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Study of the Performance of the Biological and Microbiological Treatment of Domestic Wastewater by Biological Aerated Filters with Packed Media

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Abstract— *The objective of this study is to study the performance of biological and microbiological treatment of domestic wastewater by two aerated biological reactors (R1 and R2), having the same characteristics and operating in batch mode. They are filled with plastic packing media of the same type but of different sizes. Therefore, four (4) adaptation tests were carried out. Successful results have been obtained in Chemical Oxygen Demand (DCO), turbidity, and microbiology. The abatement rate of these parameters got improved during the adaptations. So is for the dissolved oxygen and the pH which increases in each of the tests, as for the conductivity, it varied very slightly in all the tests denoting the important role of the acclimation of the bacteria in the elimination of the pollutants of wastewater. The results of the various pollution parameters are generally more benefit the R1 bioreactor filled with small plastic packing media. This is due to the possibility offered by this plastic packing media to favor its colonization by larger fixed biomass. These tests lead to the conclusion that biological treatment by the aerated biological filter is very effective in the elimination of the main pollutants of domestic wastewater: COD, turbidity and fecal pollution.*

Keywords— *Aerated Biological Filter; Fecal Coliforms; Microorganisms; Pseudomonas; Streptococci; Total Coliforms.*

I. INTRODUCTION

It is commonly accepted that domestic effluents pose a real threat to water resources. Because of their variable physicochemical and bacteriological composition, their raw rejection in the natural environment leads to high concentrations of pollutants, and leading to contagious diseases that can lead to serious epidemics, threatening the environment and human health [1]; [2]; [3]; [4]. According to WHO, 80% of these diseases are linked partiallyto inadequate sanitation of domestic and industrial wastewater, because wastewater contains high concentrations of fecal bacteria; Approximately 10^9 UFC/L for *E. Coli* and 10^8 UFC/L fecal enterococci Ra-Eaux Usées (2008).

In addition to these two types of bacteria, domestic rejects contain a wide range of pathogenic bacteria or opportunistic pathogens. To eliminate this fecal pollution, several physico-chemical or biological operations have been carried out. Regarding the biological treatment, several studies have shown its effectiveness. In this regard, biological aerated filters (BAFs) have shown, in addition to their effectiveness in removing dissolved pollution [5]; [6]; [7], excellent performance in eliminating bacterial load, especially total coliform and *E Coli.* These BAFs consist of media made of different natures and characteristics (diameter, specific surface, etc.). This configuration enables the development of a biofilm on a larger area of colonization which enables a better exchange of matter. These media can also trap suspended material.

The choice of the size of the media is a determining factor concerning the efficiency of the treatment. In fact, the pilot studies carried out by some authors [8] and [9] in a BAF comprising supports of different sizes, have shown that those of small size (large specific surfaces) give a better efficiency of elimination of the COD than the media larger in size.

[10] evaluated the performance of four types of media: glass, plastic, pozzolan, and arlita in a pilot-scale BAF in terms of organic matter and removal of suspended matter. The COD removal efficiency with the plastic medium varied between 30% and 70%, while the removal efficiency was 67% for the arlita medium with a large area. The roughness of the media plays an important role in improving the performance of the reactor because it enables a better fixation of the biofilm on the media.

In this study, adaptation tests were carried out to evaluate the capacity of the aerated biological filter to eliminate physicochemical and microbiological pollution of fecal origin. Therefore, two R1 and R2 bioreactors each filled with plastic packing media were used. These two packing media are of the same type, but of different sizes.

II. MATERIALS AND METHODS

A. *Presentation of the Study Area*

The wastewater used in this study came from a suburb that was not connected to a municipal network and located 15 km away from the city of Casablanca. Wastewater samples collected in an open channel were placed in a 30 L can and immediately transported to the laboratory for physicochemical and bacteriological analysis.

Fig. 1. The site and sampling channel

A. Description of the Experimental Pilot

In this study, four (4) adaptations tests were carried out daily and 2 adaptations tests were tracked hourly in two pilot reactors (R1 and R2) used as an aerated biological filter, operating in batch mode (Figure 2). These two biological reactors were each initially filled with plastic packing media. They consist of a cylindrical column with 70 cm height and a diameter of 10 cm. R1 being filled with a small gray plastic packing media and R2 with a plastic packing media of the same type and the same plastic material, but larger. The characteristics of the two linings are shown in Table I. Each of the bioreactors is filled with a volume of domestic wastewater of 5 liters. The aeration is dispensed by a rigid expanded polyurethane aerator 9 cm long and 1 cm wide, placed at the bottom of the BAF and delivering airflow of 0.5 L / s. Sludge being detached from the biofilm during the biological process is removed from the BAF by a purge valve located under the aerator. Samples are taken from a valve at the bottom of the bioreactor (Figure 2). A grid was placed above the plastic packing media to prevent it from floating under the effect of air bubbles from the diffuser.

