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Notes

Filter based on sugar cane bagset for the treatment of wastewater from car washers in the city of Ambato, Ecuador

Filtro con elementos de bagazo de caña de azúcar para el tratamiento de aguas residuales de lavadoras de autos en la ciudad de Ambato, Ecuador

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Abstract

The effects of the oil industry continue to cause damage today. For example, car washers and their components still pollute sewage. This work assesses the efficiency of an artisan filter made of sugarcane bagasse, sand, crushed brick, and pumice stone. The research was carried out in the Chemistry Laboratory of the Faculty of Civil and Mechanical Engineering of the Technical University of Ambato, Ecuador, and as effluent, wastewater from a small car washing machine was used. To prove the efficiency of the filter and its limitations, the variation index in different parameters of this water was measured for 31 days, such as total solids, total suspended solids, BOD5 (biological oxygen demand), COD (chemical oxygen demand), pH, oils and fats, turbidity and TPH (total petroleum hydrocarbons). The preliminary results showed a significant improvement in the treated effluent's quality, especially in turbidity, TPH, total suspended solids, and pH.

Keywords: Efficiency, organic bagasse filter, water treatment, turbidity.

Resumen

Los efectos de la industria petrolera siguen causando daños hoy día. Por ejemplo, las lavadoras de autos y sus componentes generan aún contaminación a las aguas servidas. En este trabajo, entonces, se analiza la eficiencia de un filtro artesanal hecho de bagazo de caña de azúcar, arena, ladrillo triturado y piedra pómez. El estudio se realizó en el Laboratorio de Química de la Facultad de Ingeniería Civil y Mecánica de la Universidad Técnica de Ambato, Ecuador, y como efluente se utilizó el agua residual proveniente de una lavadora de autos ligeros. Para comprobar la eficacia del filtro y sus limitaciones, se midió durante 30 días el índice de variación en diferentes parámetros del agua residual como: sólidos totales, sólidos suspendidos totales, DBO_5 (demanda biológica de oxígeno), DQO (demanda química de oxígeno), pH, aceites y grasas, turbiedad, y TPH (hidrocarburos totales de petróleo). Los resultados preliminares arrojaron una significativa mejora en la calidad del efluente tratado, especialmente en la turbiedad, TPH, sólidos totales suspendidos y pH.

Palabras clave: eficiencia, filtro orgánico de bagazo, tratamiento de agua, turbiedad.

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Introduction

The advancement of the automobile industry has given way to the increase in the number of vehicles that circulate daily in cities around the world; this growth is not only a matter of an increased number of vehicles but also of the toxic and hazardous substances emitted into the environment (Caldera, Rodríguez, Oñate, Prato, & Gutiérrez, 2011; Radin-Mohamed, Nadira-Kutty, & Amir-Kassim, 2014). Because of this demand for cars, small industries dedicated to car washing are on the rise; this activity generates water pollution emitting a wide range of pollutants, especially oils and fats, detergents, and other hydrocarbons (Caldera *et al*., 2011; Loos *et al*., 2013; Aly, 2015).

There is a wealth of documented research and proposals for treating car wash wastewater in various countries (Daneshyar & Ghaedi, 2015; Malakootian, Toolabi, Derakhshan, & Taghi, 2016). In this sense, chemical coagulation, microfiltration, flocculation and coagulation, electrocoagulation, and ion exchange membranes are widely used (Daneshyar & Ghaedi, 2015; El-Ashtoukhy, Amin, & Fouad, 2015). Today, even the nanotechnology industry has contributed to the decrease of pollutants in water (Berekaa, 2016; Qu, Alvarez, & Li, 2013).

The concern has been mainly about water supply in Ecuador, but not always water quality. The high levels of contamination in several areas of the country are well known, especially the level of concentration found in the effluents discharged directly into the public sewage system (Guamán, 2014; Guamán, Guamán, & Álvarez, 2016). Today there are some projects to improve the physicochemical and microbiological quality of water in cities such as Cuenca, Ambato, Otavalo, etc., although they are still insufficient (Veintimilla, 2014; León & Lucero, 2008).

It is, therefore, necessary to promote new techniques that take advantage of materials whose properties have not been fully exploited, especially those that are cheaper and easier to acquire. Therefore, the main objective of this work is to study and analyze the efficiency of a handmade filter or biofilter in reducing effluent pollutants made from pumice, sugarcane bagasse, sand, and crushed brick.

