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Treatment study of domestic wastewaters with low and high loads in an aerated biological filter

S. Ngala Nsakou[1, 2], B. Lekhlif [1, 2], El H. Malil [1]

[1]*Applied Research Team on Polymers of Higher National School of Electricity and Mechanics, University Hassan-II. Km 7 El Jadida Road B.P 8118 Oasis, Casablanca Morocco.*

[2]*Research team Hydrogeology, Water Treatment and Climate Change, Environment Engineering Laboratory of School Hassania of public works, Km 7, El Jadida Road, B.P 8108 Oasis, Casablanca, Morocco.*

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stenelviengala@gmail.com
Phone: +212604004282

Abstract
This work was conducted to study the biological treatment of the domestic wastewaters in a Biological Aerated Filter with plastic packing media. The necessary time to eliminate the quasi-totality of the COD depended on the reject initial concentration and the adaptation degree. For the first adaptation, the time corresponding to an abatement rate of 100 % was 7 days for the low pollution load, whereas for the high pollution load this time was 19 days. For the advanced adaptations, the abatement occurred only during 8 hours with COD elimination rates between 57 and 96%. The turbidity decreased for all the tests, except that corresponding to the first adaptation relative to the high pollution load, it increased in first from 108 to 235 NTU due to the increasing of the population of the dispersed non-adapted bacteria. Then it decreased because of some factors (decantation of the bacteria and their aggregation on biofilm by biofloculation). For the high pollution loads the initial DO varied between 0.30 and 0.53 mg/L; at first, it increased and reached value varying between 3 and 13 depending on the adaptation degree and then it decreased. For the low pollution loads, the initial DO varied between 2 and 6 mg/L, at first, it increased and reached a value varying between 4 and 9mg/L and then it decreased except for an advanced adaptation where the DO decreased from the beginning. Concerning the pH, it varied between 6.5 and8.5 during all the tests of adaptations.

1. Introduction
Domestic wastewaters became a serious problem towards the environment and health, resulting in several negative impacts[1-2]. To mitigate these impacts, the Moroccan state had launched in 2006 a program for sanitation of cities and urban centers, entitled the "National Liquid Sanitation and Wastewater Treatment Program" (PNA). For rural areas, the sanitation was insufficiently developed. But recently, a study was conducted to define the ''National sanitation program and the reuse in the rural areas in Morocco" (PNAR), to generalize sanitation to all rural agglomerations. This program had integrated several processes of wastewater treatment like the natural lagoon [3], the planted filter [4],and the sand filter [5-6], considering specificities of rural area, like socio-economic environment (habitat, culture), climate, geology, etc.

Intensive purification processes such as aerated biological reactors (BAFs) was not listed among the processes retained by the PNAR.BAF is a flexible reactor, which provides a small footprint process option at various stages of wastewater treatment. Basic operating principle of BAF is based on a conventional biofilter operating in a submerged mode. They are widely used in the treatment of different types of rejection[7]. The literature indicated that they had excellent performances and could be operated to higher loads than trickling filter and activated sludge processes and required less equipment [8]. They were successfully used to treat a variety of wastewaters (municipal and industrial). In addition, in a single unit operation, they could be applied to the treatment of refractory wastewaters ([9-11]). They allowed good removal of organic and solid matter improving the oxygen transfer, and could go as far as nitrification-denitrification and removal of phosphorus.

The aeration might erode the biofilm and prevent the filter media clogging, and also ensured good contact between substrate and microorganisms. On the other hand, the BAFs were easy to install, required small space than the other processes, particularly the extensive ones like natural lagoon, planted filter, sand filter, etc., and had a relatively low capital cost investment.
In comparison with conventional activated sludge processes, the BAFs could work with volumetric organic loads five times higher than that commonly applied. They had reduced Hydraulic Retention Times(HRTs) and Solid Retention Times(SRTs) extended. The concentration of active biomass in the reactor was higher than in an activated sludge process. It was maintained in the system for a longer period of time. So, it could facilitate the biodegradation of some refractory substances, and would produce higher quality effluents.
In a study ordered by the Canadian Council of Ministers of the Environment, it was indicated that the BAFs could remove several pollutants (Biochemical Oxygen Demand BOD, Ammonium NH_4^+, NitrateNO_3^-, Phosphorus P, Solids). Otherwise, Lazarova et al.[12] have conducted a comparison between some processes used for the grey water treatment. They found that the required total volumes for BAF as well as its energy demand were the lowest, compared to the Membrane Bioreactor(MBR), Sequencing Batch Reactor(SBR) and the activated sludge. All these elements presenting the BAFs advantages showed that they do not require large areas and were more energy efficient and were efficient. So, they could be considered as low-cost bioreactors.