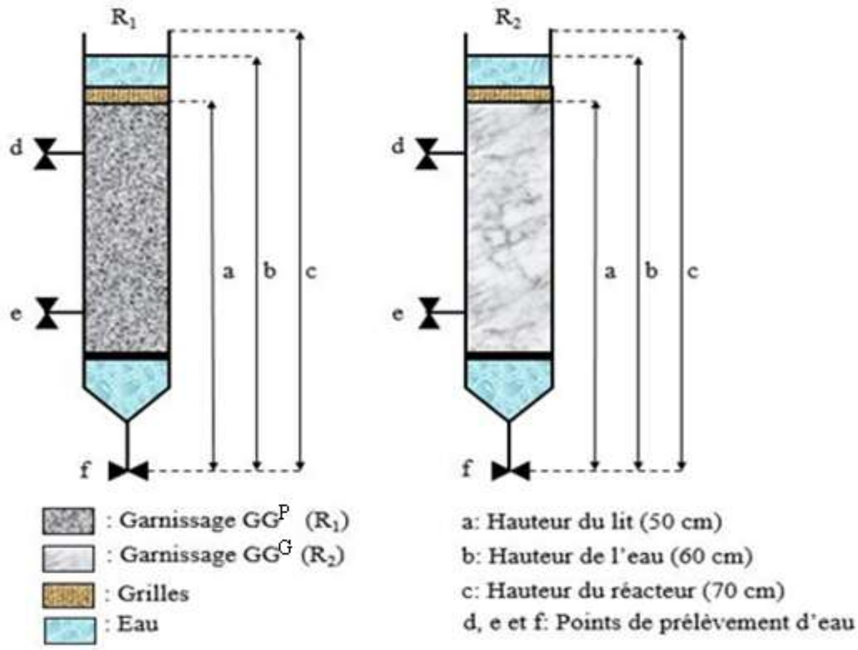

Fig. 2. Experimental Design and plastic packing used

After each test, when the Chemical Oxygen Demand (COD) reached the maximum of removal, the residual discharge is removed from the BAF and replaced with a new domestic wastewater solution. This operation was repeated several times until good acclimatization of the bacteria was achieved. These two bioreactors operated at the same time and under the same conditions.

TABLE I. Characteristics of the plastic packing media

	Packing plastic media R1	Packing plastic media R2
Color	Gray	Gray
Diameter (mm)	19.5	17.5
length (mm)	35	35
Specific surface (m^2/m^3)	~419	~869
Porosity (%)	85	87

B. *Physico-chemical Analysis of Wastewater*

The monitored parameters are: COD and turbidity, measured using the Palintest 7000 photometer, Dissolved Oxygen (OD), measured using the "Hach 40d-HQ multi Oxymeter" oximeter. PH and temperature were measured with the same device. Conductivity was determined using the "Orion Model 125" conductivity meter. The characteristics of the releases used during the different adaptation tests are presented in Table II.

TABLE II. Characteristics of raw wastewater

Physicochemical parameters	Daily tracking				Hourly tracking	
	Adapt1	Adapt 2	Adapt 3	Adapt 4	Adapt 5	Adapt 6
COD (mgO_2/l)	1550	1500	1450	1430	1400	1400
Dissolved oxygen (mg/l)	2.37	0.5	0.32	1.25	1.07	1.14
Turbidity (FNU)	470	450	440	420	422	460
Conductivity (m s/cm)	5.59	5.58	5.57	5.58	5.75	5.72
pH	7.17	6.58	6.71	7	6.73	6.99
Temperature (°C)	17.1	15.6	14.2	12.8	16.3	12.3
TC Log (UFC/ml)	7.48	7.48	3.9	3	4.3	4.23
E. Coli Log (UFC/ml)	4.25	4.01	3.48	3	2.6	0
Streptococci Log (UFC/ml)	3.79	3.75	0	0	0	0
Pseudomonas Log (UFC/ml)	3.95	3.79	0	0	0	0

C. *Bacteriological Analysis*

The identification and enumeration of total coliforms (TC) and thermotolerant coliforms Escherichia Coli (*E.Coli)* of wastewater samples were performed using the membrane filter technique; it consists of filtering a known volume ofwater on a porous membrane, calibrated to retain the bacteria (0.45µm). This membrane is then put under given conditions (temperature, incubation time and culture medium) allowing the development of bacteria:

