

Pretreatment of textile industry effluents with a perforated intermittent sand filter

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ABSTRACT: The textile industry generates a large amount of wastewater containing various pollutants (dyes, heavy metals, salts, etc.), which cause severe problems to the environment. The treatment of these effluents by classical methods (activated sludge and physico-chemical) is very expensive for developing countries. In this context, alternative low-cost technology may be investigated. Among others, the treatment efficiency of a perforated intermittent sand filter was studied on a textile industry effluent in Abidjan. Various filter configurations (perforation area: 150, 300 and 600 cm²) were used. Conductivity, pH and light absorbencies at 436, 525 and 620 nm of the effluent and the filters filtrates were followed up. The relevant results are a decrease of pH from 11 to 6 and 9, desalination and a discoloration of about 45 % of the raw effluent at 436 nm. The best pretreatment of the raw textile effluent was obtained with the perforated intermittent sand filter having 150 cm². The intermittent filtration of textile industry effluent on a perforated sand filter with an area of 150 cm² seems to be a promising alternative for the pretreatment of textile effluent.

KEYWORDS: Treatment; adsorption; sand filter; textile effluent; intermittent.

1 INTRODUCTION

The conservation of a better living environment requires fighting against all forms of environmental pollution. The industrial effluents constitute one of the main sources of the environment degradation [1]. Textile industries use many chemicals (dyes, salts, weld, etc.) which are released into effluents [2], [3], [4]. These industries also generate large amount of wastewater, which may color receiving water, even to weak concentrations (5 µg l⁻¹) [5], [6], [7], [2], [8], [9]. Some of these chemicals and their degradation by-products (amines) are carcinogenic, mutagenic and toxic for humans and the aquatic fauna and flora [10], [11], [12], [13], [14], [15], [16]. Besides dyes agents, these effluents contain suspended solids (> 500 mg.L⁻¹), nitrogen (> 30 mg N.L⁻¹), phosphorus (> 1 mg P₂O₅.L⁻¹), and heavy metals. [14], [17], [18], [19], [13]. The presence of salts in these effluents generally makes their conductivity superior to 2 500 µS.cm⁻¹ [20]. The suspended solids contained in textile industry effluents impact aesthetics of the receiving aquatic environment by increasing their turbidity [21]. As a consequence, photosynthesis is reduced and water column deoxygenated [22], [15], [9], [16]. Heavy metals such as Cd and Cu have disastrous effects on the receiving water bodies' biodiversity. Cd is toxic for seaweeds at 0.1 mg.L⁻¹ and Cu at elevated concentration inhibits photosynthetic activity, alters fish gills and delays egg laying [23]. Physico-chemical processes used to treat textile industry effluents (TIE) (ultrafiltration, oxidation, adsorption) [24], [25], [3], [12], [7] are expensive for developing countries. For preventing environment pollution by these effluents, it is important to investigate a low-cost technology for their treatment. Filtration of such effluents on sand appears to be an interesting alternative, because sand is used as a cheap process to absorb dyes, metals, and to retain suspended solids [26].

The purpose of this research was to study the pretreatment of textile industry effluents (TIE) with a perforated intermittent sand filter. The efficiency of three perforations area (150, 300, 600 cm²) was tested followed, using an effluent from the textile industry UNIWAX at Abidjan (Côte d'Ivoire).

2 MATERIALS AND METHODS

2.1 FILTER DESCRIPTION

Two types of filters were used; a non-perforated filter (F_{NP}) used as control and a perforated filter (F_{IP}) (Figure 1). The filters consisted in iron cylindrical barrels of 122 L painted with an anti-corrosive and laterally perforated. Perforations areas of 5x30, 10x30, 20x30 cm² were used. These filters have been respectively named in the text F_{5P} , F_{10P} , F_{20P} . Filter F_{NP} as the others filters were equipped with an exhaust tip to drain out the filtrate. It was then filled from its bottom to the upper surface by 5 cm of gravel and a geotextile above which 40 cm of white sand was disposed. The sand used to fill the barrels was uniform medium grain sand (mean value = 0.44, uniformity coefficient value = 0.57) from the Ebrié lagoon in Abidjan. The sand was washed, dried and sieved on a two (2) mm mesh, to remove the impurities. A sieve was used above the upper surface of the sand to insure the homogeneous distribution of the TIE on the filter surface.

