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Research Article

Microbiological and Physicochemical Characterization of Hospital Effluents before and after Treatment with Two Types of Sawdust

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Physicochemical and microbiological analyses of liquid hospital effluents have demonstrated that they are loaded with organic and inorganic pollutants then discharged into the sewerage networks without treatment. The aim of this study is to suggest an effective solution for their treatment. Column filtration is an adequate method to reduce the pollutant load which makes it possible to have a rate of abatement of 97% and 79% by filtering the pollutant material using sawdust of catia and red sawdust, respectively, with a filter bed height equal to 13 cm. Physicochemical parameters such as chemical oxygen demand, biological oxygen demand, nitrate, ammonia, phosphorus, electrical conductivity and the bacteriological parameters like fecal coliforms, *Streptococci*, and *Staphylococci* have been measured. The analysis of heavy metals displays compliance with the World Health Organization standards. The red sawdust and catia sawdust have been characterized by scanning electron microscopy and Fourier-transform infrared spectroscopy.

1. Introduction

The effluent generated by hospital activities threatens the environment much more than the urban effluents [1, 2]. It constitutes a source of transmission of infections and epidemic diseases [3], which may present a potential danger to humans and their environment. Moreover, given the nature and importance of the toxic substances and contaminants these effluents contain such as drug residues, chemical reagents, antiseptics, detergents, developers, and potentially pathogenic microbacteria, viruses, and mushrooms, they are disposed in the same way as conventional urban waste to the municipal sewage network without prior treatment [4–6]. Additionally, from the ecological point of view of such effluents, if they are not treated correctly and thus their quality is reduced to regulatory standards before being rejected, they can degrade the natural environment and create a biological imbalance.

However, taking care of this problem within the health facilities is important for monitoring their traceability until they are eliminated [7]. This problem must be placed in a holistic perspective of risk substance management, which is one of the major current health and environmental concerns, from generation to ultimate treatment. In this context, a number of studies on hospital effluents investigated their physicochemical and bacteriological characterizations [8–12] and studied their ecotoxicity [13, 14] and the rate of drug rejections [15, 16] and also their treatments [17, 20].

The current research focuses mainly on lower-cost treatment processes including the quality of these effluents before rejecting them. Physicochemical and biological treatments are among the most widely used methods [21]. Thus, they have been the subject of several research projects [22–24].

There are many treatment processes that can be used for the removal of pollutants from polluted wastewater including coagulation-flocculation, adsorption, oxidation, and column filtration [25–27]. Among these processing methods, filtration remains one of the most promising techniques because of its convenience and ease of use. Certainly cost is an important parameter for the application of this process; thus, in recent years, many researchers are increasingly interested in the use of natural adsorbents that will be both effective and low cost, including clay, activated carbon, oil shale, sand, pyrophyllite, and silica [28, 29]. The present work aims to study a practical and economical method of removing organic matter from hospital effluents by column filtration with sawdust obtained from different wood precursors, red sawdust (RS) and catia sawdust (CS) used as new natural adsorbents.

2. Materials and Methods

2.1. Study Site. The samples have been taken at the intensive care unit of Hassan II Hospital in Fez, Morocco.

2.2. Used Filtering Materials. The two types of wood used come from a company located in Sidi Brahim in Fez, Morocco. For this reason, these two materials have been previously washed with hot water, dried in the open air for 24 hours, and then ground to obtain a fraction of the order of 120 μm to 450 μm. The latter are washed many times with magnetic stirring until the pH value of the supernatant is neutralized and then dried in the oven at 100°C for 48 h (Figure 1).

2.3. Methodology

2.3.1. Characterization of Filter Materials. Both wood materials have been analyzed by scanning electron microscopy (SEM) (Quanta 200 FEI) and Fourier-transform infrared spectroscopy (FTIR) from Bruker (Vertex70) over a wavelength range of 400–7500 cm^{-1}.

2.3.2. Characterization of the Effluent. The effluent has been analyzed by measuring several parameters:

(i) Physicochemical parameters such as pH, electrical conductivity, COD, BOD_5, NH_4^+, PO_4^{2-}, and NO_3^-, in this respect, are analyzed according to the protocols recommended in [30].

(ii) Bacteriological parameters have been anatomized according to the analysis protocol in [31], which consists of the enumeration of fecal coliforms, *Streptococci*, and *Staphylococci*.

(iii) Heavy metal analysis has been performed using inductively coupled plasma emission spectrometry (ICP-AES) technique at the Regional Interface University Center (RIUC) of Fez.