- For total coliforms, seeding is done on TTC Tergitol medium (2-3-5 Triphényl-Tétrazolium chloride), with incubation at 37 ° C / 24 hours;

-With regard to *E.Coli*, the seeding is done on the same medium Tergitol TTC, with incubation at 44 ° C / 24 hours; thus confirmation of *E. Coli* was made on KliglerHajna medium and by seeding on peptone water free of indole to which 2 to 3 drops of Kovac reagent are added;

-The streptococci were seeded on the Slanetz and Bartley medium and incubated at 37 ° C./24 hours;

-As for the Pseudomonas, the seeding is done on Cetrimide agar and incubated at 37 ° C./48 hours.

The enumeration results of these bacteria are expressed in colony-forming units (CFU) / 100 ml of filtered water.

The analysis of the wastewater samples required dilution of 10^{-3} for raw water and 5.10^{-2} for treated water.

The reduction of the different types of indicators of fecal contamination is expressed as a percentage calculated according to the following formula:

$$\text{Abatement (\%)} = (C_i - C_f) / C_i) \times 100$$

C_i: Initial concentration at the reactor inlet

C_f : final concentration at the reactor oulet

III. Results and Discussions

A. *Tracking of the Physicochemical Parameters*

COD decreases during different adaptations (Figure 3a). High abatement rates are reached. However, the time required to achieve these rates decreases with adaptation (Table III). This improvement is probably due to the progressive adaptation of the bacteria and their development on the surface of the lining, thus forming a biofilm, favoring a better

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degradation of the pollution. The abatement rate is slightly elevated in the case of the R1 bioreactor because it contains the plastic packing media of larger surface area, thus providing a larger colonization area (TABLE I) [11]; [12].

The advanced adaptation in tests 5 and 6 (Figure 3c) yielded COD removal rates of 60.71% (R1) and 55.71 (R2) (adaptation 5) and 67.86 (R1) and 70% (R2) (adaptation 6) (Figure 3d). These rates can be further improved with new adaptations.

Adaptation tests showed a decrease in turbidity (Figure 4). This could be explained by the retention of the suspended material by a physical interception by the plastic packing media and their aggregation by bioflocculation in the biofilm, using EPS extracellular polymeric substances [13]; [14];[15]. The rate improvement during adaptations could be explained by the increase in the packing area and its colonization by more biofilm [16].