As a background of the materials used, the study carried out by Armada, Barquinero, and Capote (2008), is taken as a reference, in which sugarcane bagasse is used as an absorbent material in oil spills. In this research, with the same principle mentioned, the study of bagasse and other materials is expanded to analyze its efficiency as a filter for the effluent of a car washing machine.

Methodology

Materials

Figure 1 (A and B) shows the design and construction of the filter used in this work. It consists of a metal structure placed vertically divided into equidistant sections of equal size, which hold plastic containers with a capacity of 30 l. These containers have 7.54 mm diameter holes at their base and are covered by an organza membrane; each one stores gravel with a diameter between 19-25 mm that acts as a porous filter bed. This arrangement allows separation into mobile layers to facilitate the visualization of the physicochemical changes that occur in the effluent as it descends at each level. The experiment was developed in the Chemistry Laboratory of the Faculty of Civil and Mechanical Engineering of the

Technical University of Ambato (FICM-UTA) to maintain the integrity of the filter and facilitate the conservation of the elements. Figure 1B shows the design and its dimensions. The system consists of a series of filters. The wastewater is initially discharged from the upper compartment and continuously descends into the lower chambers in contact with the materials in Figure 2. The treated liquid is collected in the final base.

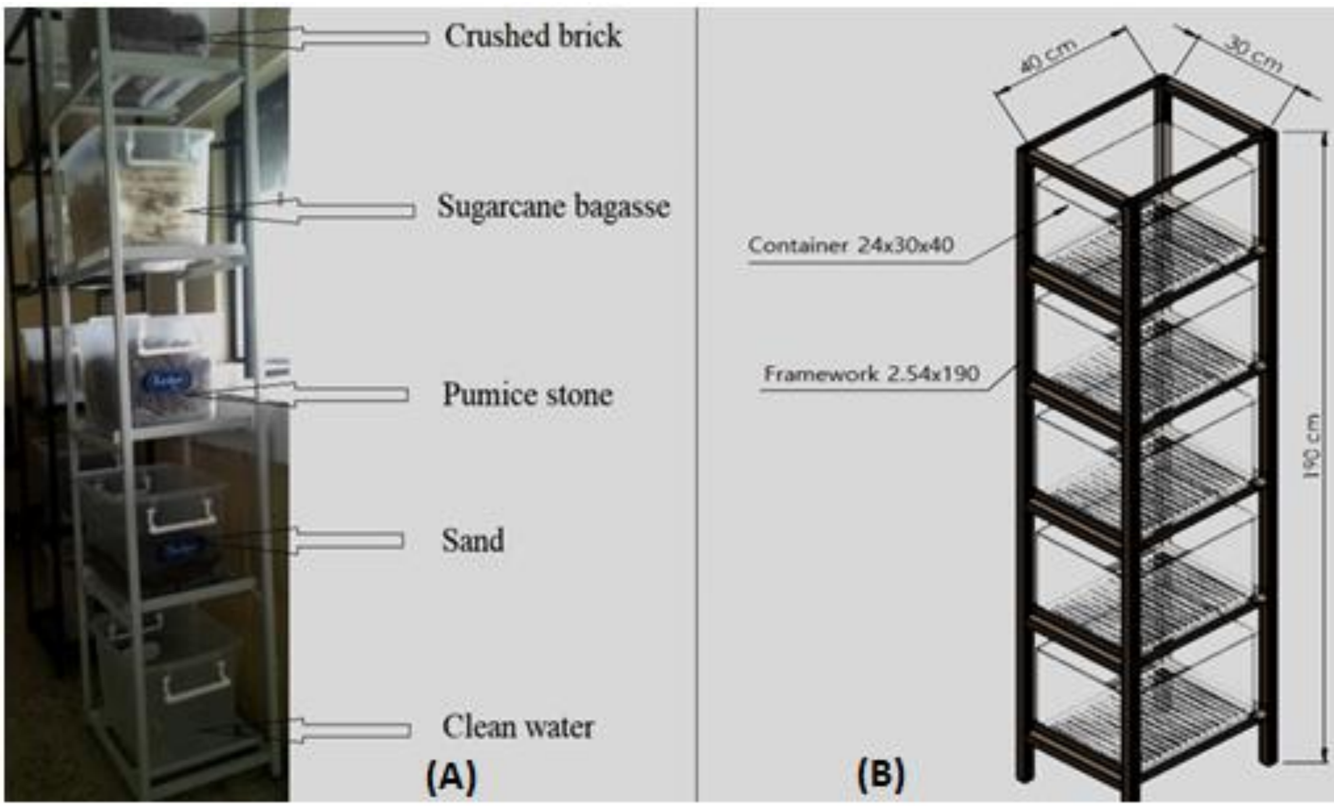

Figure 1. Vertical metallic structure where the filtering elements are grouped: A) the material for the wastewater treatment is placed on each level; B) the design with its dimensions is observed.