(a)

(b)

Figure 1: Visual aspect of the two filter materials: (a) red wood sawdust (SBR); (b) catia wood sawdust (SBC).

2.3.3. Filtration Procedure. The filtration experiments have been carried out in parallel with two columns 3 cm in diameter; one filled by the red sawdust (RS) and the other by the catia sawdust (CS).Additionally, the kinetic and colorimetric study consists on taking a sample of the filtrate every 5 minutes. Furthermore, a parametric study was done for the three heights of the filter beds: 5cm, 9cm and 13cm.

3. The Characterization Results of the Two Filter Materials

3.1. Characterization by Infrared Spectroscopy (FTIR)

3.1.1. Red Sawdust (RS). The transmission infrared spectrum obtained for red sawdust is represented in Figure 2.

The analysis of this spectrum exhibits the existence of various bands:

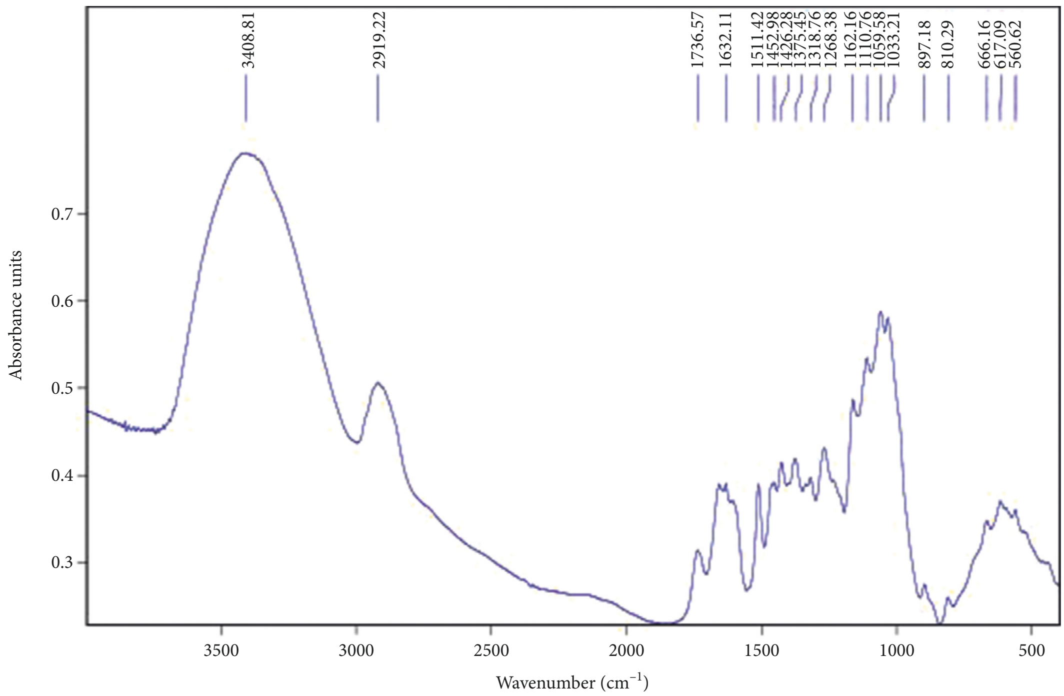
(i) The band at 897.18 cm^{-1} and other bands appearing at the frequency between 720 and 400 cm^{-1} are characteristic of the C-H group in cellulose [32].

(ii) The band at 1033.68 cm^{-1} identifies with the vibrations of the valence of the C-O and C-O-C cellulose [32].

(iii) A band that appears at 1736.57 cm^{-1} characterizes the stretching vibration of CO.

(iv) The band at 1266 cm^{-1} is attributed to the vibration ν (C-O) of lignin methoxy groups [33].