In order to study the possibilities of using the BAFs in the purification of small communities' discharges, particularly in rural areas, tests were carried out on domestic wastewaters from the campus of the Hassania School of Public Works with low loads, and from a suburban site (Hay Iraqui) located at 15 km from Casablanca (Morocco) with high loads. These tests were conducted in two BAFs, working in a batch mode, fulfilled of a random packing media made of plastic because of its low density and its high specific surface area to fix great amount of biofilm. Its size was bigger than those usually used in conventional BAFs (Biolite, pozzolana, arlita, etc.) [13-14] to ensure a good air circulation and evacuation of detached pieces of biofilm colonizing the plastic packing media.

2. Material and Methods

2.1. Study area

The studied domestic wastewaters came from the campus of the Hassania School of Public Works (EHTP), which hosted nearly 1000 students, and from a suburban site located about fifteen kilometers from Casablanca. The wastewaters of the two sites were collected and was put in 30liter cans and immediately transported to the laboratory for analysis.

2.2. Description of the experimental pilot

The aim of this work was to characterize the physicochemical parameters of wastewaters, to carry out tests to evaluate the adaptation of purifying bacteria and to assess the treatment performances in the BAF. For this purpose, a cylindrical column made of PVC as a pilot and operating in batch mode(Figure 1). It was implemented in the laboratory.

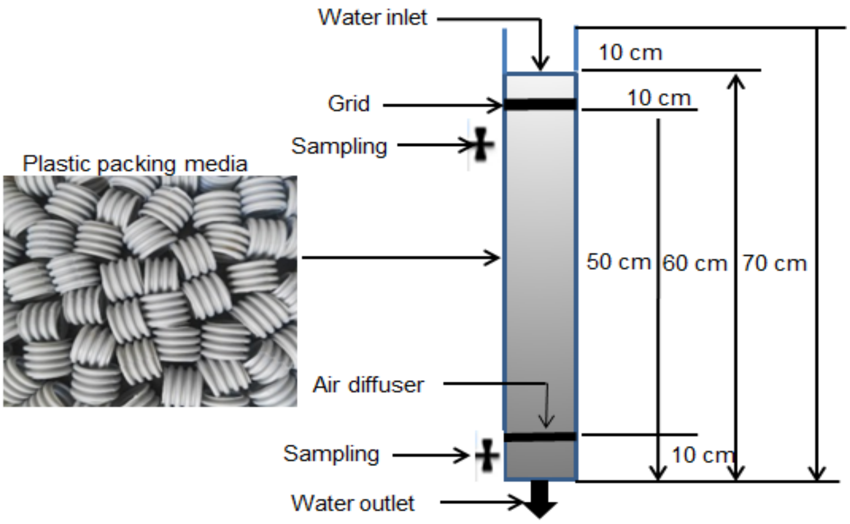

Figure 1: Experimental Design

The column is of 70 cm height and a diameter of 10 cm. It was fulfilled of a random plastic packing media, which characteristics are shown in Table 1. It was aerated by a polyurethane foam diffuser (9 cm length and 1 cm width), placed horizontally at the bottom of the BAF, providing an air flow rate of 0.5 L/s. A purge valve located under aerator allowed evacuation of treated wastewater and the sludge detached from biofilm. Samples were taken 15 cm above the polyurethane foam diffuser. A grid was placed above the plastic packing media to prevent its flotation by the effect of air bubbles. The characteristics of wastewaters used in different tests are shown Table II.

