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Study of Coffee Husk (*Coffea arabica L.*) Activated Carbon in the Treatment of Aquifer Water: Adsorption of Turbidity, Colour and Metals (Iron-Manganese)

Yrwin F. Azabache Liza[a,*], Fabián Centurión Tapia[a], Ronald F. Rodriguez Espinoza[b], Ronald Julca Urquiza[a], Ricardo R. Layza Castañeda[a], Juan J. Pinedo Canta[a], Luz K. Quintanilla Morales[a], Bany L. Quispe Burga[a]

[a]Universidad Nacional de San Martín, Tarapoto, Perú
[b]Universidad Nacional José Faustino Sánchez Carrión, Huacho, Perú
yfazabache@unsm.edu.pe

The aim of this study was to determine the effect of activated carbon obtained from coffee husk (*Coffea arabica L.*) on the adsorption of turbidity, colour and metals (iron-manganese) present in aquifer waters, in order to contribute to the treatment of confined waters susceptible to contamination, in a natural way due to the geographical conditions of the soil. The variables evaluated were: activated carbon from coffee husk and adsorption of turbidity, colour and metals (iron-manganese). The adsorption capacity of the activated carbon of an agro-industrial waste was determined by applying different concentrations of the substance obtained experimentally on the water of the aquifer to be treated. The data were statistically analysed at two points in time; by means of the analysis of variance it was possible to show that the variations in the weight of the carbon, speed, volume and mixing time did not significantly influence the removal of pollutants; the removal percentage was determined, where the results obtained demonstrated the adsorbent effect of the activated carbon on turbidity, colour and metals (iron-manganese).

1. Introduction

The present of our societies and, even more, our future, depends on the way in which we know how to solve the problems associated with insufficient and untimely water supply, scarcity and unequal distribution of this resource, and the pollution of groundwater and surface water (Villalobos et al, 2017).
In recent years, population growth and industrial processes have created a strong demand for good quality water, unfortunately many surface waters sources have become polluted and groundwater now needs to be exploited (Gramajo, 2004). The extraction of groundwater is a well-known example of the problems associated with common goods, where the absence of exclusivity of use acts as an incentive to achieve a rate of exploitation higher than the socially optimal. The world's natural reserve of groundwater, on which some 2 billion people depend, has declined at an alarming rate, with water levels dropping by about three metres every year in most developed countries and is in constant danger as a result of population growth, agricultural development and human settlement in areas unsuitable for that purpose (Arbito, 2015).
According to Egas et al., (2018), Peru has a competitive advantage in coffee production, since it has different ecological zones and microclimates that are relevant factors for its production. They also point out that Peru is one of the main world exporters of organic coffee and that its attractiveness lies in the fact that it offers economic benefits due to the differentiated prices and the type of cultivation, which is environmentally friendly.
The San Martin region stands out as the region with the greatest agricultural potential in the high jungle with a great variety of products such as rice, hard yellow corn, coffee, cocoa, oil palm, which plays an important role in the agro-industrial activity for its development, and needs special attention to continue boosting its growth (Del Aguila, 2018). The province of Moyobamba is a national coffee producing area and exports to other

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countries; this grain is widely used, leaving the husk for waste and compost, in this respect, Torres Castillo et al. (2021), state that the growth of the coffee market is generating an increase in coffee processing by-products, in the specific coffee husk, where for every tonne of coffee produced, half a tonne of coffee husk is generated; the question therefore arises as to how the chemical characteristics of this waste should be used for water treatment. In this regard, Lahti et al. (2017), state that activated carbons are widely used in different industrial processes, for example as adsorbents or as support materials, and their advantage is that these carbons can be prepared from residual or waste biomass materials.
In this context, the present work was carried out with the aim of determining the effect of activated carbon from coffee husk (*Coffea arabica L.*) in the treatment of aquifer water: removal of colour and metals (iron-manganese).

2. Materials and methods

The study used the analytical method carried out by means of experimentation, where the parameters turbidity, colour and metals (iron-manganese) present in the aquifer water were analysed. The experiment consisted of introducing activated carbon obtained from coffee husks (*Coffea arabica L.*) under the assumption that the percentage of adsorption of the aforementioned parameters is significant.

2.1 Research design

A randomized complete block design was used, the blocks in each case being variations in charcoal weight (1.0, 1.5 and 2.0 g), mixing speeds (100, 200 and 300 rpm), mixing volumes (40, 80 and 160 mL) and mixing times (3, 4 and 6 min). The treatments for each case were determined by the parameters: turbidity, colour and metals (iron-manganese); these parameters were determined using the analytical techniques of the American Public Health Association (2005). Using analysis of variance with a significance level of 5%, it was determined if variations in activated carbon weight, mixing speed, mixing volume and mixing time significantly influenced the adsorption of the substances. Subsequently, the average adsorption percentage was calculated for each parameter considered in the study, which allowed to verify the efficiency of activated carbon.