(v) The band that appears at 3408.70 cm^{-1} is a characteristic of the OH group and sufficiently broad in



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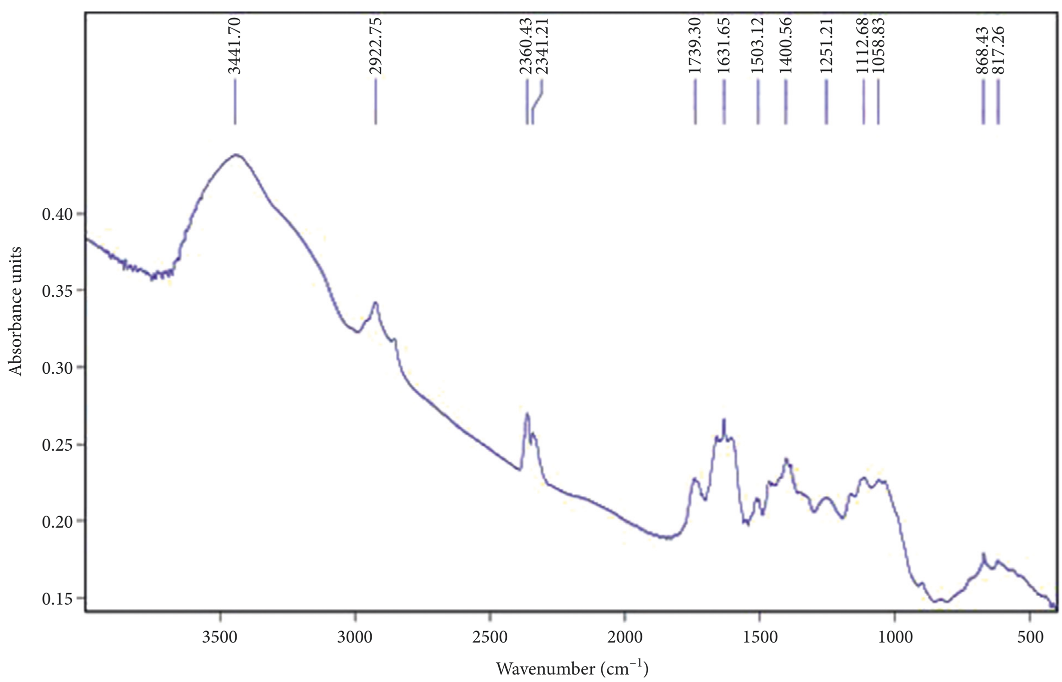


(b)

Figure 2: (a) Infrared spectrum of the RS; (b) infrared spectrum of the CS.

the grafted wood spectrum can be attributed to the OH groups of the carboxylic acid function [34].

3.1.2. Catia Sawdust (CS). The transmission infrared spectrum taken out for the CS filtrate is represented in Figure 2.

The analysis of this spectrum shows the existence of several bands:

(i) The band around 1739 cm^{-1} is a characteristic of the vibration link of (C=O) [35].

(ii) A band that appears at 1508 cm^{-1} is attributed to the deformation (C=C) of aromatic rings of lignin [33].

(iii) The both bands of 668.43 cm^{-1} and 617.26 cm^{-1} are characteristic of the C-H group in cellulose [33].

(iv) A band of 1112 cm^{-1} coincides with the C-H planar strain vibration of the phenolic group [34].

(v) A band of 1058 cm^{-1} is assigned to symmetrical and asymmetrical stretching C-O-C, C-H and C-O [36].

(vi) The band that appears at 3408.70 cm^{-1} can be attributed to the OH groups of the carboxylic acid function [34].

3.2. Characterization by Scanning Electron Microscopy (SEM). The images acquired following the analysis of the surface morphology of the two RS and CS adsorbent materials by scanning electron microscopy are displayed in Figure 3.

The analysis of all the images with magnifications of 1000 and 4000 shows that the two materials have a similar appearance and exhibit both an amorphous nature and a heterogeneous morphology with cellulosic fibers of different sizes. This explains the fact that the two types of sawdust have a porous appearance that facilitates the adsorption of pollutants. Consequently, similar images of adsorbent material have been found by Miyah et al. [28].

4. The Results of the Effluent Treatment by Two Filtering Materials

4.1. Visual Effect of the Color. Visual observation of the raw effluent and the two filtrates obtained after treatment with the two types of wood studied is shown in Figure 4.

The visual appearance of the two filtrates treated with RS and CS displays a clear clarification of the color which changes from the yellow color of the raw effluent to a lighter color for the effluent treated mainly with CS. Hence, the latter is closer to the transparent color of the water.

4.2. The Material Nature Effect on the Discoloration Rate. The outcome of the material nature effect on the fading rate is shown in Figure 5.

The shape of the curve is the same for both materials. In this case, the discoloration rate increases rapidly during the first five minutes and reaches the value of 79% for RS and 97% for CS and then undergoes a gradual decrease which leads to the state of stabilization which means the beginning of the two filters saturations. Thus, this saturation starts at $t = 45$ min for RS and at $t = 60$ min for CS with values that are 69% and 83%, respectively.