Perforated filters (F_{5P} , F_{10P} , F_{20P}) were equipped from their bottom to the upper as follow: five (5) cm of gravel, a geotextile above the gravel surface, then 20 cm of sand were arranged on the geotextile. Above the opening level, a bar was disposed and covered with a geotextile to support the others 20 cm of sand. A sieve was also disposed to insure the homogeneous distribution of the TIE on the filter surface.

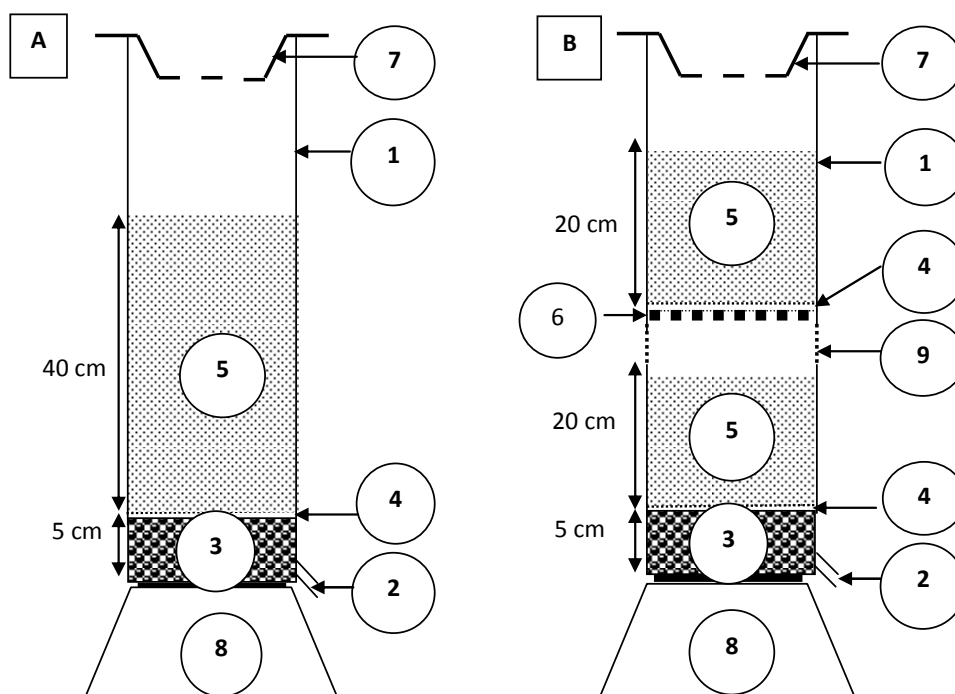


Figure 1: Description of the filters used. A: non perforated filter used as control; B: perforated filter. (1) : Iron barrel (122 liters capacity); (2) : stick for filtrate; (3) : gravel (15/10); (4) : geomembrane; (5) : white sand ; (6) : rack; (7) : sieve; (8) : stool ; (9) : perforation.

2.2 WASTEWATER APPLIED ON THE FILTERS

TIE used were taken from a buried channel draining out the textile company UNIWAX process effluent (Figure 2). Every day, 20 L of TIE were applied to the filters and a sample of TIE and filtrates were collected and kept at 4°C until analysis.

2.3 ANALYSIS OF POLLUTANT PARAMETERS

The pH and the conductivity of samples were measured respectively with the multi-parameters Consort C830 and Aqualytic CD24. As the TIE used contained a mixture of dyestuffs, measurement of absorbance was done at standard wavelengths; 436, 525 and 620 nm according to German standard method [27] and [28]. The color intensity of the sample was expressed as an absorption coefficient and it was calculated according this relation:

$$\alpha(\lambda) = \frac{Abs * f}{c}$$

With $\alpha(\lambda)$ (m^{-1}) = spectral absorption coefficient in the wavelength λ ($\lambda = 426, 525, 620$ nm); Abs = absorbance in the wavelength λ ; f = dilution factor, c = pathlength (m).

Filter efficiency for the removal of a parameter was calculated according the following relation.

$$R = \frac{Vr - Vf}{Vr} \times 100$$

With R = Removal (%); Vr = value of the parameter in TIE; Vf = value of the parameter in the filtrate.