2.2 Materials

The equipment and reagents used during the research are: Cooker Memmert UF75, Magnetic Hotplate Stirrer equipment (Model 984 VW7CHSEUA), analytical balance PGW 753i, muffle furnace Thermolyne 1400, colourimeter DR 900, turbidimeter Turbiquant 1100 IR, pH meter, phosphoric acid (H_3PO_4) at 85%.

2.3 Procedure

The study was carried out in the following stages: collection of coffee husks (which is a residue obtained from coffee processing), removal of moisture (in a cooker at 85 °C during 72 hours to constant weight), coffee husk grinding, sieving and impregnation with phosphoric acid (activating agent) in a 1:1 ratio, at room temperature for 24 hours.
The carbonisation-activation was carried out in the muffle furnace, under anaerobic conditions. The calcination temperatures were: 500 ºC, 600 ºC, 700 ºC, for a time of 30 minutes; after which grinding was carried out. Washing and neutralisation was carried out with NaOH 1M, as developed by Gimba et al. (2009).
With the substance obtained, adsorption took place for the parameters: turbidity, colour and metals (Iron and Manganese), varying the mass of activated carbon, time, volume and mixing speed.

3. Results and discussion

Table 1 shows the results of the sample analysis; the indicated values show that they contain high amounts of colour, iron and manganese.

Table 1: Parameters of the sample water to be treated with activated carbon

Parameter	Unit	values
Temperature	°C	25.2
Turbidity	NTU	20.01
Colour	PCU	213
Iron	mg/L	1.29
Manganese	mg/L	1.46

Table 2 shows the adsorption percentages of the parameters, showing that the highest percentage was recorded for iron with 97%, applying 2.0 g of activated carbon. This coincides with Paredes (2011), who concludes that the efficiency of the use of charcoal as an adsorbent also depends on solubility and weight. Similarly, Ensuncho, Robles and Carriazo (2015), evaluated adsorption taking into account the initial concentration and the amount of adsorbent, as well as the contact time and pH.

Table 2: Adsorption percentages with variations in activated carbon weight

Parameter	Weights			Average
	1.0 g	1.5 g	2.0 g	
Turbidity	56	86	90	77
Colour	67	95	100	87
Iron	96	97	97	97
Manganese	95	95	96	95

Table 3 shows that the probability value (P) is greater than the alpha value (0.05), therefore, the variation in the weight of the activated carbon does not significantly influence the adsorption of the substances.

Table 3: Analysis of variance for adsorption percentage performing variations in activated carbon weight

Origin of variations	Sum of squares	Degrees of freedom	Mean squares	F	P	F critical
Parameters	713	3	237.67	2.27	0.18	4.76
Weight	695.17	2	347.58	3.31	0.11	5.14
Error	629.5	6	104.92			
Total	2037.67	11				

The results in table 4 show that, when activated carbon is applied at different mixing speeds, adsorption is generated significantly, with very acceptable results being obtained from 100 rpm onwards. With regard to velocity variation (Çeçen and Aktas, 2011), it indicates that the main design parameters of a filtration system are contact time and linear velocity. Bastidas et al (2010), indicate that activated carbon in the reduction of pollutants, has a high probability of being used in drinking or wastewater treatment and can provide good performance in adsorption systems.

Table 4: Analysis of parameters for different variations in mixing speed

Parameter	Unit	Speeds			
		0 rpm	100 rpm	200 rpm	300 rpm
Turbidity	NTU	20.01	1.34	0.98	2.27
Colour	PCU	213	5	4	3
Iron	mg/L	1.29	0.06	0.05	0.06
Manganese	mg/L	1.46	0.063	0.055	0.047

In table 5, it is observed that the highest percentage of adsorption, on average, occurred in the colour parameter with 98%. The sample analysed changed from a yellowish colour (characteristic of the presence of iron and manganese) to a colourless appearance, decreasing in parallel with the other parameters evaluated. Likewise, it was determined that, at 200 rpm of mixing speed, the highest adsorption of the parameters occurs. In the research on activated carbon adsorption tests, Ramírez, Martínez and Fernández (2013) determined the optimum adsorption speed as 220 rpm; and in another research to remove lead, Lavado, Sun and Bendezú (2010), managed to remove up to 99.9%.

Table 5: Percentages of adsorption making variations in mixing speed

Parameter	Speeds			Average
	100 rpm	200 rpm	300 rpm	
Turbidity	73	95	89	86
Colour	98	98	99	98
Iron	95	96	95	95
Manganese	96	96	97	96

Table 6 shows that the variation in the mixing speed has not produced significant changes in the adsorption percentage of the parameters considered, given that the probability value (P) is greater than the alpha value (0.05); furthermore, there are no significant differences between the mixing speeds, that is, when experimenting with 100 rpm, 200 rpm and 300 rpm speed, the adsorption percentage did not change significantly.