The comparative study of the two filter materials showed that MS treatment is more effective than the one with RS.

4.3. The Height Effect of the Filter Bed on the Discoloration Rate. The curves that explain the effect of RS and CS filter bed height on the fading rate are shown in Figure 6.

The analysis of the curves explains that the filtration capacity increases with the increase of the height of the bed for the two types of wood studied, and the percentage of reduction is maximum for the filter bed of 13 cm with the CS and RS which is 97% and 79%, respectively.

The interpretation of the results makes it possible to clarify that the increase in the height of the filter bed results in a decrease in the filtration rate and therefore the flow rate decreases. Furthermore, the higher the height of the filter bed, the more the retention of the pollutants in the effluent, which is better favored by the large number of filtration sites.

4.4. The Results of Physicochemical Analysis. The outcome of physicochemical analysis parameters of the raw effluent and the two filtrates obtained by RS and CS are reported in Table 1.

The values of the treated effluent parameters decrease with the height of the filter bed.

The values decrease more with the CS than with the RS, especially for a filter bed height equal to 13 cm.

The values of the physicochemical parameters of the raw effluent are quite high compared to Moroccan standards in relation to the discharge standards established by the World Health Organization which are given in Table 2 [37, 38]. In fact, the COD value of the raw effluent, which is 1593.6 $mgO_2 \cdot l^{-1}$, remains well above the WHO standard of 90 $mgO_2 \cdot l^{-1}$ and the value of the BOD_5 which is 131.28 $mgO_2 \cdot l^{-1}$ against 30 $mgO_2 \cdot l^{-1}$ [39]. This can be clarified due to the presence of a high organic load caused by the excessive use of both pharmaceutical and chemical products within the service.

The electrical conductivity which reflects the presence of ionic charges has an average concentration of the order of 230000 $\mu S \cdot cm^{-1}$, which largely exceeds the standard of 2700 $\mu S \cdot cm^{-1}$. In this respect, all values of other parameters such as NO_3^-, PO_4^{2-}, and NH_4^+ also exhibit slightly higher concentrations than WHO standards.

The characterization after filtration of the raw effluent by the two kinds of wood studied shows a net reduction of all the studied parameters especially for the effluent treated with CS and with a height of bed equal to 13 cm. In fact, the value of the chemical oxygen demand (COD) goes from 1593.6 $mgO_2 \cdot l^{-1}$ to 321 $mgO_2 \cdot l^{-1}$, which is closer to the value given by the WHO, and the value of the biological oxygen demand (BOD_5) is decreased from the value of 131.32 $mgO_2 \cdot l^{-1}$ to 24.45 $mgO_2 \cdot l^{-1}$ of the order of value set by WHO. However, the values of the other parameters obtained after treatment are much less compared to the limits fixed by the WHO: the conductivity (Cond) passes from 230000 $\mu S \cdot cm^{-1}$to 950 $\mu S \cdot cm^{-1}$, the nitrate (NO_3^-) from 7.62 $mg \cdot l^{-1}$ to 0.62 $mg \cdot l^{-1}$, the phosphate (PO_4^{2-}) from 5.33 $mg \cdot l^{-1}$ to 0.53 mg/l, and the ammonia (NH_4^+) from 2.53 $mg \cdot l^{-1}$ to 0.48 $mg \cdot l^{-1}$.

4.5. The Results of Bacteriological Analysis. The results of the microbiological characterization of the raw effluent and the two filtrates are shown in Table 3 and Figure 7.

The bacteriological enumeration of the raw effluent demonstrates the existence of a very high number of fecal coliforms, fecal *Streptococci*, and *Staphylococci*, which is n the order of $60 * 103$ CFU/100 ml, $216 * 103$ CFU/100 ml, and $40 * 103$ CUF/100 ml, respectively, and which exceeds widely the standard given by the WHO which is 1000 CFU/100 ml. Fortunately, this is in agreement with the results mentioned in [10].