Figure 2. Organic materials used to make the filter: Sugarcane bagasse (upper left), pumice stone (upper right), sand (lower left) and crushed brick (lower right).

Method

The wastewater was collected through a simple and random sampling in three car washers in the city of Ambato, for two weeks, with the objective of achieving a synthesized sample. These samples were stored in five 30 l plastic jars that were transferred to the FICM-UTA laboratory and refrigerated at 4 °C for its conservation. Next, its physicochemical parameters were measured, before and after each filtration process. These measurements were repeated seven times over 31 days. Figure 3 gives us a representation of each experiment, where an initial volume of 20 l of water, 10 l of filter material in each vessel, 15 l/min of estimated feed flow and the remaining 10 l of crude liquid were used to measure their initial concentrations.

Figure 3. Filtration process. The wastewater is initially discharged from the upper compartment and flows down in contact with the materials into the lower chambers, where the treated liquid is collected at the bottom.

The study of the materials, in Figure 2, as potential effluent pollution reducing agents, establishes in this research, an experimental design of the pure type. In this first phase there is an interest in determining whether the quality of the liquid changes substantially or not, through the monitoring of its parameters. Therefore, let the null hypothesis be:

H_0*: The quality of the effluent remains almost unchanged.*

and the alternative hypothesis:

H_1*: The quality of the effluent is significantly modified.*

If H_1 is accepted (and H_0 rejected) in a second phase, it would then be determined how the effluent quality varies if it increases or decreases. For this research job, *efficiency*, a variable that is dependent on the concentration of the control parameters, measures: total solids (ST), total suspended solids (SS), biological oxygen demand (BOD_5), chemical oxygen demand (COD), oils and fats (OF), turbidity (T), total petroleum hydrocarbons (TPH) and pH.

Theoretical aspects

The materials of which the filter is composed were selected based on information provided in previous research on their characteristics, such as sugarcane bagasse, which was tested as an absorbent material in oil spills (Armada *et al*., 2008). Brick is an element composed of 100 % clay which has been studied as a filter for wastewater with pesticides (Celis, 2014). Sand is a material used in slow filters as a filter material (González, Martín, & Figueroa, 2018).

Table 1 shows the parameters that were considered, considering the origin of the effluent, to perform the physicochemical analysis of the effluent. Likewise, the limit values allowed for discharge to the public sewer are shown, in accordance with the Unified Text of Secondary Environmental Legislation TULSMA.

Table 1. Discharge limits to the public sewer system, extracted from Caldera *et al*. (2011).

Parameters	**Symbol**	**Unit**	**Limit**
Turbidity	T	NTU	-
Biochemical Oxygen Demand (at 5th day)	BOD_5	mg/l	250
Chemical Oxygen Demand	COD	mg/l	500
Total Suspended Solids	TSS	mg/l	220
Total solids	TS	mg/l	1 600
Hydrogen potential	pH	-	6-9

Oils and Fats	OF	mg/l	70
Total Petroleum Hydrocarbons	TPH	mg/l	20

The main objective of primary treatment is the reduction of suspended solids (SS) in the wastewater, separating or removing approximately 40 to 60 % of solids in water. The objective of secondary treatment is the transformation or stabilization of organic matter, i.e., the variation of BOD_5 and COD values, and the elimination of non-sedimentable colloidal solids. With the application of a tertiary treatment, better BOD_5 removal efficiencies between 95-98 % and SS 95-96 % are obtained (Jaume, 2013; Falcon, 1974). Depending on the results obtained, it will be possible to discuss for which type of treatment this filter would be most effective.

Efficiency calculation

To assess the efficiency of the filter, the following terms must be specified: *individual efficiency* and *overall efficiency*. *Individual efficiency* is a concentration-dependent variable for each parameter. *Overall efficiency*

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symbolizes how the overall pollutant load in the effluent decreases; it is a function of all the individual efficiencies. Figure 4 represents, briefly, a qualitative form of what this variable symbolizes; its quantitative value would be given by some mathematical expression as a function of *individual efficiencies*. However, in this work we will focus on the analysis of the individual efficiencies; an indicator that provides exactly which parameters decrease their pollutant load and which do not, due to the presence of the filtering materials.

