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Study of techniques improving the Domestic Wastewaters Treatment

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Abstract

The purpose of this article was to show the treatment capacity of bioreactors and their purification performance regarding the improvement of oxygen transfer by removing dissolved matter and suspended solids from domestic wastewater. For this purpose, three sets of tests were performed: Bacteria Adaptation in an aerated biological filter, Adsorption/Biosorption in anon-aerated Biological Filters and percolation in a trickling filter with three packed plastic media for evalued their performance. The results showed that for the adaptation tests DO concentration varied between 0.2 and 9 mg / L, which allowed a good aeration in the bioreactor. The removal performances of the organic material was 96.9% with an initial COD of 3200 mgO_2/L, the turbidity has reached an abatement rate of 97.4% with an initial value of 625 NTU. For the Adsorption/Biosorption tests in a non-aerated Biological Filter, the performances of COD and turbidity reached a yield between 24 and 61%. For percolation, the yields found varied between 41 and 68% for the COD and turbidity. The OD concentration for his two tests varied from 0.2 to 1 mg/L. These results showed the use of several wastewater treatment techniques in a bioreactor.

Key words: Adsorption, Biosorption, Biological Aerated Filter, Dissolved

1.Introduction

Domestic wastewaters caused a serious problem in arid and semi-arid regions like Morocco [1 2]. They affected the environment and people's health. These wastewaters should be treated to reduce their negative impacts. For this purpose, several techniques could be used to eliminate their pollutants. Recently, the Biological Aerated Filters (BAF) was one of the interesting techniques that could treat efficiently the domestic wastewaters [3, 4]. It was widely used in aerobic wastewater treatment and provided excellent purification performances [5, 6, 7]. These bioreactors were fulfilled by several types of packed media. Their efficiency depends upon the types of media, sizes and surface porosity etc. In this technique, oxygen was the key element in the biological purification process. However, when it was limited by colloidal and dissolved matters present in the wastewater. Their prior elimination would improve the biological degradation process by enhancing the oxygen transfer. In the presence of the biofilm, colloidal matter could be eliminated by adsorption/biosorption. Dissolved matter could be removed by a complex mechanism involving convection, diffusion, adsorption, hydrolysis and finally the degradation reaction itself. Some pollutants like heavy metals, dyes and refractory organic matter could be removed by biosorption through absorption, ionization and ion exchange. The role of the biofilm in the purification process became important when the bacteria were adapted, because their increasing population allowed them to further colonize the surface area [8, 9]. During wastewater percolation in a trickling filter, some dissolved gases like H_2S could be removed by stripping because of the spreading of the wastewater on the packed plastic media. On the other hand, the contact between the biofilm formed on the packed plastic media and the dissolved and the suspended matters increased heir elimination and improving the dissolved oxygen. This study aimed to show the purification performance of bioreactors (BAF, no-aerated biological filter and trickling filter) to eliminate the dissolved pollution and suspended solids of domestic wastewaters.

2. Materials and Methods

2.1. Presentation of the study area

The wastewater used for the purpose of this study came from a suburban area, which was not connected to a municipal network, and was located 15 km from Casablanca city. Sewage samples were collected in an open channel, placed in a bottle of 30 L can and immediately transported to the laboratory for physicochemical alanalysis.

Figure 1. Sampling site

2.2. Description of the experimental pilot

Tests of adaptation were performed in a PVC pilot reactor used like Biological Aerated Filter, and operating in batch

mode (Figure 2). It consisted of a cylindrical column with a height of 70 cm and a diameter of 10 cm. It was fulfilled with a packed plastic media **1** (Figure 2), which characteristics were shown in Table 1. It was aerated by an aerator made of rigid expanded polyurethane like a diffuser (length of 9 cm and width of 1 cm), placed at the bottom of the BAF, and giving an air flow rate of 0.5 L/s. The sludge extracted from the biofilm during the biological process was evacuated from the BAF by a purge valve located under the aerator. The sampling was made from a valve located at the bottom of the bioreactor. A grid was placed above to fix the packed plastic media to prevent its flotation by the air bubbles coming from the diffuser. These tests were carried out for 60 days until bioflm development on the packed plastic media to ensure a good degradation of the organic matter. Tests of adsorption/biosorption were made in the same reactor that one used for adaptation tests, functioning in a batch mode without aeration, with the same packed plastic media. Tests were done in triplicate. For percolation, tests were performed in three reactors functioning like a trickling filter in continuous mode. They were fulfilled respectively by packed plastic media 1, 2, 3 (Figure 2). The tests were carried out in triplicate.