Table 6: Analysis of variance for the adsorption percentage by varying the mixing speed

Origin of variations	Sum of squares	Degrees of freedom	Mean squares	F	P	F critical
Parameters	286.25	3	95.42	3.05	0.11	4.76
Speed	73.17	2	36.58	1.17	0.37	5.14
Error	187.50	6	31.25			
Total	546.92	11				

The results in table 7 show that, when applying the activated carbon by varying the volumes of the mixture, adsorption varies in the parameters considered, with the best result being recorded when the mixture is made at 40 mL. Navarro Santos et al (2016), indicate that the best results are obtained with the use of activated carbons with an additional modification, so in the present research the use of activated carbon with phosphoric acid was chosen.

Table 7: Results obtained by making the variations of the mixing volume (200 rpm, 2 min)

Parameter	Unit	Volume			
		0 mL	40 mL	80 mL	160 mL
Turbidity	NTU	20.01	0.98	0.47	0.49
Colour	PCU	213	4	5	5
Iron	mg/L	1.29	0.05	0.05	0.06
Manganese	mg/L	1.46	0.06	0.05	0.06

Table 8 shows the results with increases in the volume of the mixture, where all the treatments show high adsorption percentages. The activated carbon maintains the capacity for all the parameters considered (greater than 96%), keeping the dose of 2 g constant, the stirring speed at 200 rpm and the time at two minutes.

Table 8: Percentages of adsorption by making variations in the volume of the mixture

Parameter	Volume			Average
	40 mL	80 mL	160 mL	
Turbidity	95	98	98	97
Colour	98	98	98	98
Iron	96	96	95	96
Manganese	96	97	96	96

In table 9, it is observed that the probability value (P) is greater than the alpha value (0.05), therefore the variation in the volume of the mixture maintains the adsorption of the substances in all the treatments.

Table 9: Analysis of variance for the adsorption percentage by varying the volume of mixture

Origin of variations	Sum of squares	Degrees of freedom	Mean squares	F	P	F critical
Parameters	8.92	3	2.97	3.34	0.10	4.76
Speed	2	2	1	1.12	0.38	5.14
Error	5.33	6	0.89			
Total	16.25	11				

The results in table 10 show the high adsorption capacity of the activated carbon obtained, by achieving a decrease in the concentrations of all the parameters evaluated, from the 3 minutes to which the process was subjected.

Table 10: Results obtained by varying the mixing time

Parameter	Unit	Times			
		0 min	3 min	4 min	6 min
Turbidity	NTU	20.01	0.8	0.52	2.01
Colour	PCU	213	0	5	5
Iron	mg/L	1.29	0.03	0.05	0.06
Manganese	mg/L	1.46	0.04	0.045	0.05

Table 11 shows the high percentage of adsorption of all the parameters evaluated, in compliance with the various water quality regulations. The minimum numerical percentage of adsorption is 94%, for which a time of 3 minutes is sufficient for adsorption to occur. Terrones (2014), demonstrated the use of charcoal as an adsorbent by obtaining 76.9% efficiency with a contact time of 2 minutes.

Table 11: Percentages of adsorption by varying the mixing time

Parameter	Times			Average
	3 min	4 min	6 min	
Turbidity	96	97	90	94
Colour	100	98	98	99
Iron	98	96	95	96
Manganese	97	97	97	97

Table 12 shows that in both cases the probability value (P) is greater than the alpha value (0.05), so the variation in mixing time is significant in all cases.

Table 12: Analysis of variance for the adsorption percentage by varying the mixing time

Origin of variations	Sum of squares	Degrees of freedom	Mean squares	F	P	F critical
Parameters	28.92	3	9.64	2.92	0.12	4.76
Speed	16.17	2	8.08	2.44	0.17	5.14
Error	19.83	6	3.31			
Total	64.92	11				

Table 13 shows the average adsorption percentages, for turbidity was 89%, for colour was 96%, for iron was 96% and for manganese was 96%. In all cases, a high adsorption efficiency of the evaluated parameters is evident, results that are similar to those obtained by Ensuncho, Robles and Carriazo (2015).

Table 13: Summary of the average percentage of adsorption

Parameter	Weight variation	Mixing speed	Mixing volume	Mixing time	Average percentage
Turbidity	77	86	97	94	89
Colour	87	98	98	99	96
Iron	97	95	96	96	96
Manganese	95	96	96	97	96

4. Conclusions

The stirring speed and the dose of activated carbon from coffee husk (*Coffea Arabica L.*) influence the adsorption processes, evidenced by the levels of colour and metals (iron-manganese) in the aquifer waters.
The best experimental conditions for the use of coffee husks (*Coffea arabica L.*) for colour adsorption were 2 g in 40 mL of solution, contact time of 2 min, speed of 60 rpm; achieving a decrease in colour of 100%, iron of 96.90% and manganese of 95.89%.

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