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Remediation of wastewater from the semi-artisanal tanning process using microalgal consortium

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ABSTRACT

Human, commercial and industrial activities are polluting the waters that are normally used for agricultural productivity. The Ministry of the Environment (MAE) regulates these activities by demanding, according to environmental legislation, that the water collected be returned upstream in equal or better conditions than the initial ones, and within the parameters of the unified text of environmental legislation when it is discharged into the sewage system. The poor disposal of liquid effluents with the presence of chromium by various industries, especially tanneries, is causing pollution of water bodies. The percentage removal efficiency was presented 10 days after the start of the experiment, showing the highest removal for the heavy metals cadmium, arsenic and lead at 100%, followed by a reduction in the amount of total coliforms (98), faecal coliforms (100), total solids (78) and nitrates (97%). The removal of total phosphorus corresponded to 72%, while for total phosphorus it was 72%. It is also observed that the biological oxygen demand (BOD5) was reduced by 82% and the biochemical oxygen demand (COD) by 89% with respect to the initial values found reported in tannery wastewater before the experiment. Alternately these effluents could be used as alternative substrates for the growth of microalgae, which would generate a positive impact on the total costs of biomass production at large scales.

Keywords. Remediation, microalgal consortium, tanning wastewater.

1. INTRODUCTION

The Organization Of United Nations mentions that "more than 80% of wastewater in developing countries is discharged without treatment, polluting rivers, lakes and coastal areas" (UNESCO, 2010). Furthermore, according to the United Nations Educational, Scientific and Cultural Organization (UNESCO), the manufacturing sector is one of the sectors that generates the largest amount of wastewater, with data from some countries indicating that only a fraction of their wastewater from this sector is treated before being discharged into receiving bodies (UNESCO, 2017).

With regard to manufacturing industries, it is worth highlighting that the tanning industry is one of the most polluting industries, since in operations and processes they generate liquids and solids that are characterized by presenting a high organic load and chemical agents that can have toxic effects, such as sulphur and chromium (Miranda, 2019; Rosales and Rodríguez, 2018).

The presence of chromium in water bodies is caused by natural and anthropogenic factors. In the first case, it is caused by the degradation of rocks, as this metal is found naturally in the environment (Mena, 2019). On the other hand, there are anthropogenic factors, specifically from different industries, which discharge their effluents without having carried out adequate treatment, as well as wastewater collection systems that do not allow the separation of urban and industrial effluents (Arauzo et al., 2003), and finally, conventional systems for wastewater treatment that have deficiencies in removing heavy metals (Trujillo, 2015).

Within the field of bioremediation is the use of green algae, because they have the capacity to accumulate heavy metals, which are considered high risk due to their toxicity and capacity for accumulation in living tissues, such as Cr (VI). Their use for pollution control is limited to the factors present in the environment, such as pH, hardness, chlorides, sulphates, etc. These factors can limit the biological processes of the algae, reducing the availability of oxygen and therefore the presence of algae. Likewise, microalgae through biosorption in living or dead biomass have a high potential to reduce toxicity levels and to transform toxic compounds into harmless ones (Moreno and Téllez, 2020). Also, Arias (2017) indicates that microalgae have remediation properties, as they do not generate pollutants as a result of their process, due to the fact that the biomass obtained after the remediation process allows the recycling of nutrients. For these reasons, the purpose of this research was to evaluate microalgal consortia in the decontamination of water effluents from the manufacturing industry such as tanneries.

2. MATERIALS AND METHODS

Sampling, storage, processing, packaging and chain of custody for water quality analysis obtained from leather washing. The wastewater from the tanning process was collected at the discharge point of the tannery industry located in the municipality of Sampués, Department of Sucre. The physical and chemical properties of the wastewater collected will be analyzed according to the parameters established by resolution 2115 of 2007 of the Ministry of Environment, Housing and Territorial Development and the Ministry of Social Protection, which are: dissolved oxygen, pH, temperature, conductivity, total suspended solids, BOD_5, COD, nitrites, nitrates, fats and oils and metals such as Cd, Cr, Pb, Hg, Pb, faecal and total coliforms.