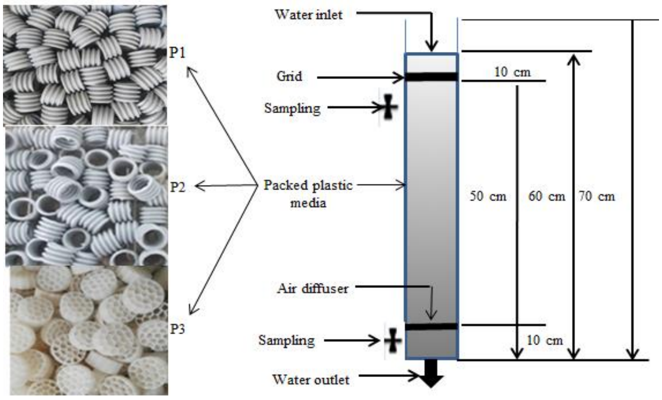

Figure 2. Experimental pilot and packed plastic media used in the reactor for the three experiments.

Table 1. Characteristics of the packed plastic media

	Packed media 1	**Packed media 2**	**Packed media 3**
Color	Grey	Grey	White
Diameter (mm)	19.5	15	25
Length (mm)	15	15	12
Specific surface (m^2/m^3)	~ 419	~ 869	~ 427
Porosity (%)	85	87	92,5

2.3. Operating protocol

In the laboratory, three series of tests have been done:

- Adaptation of the bacteria through seven tests, conducted in a BAF fulfilled with a clean random packed plastic media, operating in batch mode. After each test, when the COD reached maximum elimination, the residual reject was evacuated from the BAF and replaced by a new domestic wastewater solution, more concentrated. This operation was repeated several times until reaching good bacteria acclimatization developed on a biofilm. The characteristics of the rejects used during different adaptation tests were presented in Table 2. These experiments were conducted in three bioreactors functioning in the same time and in the same conditions.

Table 2. Characteristics of wastewater during adaptation tests

Parameters	Dilution ratio	COD (mgO_2/L)			Turbidity (NTU)			DO_i	DO_f	T°C
		L0	L	Y (%)	L0	L	Y (%)	(mg/L)	(mg/L)	
Adaptation 1	5	560	100	82.1%	170	10	94%	7.07	9.42	18.1
Adaptation 2	5	590	90	84.7%	160	8	95%	0.42	9.5	19.1
Adaptation 3	3	1000	50	95%	280	20	92%	0.47	9.23	17.6
Adaptation 4	2	1750	40	97%	280	20	92%	0.29	9.49	18.9
Adaptation 5	1	2700	90	96.7%	550	22	96%	0.29	9.12	17.9
Adaptation 6	1	3000	135	95.5%	750	28	96.3%	0.49	9.22	17.4
Adaptation 7	1	3200	100	96.9%	625	16	97.4%	0.33	8.73	18.2

- Adsorption/biosorption tests were conducted in a non-aerated BAF with packed plastic media, colonized by adapted bacteria and operating in batch mode. Four tests were performed. For each one, when the adsorption/biosorption reached its maximum, the wastewater was removed from the bioreactor. It was then replaced by a new solution. Table 3 presented the characteristics of wastewaters used in the adsorption/biosorption tests.

Table 3. Characteristics of wastewater during adsorption/biosorption tests

Parameters	Essay 1		Essay 2	Essay 3	Essay 4
COD (mgO_2/L)	L0	3000	2200	1800	1550
	L	1150	1250	1000	1000
	Y (%)	61.7%	43%	44.4%	35.5%
Turbidity (NTU)	L0	525	580	520	440
	L	380	440	300	180
	Y (%)	27.6%	24%	42%	59%
DO_i (mg/L)	0.3		0.31	0.31	0.27
DO_f (mg/L)	0.44		0.29	0.32	0.57
$Cond_i$ (mS/cm)	6.01		5.99	6.02	6.09
$Cond_f$ (mS/cm)	6.02		5.97	6.01	6.07
pH_i	7.28		7.42	7.28	7.4
pH_f	7.7		7.65	7.49	7.71
T°C	19.4		21.1	20	21.8

- Percolation of wastewaters in a trickling filter. The tests were carried out on three clean non-colonized packing media, with three rates for each one: 0.106, 0.212 and 0.318 m/h. The characteristics of wastewaters were presented in Table 5.

2.4. Methods and used materials

Samples wastewater were collected every day in the bioreactor for each tests realized for to investigate biomass evolution and the system performances. Chemical Oxygen Demand (COD), was determined according to standards methods [10, 11], Dissolved Oxygen (DO) was measured by the iodometric probe method [11] connected to the « Hach 40d-HQ multi oximeter » oximeter. The pH was measured by the same device. Turbidity was measured by the nephelometric method by the Palintest 7000 photometer with a wavelength of 540 nm [12]. The conductivity was determined by using the conductimeter « Orion model 125». The bioreactor performances could be expressed by the abatement rate and abatement, respectively by the following equations:

$\boldsymbol{Y}$ (%) = $(\boldsymbol{L_0} - \boldsymbol{L})/\boldsymbol{L_0}$ (1)

Abt= $\boldsymbol{L_0} - \boldsymbol{L}$ (2)

Where: $\boldsymbol{L_0}$: initial value (Turbidity, COD); $\boldsymbol{L}$: final value (Turbidity, COD); Y: abatement rate, Abt: abatement (Turbidity, COD).

