

Efficiency of a Biofilter Based on Human Hair and *Cariniana decandra* Sawdust for the Treatment of Laundry Water

Franco A. Esquivel Rafaele, Carlos A. Castañeda-Olivera*

Universidad César Vallejo, Campus Los Olivos, Lima, Perú
 caralcaseo@gmail.com

Nowadays, water pollution has become a problem that affects a large part of the population and the environment. The exponential increase of the population has generated that the laundry industries have a high demand, generating large amounts of wastewater. Thus, this research evaluated the efficiency of five biofilters composed of different proportions of human hair and *Cariniana decandra* sawdust in the reduction of physicochemical and microbiological parameters of laundry water. The biofilter components were physicochemically characterized to determine humidity, density, porosity, among others. The results showed that the biofilter composed only of hair at 2 hours of hydraulic retention had a higher treatment efficiency with reduction values of 75% in COD, 77.8% in BOD, 83% in phosphates, 77.3% in total nitrogen, 50% in sulfates, 91.1% in detergents, 68.6% in hardness, 29.4% in turbidity, 71.5% in electrical conductivity, 90% in total coliforms, 95% in thermotolerant coliforms and 91.5% in *Escherichia coli*. Finally, it is concluded that the *Cariniana decandra* hair and sawdust biofilters are friendly and efficient systems for treating laundry water.

1. Introduction

Currently, water pollution has become a major problem affecting much of society and consequently the environment. This is due to the discharge of untreated wastewater into water bodies such as rivers, lakes, lagoons, sea and ocean (Noblet and Schweitzer, 2018). Exponential population growth has led to environmental degradation due to excessive consumption of water resources, generating emissions of higher volumes of effluents (Helm et al., 2021). In sub-Saharan Africa, more than 50% of the population lacks sanitation systems (UNICEF and WHO, 2019), and developing countries such as the United States emit 1.2 billion gallons of industrial wastewater annually (Riverkeeper, 2011). The high demand of the laundry industry has been generating higher volumes of effluents that cause environmental degradation (Mauchauffe et al., 2012). Residential laundry machines emit a total of 41 gallons of water per single use, while commercial laundry machines emit an average of 34.74 thousand gallons of wastewater (US National Park Service, 2021).

Wastewater generated in laundries generally uses surfactants, enzymes and bleaching agents that remove stains and dirt (Hickey 2011). Laundry wastewater causes impacts on the environment due to the diversity of products (soap, detergents, carbonates, salts, and soda) used in the washing process (Patel et al. 2017). These waters go directly to sewage systems and end up in bodies of water, generally rivers, which are used as a source of irrigation for agricultural areas and recreational areas, thus generating problems for human health (Valenzuela and Campuzano, 2018).

In Peru, 68% of wastewater is not treated before being discharged into water bodies, causing environmental degradation and, consequently, the spread of diseases is imminent. In the city of Cusco, Peru, water from laundries is discharged into the Huatanay River, presenting a high load of inorganic compounds, total suspended solids and detergent compounds (Vega and Regaño, 2020). Faced with this problem, many researches have been experimenting with the use of biofilters as systems for the removal of pollutants in water, which is generally composed of organic and inorganic material. These biofilters are systems that mimic wetlands by purifying water naturally (Yocum, 2014). Therefore, the present research aimed to evaluate the efficiency of biofilters composed of human hair and sawdust of *Cariniana decandra* for the treatment of laundry water.

2. Materials and methods

2.1 Obtaining and processing of human hair and sawdust from *Cariniana decandra*

Human hair (10 kg) was obtained from hairdressers located in the city of Cusco in Peru. The hair was washed with distilled water to remove impurities and any particulate matter present. Subsequently, the human hair was dried outdoors for 2 days to eliminate moisture. On the other hand, *Cariniana decandra* sawdust (10 kg) was obtained from a timber mill located in the district of San Jerónimo in Cusco. The total amount of sawdust was sieved to eliminate dust and obtain a particle size of 3 cm.

2.2 Characterization of the filter beds

The filter beds were physicochemically characterized to evaluate porosity, humidity, apparent density, actual density, volume and buoyancy.

2.3 Biofilter design

The biofilter had the shape of a straight circular cylinder, with a diameter of 10.16 cm and a height of 40 cm. The biofiltration system is shown in Figure 1, and the percentage of components (beds) in each biofilter is shown in Table 1.