Figure 4. The sequence of wastewater treatment (A → B → C) as it is treated. A gradual decrease in turbidity and suspended solids in the water is evident.

To calculate the *individual filter* efficiency in relation to the concentration of each monitored parameter, except for pH, equation (1) was applied:

$$E_n(C_0, C_n, t) = \left[\frac{C_0 - C_n(t)}{C_0}\right] \cdot 100\ \% \qquad (1)$$

Where C_0 is initial concentration of the nth parameter in the wastewater, and $C_n(t)$ is concentration at time t of the nth parameter in the treated water.

In this equation, 100 % efficiency is achieved if the filter completely removes the concentration of that contaminant. Equation (2) was applied to calculate the pH efficiency; it has the same logic as (1), with the ideal outcome of stabilizing the pH to its neutral value. *Efficiency* is an intensive and dimensionless variable, so it offers advantages when comparing different magnitudes with different units.

$$E_{pH}(pH, t) = \langle 1 - \frac{|pH(t) - 7|}{7} \rangle \cdot 100\ \% \qquad (2)$$

Where $pH(t)$ is the pH value of the treated water on day t.

Results and discussion

Figure 5, Figure 6, Figure 7, and Figure 8 show the concentration graphs of the affluent, for four of the parameters, during the month of monitoring. Measurements were taken over seven evenly spaced days. A significant decrease is observed in Turbidity and suspended solids in water. This is evident in Figure 4.

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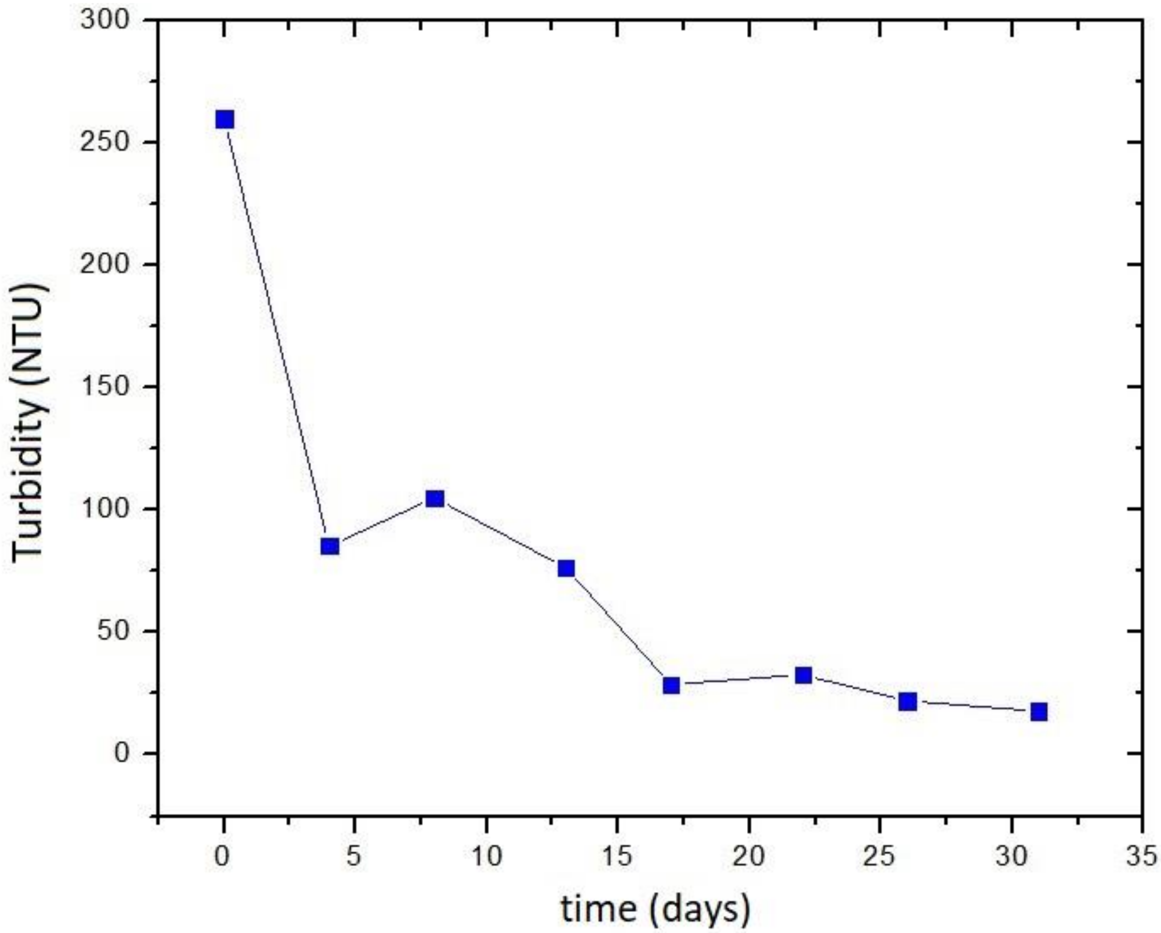