3. Results and Discussions

3.1. Adaptation tests

The composition of domestic wastewater varied with time and rate of water used and it also depended on living conditions and habits, culture, climatic conditions, community size, and developmental level [13]. The measured parameters were: the electrical conductivity EC, pH, COD and temperature. –COD decreased during time and during the different adaptations essays (**Table 2**).The abatement rate of COD (**Figure 3a**), improved further when the bacteria responsible of the biodegradation reached a high degree of adaptation (**Figure 3b**). The monitoring of COD during adaptation tests showed that the necessary time to eliminate almost all of the COD depended on the initial wastewater concentration. Dilutions of raw wastewater were realized (**Table 2**). For a dilution ratio of 5 to 3, the concentration COD was low (between 560 mgO_2/L and 1000 mgO_2 / L,) with an elimination time higher than 72 hours. For a low dilution (between 2 and 1), the concentration of COD was between 1750 mgO_2/L and 3200 mgO_2/L, with an elimination time higher than 120 hours [13]. Regarding efficiency, good results have been obtained (**Figure 3b**) which could be explained by the adsorption of organic matter on the filter material and the persistence of bacterial activity. This phenomenon could be justified by the likely formation of biofilm especially at the level of the superficial layer of reactors, which boosted the decantation of organic matter. Evolution of the COD has indicated good performance of removal of organic matter [15]. The improvement of COD abatement was corroborated by different authors [5-16, 17]. They have shown that the abatement rate improved with the increase of the initial concentration of the COD, in adaptation tests realized on synthetic solutions of glycerol as an organic substrate. Similarly, [18] showed that in comparative tests between two BAFs, one fed by synthetic wastewater and the other by domestic wastewater with increasing COD, the biodegradation kinetics improved when the COD increased. The turbidity of water was due to the presence of finely divided suspended matter: clay, silt, silica grains, organic matter, etc. The assessment of the abundance of these materials measured its degree of turbidity. This one will be even weaker as the water treatment has been more effective [19, 20]. The wastewater presented variable initial of turbidity values (**Table 2**). During the adaptation tests, it decreased (**Table 2**). **Figure 4** showed the elimination rate; it depended on the adaptation degree during the first hours, but then it reached about 97% after 96 hours for the whole adaptation tests. The elimination of the turbidity was due to the suspended matter retention in the bioreactor, which probably occurred because of 1) the physical interception

phenomena by the packed plastic media and/or 2) the bioflocculation by extracellular polymeric substances (EPS) of the biofilm, increasing further when bacteria adaptation improved [21, 22, 23, 24, 25]

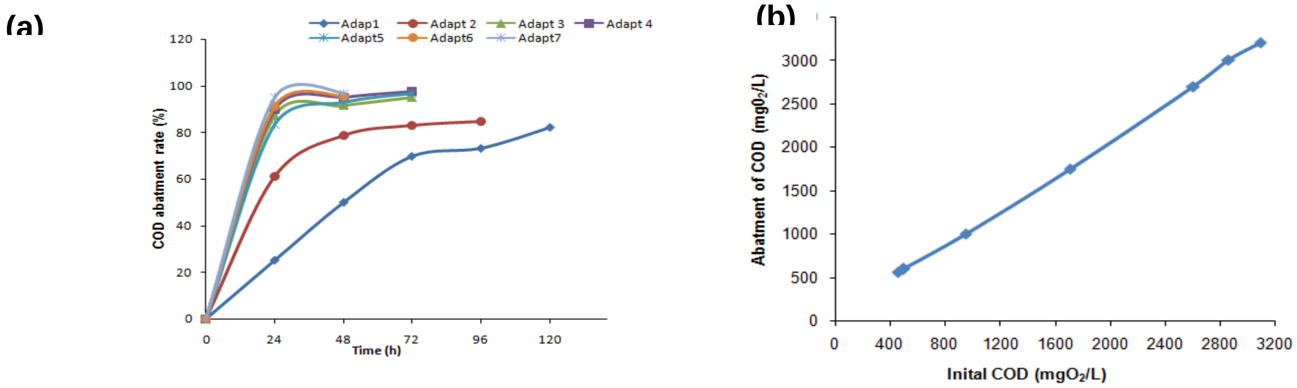

Figure 3. **a**) COD evolution during the different adaptations **b**) Evolution of the rate of reduction COD during the various adaptations.