Sedimentation and bioremediation test. The treatment systems consist of 6 funnels, each with a capacity of 1000 mL of water. In the two initial tanks the water from the tanning process will be collected, in this initial stage a flocculants will be applied which allows all the sediment from the fleshing process to precipitate to the bottom of the tanks, these sediments will be collected to carry out a composting process (Tzoupanos & Zouboulis, 2008). In turn, the water will be deposited in two reactors (1000 mL Erlenmeyer), each reactor will be inoculated with 10 mL of microalgal consortium in its exponential phase and left in constant agitation for biological treatment. A control with tanning process waste water without microalgal consortium will be used.

Statistical analysis: The results were expressed as the mean ± Standard Deviation, an analysis of variance was carried out using a completely randomized design, with a 2x3 factorial arrangement; previously determining the normality criterion by means of the Shapiro Wilk test (5%). Significant statistical differences were determined by Tukey's test ($p < 0.05$). All experiments were performed in triplicate and analyzed in the free version of InfoStat software.

3. RESULTADOS Y DISCUSIÓN

Figure 1 shows the process used for the sedimentation and bioremediation of wastewater from the tanning process.

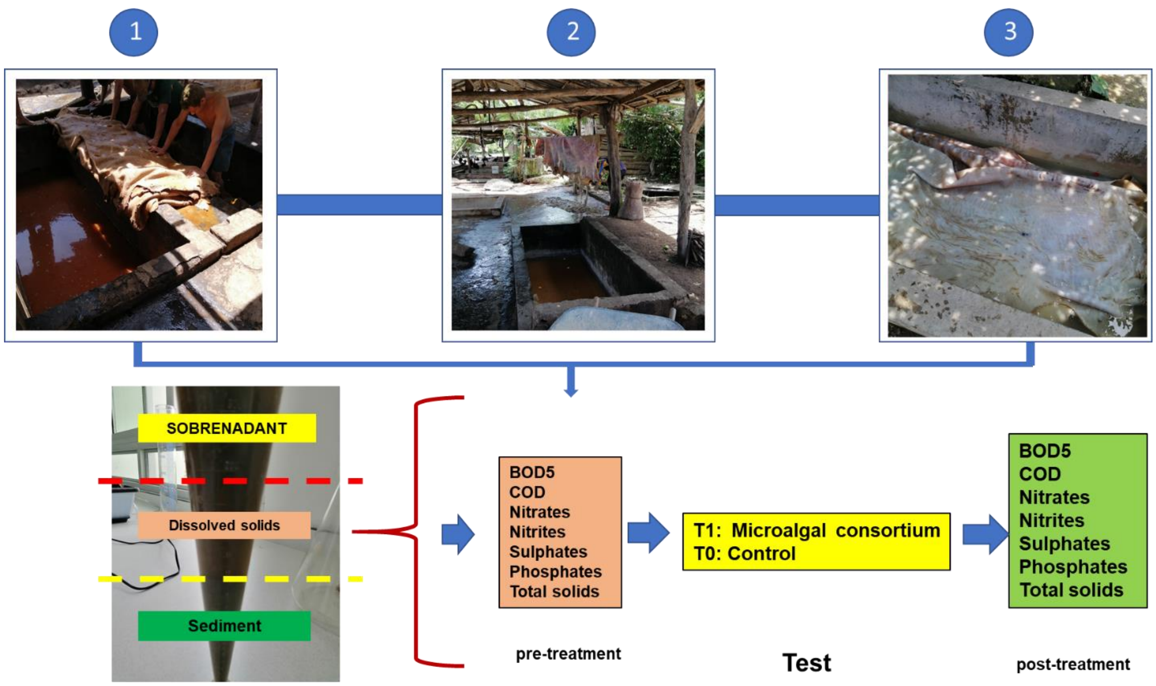

Figure 1. Sedimentation and bioremediation test.

The figure 2, shows the growth of the microalgal consortium during the test.

