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Removal of Color and Turbidity in Runoff Water using Coconut (*Cocos Nucifera*) Endocarp Activated Carbon

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The aim of this research was to determine the efficiency of activated carbon obtained from coconut (*Cocos nucifera*) endocarp in the reduction of color in runoff water to improve its quality. For this purpose, activated carbon was produced at a carbonization temperature of 700 °C in a time of 30 minutes and phosphoric acid at a concentration of 85% was used as an activating agent. A completely randomized design was used, consisting of 3 treatments (100, 50 and 25 g of activated carbon) and a control (without treatment), with three replicates of each treatment, where 1 L of water from the uptake was filtered. It was determined that the best percentage removal was obtained with treatment 3 (T3) in the reduction of color and turbidity with average values of 97.56% and 97.11%, respectively. An activated carbon filter was installed in the San Lorenzo - Moyobamba sector in a similar way to the laboratory tests, in which the efficiency of this product in reducing the color and turbidity of the water was demonstrated, achieving values suitable for human consumption.

1. Introduction

Global population growth has increased the demand for water, with approximately 80 percent of Latin America's population concentrated in urban areas. This, together with the effect of climate change and the resulting domestic, industrial, agricultural, livestock, mining and other activities on water sources that were once safe and are no longer so, has made water an increasingly scarce resource, making it a valuable resource that must be preserved in order to maintain a permanent supply. Consequently, pressure on water resources and water management in cities represent major challenges (Cabezas, 2018; Aguilar Barajas et al., 2018).
Water quality is the set of chemical, physical and biological characteristics of water that make it suitable for different uses. In this sense, water quality is an essential ecological value for health and economic growth, considering that physico-chemical treatment is becoming increasingly costly for drinking water companies (Herrera et al., 2018; Villena, 2018). For this reason, water intended for human consumption must meet quality requirements, which are increasingly difficult to achieve due to the presence of substances of very different origin in the receiving streams, the cleaner the source water or raw water is, the cheaper the treated water will be and the healthier it will be to drink (Pauta et al., 2019).
Increasing access to safe drinking water has been monitored over the last few years in order to achieve the so-called "Millennium Development Goals", the deadline for which was 2015. Looking ahead, the so-called "Sustainable Development Goals", which have been proposed for the year 2030, aim to ensure access to safe water for the entire world's population (Rodriguez et al., 2017).
Water color is an important parameter in the assessment of water quality (Chen et al., 2021; Zobkov and Zobkova, 2020). Color, as one of the organoleptic properties of water, is affected by the presence of dissolved, suspended or colloidal material, which may be ions, organic matter or industrial waste (Osorio and Martínez, 2018; Herrera et al., 2018).

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Along with color, the presence of suspended solids alters the physico-chemical properties of water and can affect its color and taste, in some cases leading to microbiological contamination (Rosero and Suárez, 2019). Therefore, the coagulation process is the most important process in conventional water treatment. Their application includes the removal of suspended species through the addition of chemical coagulants, the use of which has disadvantages associated with high acquisition costs, production of large volumes of sludge and the fact that they affect the pH of the treated water (Guzmán et al., 2013).
Several coagulants/flocculants have been studied in order to remove color and turbidity of raw water, having the natural ones demonstrated advantages in relation to chemicals (Madrona et al., 2017). Among the commonly used adsorbent materials is commercial activated carbon, which, although it is very efficient in the adsorption process due to its high surface area, good pore volume and different surface active functional groups, has a high production cost, so it has been decided to look for alternative adsorbents that have a better cost-effectiveness ratio such as agricultural waste, the use of which is environmentally friendly, as well as being a low-cost alternative because it uses biomass (Ramírez et al., 2017; Shukla et al., 2020; Shamsuddin, Yusoff and Sulaiman, 2016). Activated carbons are of great interest due to their exceptional physical and chemical properties. They are presented in granular or powder form and are a material used industrially in gas adsorption, filtration, liquid cleaning and as a support for catalysts in non-oxidizing media (García, Múzquiz and Ríos, 2019; Colpas, Tarón and González, 2017).
The objective of the research was to determine the efficiency of activated carbon obtained from coconut (*Cocos nucifera*) endocarp in the removal of color and turbidity from runoff water in the San Lorenzo - Moyobamba sector, in order to improve its quality.