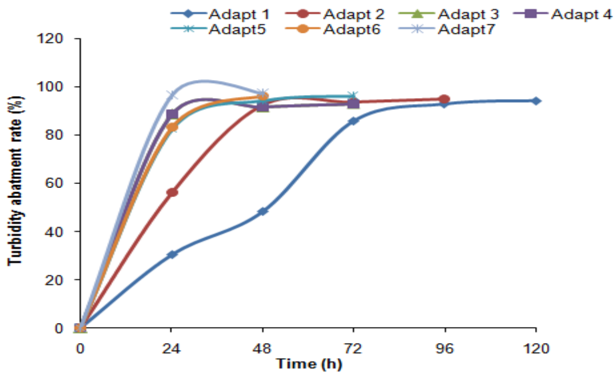

Figure 4. Evolution of turbidity abatement rate according time

According to **Table 2**, it was noted that at the exception of the 5 times diluted wastewater, which initial DO was equal to 7.07 mg/L (adaptation 1), the DO for the other samples was low and it was between 0.29 mg/L and 0.47 mg/L (**Figure 5a)**. These low values were both due to the dissolved matter which presence increased viscosity of wastewater [26] and to the suspended matter which affected negatively the gas-liquid oxygen transfer on the one hand, and on the other hand, the bacteria adaptation (with an increase in population) which accelerated the catabolism process. With time and the various adaptations, this concentration increased. For a long time, it reached about 9 mg/L for all the tests, because of the reduction of suspended and dissolved matters. The presence of dissolved oxygen conditions the aerobic degradation reactions of the organic matter. The lack of complete oxygen is generally accompanied by the appearance of H_2S in the air, resulting from the reduction of sulfur compounds present in the effluents. Thus, **Figure 5b, c** showed the effect of OD on the elimination of bioflocculation turbidity and biologically COD. It was noted that as DO concentration increased, turbidity and COD decreased.

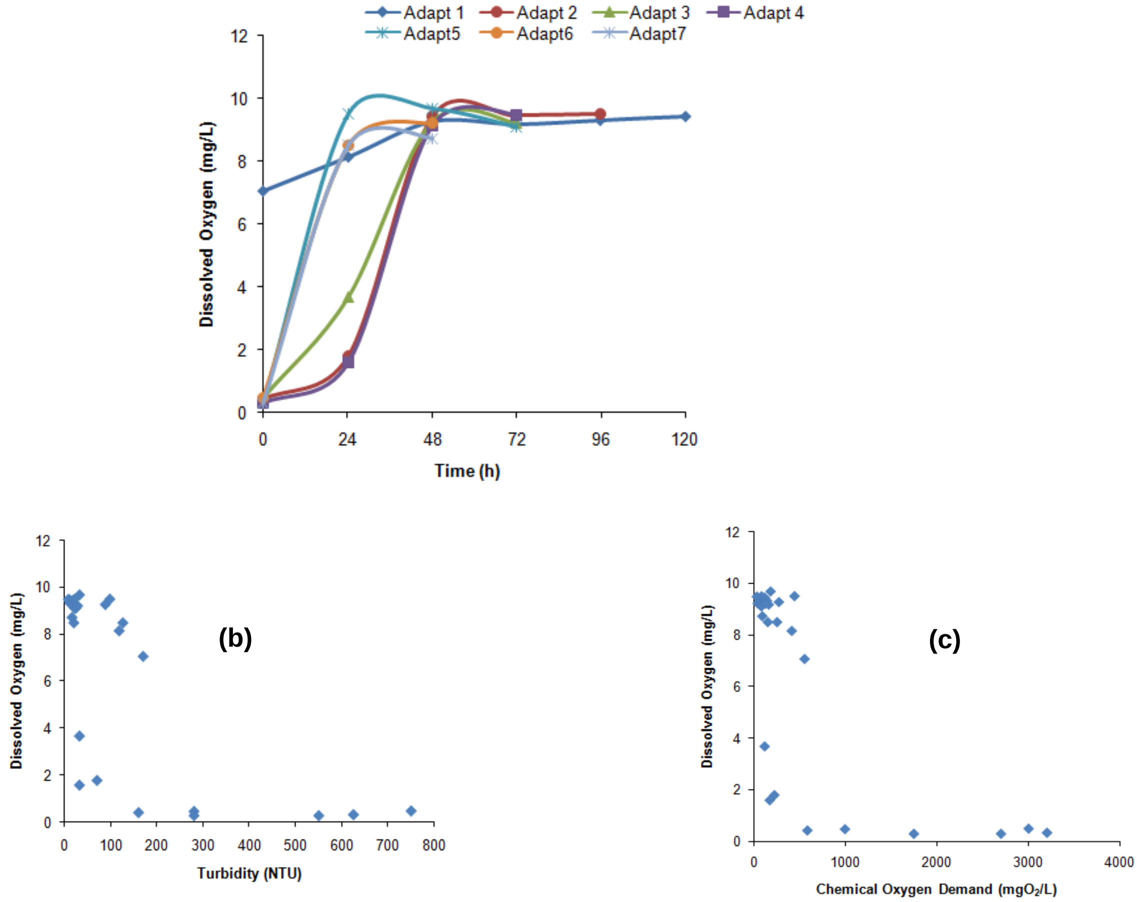

Figure 5. a) Evolution of DO **b**) Correlation between DO and turbidity **c**) Correlation between DO and COD