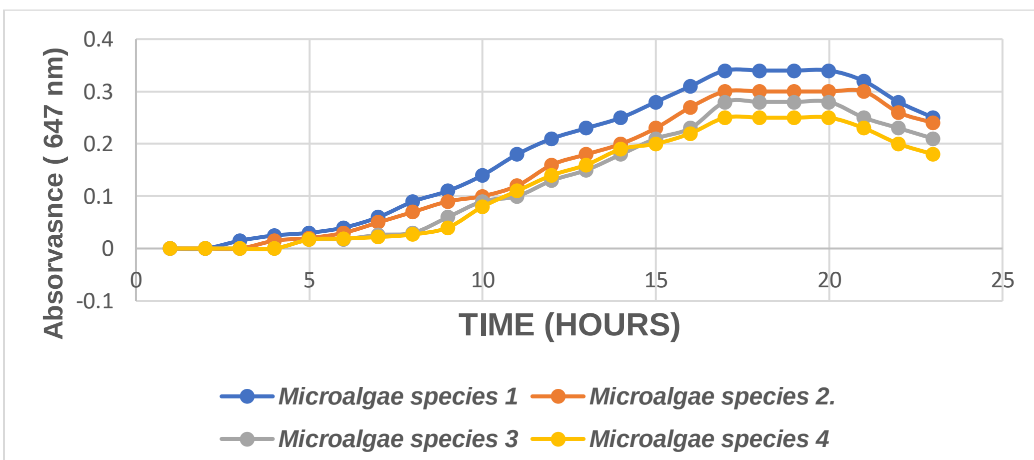

Figure 2. Growth curve of microalgal consortium used in tannery wastewater remediation and sedimentation test.

Table 1 shows the results of the remediation trial using the microalgae consortium. The presence of inorganic nutrients also has a direct effect on the growth of microalgae. The piggery wastewater used contained total nitrates, orthophosphates and phosphorus (table 1), both of which could be used by the microalgae consortia during the time of the trial, and their concentration (percentage removal) was reduced after 10 days of the experiment.

Table 1. Results of wastewater remediation process from tanning process using microalgae consortium.

Pollution indicators	***Pre-treatment***	***post-treatment***	***Results***
	0 day	**10 days**	**% removal**
Dissolved Oxygen (In situ)	1,5	5,58	increases
Turbidity	26,6	140	decreases
Salinity	0,427	0,189	decreases
Total Solids	341	81	90
BOD_5	18520	2105	89
COD	85,6	52	82
Nitrates	4,75	0,7	97
Orthophosphate	1,43	0,952	76
Phenols	0	0	0
Total Phosphorus	2,19	1,02	72
Faecal Coliforms	15 000	1	100
Total Coliforms	590 000	21 000	98
Arsenic	0,001	0	100
Cadmium	0,001	0	100
Mercury	0	0	0
Lead	0,017	0	100

The microalgal consortia used in this study were different species of microalgae (1, 2, 3 and 4) (figure 2). In figure 2, it is observed that all the species used in the consortium showed growth up to 17 days and after this time they entered the stationary phase. It can also be seen that microalgae species 1 had the highest growth rate compared to the other species.

The percentage removal efficiency was presented 10 days after the start of the experiment, showing the highest removal for the heavy metals cadmium, arsenic and lead at 100%, followed by a reduction in the amount of total coliforms (98), faecal coliforms (100), total solids (78) and nitrates (97%). The removal of total phosphorus corresponded to 72%, while for total phosphorus it was 72%. It is also observed that the biological oxygen demand (BOD5) was reduced by 82% and the biochemical oxygen demand (COD) by 89% with respect to the initial values found reported in tannery wastewater before the experiment (table 1).