The treatment of the effluent by the two types of wood makes it possible to obtain a total elimination of *Staphylococci*, a clear reduction of the fecal coliforms and fecal

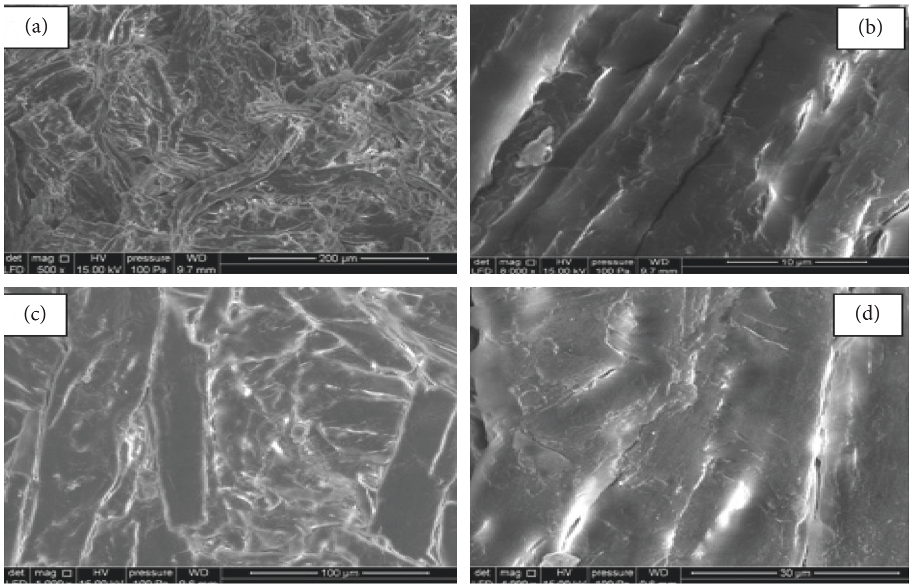


Figure 3: (a, b) Characterization of red sawdust by scanning electron microscopy. (c, d) Characterization of catia sawdust by scanning electron microscopy.

Figure 4: Visual appearance of raw effluent and RS (1) and CS (2) filtrates.

Streptococci especially with the SBC and with a height of the filtering bed equal to 13 cm (Figure 8).

4.6. The Results of Heavy Metal Analysis. The analysis of heavy metals by inductively coupled plasma emission spectrometry (ICP-AES) gives the values shown in Table 3, which explains that the concentrations of the metals present in both the raw effluent and the two filtrates studied comply with the standards in force.

5. Discussion

According to the results obtained, the characterization of the two sawdust shows that the two SBR and SBC materials have a porous and branched appearance with the presence of certain interspaces which appear as luminous spots and a heterogeneous morphology with the presence of cellulosic fibers. This morphology would give the material a greater adsorption capacity. These results confirm those mentioned in [40]. These sawdust varieties are relatively simple and consist mainly of tracheids, provide the mechanical stability, and contain the largest amount of polymers, namely, cellulose, lignin, and hemicellulose. These contain organic functional groups such as alcohols, aldehydes, and especially carboxylic and phenolic groups on their surfaces. These groups have been shown to participate in cation bonds due to their ability to ionize in aqueous solution, which allows for intermolecular and intramolecular linkages.The characteristic vibration bands found in our study are in agreement with the literature data [40, 41]. However, the physical properties of sawdust have a high percentage of carbohydrates in both sawdust varieties and suggest that the main functional groups present in the adsorbent are the CH and OH ends [42]. The wavelength at which the OH-group appears indicates that the sawdust is basic in nature. It is therefore this OH- function of the phenolic or carboxylic compounds of the adsorbent bind with the COOH groups of the organic pollutant by an esterification bond. The other functional groups present are proposed as coming from the protein and lipid parts of the adsorbent. As a result of these properties, sawdust has a high tensile force which reflects a considerable adsorption capacity of organic pollutants [44].

In addition, some studies have shown that the surface functions of sawdust have a specific surface area typically of the order $3\,m^2/g$ and essentially include macropores allowing the attachment of organic materials. Our results are similar to those obtained by Josse [45] who obtained TD of the order 69.73% using eucalyptus wood..

However, the study of the effect of the material on the degree of discoloration shows that the residence time varies according to the nature of the filter material and that the results of the filtration are more significant with the sawdust whatever the height of the filter bed with TDs of the order of 80% for CS and 79% for RS. This is probably due to the greater surface area of the latter. In addition, the type of sawdust plays a key role in the removal of organic pollutants, as previously described by Karime [46], who compares the adsorption power of three types of wood. The results showed