2. Materials and methods

The study was carried out in the following stages: collection of coconut endocarp, moisture removal, grinding of the raw material, sieving, impregnation with the activating agent phosphoric acid in a 1:1 ratio for 24 hours. Carbonization-activation in the muffle, under anaerobic conditions, the calcination temperature was 700 ºC for a time of 30 minutes, followed by grinding, washing, neutralization with NaOH 1M and drying. With the substance obtained, adsorption was carried out by varying the mass of activated carbon.
In the design of filters for laboratory tests, the research of Suárez (2014) was considered as a basis for the determination of the dimensions of the filters, and it was determined the filtration area (cm^2), filter diameter (cm), height of the activated carbon bed (cm), filter height (cm).

2.1 Materials

The equipment and reagents used in the research are: turbidimeter Turbiquant 1100 IR, Magnetic Hotplate Stirrer equipment (Model 984 VW7CHSEUA), colorimeter DR 1900, muffle furnace Thermolyne 1400, Cooker Memmert UF75, analytical balance PGW 753i, pH meter pHC 101.

2.2 Reagents

Activation of coconut (*Cocos nucifera*) endocarp activated carbon was carried out with 85% phosphoric acid (H_3PO_4).

2.3 Percentage Removal of turbidity and color

The percentage of turbidity and color removal was calculated as follows:

$$Removal\ percentage(\%) = \frac{V_i - V_f}{V_f}$$

Where V_i: initial value and V_f: final value (these values could be turbidity or color).

Initial values of turbidity and color were taken from Table 2, and each removal percentage was and average of three experiments for each treatment.

2.4 Statistical analysis

The experimental design used was completely randomized, which consisted of 3 treatments of 25 g, 50 g and 100 g and a control, with 3 repetitions. Each treatment was coded as T1, T2 and T3 respectively. The treatments for each case were determined by the parameters: turbidity and color. Therefore, the analysis of variance was used with a significance level of 5%, it was determined whether variations in activated carbon weight significantly influenced in the adsorption of the color and turbidity. Subsequently, the average removal percentage was calculated for each parameter considered in the study.

3. Results and discussion

3.1 Obtaining activated carbon from coconut endocarp

After treating 34 samples of coconut endocarp of 38 g each, an average of 18.74 g of dry activated carbon is obtained as can be seen in Figure 1. For this research, 1292 g of coconut endocarp were used and 637 g of dry activated carbon were obtained.

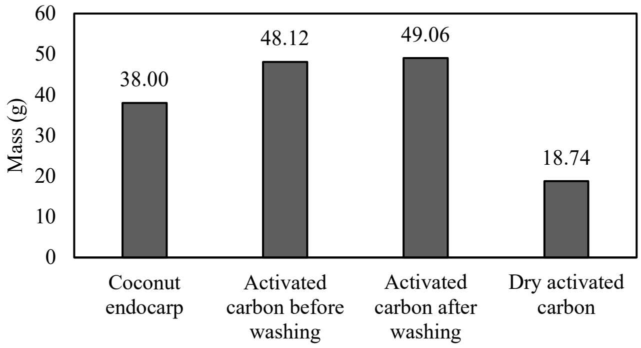

Figure 1: Average weight of activated carbon in the stages of the carbonization process (grams)

3.2 Characteristics of activated carbon obtained from coconut endocarp

Table 1 shows the percentages of yield, moisture and burn off of the activated carbon obtained.

Table 1: Characteristics of activated carbon obtained from coconut endocarp

Characteristic	Percentage %
Obtaining yield	49.30
Humidity	13.30
Burn off	50.68

Activated carbons with a burn rate of less than 50% contain micropores and greater than 75% contain macropores. Between the range of 50% - 75% a mixture of micropores and macropores is formed (Mohd, Peng and Marzuki, 2013).