The conductivity presented in the **Table 4** varied according to the adaptation degree and gave values from 7.07 to 9.33 mS/cm for the first adaptation, and values varying between 2.26 and 6.17 mS/cm for the other adaptations. These values were a little bit higher than those of domestic wastewaters met in Morocco [27]. The conductivity increased for the first adaptation could be explained by the hydrolysis of long-chain organic matter into little molecules which involved the conductivity increasing, and in the same time the absence of sufficient biomass that allowed the elimination of solution ions, including metal cations, by biosorption [18]. Indeed, during the first adaptation, characterized by slow biodegradation kinetics, the packed plastic media was clean and the bacteria took some time to adjust their enzymes, and then to colonize it. The conductivity decrease was probably due to some phenomena: the biosorption of the organic matter by biofilm extracellular polymeric substances, the reduction of the mineral fraction by biological reaction as trace elements, the complexation of metals by the hydrolyzed organic matter and their biosorption on the biomass with formation of metal bridges and/or metals precipitation resulting from the pH increase (**Table 4)** [28]. The pH of the different solutions increased for all adaptations (**Table 4**), it varied between 6 and 9 with an average value of around 8 indicating a low water alkalinity. This average is in the range of wastewater in Morocco [29]. This behavior has been observed by other authors [17-30]. This could either be due to the elimination of CO_2 by aeration or to the denitrification that could be happening in the biofilm, especially when its thickness increased. [31, 32] have mentioned that the organic matter decomposition in anaerobic conditions led to the increase of pH. Otherwise, they have shown that this increase could be explained by the consumption of nitrogen compounds during the reactor aeration. They have also shown an identical pH behavior after two hours of aeration in a sequencing batch reactor.

Table 4. Values of measured of Conductivity and pH

Parameters	Dilution ratio	Conductivity$_i$ (mS/cm)	Conductivity$_f$ (mS/cm)	pH$_i$	pH$_f$
Adaptation 1	[illegible]	7.07	9.33	6.56	8.04
Adaptation 2	5	2.39	2.28	6.91	8.18
Adaptation 3	3	4.35	3.85	6.73	9.95
Adaptation 4	2	4.35	3.85	6.73	9.95
Adaptation 5	1	5.91	5.28	6.72	8.64
Adaptation 6	1	6.17	5.28	6.77	8.88
Adaptation 7	1	6.12	5.51	7.23	8.73

Adsorption/Biosorption tests

Figures 6a and **6b** presented respectively both the evolution of the COD and its abatement rate for the four tests. The COD reduced probably because of the dissolved matter retention on biofilm by biosorption. It was better when the COD was high (**Figure 6c**). This could be probably explained by a better matter transfer by diffusion in the boundary layer, which was created (in the absence of agitation) between the liquid phase and the biofilm [33, 34]).