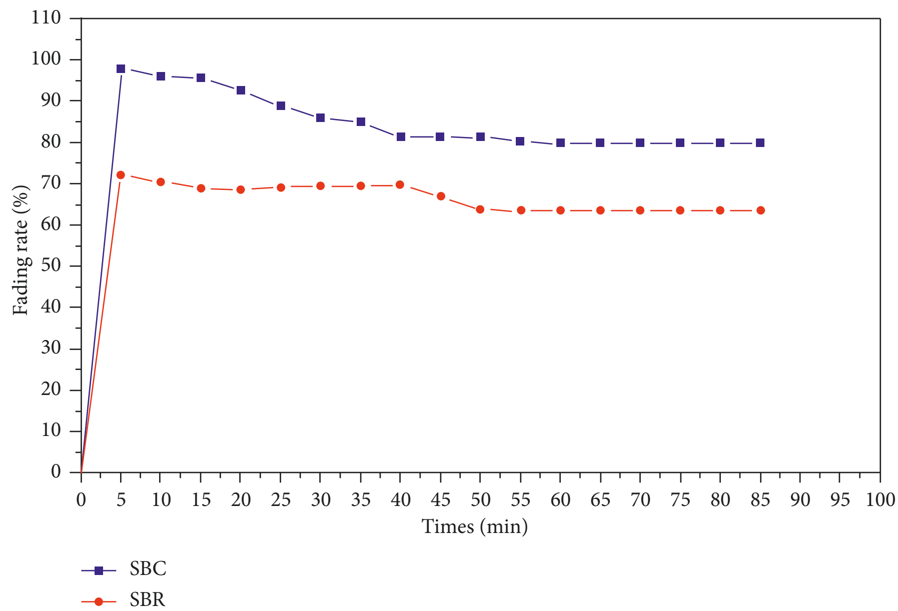


Figure 5: The evolution of the effluent discoloration as a function of time for both types of RS and CS wood.

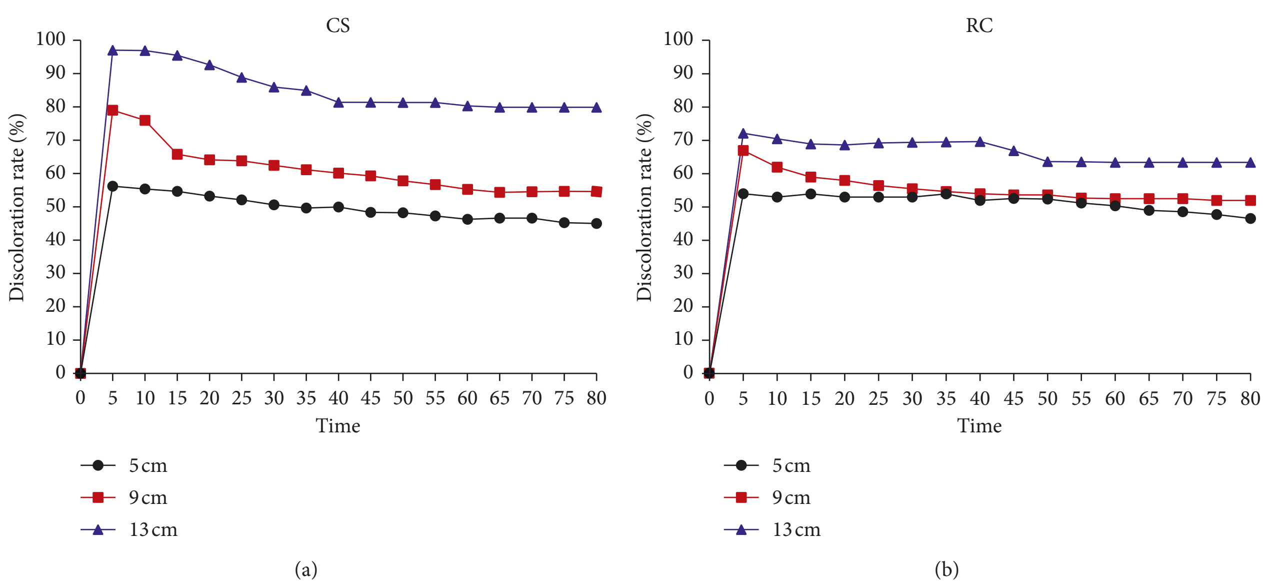


Figure 6: Effect of RS and CS bed height on discoloration rate.

Table 1: Physicochemical characterization of the effluent before and after treatment by the two types of wood.

Parameter	WHO standards	Moroccan standards
pH	5.5–8.5	6.5–8.5
Conductivity (μS/cm)	2700	2700
DCO ($mgO_2 \cdot l^{-1}$)	90	120
DBO_5 ($mgO_2 \cdot l^{-1}$)	30	40
NO_3^- (mg/l)	1	—
PO_4^{2-} (mg/l)	1	—
NH_4^+ (mg/l)	0.5	—

that sawdust had a high adsorption capacity of organic substances at 146 mg / g, followed by cedarwood (142.3 mg / g) and softwood (10 mg / g) [44, 46].