Figure 5. *Turbidity vs. time*. Turbidity decreases considerably, this parameter does not present a limit value in the TULSMA standard.

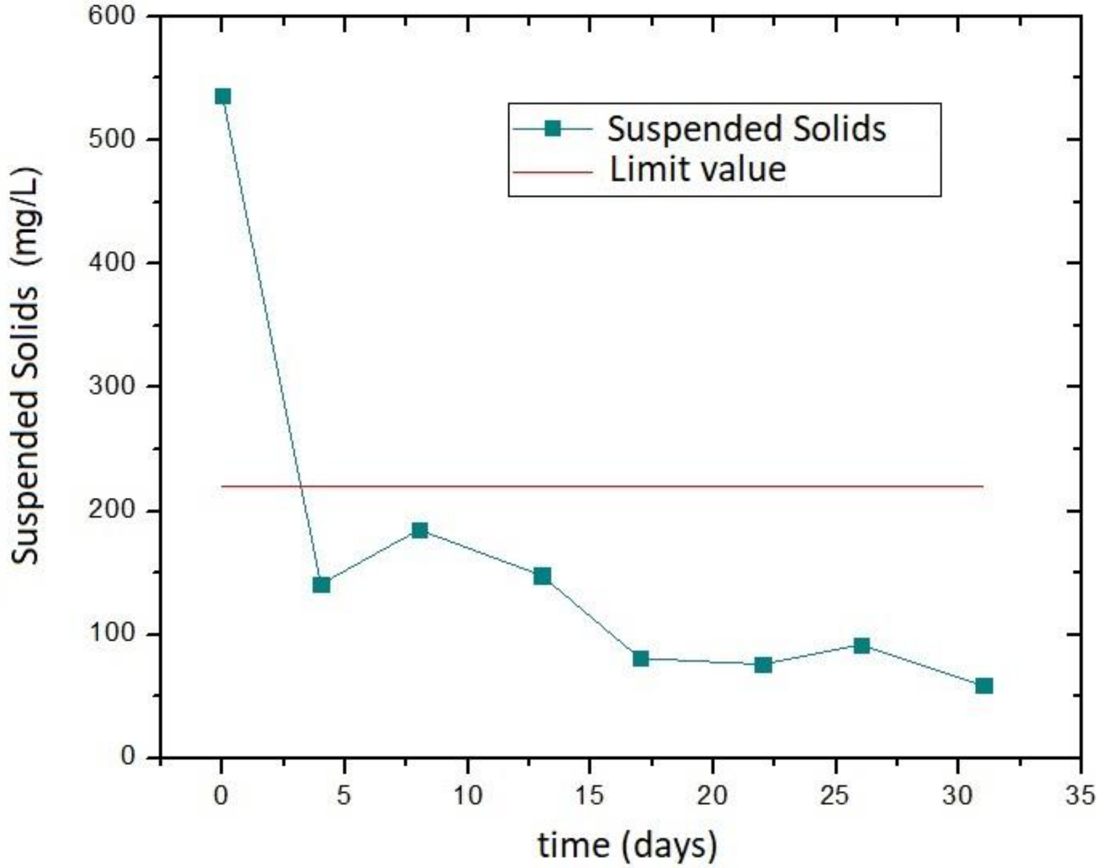

Figure 6. *Suspended solids vs. time*. A notable decrease in the concentration of SS is observed, below the limit value, according to Table 1.