Figure 2: Sampling site for the TIE outside of the textile industry UNIWAX

2.4 STATISTICAL ANALYSIS

A non-parametric Kruskal-Wallis test was used to compare the parameters (pH, Electrical Conductivity, Absorbance). The zero hypothesis of the test was that the difference is significant if the probability (P) is lower or equal to 0.05.

3 RESULTS

The pH of the TIE and the filtrates was measured over time (Figure 3). The pH of the filtrates ($7.9 \leq \text{pH} \leq 10.2$) was inferior to that of the TIE (pH = 11.4). However, the pH of the filtrate of the filter FNP was superior to that of the perforated ones. The difference between the pH of the TIE and those of the four filters filtrates was significant ($P < 0.05$). But the pH mean value of the filtrates compared to each other was not significantly different ($P > 0.05$).

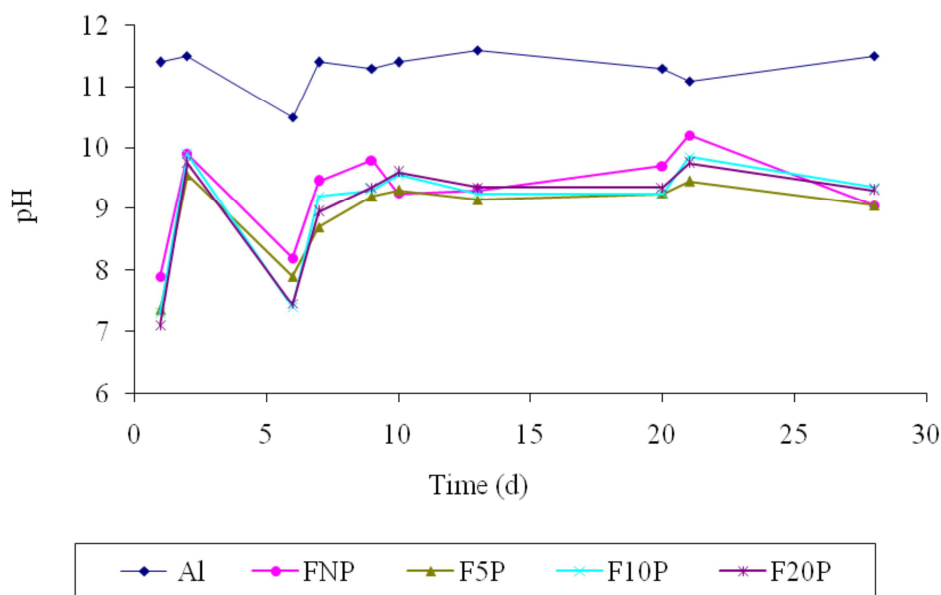


Figure 3: Influence of filter configuration on the pH of the filtrate. AI: TIE; F_{NP}: filtrate of the control filter; F_{5P}: filtrate of the filter with a 150 cm² perforation; F_{10P}: filtrate of the filter with a 300 cm² perforation area; F_{20P}: filtrate of the filter with a 600 cm² perforation area.

The electrical conductivity (EC) of the TIE and the filter filtrates was measured over time (Figure 4). The EC of the TIE was superior ($1\ 067 \leq EC \leq 3\ 020 \mu\text{S}\cdot\text{cm}^{-1}$) to that of the filtrates ($195 \leq EC \leq 2\ 040 \mu\text{S}\cdot\text{cm}^{-1}$). But the EC of F_{NP} and F_{10P} filtrates were inferior to those of the filters F_{5P} and F_{20P} filtrates. The EC of the TIE was significantly different from the EC of F_{NP} and F_{10P} filtrates ($P < 0.05$), but not of F_{5P} and F_{20P} filtrates.