3.3 Determination of runoff water quality

Table 2 shows the turbidity and initial color of the control sample, observing that they exceed the limit values allowed according to the Peruvian standard.

Table 2: Results of the initial conditions of the color and turbidity parameters of the control sample (runoff water from the San Lorenzo Sector)

Parameter	Unit	Value obtained in laboratory	Maximum allowable limit
Color	PCU	265	15
Turbidity	NTU	51.88	5

As can be seen in Table 2 the water needs treatment to reduce color and turbidity, which are probably due to presence of contaminants such as suspended solids, trace metals, chemical and biochemical compounds (Amosa et al., 2016).

3.4 Evaluation of turbidity and color reduction with activated carbon

Figure 2 reveals that high percentage of turbidity and color removal are obtained with the T3 treatment. The activation of carbons with phosphoric acid, generates a greater development of pores and surfaces with a high content of acidic functional groups. The high specific surface area and pore volume, achieved with acid activation, allows to obtain good adsorbent materials, ideal for water treatment (Hoa et al., 2006). Similar investigations with a contact time of 3 h, achieved a maximum removal of turbidity of 99.59% from 1 g of activated carbon. Likewise, the maximum color reduction with the methylene blue test was 98.99% (Kasimu, 2018).

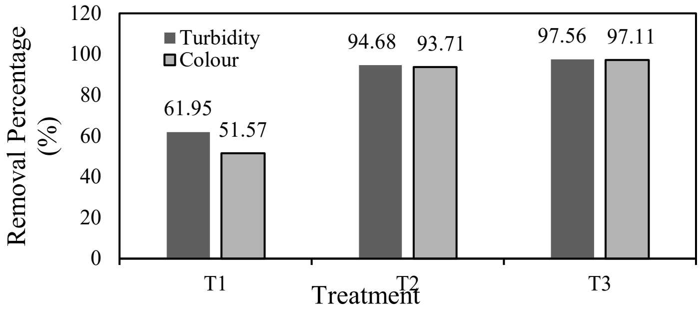

Figure 2: Average removal percentages of turbidity and color for the different treatments

Table 3 show the analysis of variance for the percentages of removal of turbidity and color.

Table 3: Analysis of Variance for Turbidity and Color

Source	% Turbidity removal					% Color removal			
	DF	SC Adjust	MC Adjust	F	p	SC Adjust	MC Adjust.	F	p
Treatment	2	2346.90	1173.50	91.60	0.00	3860.30	1930.20	32.60	0.00
Error	6	76.80	12.80			355.70	59.30		
Total	8	2423.70				4216.0			

DF: Degrees of freedom, SC Adj.: Adjusted sums of squares, MC Adj.: Adjusted mean squares
The p values for both percentages are less than 0.05 and therefore the differences between some of their means are significant.

Tables 4 and 5 show the Tukey analysis for the percentages of removal of turbidity and color.

Table 4: Tukey analysis for turbidity

Adjusted level difference	% Turbidity removal				
	Difference of means	Standard error of	95% confidence interval	T value	p value
T2 - T1	32.73	2.92	(23.76; 41.69)	11.20	0.00
T3 - T1	35.60	2.92	(26.64; 44.57)	12.19	0.00
T3 - T2	2.88	2.92	(-6.09; 11.84)	0.98	0.61

Individual confidence level = 97.80%

Table 5. Tukey analysis for color

Adjusted level difference	%Color removal				
	Difference of means	Standard error of difference	95% confidence interval	T value	p value
T2 - T1	42.14	6.29	(22.84; 61.43)	6.70	0.00
T3 - T1	45.53	6.29	(26.24; 64.83)	7.24	0.00
T3 - T2	3.40	6.29	(-15.90; 22.69)	0.54	0.86

Individual confidence level = 97.80%
Tables 4 and 5 which indicate that there is significance between the differences of the means of the treatments T2 with T1 and T3 with T1. Among the T3-T2 treatments, the difference in their means is not significant, basically because their average percentages are similar. This value simply leads us to deduce that from the T2 treatment, high values of percentage removal of turbidity and color are already obtained.