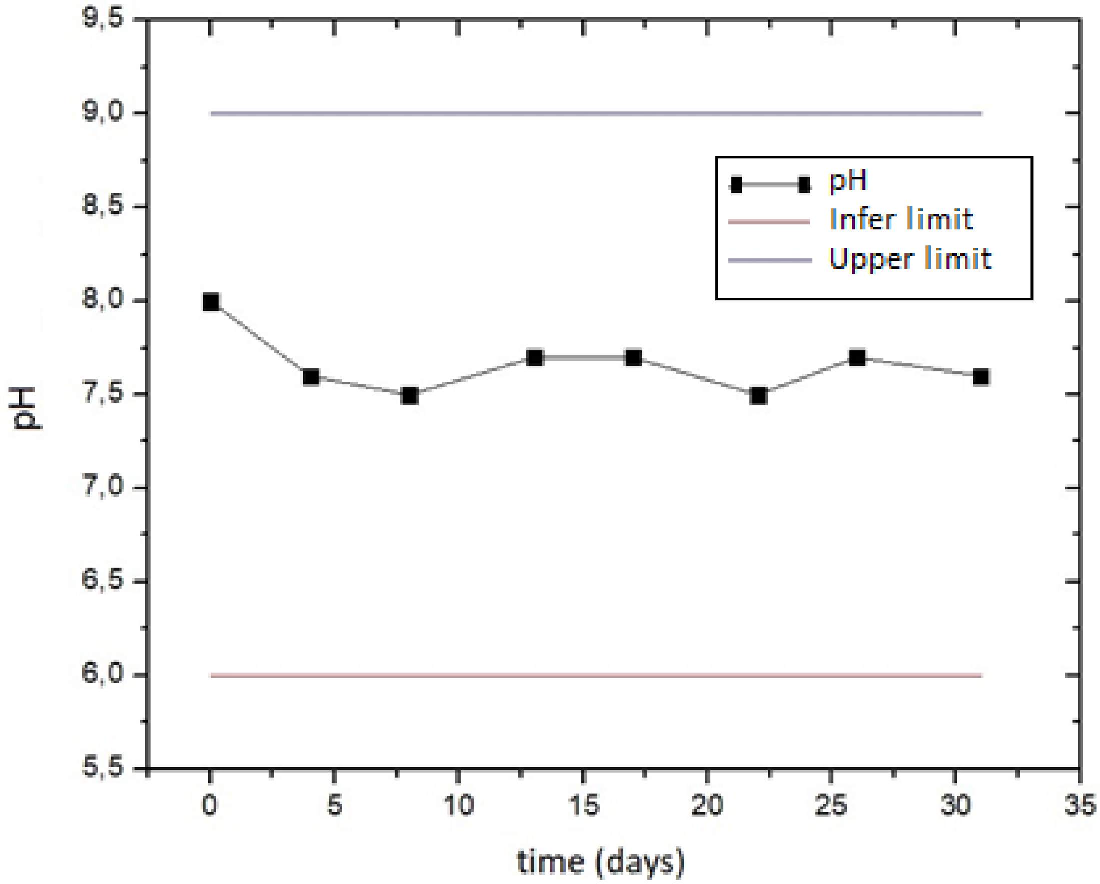

Figure 7. Variation of pH *vs*. time. Filter properly contributes to stabilize the pH in wastewater, between 6 and 9.