The values of the abatement rates increase in proportion to the increase in the height of the filter bed. Indeed, increasing the height of the filter bed also slows the solute-solid exchange rate and therefore the residence time increases. This can be explained by the increase in the number of filtration sites, which favors the retention of the molecules present in the effluent. This porosity is shown by observation with a scanning electron microscope (SEM) [33].

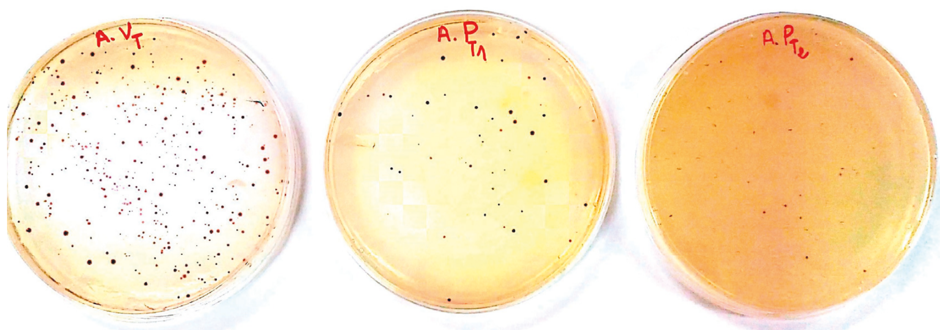
The analysis of the physicochemical parameters shows a significant reduction of all the studied parameters and especially for the COD of which the TDs are of the order of 76% and 79% for the CS and RS, respectively, and BOD_5 with TD of 81% for CS and 77% for RS. This reduction is also proved in [40] with TDs of the order of 86% of COD and

Table 2: Release standards established by the World Health Organization and Moroccan ones.

Parameter	Raw	Red sawdust (RS)			Catia sawdust (CS)		
		5 cm	9 cm	13 cm	5 cm	9 cm	13 cm
pH	8.28	6.7	6.5	6.42	6.42	6.31	6.26
Conductivity (μS/cm)	230000	77600	1430	1280	77000	1720	950
DCO ($mgO_2{\cdot}l^{-1}$)	1593.6	425.9	386.36	376	420	378.1	321
DBO_5 ($mgO_2{\cdot}l^{-1}$)	131.28	33	29.9	29.5	32.37	29.22	24.45
NO_3^- (mg/l)	7.72	1.21	0.99	0.96	1.21	0.94	0.62
PO_4^{2-} (mg/l)	5.33	0.93	0.78	0.74	0.90	0.75	0.53
NH_4^+ (mg/l)	2.53	0.95	0.75	0.48	0.78	0.76	0.48

Table 3: Means concentration of heavy metals before and after treatment.

Metal	Standard	Raw	Red sawdust (RS)			Catia sawdust (CS)		
			5 cm	9 cm	13 cm	5 cm	9 cm	13 cm
As	0.5	0.23	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cd	0.2	0.02	<0.01	0.147	<0.01	<0.01	<0.147	<0.01
Cu	3	0.698	0.352	0.138	0.0284	0.352	0.138	0.028
Pb	1	0.14	<0.01	<0.01	<0.164	<0.01	<0.01	<0.164
Cr	0.5	0.26	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01



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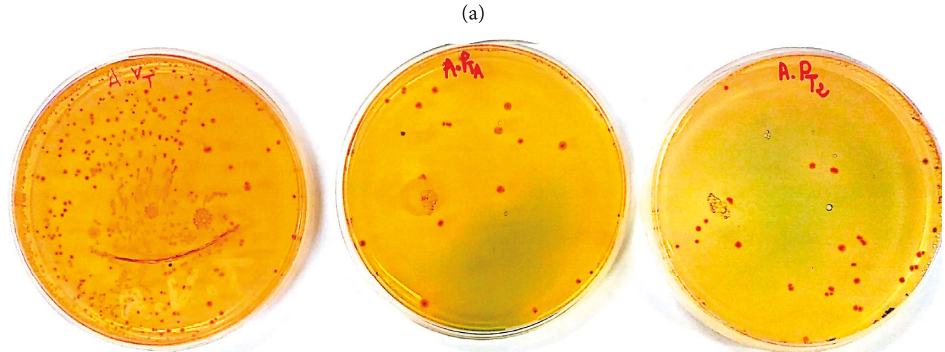