Tanning is the process of transforming animal skin into leather by stabilizing the collagen fibers with tanning agents, either natural agents (black acacia bark, quebracho and mimosa extract) that require a prolonged time of 1 or 2 weeks; or by chemical tanning agents (caustic soda, taurol, ammonium sulphates, sodium bisulphite, chromium sulphates, dyes, among others) (Hernández, 2018) with a processing time of 8-24 hours, which avoid the decomposition of the leather and facilitate its use for the manufacture of leather goods, saddlery, among others (Cristancho Montenegro et al. , 2019). This process is carried out in three stages: the bank, where the skin is prepared to be tanned, cleaned and conditioned, until it is divided into two layers, the fleshing and the leather itself. The tanning process prepares the hide to be transformed into strong, rot-resistant materials by using tanning agents, mentioned above, which bind to the collagen fibres. Finally, the finishing is subdivided into two stages: wet finishing, where the characteristics of softness, color and touch are conferred through retaining, dyeing and wringing processes; and dry finishing, where the leather is given the final aspect of color and shine, allowing the control of possible imperfections of the product, through drying, softening, pigmenting and ironing.

In Colombia, the regulations governing the discharge of waste into water by the industrial sector have developed the Water Quality Index (ICA), which allows, through physicochemical variables, to know the quality conditions of a body of water (Franco González et al., 2017). These variables are consolidated and stipulated in Resolution 0883 of 2018 of the Ministry of Environment and Sustainable Development (MADS, 2018).

The presence of inorganic nutrients also exerts a direct effect on the growth of microalgae. The effluent used had the presence of nitrates and phosphates, both utilizable by the microalgae, which allowed growth during the time of experimentation, while being reduced in concentration, primarily in undiluted water (100%). These characteristics of industrial wastewater and the effect on the growth of microorganisms are widely recognized (Abdel-Raouf, et al., 2012; Craggs et al., 1997) and have led many to examine their potential as alternative substrates for growth, with the aim of reducing the costs of biomass production for biotechnological processes.

metals such as cadmium and lead were present at concentrations below the detection limits of the technique implemented. The removal percentages obtained in this study are similar to those reported by other authors (Ajayan et al., 2015; Peña-astro et al., 2004).

The biochemical oxygen demand is one of the principal parameters when assessing the characteristics in waste water from the tanning process. In the tannery water used in the present study, the initial BOD_5 value was 18520 mg/L which was reduced during treatment with microalgal consortium to 2105 mg/L, showing a percentage removal of 89%, higher than reported in the work of Ajayan et al., 2015 for tannery waters with microalgae of the genus *Scenedesmus*.

The ability of the microalgal consortia to removeinorganic nutrients in wastewater is a widely studied phenomenon. Elimination rates higher than 90% have been reported (Abdel-Raouf et al., 2012; Martinez et al., 2000). These nutrients are rapidly metabolized by the microalga, and nitrogen can be assimilated as ammonia or nitrates and transformed into organic nitrogen (Jimenez-Perez et al., 2004). Likewise, the phosphor in the form of phosphate ($H_2PO_4^-$ o HPO_4^{2-}) is used by the cell for the production of phospholipids, nucleic acids, and adenosine triphosphate (ATP), the latter essential to all cellular processes. In addition, microalgae derived from photosynthetic activity that generates pH changes can promote the precipitation of the phosphorus and nitrogen (Muñoz and Guieysse, 2006).

Additionally, the study showed a decrease in the concentration of evaluated nutrients over the course of the treatment (Table 1). The nitrates had an initial concentration of 4,75 mg/L, which was reduced to <0.7 mg/L, equivalent to approximate removal percentages of 97%. The phosphates and sulfates displayed similar behavior, with removals of 99% and 92% respectively.

CONCLUSIONS

Como perspective further research is needed as a perspective to evaluate the biotechnological potential of this biomass, which has a high load of heavy metals and other highly polluting substances, as well as evaluating the response of other microalgal species, in order to determine whether our results can be generalized or o specific for bioremediation processes of waste water from tanneries.

AUTHOR CONTRIBUTION.

Alexander Perez Cordero: experiment execution, data analysis. Donicer Montes V and Yelitza Aguas M, conceptualization, writing - revision and editing. All authors have read and approved the manuscript.

CONFLICT OF INTEREST.

All the authors of the manuscript declare that they have no conflict of interest.

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