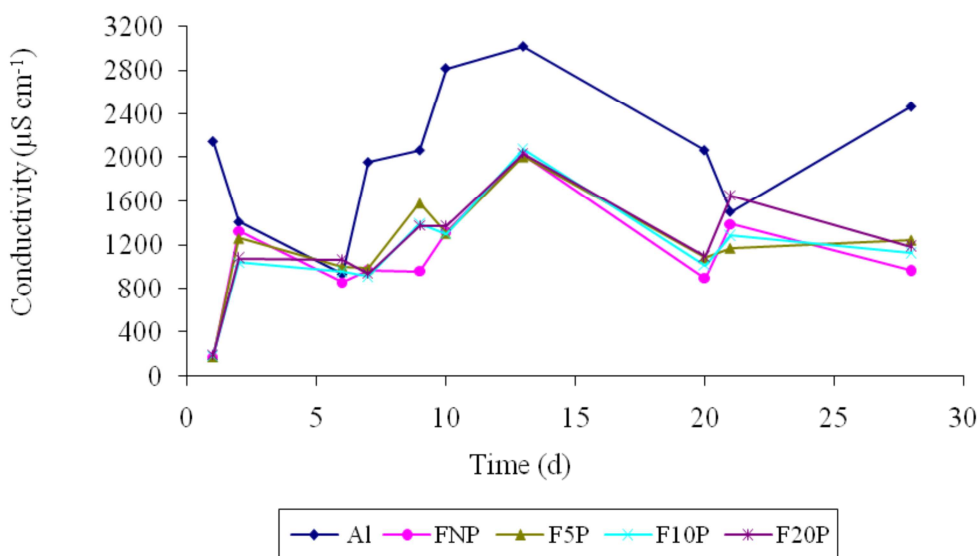


Figure 4: Influence of filter configuration on the electrical conductivity of the filtrate. AI: TIE; F_{NP}: filtrate of the control filter; F_{5P}: filtrate of the filter with a 150 cm² perforation; F_{10P}: filtrate of the filter with a 300 cm² perforation area; F_{20P}: filtrate of the filter with a 600 cm² perforation area.

The absorption of the TIE and the filtrates was measured at 436 nm over time (Figure 5). Absorbance was generally lower in the filtrates than in the TIE except the second day where there was an increase in the absorption amplitude. The increase in absorbance the second day was more pronounced in the filters F_{NP}, F_{10P} and F_{20P} filtrates (Figures 5 a, c and d) than in the filtrate of F_{5P} (Figure 5 b). The decrease in absorbance of the filtrates was about 100 % the first day. The following days, the filter removal efficiencies decreased. The highest discoloration (45 %) at 436 nm was obtained with the filter F_{5P}, against 41 %

and 35 % respectively for the filters F_{NP} , F_{10P} and F_{20P} . However, there were no significant difference ($p > 0.05$) between the absorbance of these filters filtrates and the TIE.