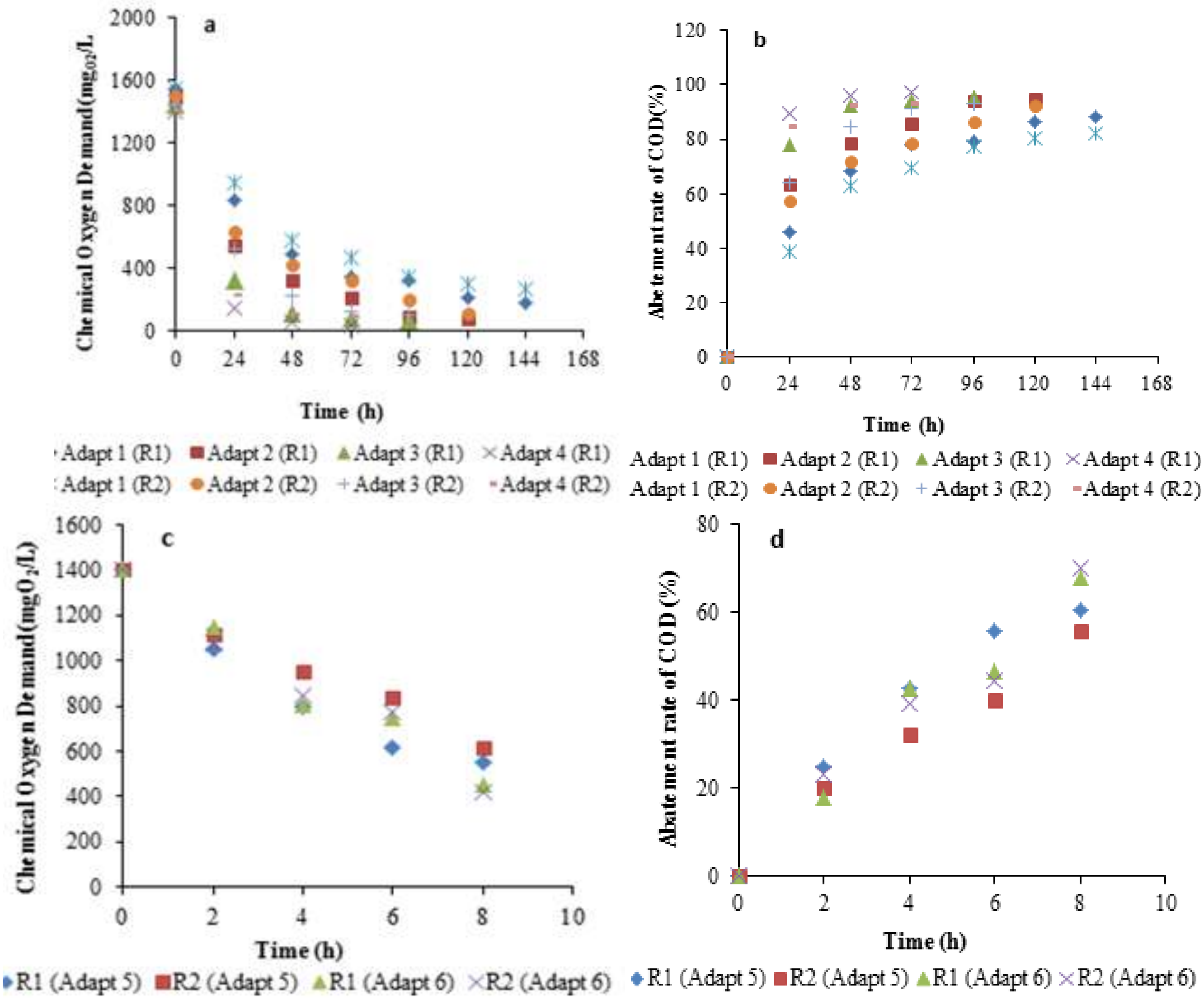

Fig. 3. Evolution of the COD and its elimination efficiency (**a**) (**b**) in daily tracking and (**c**) (**d**) in hourly tracking.

TABLE III: Initial, Final values and removal rate of COD

		C_i (mgO_2/L)	C_f (mgO_2/L)	Abatement (%)	Abatement time
Adapt 1	**R1**	1550	180	88.39	120 h
	R2	1550	273	82.39	120 h
Adapt 2	**R1**	1500	80	94.67	120 h
	R2	1500	110	92.67	120 h
Adapt 3	**R1**	1450	65	92.41	72 h
	R2	1450	105	91.38	72 h
Adapt 4	**R1**	1430	35	96.07	48 h
	R2	1430	95	92.50	48 h