Table 1: Characteristics of the plastic packing media

Materials	PVC
Color	Grey
Porosity	87%
Length (mm)	15
Diameter (mm)	19.5
Average specific surface (m^2/m^3)	~500

Table 2: Physicochemical characteristics of the two types of wastewater

		Parameters	COD (mg O_2/L)	DO (mg/L)	Turbidity (NTU)	Conductivity (mS/cm)	pH	T°C
EHTP wastewater	Daily monitoring	Adapt 1	900	4.62	74	6.11	8.34	23.3
		Adapt 2	150	5.48	52	5.92	8.25	23.6
	Hourly monitoring	Adapt 3	115	2.54	106	6.13	8.11	22.6
		Adapt 4	101	5.94	96	5.59	8.25	22.4
Hay Iraqui wastewater	Daily monitoring	Adapt 1	2350	0.3	108	8.25	7.11	25.4
		Adapt 2	1700	0.37	90	8.3	6.86	26.4
		Adapt 3	850	0.45	190	8.29	7.01	26.1
	Hourly monitoring	Adapt 4	1600	0.49	185	8.9	6.98	27
		Adapt 5	2350	0.38	180	8.26	6.88	27
		Adapt 6	1750	0.53	225	8.2	6.95	26.4

2.3. Monitoring parameters and equipment used

During the different tests, the monitoring of the treatment performances was conducted by measuring some parameters such as: Chemical Oxygen Demand (COD), Turbidity, Dissolved Oxygen (DO), Conductivity and pH, measured in five samples to determine the average of the measurements. The COD and turbidity were determined by a photometer type Palintest 7000. The DO was measured by Hach sensor 40d-HQ-Multi parameters which could also measure water temperature. Conductivity was measured by an Orion model 125.

2.4. Operating protocol

Two series of adaptation tests were conducted in two BAFs, each one filled with 5 liters respectively, of the wastewater of the Hassania School of Public Works campus and the wastewater of the suburban site (Hay Iraqui). During the first test of each series, the BAF was fulfilled of a clean random plastic packing media. For the others tests, experiments were conducted on a plastic packing media colonized by a biofilm (developed during the other adaptation tests) [15-16].The follow-up of the biodegradation was provided by parameters mentioned above. When the COD reached a minimal value, the bioreactor solution was evacuated and fulfilled again of a new wastewater solution.

3. Results and discussion

3.1. Analysis of sampling results

The composition of domestic wastewater varied in the different samples. Generally, this variation depended on time and rate of water used and depends upon the life quality, living habits, culture, climatic conditions, community size, and developmental level [17].

The temperature varied between 22.4 and 27.00°C for all domestic wastewaters. The average value for the rejects of the EHTP site was 23°C, whereas the one of the Hay Iraqui was 26°C. This parameter had a considerable influence on the organic biodegradation, the nitrification and the denitrification [21-18-19].
For the CODit was noticed that the values of the EHTP site rejects varied between 100 and 900 mgO_2/L with an average value of 316.5 mgO_2/L. They were inferior to those of the Hay Iraqui site, which varied between 1600 and 2350 mgO_2/L with an average value of 1925 mgO_2/L (Figure 2).The COD values of both sites were in the range of those of domestic wastewaters in Morocco [20-22].
The concentration of the dissolved oxygen (DO) presented high values for the EHTP site rejects (Figure 2). It varied between 2.54 and 5.95 mg/L with an average value of 4.65 mg/L. They were superior to those of the Hay Iraqui site, which varied between 0.30 and 0.53 mg/L with an average value of 0.42 mg/L. These values were in the range of those met habitually in Morocco for domestic wastewater [21].
The lowest values of the DO of the Hay Iraqui site were due to the high values of the COD (including surfactants), the turbidity (Figure 3) and the conductivity (including salts) (Figure 3), which affected negatively the oxygen transfer, as shown by some authors [23-27].The values of DO might be also due to the temperatures, which they were higher in domestic wastewaters of a suburban site than those of the EHTP site.