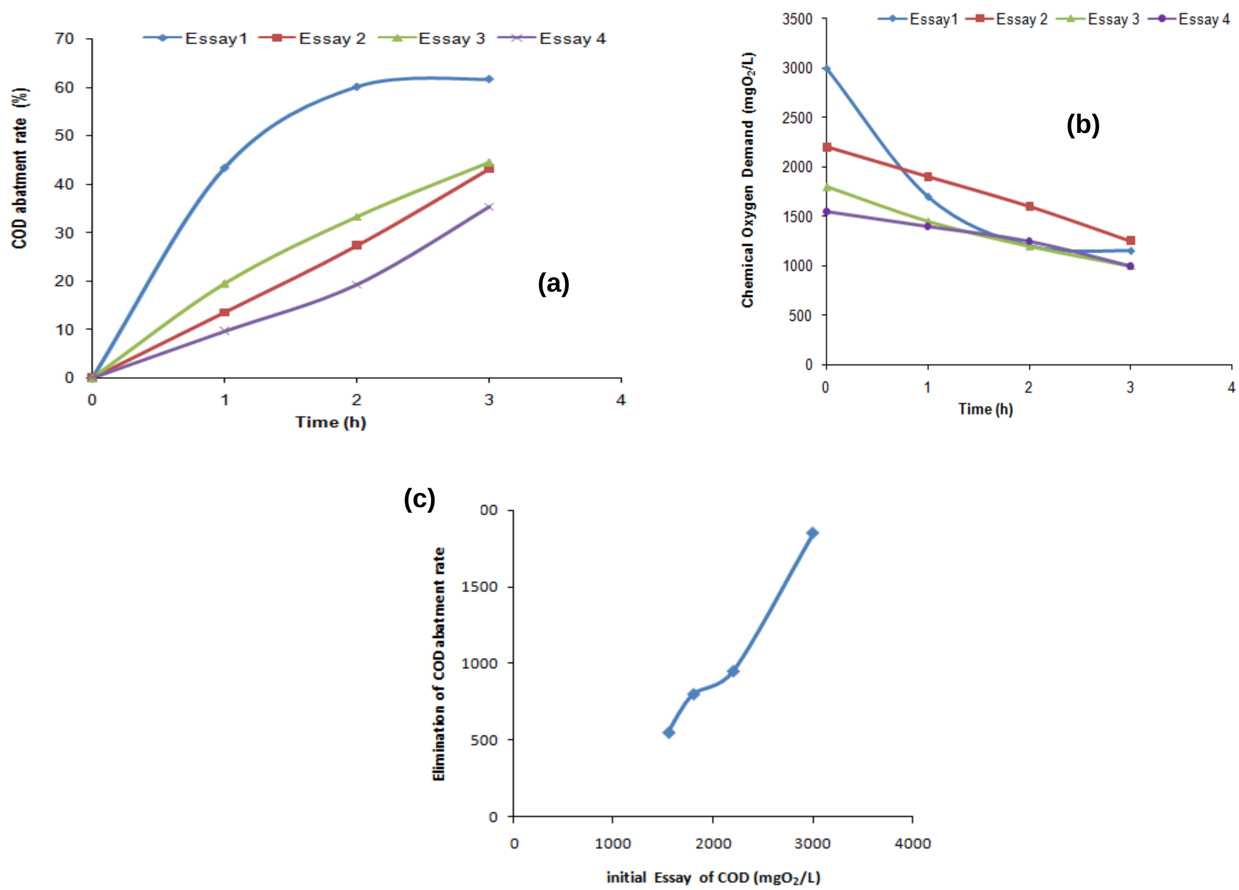

Figure 6. a) COD evolution during the different essay **b**) Evolution of the rate of reduction COD **c**) Elimination of COD abatement rate according initial COD values

Figure 7a showed that turbidity eliminated for all tests. Nevertheless, when its values increased its abatement rate decreased (**Figure 7b**). This could probably be explained by the limited biofilm capacity to absorb efficiently the colloidal matter. The eliminations of colloidal and dissolved matters seemed to be different. They occurred according to different mechanisms. Colloidal matter was eliminated by adsorption on the limited surface area of the biofilm, whereas dissolved matter eliminated by biosorption on a high surface area including that of the internal porosity of the biofilm [35].

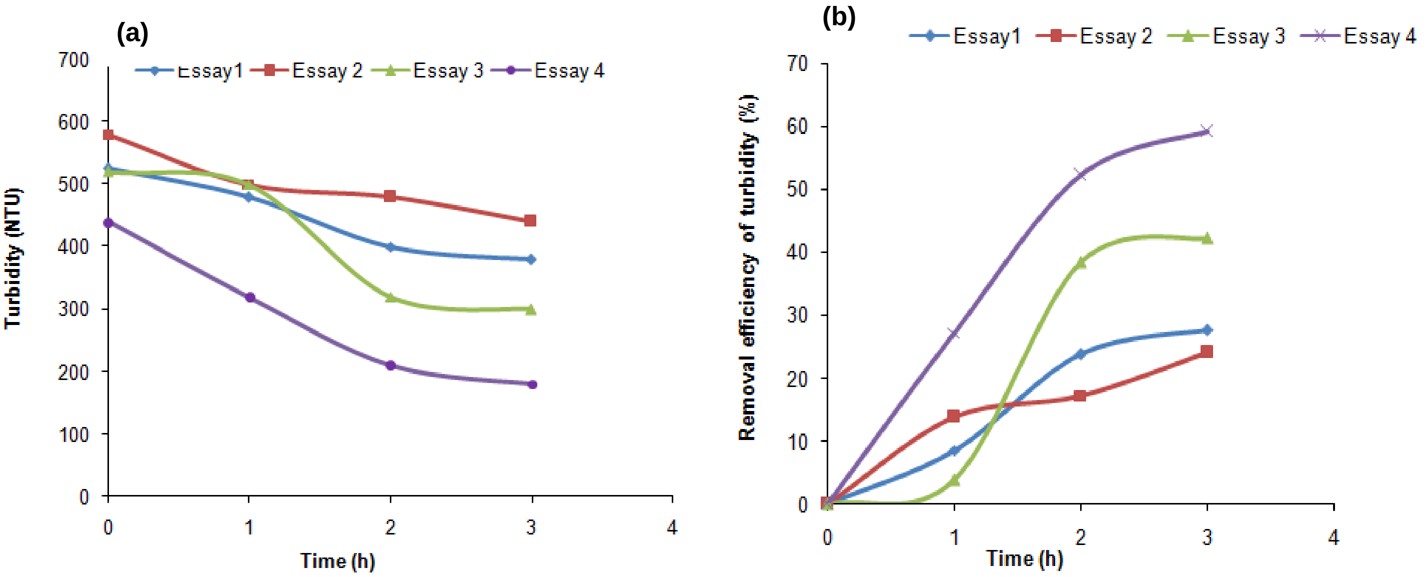

Figure 7. a) Evolution of turbidity for all tests **b**) Removal efficiency of turbidity according time.