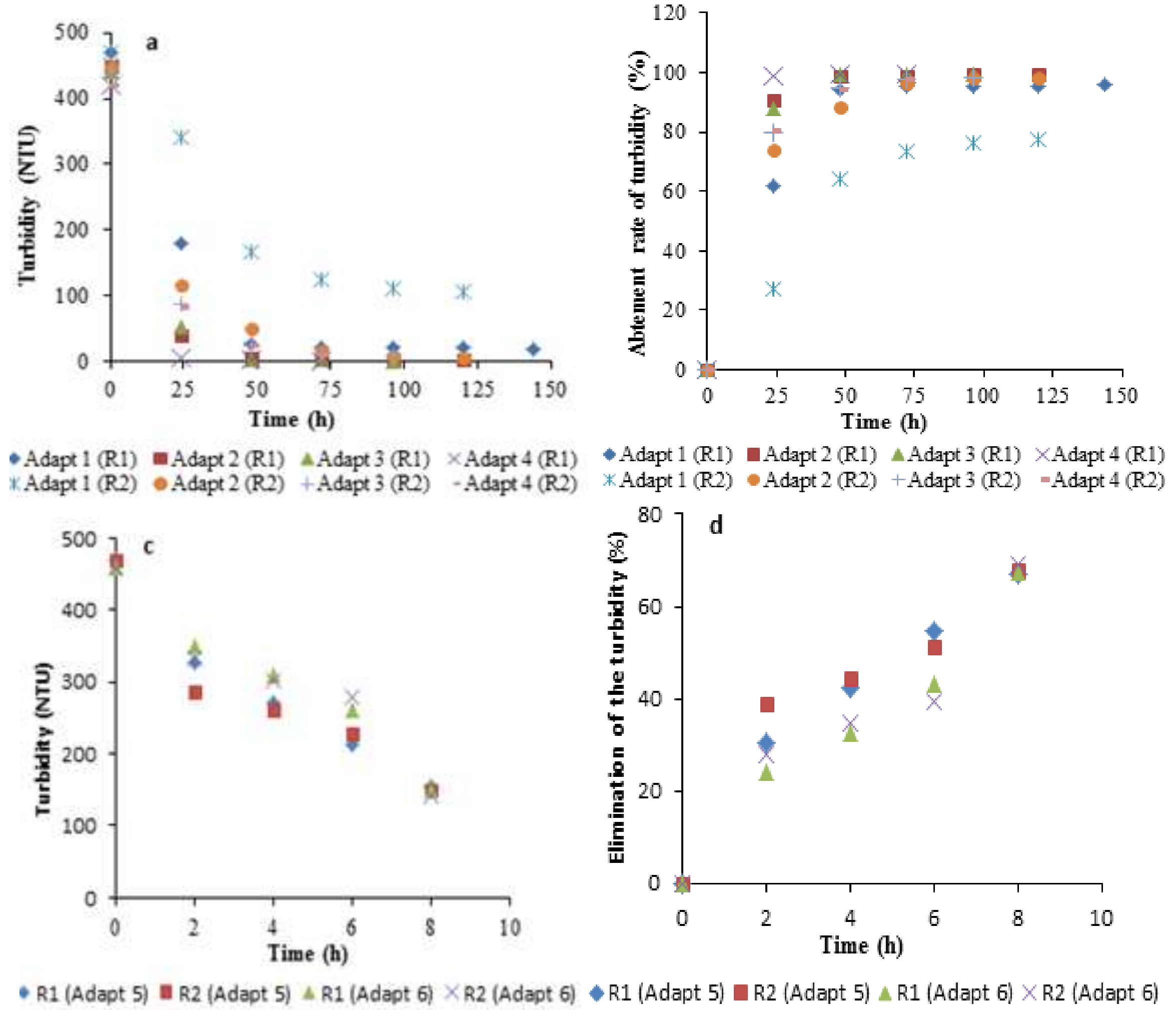

Fig. 4. Evolution of turbidity and its elimination rate: (**a**) (**b**) in daily tracking and (**c**) (**d**) in hourly tracking.

TABLE IV: Evolution of turbidity and its elimination rate during adaptations

		C_i (mgO_2/L)	C_f (mgO_2/L)	Abatement (%)
Adapt 1	**R1**	470	20.3	95.68
	R2	470	105.2	77.62
Adapt 2	**R1**	450	2.9	99.35
	R2	450	6.37	98.58
Adapt 3	**R1**	440	1.5	99.66
	R2	440	7.1	98.39
Adapt 4	**R1**	420	1.1	99.73
	R2	420	6.5	98.54

TABLE V. Evolution of the concentration of dissolved oxygen (DO), the pH and the conductivity during the different adaptations.

		OD (mg/l)		**pH**		**Conductivity (ms/cm)**	
		Ci	**Cf**	**Ci**	**Cf**	**Ci**	**Cf**
Adapt 1	**R1**	2.37	10.24	7.17	8.67	5.59	5.38
	R2	2.37	1.84	7.17	6.90	5.59	5.69
Adapt 2	**R1**	0.5	10.31	6.58	8.58	5.58	5.48
	R2	0.5	2.12	6.58	8.58	5.58	5.66
Adapt 3	**R1**	0.32	10.68	6.71	8.67	5.57	5.51
	R2	0.32	2.9	6.71	8.78	5.57	5.64
Adapt 4	**R1**	1.25	10.78	7	8.90	5.58	5.47
	R2	1.25	2.05	7	8.43	5.58	5.69
Adapt 5	**R1**	1.07	10.44	6.73	8.51	5.75	5.69
	R2	1.07	1.34	6.73	7.81	5.75	5.75
Adapt 6	**R1**	1.14	10.05	6.99	8.62	5.72	5.62
	R2	1.14	1.38	6.99	8.60	5.72	5.63

For all the tests, the results showed that the two plastic packing media used in R1 and R2 showed good turbidity elimination performance, with a slight advantage for plastic packing media of the R1 bioreactor with low residual turbidities (TABLE IV).

Raw water is characterized by a low value of dissolved oxygen (DO) concentration. After the adaptation phase, this concentration increases during adaptation tests 1, 2, 3 and 4 (TABLE V). This could be due to the improvement of oxygen transfer due to the progressive elimination of organic matter, as well as that of turbidity, and consequently the decrease in viscosity and the increase of kLa [17]. [9] obtained the same results on domestic wastewater treated in aerated biological filters operating in batch mode. This improvement is better in the case of the small plastic packing media R1. It can be explained by 1) better retention of the suspended matter, 2) better colonization by the purifying bacteria, and 3) a high radial dispersion of the oxygen bubbles allowing better oxygenation of rejection [18]; [19]; [20].