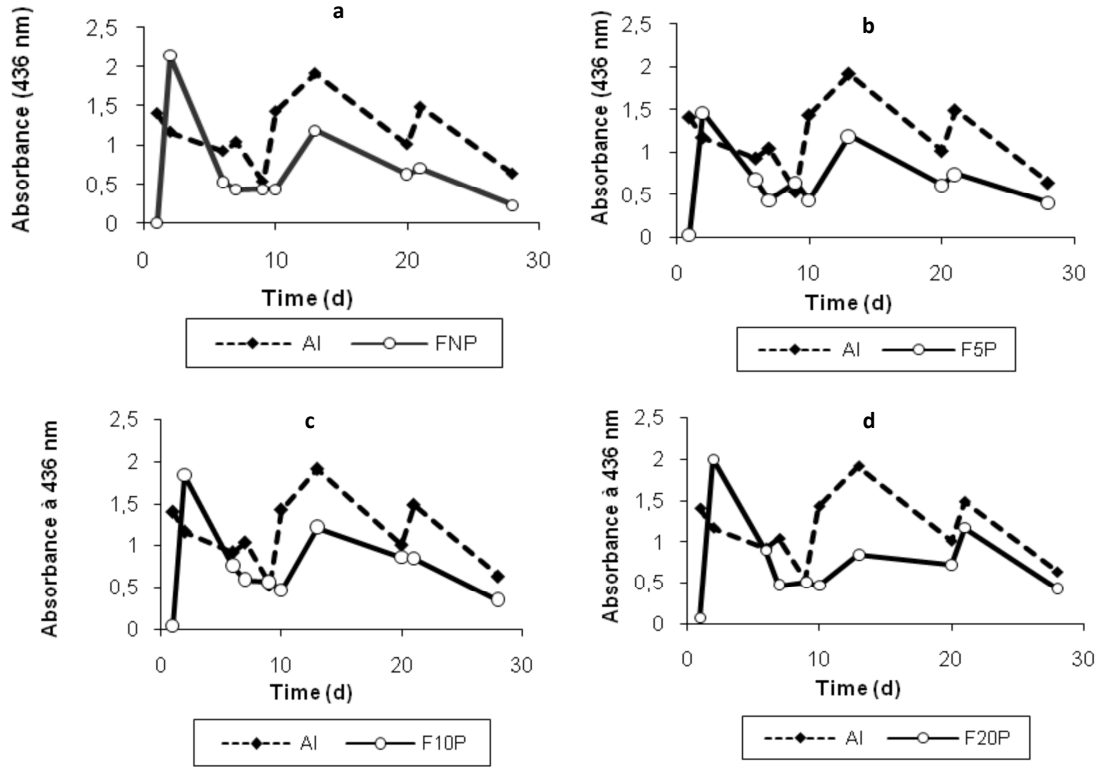


Figure 5: Influence of filter configuration upon absorbance amplitude of the raw wastewater (AI) and filtrates (a-d) at 436 nm; a: filter F_{NP} filtrate; b: filter F_{5P} filtrate; c: filter F_{10P} filtrate; d: filter F_{20P} filtrate.

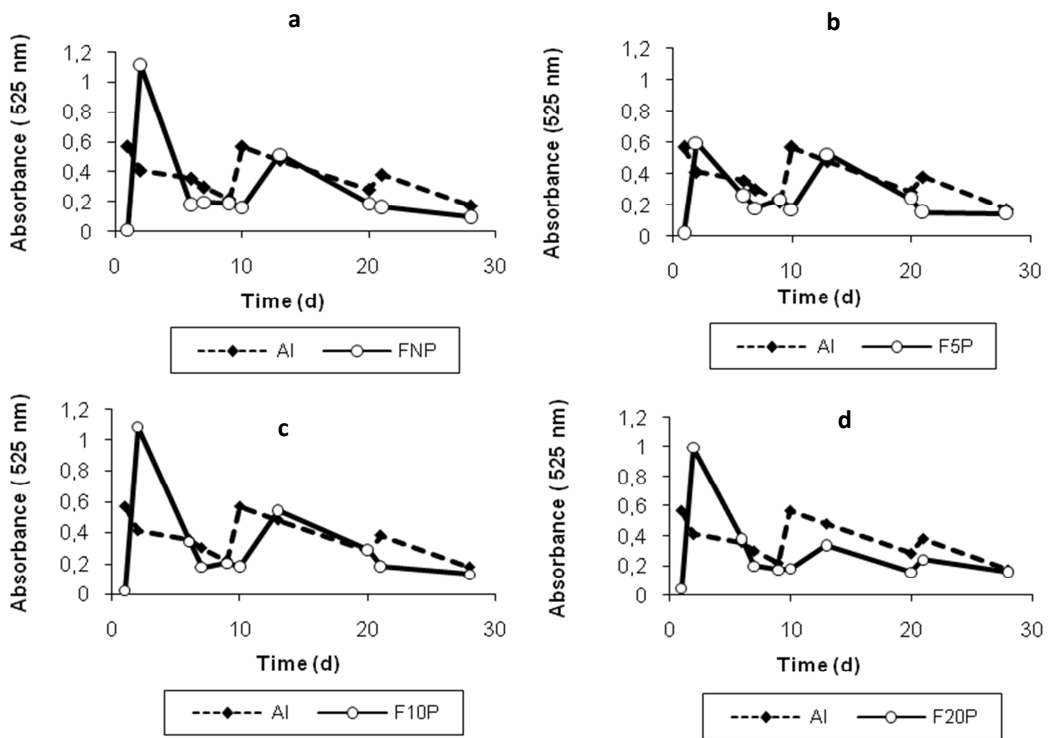


Figure 6: Influence of filter configuration upon absorbance amplitude of the raw wastewater (AI) and filtrates at 525 nm des filtrates (a-d); a: filter F_{NP} filtrate; b: filter F_{5P} filtrate; c: filter F_{10P} filtrate; d: filter F_{20P} filtrate.