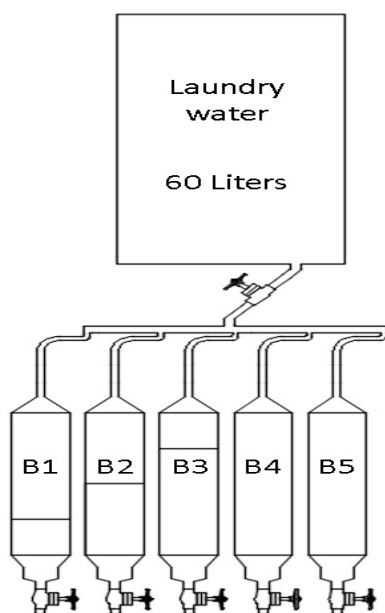


Figure 1: Biofiltration system

Table 1: Dosing of filter beds

	Biofilter	Human hair (%)	Sawdust of <i>Cariniana decandra</i> (%)
Dose	B1	25	75
	B2	50	50
	B3	75	25
	B4	100	-
	B5	-	100

2.4 Laundry water treatment

The treatment was carried out in 5 different biofilters subjected to 2 and 4 hours of hydraulic retention, according to the doses shown in Table 1. Samples were analyzed both before and after treatment, evaluating physical, chemical and microbiological parameters. The removal efficiency of each parameter studied was determined using equation 1.

$$\%EFI = \frac{(C_i - C_f)}{C_i} \times 100\% \quad (1)$$

Where: % EFI, is the percentage of removal efficiency; C_i , is the initial concentration of the sample; C_f , is the final concentration of the sample.

3. Results and discussion

3.1 Characterization of the filter beds

Table 2 shows the physicochemical characterization of the *Cariniana decandra* sawdust and human hair filter beds.

Table 2: Characterization of the filter beds

Parameter	Porosity (%)	Humidity (%)	Apparent density (g/cm ³)	Actual density (g/cm ³)	Hydraulic holding capacity (%)	
Sawdust of <i>Cariniana decandra</i>	61.4	11	0.22	0.57	35.8	
Parameter	Density (g/cm ³)	Volume (cm ³)	Buoyancy (N)	Humidity (%)	Resistant to dry heat (°C)	Resistant to humid heat (°C)
Human hair	75	1200	3.1314	20	140	220

From Table 2 it can be observed that human hair has a higher density and humidity than *Cariniana decandra* sawdust. The density and humidity values for human hair are 75 g/cm³ and 20%, respectively. Whereas, *Cariniana decandra* sawdust has values of 0.57 g/cm³ and 11% for density and humidity, respectively.

Filter beds allow the elimination of impurities present in the water, and these biofilters depend on the characteristics and properties of interaction with the substance or element to be retained. *Cariniana decandra* Sawdust was used due to its easy acquisition and low costs, and this is mainly composed of cellulose fibers linked with lignin (Quinaloa, 2017). Meanwhile, hair has keratin (α -keratin) as a component, which contains cysteine that has the capacity of alkaline organic solvent, Likewise, hair is a bioadsorbent that presents primary functional groups such as amino, carboxyl, hydroxyl and hydrogen sulfide that allow removing ions from wastewater (Gallegos 2021).

3.2 Laundry water treatment

Table 2 shows the results of analysis of physical, chemical and microbiological parameters in the 5 biofilters subjected to 2 and 4 hours of hydraulic retention. It is observed that biofilter 4, which is composed of hair with 2 hours of hydraulic retention, has the best average efficiency (75%) of the physical, chemical and microbiological parameters compared to the rest of the biofilters used in the treatment. The other biofilters had average efficiencies between 64 and 73%, indicating good reduction efficiency of the studied parameters.

The parameters with the highest percentages of reduction were microbiological parameters (Total coliforms, Thermotolerant coliforms and *Escherichia coli*) and detergents. In other research, Zhang et al. (2020) used a biofilter based on pine sawdust for wastewater treatment, achieving a 23.60% reduction in COD. Similarly, Manouchehri and Kargari (2017) used a cross-flow microfiltration system in the recovery of laundry water, achieving a 90.8% decrease in COD. On the other hand, Pulido (2018) used two biofilters of *Eichhornia crassipes*, *Cyperus papyrus* and *Alocasia macrorrhiza* for domestic wastewater treatment, having in both biofilters BOD reductions 91.23 and 91.55%. Hua et al. (2016) studied a wood chip bioreactor and recycled steel by-product filters for agricultural wastewater treatment. The woodchip bioreactor had an average phosphate removal efficiency of 17.4 - 56%. In the same way, Hu et al. (2021) used a fluidized bed of circulating pellets for the removal of hardness from graywater, achieving 80% removals. Similarly, Raketh et al. (2021) used rubber wood ash for sulfate removal in industrial wastewater, achieving reductions of 42%. On the other hand, Chambi (2018) employed the flocculation, coagulation and adsorption process for the treatment of laundry water using aluminum polychloride and aluminum sulfate, achieving detergent removal of 97.99% and 94.92%, respectively. Lopez (2018) decreased turbidity by 86% using *Opuntia ficus cactus* as a coagulating agent. Similarly, Salazar and Sisalema (2018) employed sawdust as a filtering agent for industrial wastewater treatment, achieving a 60% reduction in electrical conductivity.