The pH of the different tests has increased for all adaptations (TABLE V). It ranged between 6.58 and 8.90. The same results were obtained by [8] and [21]. The increase could be due to the elimination of CO_2 by aeration (stripping) or to the denitrification that could occur in the biofilm, especially when its thickness increases during adaptations[22].

With regard to the conductivity, during daily adaptations (1, 2, 3 and 4) two behaviors were observed (TABLE V). First, a decrease in the conductivity (~ 24 or 48 h) probably due to the consumption of substrates as shown in Figure 3a or their biosorption on the biofilm being formed. Then, an increase probably because of the mineralization occurring in the medium as a result of the degradation of the organic matter.

During adaptations 5 and 6, different behavior is observed. The conductivity decreases and remains more or less constant after 8 hours of operation of the reactors R1 and R2. This decrease can be explained by the reasons mentioned above by daily adaptations.

The development of biofilms, more in the R1 bioreactor, could further support this behavior since the conductivities in R1 are lower than those of R2 for tests 5 and 6.

B. *Bacteriological Quality Tracking*

The average bacterial load in raw wastewater was high. Its values are shown in TABLE II. In adaptation tests 1 and 2 (Figure 5), the TC concentration remains almost constant in R1 and R2. It then decreases during adaptations 3 and 4. For *E. Coli*, the bacterial load decreases from the first adaptation, but more in the bioreactor R1. Concerning *Streptococci* and *Pseudomonas*, it was noted that their abatement was low during adaptation tests 1 and 2, but improved drastically during adaptation tests 3 and 4 to reach almost zero values.