The absorption of the TIE and the filtrates was measured at 525 nm over time (Figure 6). Light absorbance of the filtrates was lower than that of the TIE. An increase of the absorbance of the filters filtrates was also observed the second day as at 436 nm. This increase was important in the filter F_{NP} filtrate and weak in the filter F_{5P} filtrate. The best discoloration at 525 nm was obtained with the filter F_{5P} (35 %), against 24%, 15% and 23% respectively with the filters F_{NP} , F_{10P} and F_{20P} filtrates. The difference between the absorbance at 525 nm of the TIE and that of the filtrates was not significant ($P > 0.05$). Also the difference between the absorbance of the filtrates compared to each other was not significantly different ($P > 0.05$).

The absorption of the TIE and the filtrates was measured at 620 nm over time (Figure 7). Generally there was a slight decrease of the absorbance of the filtrates. However, an increase of the absorption amplitude of the filters filtrates was observed on the second day. This increase was important in the filters F_{10P} and F_{20P} filtrate (Figure 7 c, d). The absorbance decrease of the filters F_{NP} and F_{5P} filtrate was more important than the two others filters filtrate. The filter F_{5P} gave the best discoloration (43 %) at 620 nm. In this wavelength, the differences between the absorbance of the TIE and the filters F_{NP} and F_{5P} filtrate were significant ($P < 0.05$). But these differences were not significant ($P > 0.05$) between the absorbance of the TIE and the filters F_{10P} and F_{20P} filtrates.

Figure 8 presents the discoloration profiles of the filters filtrates within time. This discoloration was excellent the first day (Figure 8a). However, it's degraded the following days (Figure 8 b and c).

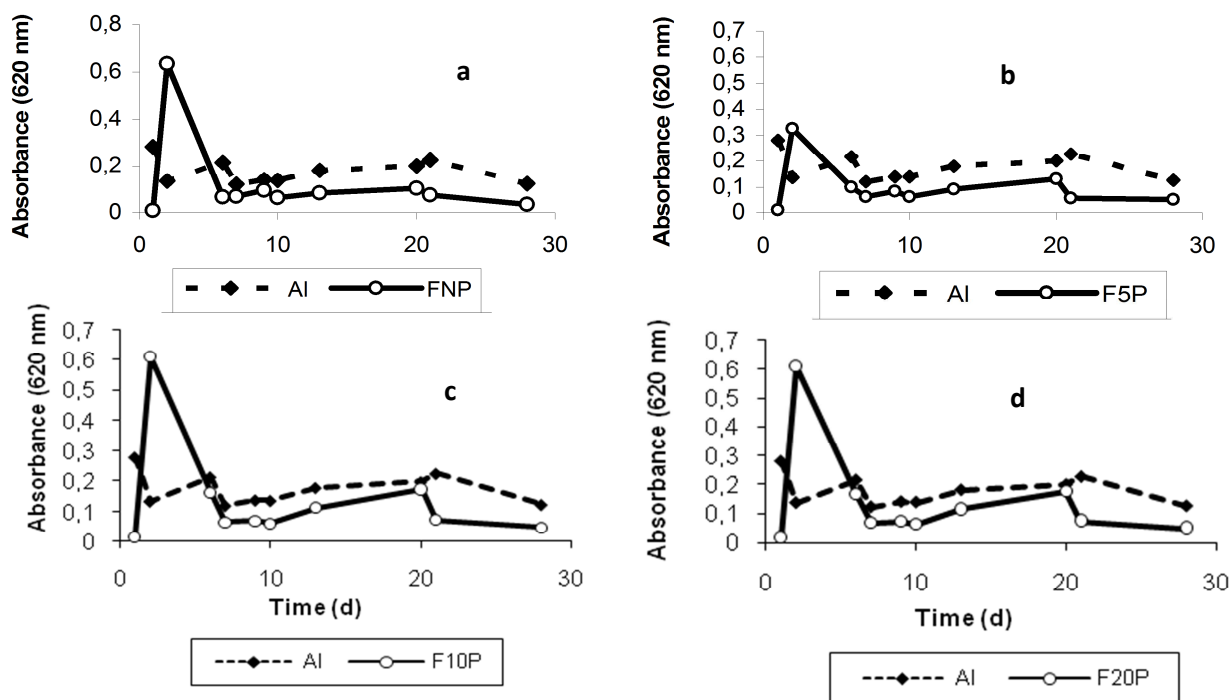


Figure 7: Influence of filter configuration upon absorbance amplitude of the raw wastewater (AI) and filtrates (a-d) at 620 nm; a: filter F_{NP} filtrate; b: filter F_{5P} filtrate; c: filter F_{10P} filtrate; d: filter F_{20P} filtrate.