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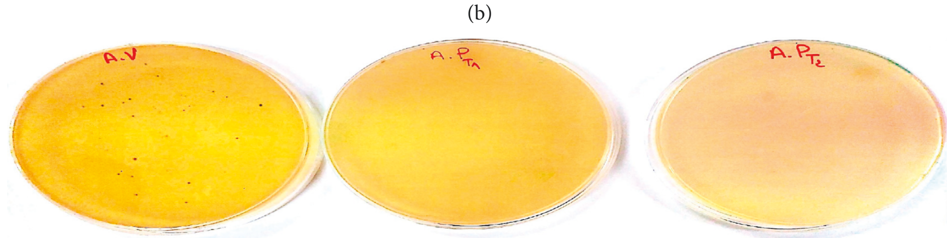

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Figure 7: The results of bacteriological enumeration of crude effluent, RS and C S filtrate. (a) Fecal coliforms, (b) fecal *Streptococci*, and (c) *Staphylococcus aureus*.

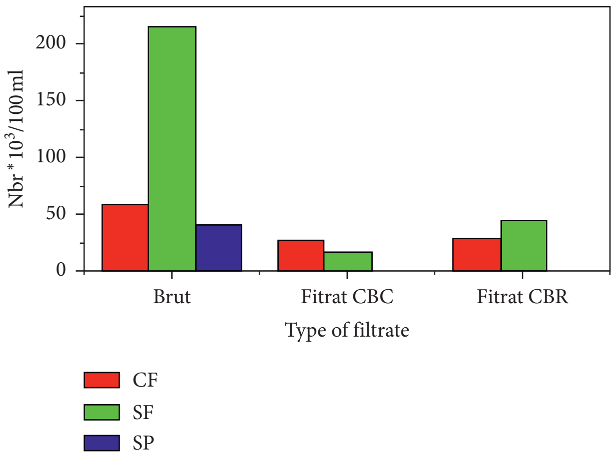

Figure 8: Microbiological characterization of the effluent before and after treatment by the two types of wood.

91% of BOD_5 with the filtrate materials of sawdust. This may be due to the abundant availability of active sites on the inner and outer surfaces of the adsorbent, resulting in an increase in the cell wall due to the hemicelluloses that bind the bundles of cellulose fibrils to form microfibrils and the presence of free hydroxyl linkages available in cellulose, hemicellulose, and lignin macromolecules. Taking these results into account, in line with those mentioned in [44], explains the reduction in fading rates. The conductivity results also show decreasing values related not only to the chemical exchanges between the water and the filter material but also to the retention of the dissolved salts contained in the effluent. These results are similar to those described with a support consisting of eucalyptus sawdust and clay [47].

The evaluation of the performance of the RS and CS filtration systems in terms of germ reduction allows a major decontamination of the bacterial load of the effluent. This can be ensured by the particle size characteristics, the thickness of the clogging which has an impermeable form and promotes the accumulation of bacteria. These results are in agreement with those found in [41] for the treatment of leachates by the filtration technique.

The results of the analysis of heavy metals before and after handling show that the WHO standards are met but note a reduction in them. Several studies have shown that passive transport mechanisms are proposed for the diffusion of metal ions from the bulk solution to the active sites of the biosorbent by the presence of functional groups such as phosphates; hydroxyls exist on the surface of the worshiper [48], so the pH of the solution increases and the amount of the two biosorbed metal ions increases, suggesting a competition of hydrogen ions with metal ions for adsorption sites on the surface of the adsorbent [49]. Contrary to the results obtained in [6], they failed to eliminate heavy metals from hospital effluents by reverse osmosis technique.

6. Conclusion

The treatment of hospital effluents by column filtration based on sawdust is an effective and less expensive treatment.

The best abatements are obtained by column filtration of catia sawdust at a height of 13 cm.

The filtration and reduction of the studied parameters seem to be influenced by the height of the filter bed and the type of wood.

The reduction in BOD_5, COD, and conductivity is explained by the fixation of organic matter and ionic ions on the surface of the filter beds.

The bacteriological count shows the decrease of the number of bacteria such as fecal coliforms and fecal *Streptococci* and the elimination of *Staphylococci*. These are trapped on the filter supports.

The heavy metal analysis exhibits compliance with the wastewater discharge standards recommended by the WHO.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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