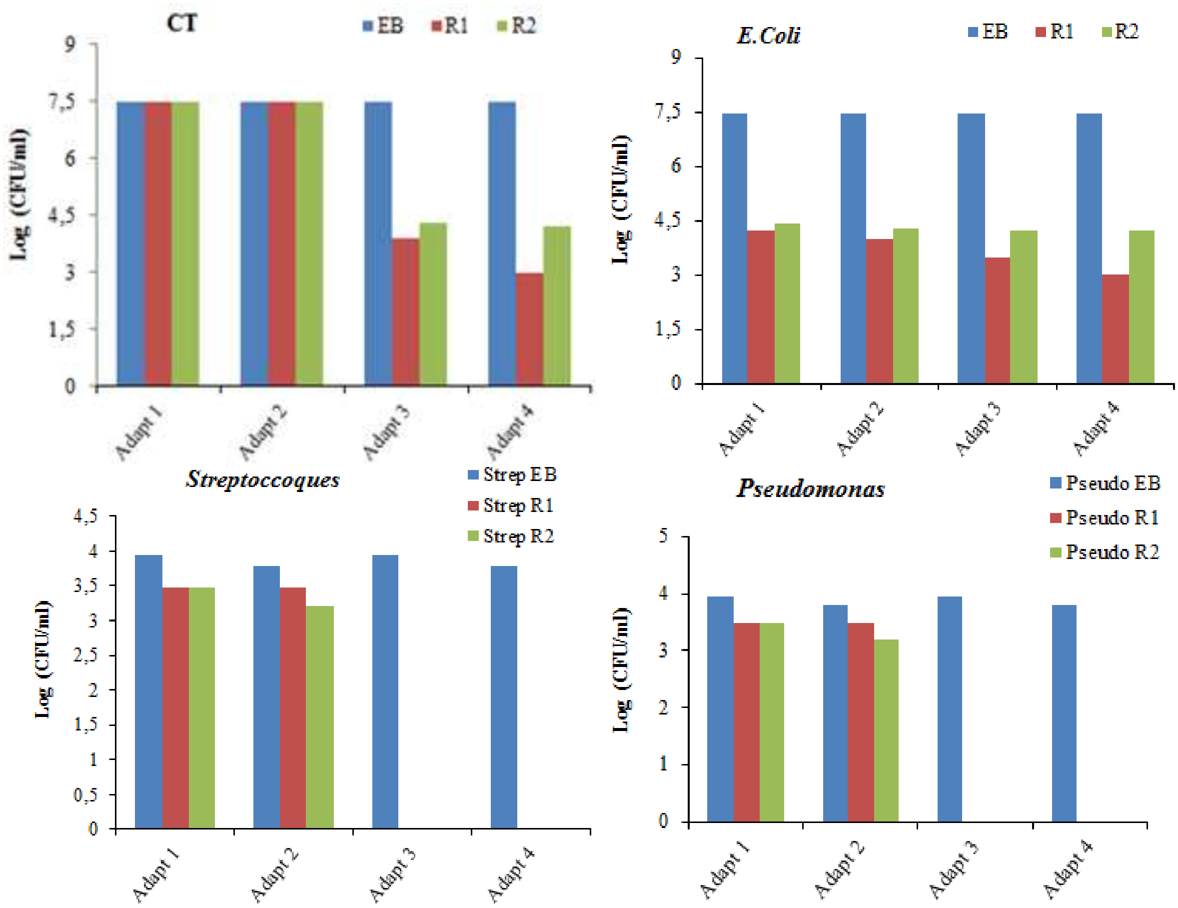

Fig. 5. CT, E. Coli, Pseudomonas and Streptococci concentrations in adaptation trials

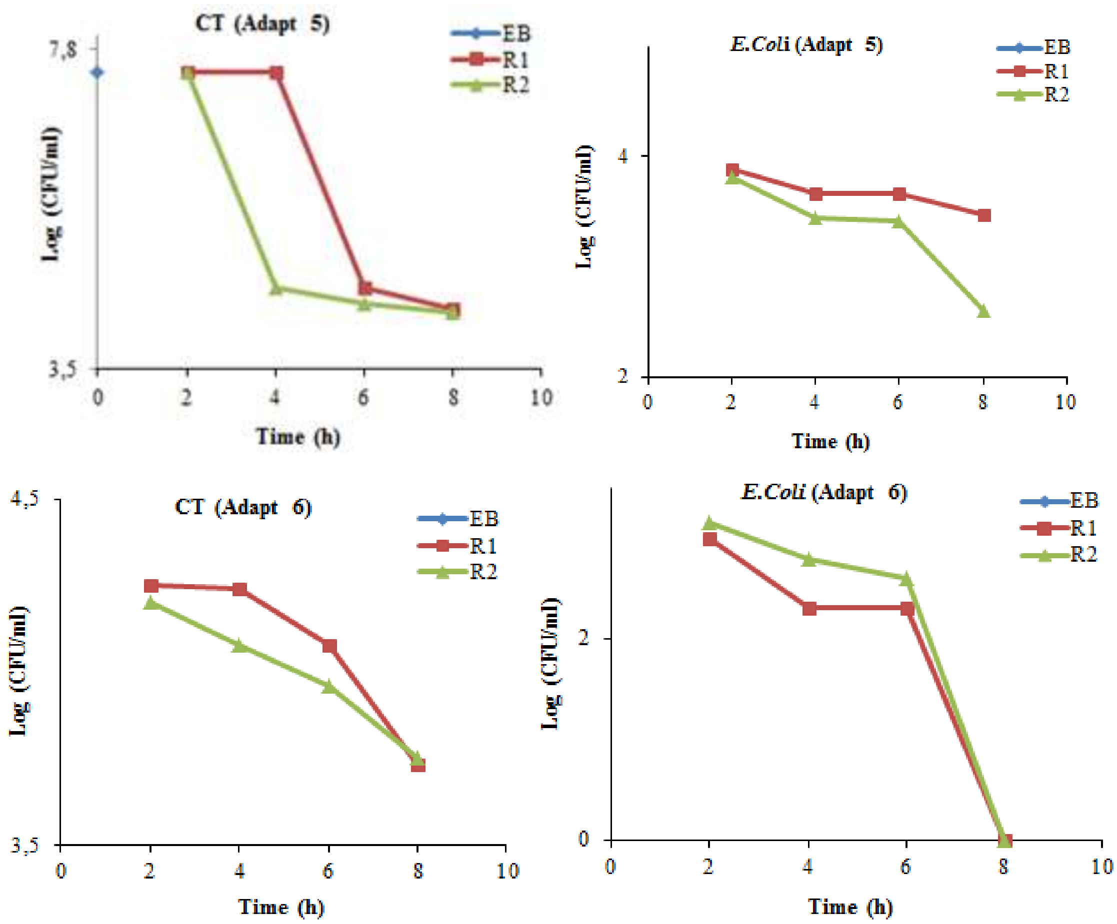

Fig. 6. Hourly tracking of total and fecal coliforms during adaptation tests 5 and 6