The absorption coefficient of both the TIE and the filters filtrates absorption coefficient are presented in the table 1. Generally there was a decrease in the filtrate absorption coefficient than in the TIE. This decrease was more important in the filter F_{5P} filtrate than in the others filters filtrates. But the absorption coefficients obtained were all superior to the standards.

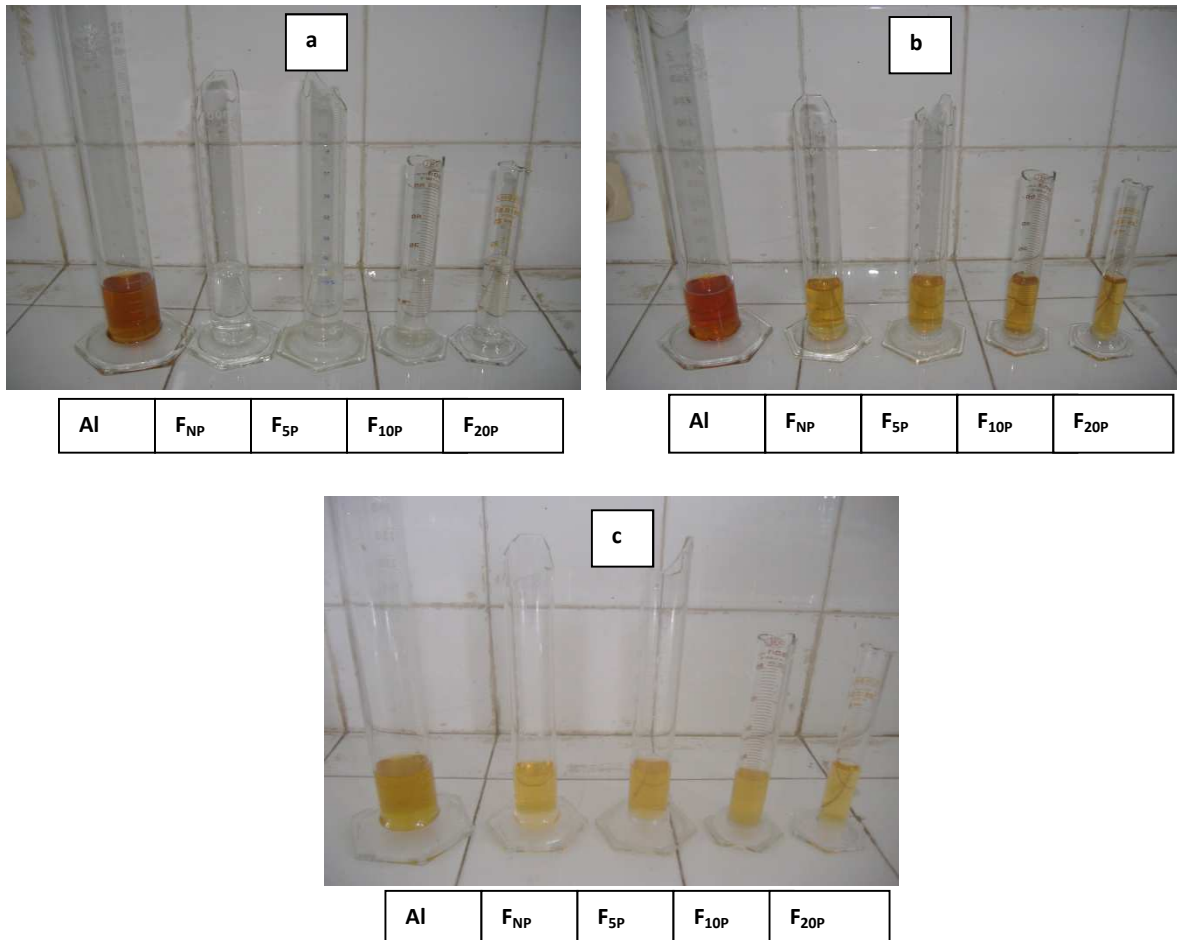


Figure 8: Effect of the filters configurations and upon their filtrates discoloration. A: first day; B: day 11; C: day 21; AI: Raw effluent; F_{ip} : Perforated filter at i wide in centimeter ($i = 5, 10$ and 20 cm).