3.5 Filter application in pilot plant in runoff water from the San Lorenzo de Moyobamba sector

The activated carbon was tested at a pilot level by designing a filter of 430 L/day with a contact time of 7.5 min, 38.9 cm height and 3” diameter whose figures 3 and 4 show the reduction of the turbidity and color to values below the maximum limits according to the Peruvian regulation on the quality of water for human consumption DS N° 31 – 2010 (See Table 2). It is important to note that the activated carbon used for the filter was the same during the six days of testing.

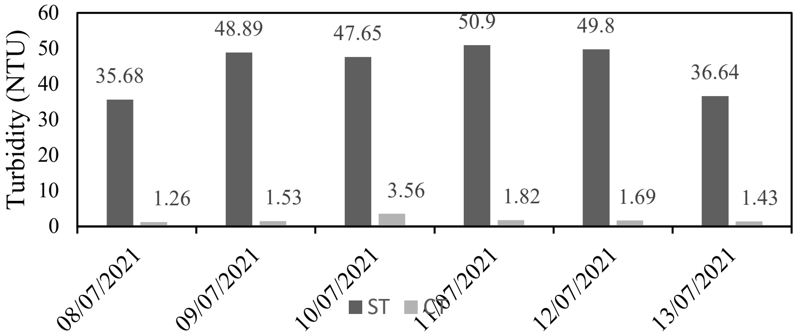

Figure 3: Results of turbidity measurements in the installation of the filter in the pilot plant of the runoff water of the San Lorenzo de Moyobamba sector - NTU (ST: Without treatment, CT: with treatment)

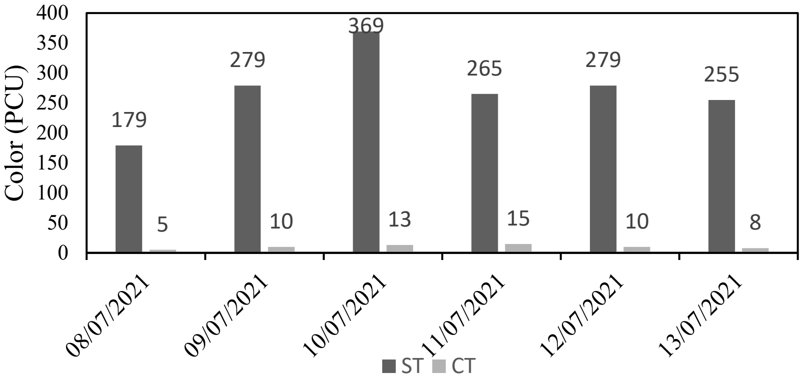

Figure 4: Results of the color measurements in the installation of the filter in the pilot plant of the runoff water of the San Lorenzo de Moyobamba sector - PCU (ST: Without treatment, CT: with treatment)

Activated carbons, demonstrate an adsorption capacity for color and turbidity (Amosa et al., 2016; Telgote et al., 2020). The endocarp has been used to reduce water hardness due to the large number of interchangeable vacant sites generated during activation (Shemeera et al., 2019). Filters has been developed with a coconut shell without carbonizing or activating, where 87.5% turbidity removal and 99.5% color removal were achieved for wastewater from paper mills (Mahajan, 2016). However, carbonization and activation allow treatments with a shorter residence time, such as the one proposed in this research work of 7.5 min.

4. Conclusions

Activated carbon made from coconut endocarp is adequate to remove turbidity and color and could be a viable alternative for the elaboration of filters that serve those people who live in houses near the runoff water of the San Lorenzo Sector of Moyobamba. The average values of maximum turbidity and color removals reached in the laboratory were 97.56% and 97.11%, respectively. In the six days of evaluation of the filters, the removal of turbidity and color allowed reaching values below the maximum permissible limits. It is recommended to evaluate what other contaminants are currently in the water and the removal capacity with the coconut endocarp.

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