Figure 2. These correspond to the control carried out in the morning hours of the 12 days of monitoring. It can be seen that for the natural coagulant *Opuntia ficus-indica* the minimum turbidity value reached was 26 NTU and the maximum value was 78.9 NTU; When using the natural coagulant *Caesalpinia spinosa*, the minimum turbidity value was 32 NTU and the maximum value was 70 NTU, and when using the conventional (chemical) coagulant Aluminum Sulfate, the minimum turbidity value was 8.67 NTU and the value 50.5 NTU maximum.

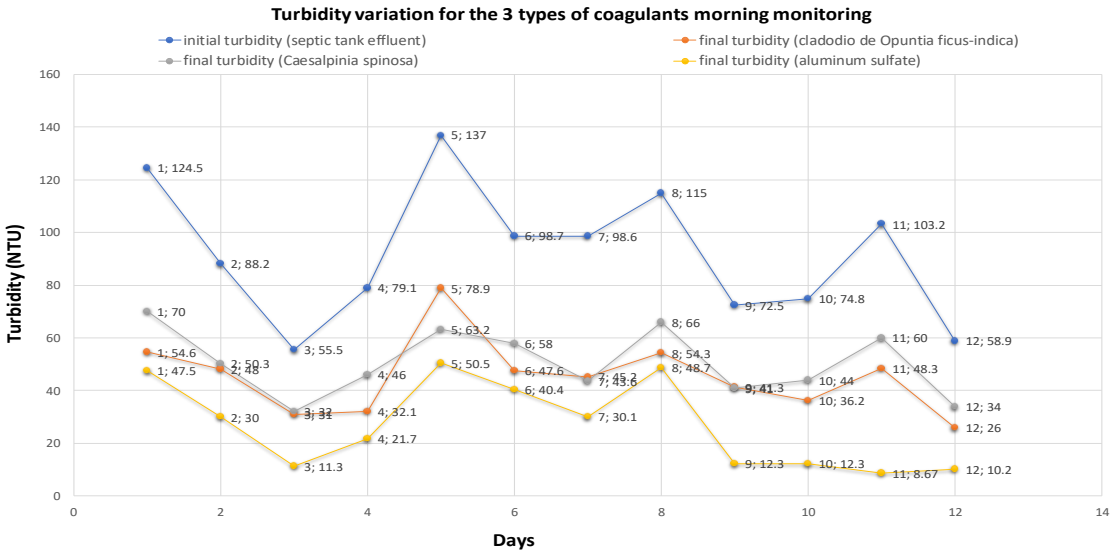

Figure 2: Variation of turbidity by treatment with natural coagulants and aluminum sulfate in the morning.

For the turbidity monitoring, which was carried out in the afternoons of the days of treatment of the UASB effluent, the most efficient coagulant for the treatment of this parameter was the conventional coagulant Aluminum Sulfate, going down to the value of 9.3 NTU, the following the coagulant was Opuntia ficus-indica with a turbidity of 24.3 NTU and then the coagulant Caesalpinia spinosa that also reduced the turbidity of 25.4 NTU. Turbidity measurements are considered to be an indicator of overall quality. It is also established that turbidity obstructs light, thus slowing the growth of plants, eggs, and larvae, which are normally found in the lower levels of an aquatic system. Turbidity does not show the result of a specific contaminant, but it is a reference to the total degree of contamination that the water may have.