Figure 8a showed that the concentration of dissolved oxygen varied between 0.26 mg/L and 0.63 mg / L. Its values remained more or less constant, particularly for the second and the third test. It improved in the fourth test after two hours, probably because of the dissolved matter retention in the biofilm and the bioflocculation of the suspended matter. From Table 3, it was noted that the OD concentration varied very slightly during adsorption / biosorption tests and only Trial 4 showed a slight increase in OD concentration (0.27 and 0.57 mg / L). This highlighted the increase of DO and the decrease in turbidity and COD (**Figure 5b, c**). So the transfer of DO has improved by eliminating turbidity and COD. The conductivity varied very slightly for all the tests (**Table 3**), in a range between 5-6 mS/cm. This small variation was probably due to concomitant reactions which have contradictory effects: 1) the elimination of electrical entities present in the solution by several phenomena: biosorption of organic ionized molecules, of metals [36] and of metal complexes, and formation of metal bridges in the biofilm, etc. [32], and 2) endogenous respiration, which could release ions in the solution following the destruction of microorganisms or the resolubilization of some metal precipitates when the pH increased (**Table 3**). For pH, there was at first an increase for all the tests and then stabilization around an average value of7.7 (**Table 3**).This was already observed in the previous adaptation tests. The increase in pH might be due to the denitrification process [37, 38].