Table 1: Absorption coefficients (α) of textile industry effluent (TIE) and the filters filtrate comparing to standard of BMZ (1995).

Filters	α at 436 nm (m^{-1})			α at 525 nm (m^{-1})			α at 620 nm (m^{-1})		
	TIE	Filtrate	Standard value	TIE	Filtrate	Standard value	TIE	Filtrate	Standard value
F_{NP}		68			28.3			12.28	
F_{5P}	115.5	63,5	7	37.4	25.2	5	17.6	10.03	3
F_{10P}		75.2			31.6			14.05	
F_{20P}		75.4			28.7			14.05	

4 DISCUSSION

The results showed that the TIE ($pH = 11$) was basic. This is in accordance with the others textile industry effluents ([18], [29]) may be because of the utilization of soda to increase cotton affinity for dyes. The decrease of the filtrates pH around 6 could be explained by the adsorption on sand grains or the precipitation of hydroxide by calcium contained in the filtering matrix to give calcium hydroxide. However, after 20 days of filtration, the pH reduction in the filtrates diminished ($pH \geq 11$ to $pH 10$). This result could be explained by the saturation of the adsorption sites on sand grains or the precipitation of all of the calcium ions. The high EC of the TIE obtained in this research is in the same order of magnitude as that the EC of textile industry effluent ($2\,500\ \mu S.cm^{-1}$) measured by [17]. The decrease in the filtrates EC may result from the adsorption of salts contained in the TIE on the filtering massif.

The high absorption amplitudes at 436, 532, 620 nm of the TIE gave evidence of the release of a mixture of dyestuff in textile processing effluents. The important decrease of the absorption amplitude obtained at all the wavelengths investigated the first day could be explained by a maximum adsorption of the dyes on the sand filter. The subsequent increase in the

absorption amplitude observed the second day in the filters F_{10P} and F_{20P} filtrates may be due to the iron precipitates $Fe(OH)_3$. Indeed, the basic character of the TIE was favorable to the formation of such a precipitate in the presence of Fe^{2+} and Fe^{3+} . The Fe^{2+} and Fe^{3+} could come from the TIE or from the filters superstructure which is in iron. The important increase of the absorption amplitude on the second day in filters F_{10P} and F_{20P} seems logical and follow the preview explanation. These filters are more aerated than the others because of their wide opening which allows air circulation in the filter. The presence of the oxygen on the inner face of filter superstructure under wet condition is favorable to the iron oxidation to Fe^{3+} . The slight discoloration observed after 20 days of the filters working could be explained by the adsorption sites saturation of the filtering massif [30].

The best discoloration obtained at 436 nm in the filtrates was different from the results of [28] and [19] who obtained a good discoloration at 620 nm. The difference between the result of this research and those of these authors can be explained by the quality of the wastewater. In this research, a TIE was used instead of the synthetic wastewater used by [28] and [19]. The latter wastewater is less complex in chemical composition and dyes than the raw TIE.

The adsorption coefficient of the raw effluent was reduced in the different filters filtrates. However, it remained superior to the standards of discharge. This result confirms the difficulty to decolorize the TIE by adsorption process alone. This may be due to the basic character of real effluents and/or the presence of salts and surfactants which may compete with dyes on adsorption sites [9], [31].

5 CONCLUSION

The pretreatment of a textile industry effluent (TIE) has been performed on a perforated intermittent sand filter. The pH, electrical conductivity, light absorbance at 436, 525 and 620 nm of the TIE and the filters filtrates were followed up. The perforated filters had demonstrated capacities to treat the TIE. The pertinent results were the decrease of the pH, desalinization and discoloration of the raw effluent. The performance of the perforated filters was generally superior to that of the control. However, the discoloration in the perforated filters was influenced by their perforation areas. The filter F_{5P} gave the best discoloration (45 %). The decrease of the TIE pH from over 11 to near 9 and its desalinization are favorable to biochemical activities and the filtrates could be treated in a biological process without the addition of chemical reagents. These results put evidence that there is a cost saving to pretreat textile industry effluent with a perforated intermittent filter before their entrance in a biological chain.

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