Table 1: Removal of physical, chemical and microbiological parameters

Biofilter		B1		B2		B3		B4		B5		
Hydraulic retention time	Hours	2	4	2	4	2	4	2	4	2	4	
Parameters	COD	Ci	400 mg/L									
		Cf	260	260	160	300	180	300	100	290	190	280
		Removal (%)	35	35	60	25	55	25	75	27.5	52.5	30
	BOD	Ci	180 mg/L									
		Cf	110	104	70	110	65	108	40	110	75	120
		Removal (%)	38.9	42.2	61.1	38.9	63.9	40	77.8	38.9	58.3	33.3
	Phosphates	Ci	1.64 mg/L									
		Cf	0.96	1.17	1.13	1.15	1.37	0.73	0.27	0.14	0.63	0.044
		Removal (%)	41.5	28.7	31.1	29.9	16.5	55.5	83.5	91.5	61.6	97.3
	Total nitrogen	Ci	22 mg/L									
		Cf	9	12	8	11	7	10	5	12	8	18
		Removal (%)	59.1	45.5	63.6	50	68.2	54.5	77.3	45.5	63.6	18.2
	Sulfates	Ci	1200 mg/L									
		Cf	310	300	304	360	305	510	600	680	550	570
		Removal (%)	74.2	75	74.7	70	74.6	57.5	50	43.3	54.2	52.5
	Detergents	Ci	494 mg/L									
		Cf	54.6	15.8	46.6	29	54	34	43.8	23.4	23.8	75
		Removal (%)	88.9	96.8	90.6	94.1	89.1	93.1	91.1	95.3	95.2	84.8
	Hardness	Ci	3500 mg/L									
		Cf	850	800	800	920	800	1100	1100	1100	1100	1200
		Removal (%)	75.7	77.1	77.1	73.7	77.1	68.6	68.6	68.6	68.6	65.7
	Turbidity	Ci	545 NTU									
		Cf	150	130	173	269	174	315	385	472	471	346
		Removal (%)	72.5	76.1	68.3	50.6	68.1	42.2	29.4	13.4	13.6	36.5
Electrical conductivity	Ci	8450 μ S/cm										
	Cf	1700	1560	1660	1830	1700	2040	2140	2380	2440	2230	
	Removal (%)	79.9	81.5	80.4	78.3	79.9	75.9	74.7	71.8	71.1	73.6	
Total coliforms	Ci	2400 UFC/100ml										
	Cf	1100	150	460	150	460	460	240	460	210	75	
	Removal (%)	54.2	93.8	80.8	93.8	80.8	80.8	90	80.8	91.3	96.9	
Thermotolerant coliforms	Ci	2400 UFC/100ml										
	Cf	460	150	210	75	210	150	120	150	75	75	
	Removal (%)	80.8	93.8	91.3	96.9	91.3	93.8	95	93.8	96.9	96.9	
<i>Escherichia coli</i>	Ci	1100 UFC/100ml										
	Cf	120	39	28	15	75	93	93	20	75	75	
	Removal (%)	89.1	96.5	97.5	98.6	93.2	91.5	91.5	98.2	93.2	93.2	
Average efficiency	%	65.8	70.2	73	66.7	71.5	64.9	75.3	64	68.3	64.9	

Ci: Initial concentration

Cf: Final concentration

4. Conclusions

Cariniana decandra sawdust and hair biofilters are efficient in the treatment of laundry water. Biofilter 4, which is composed only of hair with 2 hours of hydraulic retention, was the most efficient for the treatment of laundry water, achieving an average efficiency of 75.3% in the physical, chemical and microbiological parameters. After treatment with the biofilters, reductions of 75% in chemical oxygen demand, 77.8% in biological oxygen demand, 83.5% in phosphates, 77.3% in total nitrogen, 50% in sulfates, 91.1% in detergents, 68.6% in hardness, 29.4% in turbidity, 74.7% in electrical conductivity, 90% in total coliforms, 95% in thermotolerant coliforms and 91.5% in *Escherichia*.

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