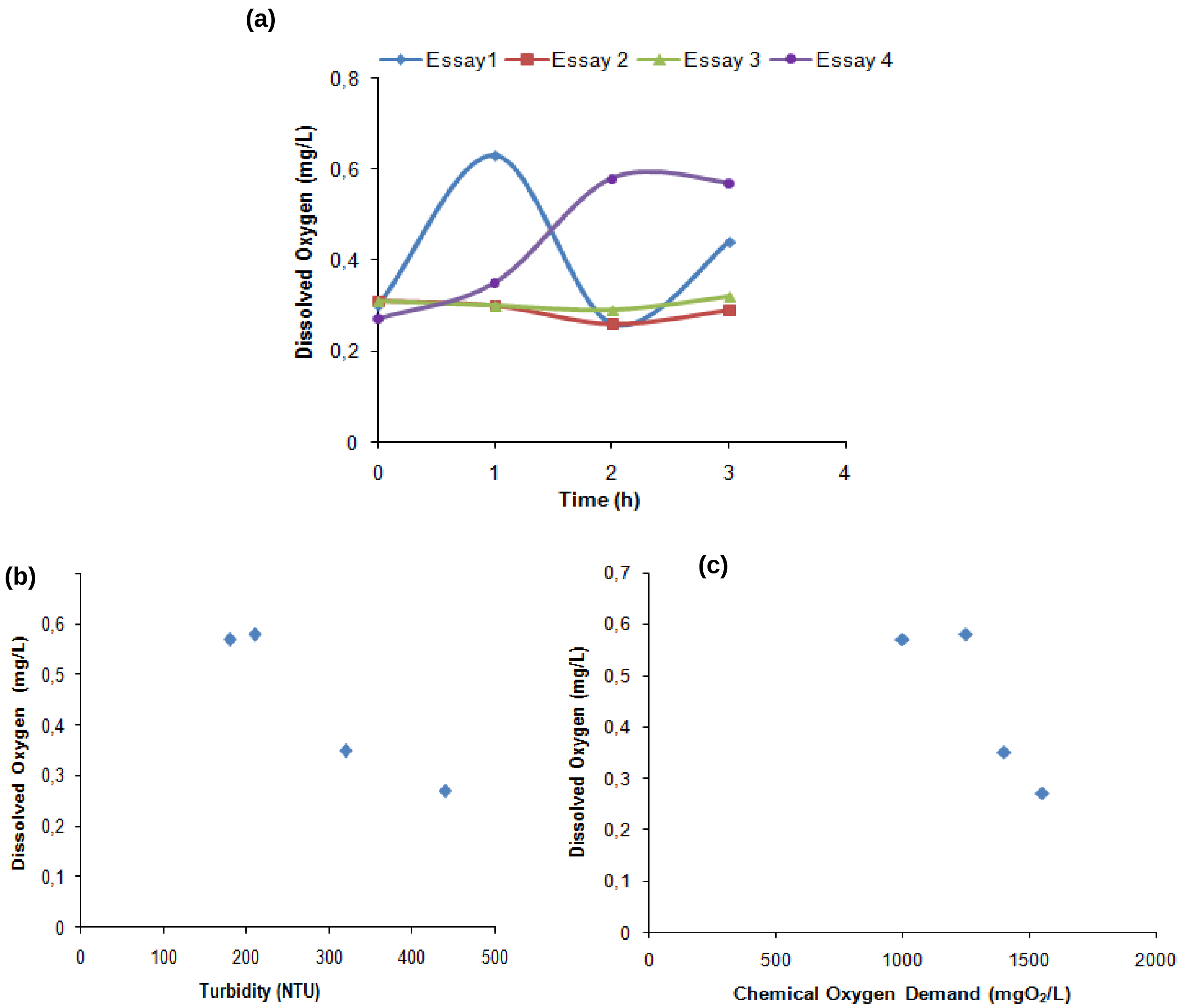

Figure 8. a) Evolution of the turbidity **b**) Evolution of the abatement rate of the turbidity.

3.3. Percolation tests

The percolation tests, giving the results presented in the following **Table 5**, showed that COD and turbidity were substantially reduced. The removed COD corresponded probably to the gaseous compounds, such as H_2S and other volatile organic compounds dissolved in the wastewater. Turbidity decreased due to retention of the suspended matter on packed plastic media P1, P2 and P3, probably by interception and decantation on its high surface area. The removal rates depended on the percolation rate and the packing media type. It varied between 26.9% and 68.4% for turbidity and between 48.14% and 65.90% for COD. Conductivity decreased slightly in all tests (**Table 5**). This could probably be justified by the volatile matter elimination, in particular H_2S which resulted in a shift of chemical equilibrium to hydrogen sulphide formation (Reaction 1 and 2).

$$H_2S \Leftrightarrow H^+ + HS^- \qquad (1)$$

$$HS^- \Leftrightarrow H^+ + S^= \qquad (2)$$

This could be confirmed by the pH increase during the various tests (**Table 5**), resulting from the elimination of H_2S. As with the Adaptation and Adsorption / Biosorption assays, the correlation between increasing DO and decreasing turbidity and COD has been shown to improve OD transfer. For the percolation tests, it was noted that the

concentration in OD was very low (**Table 5**) because the time required for the development of the bacteria in the reactor was too short.

Table 5. Results of the different trickling filter tests on the packed plastic media at different Peripheral rate (m/h)

Parameter	**Packed media 1**			**Packed media 2**			**Packed media 3**		
	Peripheral speed (mL/min)			Peripheral speed (mL/min)			Peripheral speed (mL/min)		
	0,106	0,212	0,318	0,106	0,212	0,318	0,106	0,212	0,318
L_0	2400	2700	2700	2400	2600	2600	2200	2200	2700
L	750	950	1400	1400	1500	1400	1250	1250	1050
COD yield	68.7	64.81	48.14	41.67	42.3	46.15	43.18	43.18	61.11
Initial turbidity	900	900	520	400	410	500	380	410	380
Final turbidity	420	440	380	210	170	160	120	170	140
Turbidity (Y %)	53.3	55.5	26.9	47.5	58.5	68	68.4	58.5	63.1
DOi	0.23	0.21	0.27	0.29	0.28	0.22	0.31	0.31	0.31
DOf	0.24	0.24	0.34	0.97	0,19	0.16	0.41	1.02	0.31
pHi	7.29	7.29	7.45	7.47	7.87	8.17	8.11	8	7.95
pHf	8.34	8.37	8.26	8.7	8.49	8.53	8.73	8.34	8.41

Conclusion

All the tests carried out during this work gave convincing results with regard to the limit parameters of oxygen transfer: suspended solids and dissolved solids. The adaptation tests showed that the elimination of these two parameters improved with the increase of the DO The biosorption and the percolation tests gave interesting elimination rates. So, they could be used as a pretreatment process. In addition, they required very little energy.

These tests (Adaptations, Biosorption and percolation), performed separately, showed more or less similar performance results, but they were different in terms of treatment time. The percolation performed on a clean packed plastic media seemed to have better treatment dispositions; under real operation, the clean packed plastic media would be colonized by adapted bacteria, so that could further involve high treatment performance. In addition to percolation, the phenomenon of biosorption would also occur. This could substantially improve the elimination rate of suspended and dissolved matter and improve the oxygen transfer. The obtained results showed excellent performances and revealed that BAF constituted a process with better provisions, comparatively to the conventional processes like activated sludge, trickling filter, natural lagoon or planted filter, etc. This ascertainment was confirmed by several authors. So, it could be integrated in the sanitation program for rural cities (PNAR) as a low-cost treatment system, to treat domestic of rural cities which they were not connected to a sanitation network.

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