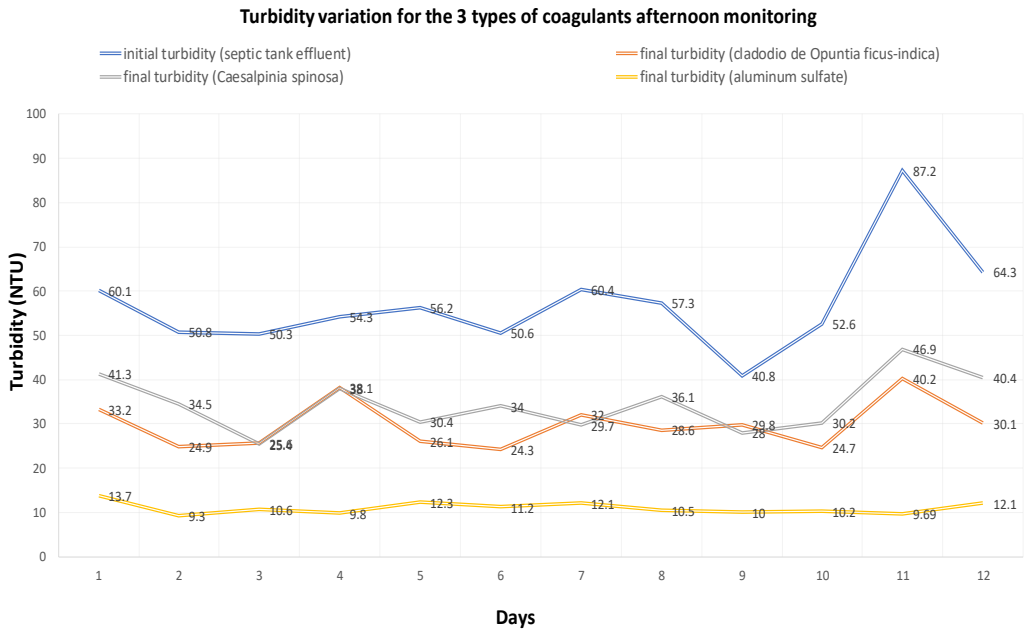

Figure 3: Variation of turbidity by treatment with natural coagulants and aluminum sulfate in the afternoom

The results obtained indicate that aluminum sulfate proved to have greater efficiency in reducing turbidity in wastewater treatment. Aluminum sulfate is the most widely used coagulant for water treatment; There is little literature that demonstrates the optimal dose needed for wastewater treatment (Wan et al., 2019), this is a disadvantage because it is a potential risk to health and the environment at levels above 0.2 mg/L, according to Colombian regulations (Ospina Zúñiga & Cardona García, 2020)

3.3 Turbidity reduction for each coagulant

Table 1 shows the percentage of turbidity reduction for each coagulant where it can be seen that the chemical coagulant has a higher value than the natural coagulants.

Table 1: Turbidity removal for each coagulant

Coagulant	Initial turbidity	Final turbidity	Turbidity removal (%)
Opuntia ficus-indica (40mg/L)	79.1	32.1	59.42
Caesalpinia spinosa (40mg/L)	98.6	43.6	55.78
Aluminum sulfate (70mg/L)	103.2	8.67	91.60

When applying the treatment using aluminum sulfate, a 91.60 % decrease in turbidity was obtained; in other cases, this coagulant can achieve a reduction of more than 96 % (Meza-Leones et al., 2018).
The use of *Opuntia ficus-indica* in the treatment resulted in a decrease of 59.42 % in turbidity, which is much higher than the decrease reported by (Wan et al., 2019) The coagulation efficiency of the mucilage can decrease from 10 % in ten days to around 30 % in 20 days. When *Caesalpinia spinosa* was used, a decrease in turbidity of 55.78 % was obtained (Terrones, 2019) which was able to decrease by 54.84 %, indicating that the higher the dose, the greater the efficiency in terms of turbidity. Several natural species with these coagulation characteristics have been studied, such as the extract of Melacactus sp. (Ibarra Cuadrado N. et al., 2018) and in others, biopolymers have been used by mixing various plants such as Opuntia dilleni, Stenocereus griseus, Cereus forbessi, Melocactus sp, Aloe arborescens and aloe vera. (Daza-Gamez et al., 2016).
The excess of organic matter deteriorates the quality of the water causing problems of taste, clarification, color and smell. In addition to increasing the consumption of coagulants and chlorine, which could result in human health problems, the coagulation-flocculation technique is a very common established method used to remove natural organic matter in water treatment. Plant-based coagulants derived from plants such as Moringa oleifera, Strychnos potatorum Linn, and Opuntia ficus indica, are great sustainable alternatives to chemical coagulants, such as aluminum sulfate, due to their abundant availability, low cost, and biodegradability (Okoro et al., 2021).

4. Conclusions

All extracts of plant origin that have been studied and reported in the scientific literature prove to be effective in removing turbidity from water in the presence of organic and inorganic particles. Compared to aluminum sulfate, natural coagulants show a lower efficiency in the coagulation and turbidity reduction process. In the research carried out with vegetable extracts of *Opuntia ficus indica* and *Caesalpinia spinosa*, this trend was also corroborated by obtaining an efficiency of 59.42 % and 55.78 %, respectively, in the elimination of turbidity, while aluminum sulfate reached 91.60 %.
Although aluminum sulfate is more efficient in turbidity reduction, scientific studies also indicate that it constitutes a risk to occupational health and safety when doses exceed 0.2 mg/L, in this way, the objective of seeking preventive procedures for the health of operators in wastewater treatment plants was met; For this reason, the use of natural coagulants, such as *Opuntia ficus indica* and *Caesalpinia spinosa*, is a replacement alternative to this process and further research is needed to optimize their use, considering all the physical and chemical parameters involved in the process, as well as the operating conditions, such as treatment time and flocculant dosage. In addition, it should be taken into account that these natural coagulants are used empirically to treat water for human consumption in rural communities in many countries, being an alternative solution for public health.

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