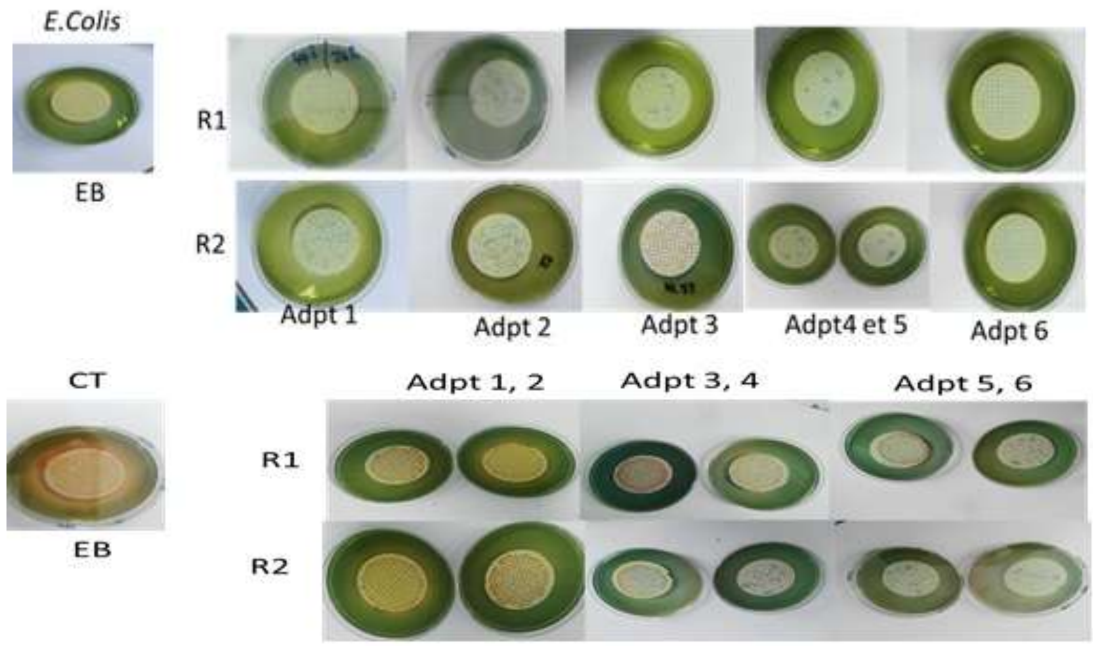

Fig. 7. Enumeration of coliforms during adaptation tests

During adaptation tests 5 and 6 (Figure 6), the bacterial load decreases more rapidly compared to previous tests. In adaptation 5, the TC abatement rate in R1 and R2 reached a value of approximately 43%, and for *E.Coli* values of 53.6% and 65.24% respectively. During adaptation 6, these rates increased, they reached about 50% for TC and 100% for E.Coli.

Figure 7 shows by images the evolution of the elimination of TC and E. Coli during the various adaptation tests.

The decrease in bacterial load during the various tests can be attributed to the adsorption phenomenon occurring in the biofilm due to EPS. [23] have shown that an increase in EPS in the biofilm could facilitate the retention of pathogenic bacteria. Pathogenic bacteria are retained because the bacterial community provides them with nutrients and shelter [24]. [25] and his collaborators reported that fecal bacteria (*E.Coli* and intestinal enterococci) are consistently present in biofilms at higher concentrations. [26] during *E.Coli* retention tests by a Pseudomonas aeruginosa biofilm, reported that in the empty spaces between aggregated biofilm structures, cell retention of *E. Coli* was observed.

IV. CONCLUSION

The results obtained in this study provided conclusive results regarding the treatment of different pollutants in domestic wastewater, including COD, turbidity and fecal matter. They highlighted the effectiveness of aerated biological filter treatment. They have enabled the role of the adaptation of the purifying bacteria to be highlighted in the elimination of the COD and the bacterial load.

The main conclusions are as follows:

- Improvement of biological degradation during adaptation tests. The degradation that is initially done over several days is achieved in a few hours during the last adaptations;
- A better adaptation for the bioreactor filled with small lining and consequently a better efficiency for all the physicochemical and microbiological parameters;
- An evolution of the different tracking parameters: COD, turbidity, OD, pH, and conductivity consistent with the biological degradation process;
- A strong abatement of total coliform pathogenic bacteria (*E.Coli*, streptococci and Pseudomonas).

The difference in plastic packing media size in both bioreactors had a significant effect on pollutant abatement. It was found from the results that the lining contained in the small R1 bioreactor had a large surface area thus providing a larger colonization area and a large exchange surface and gave slightly higher yields as the plastic packing media contained in the R2 bioreactor, which in its turn also gave good yields.

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