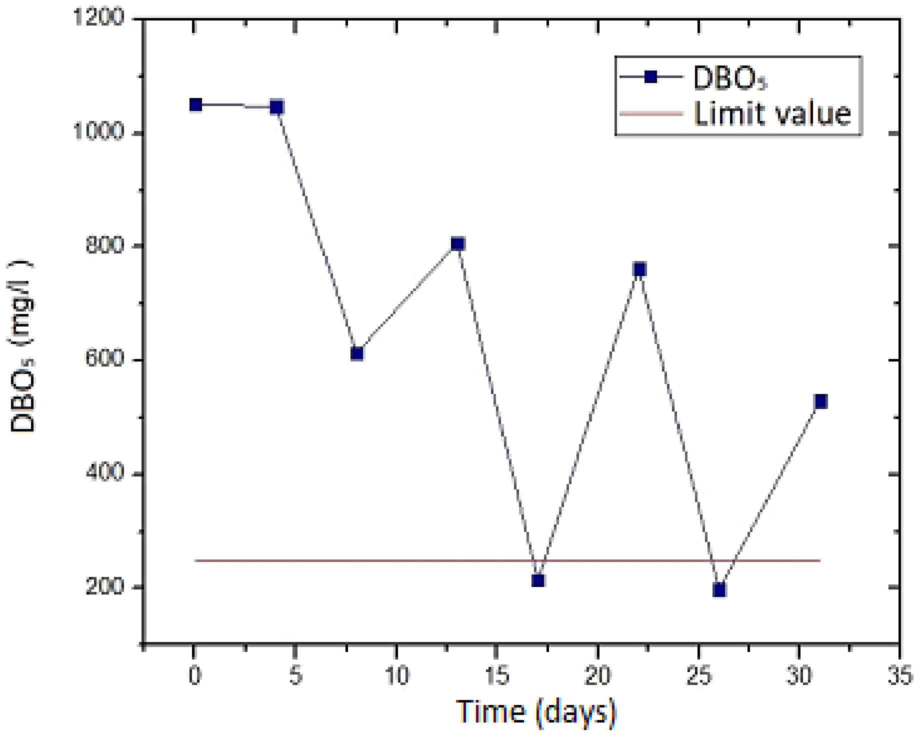

Figure 8. *BOD$_5$ vs. time*. Although the values show an oscillating behavior as the experiment was repeated, a downward trend is perceived.

Figure 7 shows the amounts of pH, well stabilized, according to the allowed limits, per Table 1. BOD$_5$, on the other hand, does not diminish as required by the standard, as can be seen in Figure 8; however, in all cases it decreases with respect to its initial concentration. Table 2 gives the concentration values present in the remaining four parameters examined in this study, ST, COD, AG and TPH; these could only be tested twice during the cycle. The average between the measurements in the second and fourth weeks can be seen in column 3, which in general were very similar in all cases. The negative efficiency at the last place indicates, that the concentration of Total Solids increased in the water after being treated; although it did not exceed the limit, according to the TULSMA standard.

Table 2. Concentrations of ST, COD, AG and TPH in wastewater, measured at the beginning (untreated) and, after the second and fourth weeks of treatment. From the latter, the average value was taken.

Parameter (mg/L)	Initial concentration	Final concentration	Efficiency (%)
TPH	228	2.8	98.7
OF	3.1	0.9	71
COD	2147	1044	51.4
TS	1049	1186	**-13***

*The increase in TS concentration, after treatment, caused a negative value in efficiency.

It was detected that the slight increase in the concentration of Total Solids would have been caused by the action of the sugarcane bagasse. This material had the shortest shelf life compared to the rest; it decomposed in about 10 days. Therefore, it is recommended to replace it in no more than one week, as well as to reduce the diameter of the sieve. Although it is possible to conclude that this decomposition also affected BOD_5, this material is essential for the removal of OF and TPH, present in car wash effluent (Armada *et al*., 2008). The rest of the materials on the 31st day of work were in perfect condition, as can be seen in Figure 9. It is important to emphasize that the order of the filter materials, as shown in Figure 1A, was chosen based on the retention times in each of them, in decreasing order. The times were not very different from each other, although this criterion was considered during the pre-test measurements made in the experimental design; from 1min:30sec, the first one, to 45sec the last one. Thus, in each run or post-test, from the upper compartment to the lower compartment the water did not take more than 5min to descend completely. The experiments have clearly shown a visible change in the concentration of several parameters after the wastewater was treated. These results are shown in graphs 5 to 8, together with Table 2; therefore, the null hypothesis H_0 is rejected and the alternative hypothesis H_1 is accepted.

Figure 9 and Table 2 also show the importance of a variable such as *individual efficiency*; since it is an intensive and dimensionless variable, it allows easy comparison of the behavior of different physicochemical quantities with different units. Most of these values were positive, which means that there was always removal of contaminants present in the liquid, so the overall efficiency of the filter can be classified as high.

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Therefore, by accepting H1, we conclude that not only is the effluent quality modified, but we can also state that it is improved.

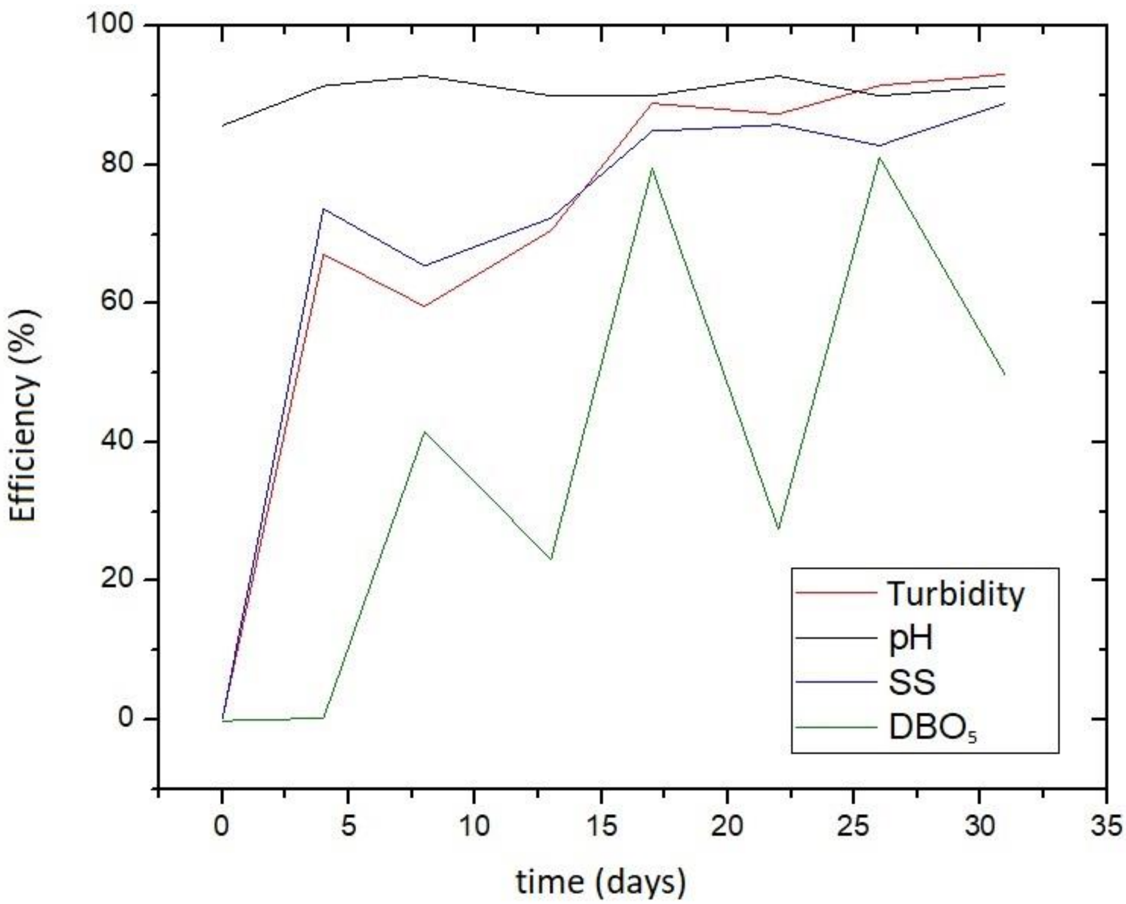

Figure 9. *Efficiency vs. time*, corresponding to the measured parameters: T, pH, SS and BOD_5.

Figure 9 reveals the filter efficiency in relation to T, pH, SS and BOD_5. The high values, especially in pH, T and SS, are remarkable. After one month, the materials perform very well – except for bagasse, as explained. Therefore, considering Table 2, where TPH and OF are highly controlled, it can be indicated that the filter is suitable for Primary Wastewater Treatments. Although the concentration of COD and BOD_5 does not decrease as much as desired, the percentage of removal of these parameters is within the reduction standards for primary wastewater treatment (Jaume, 2013).

Conclusions

A filter for wastewater treatment was designed and constructed based on relatively easy to obtain handmade materials, when compared to other research works (Daneshyar & Ghaedi, 2015; El-Ashtoukhy *et al*., 2015). At the same time, it is important to highlight the long lifetime that they have, this would reduce the cost of maintenance for replacement. Except for sugarcane bagasse, three more months of efficient use was estimated.

The high degree of efficiency of the filter in the removal of several parameters such as Turbidity, Total Suspended Solids and Total

Petroleum Hydrocarbons was verified. The pH levels in wastewater stabilized satisfactorily as shown in Figure 7.

The levels of BOD_5 and COD in water did not decrease effectively, although the percentage of removal experienced by both (about 50 %), is within the standards of reduction that a primary wastewater treatment claims.

This filter, designed and built with these materials, is recommended to be used in primary wastewater treatment; although it has been proven that the pollutant load has been reduced in several parameters, in some it did not comply with the limit established in the TULSMA standard for discharge into the public sewage system.

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