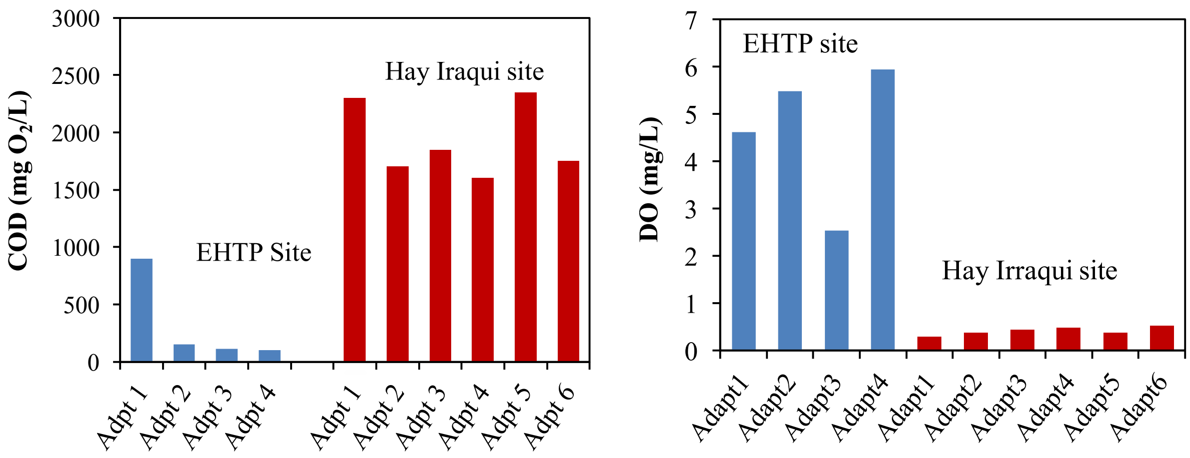

Figure 2: COD and Dissolved Oxygen of two sites wastewaters

The rejects of EHTP site presented the lower values of the turbidity, it varied between 52 and 106 NTU with an average value of 82 NTU (Figure3). Those of the Hay Iraqui site varied between 108 and 225 NTU with an average of 179.6 NTU. These values of turbidity were in the values range of city rejects in Morocco [22].

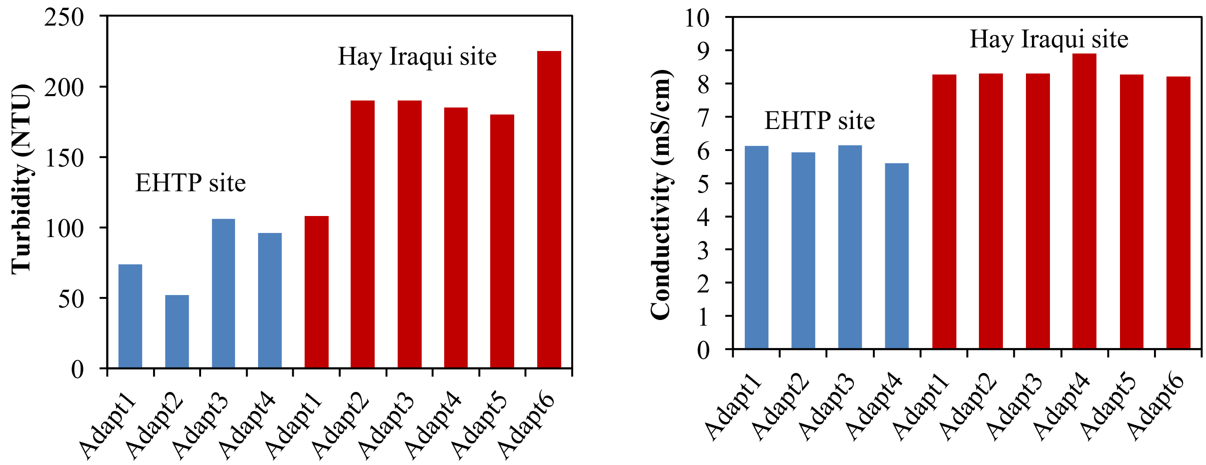

Figure 3: Turbidity and Conductivity of the two sites wastewaters

Concerning the conductivity (Figure 3), the lower values in EHTP site wastewaters were observed. It varied between 5.59 and 6.13 mS/cm with an average value of 5.93 mS/cm. Those of Hay Iraqui site varied between 8.2 and 8.29 mS/cm, with an average value of 8.36 mS/cm. These values were a little bit higher than those of domestic wastewaters met in Morocco [21,28].

The pH of the two rejects varied between 6.86 and 8.34. The average value for the rejects of the EHTP site was equal to 8.24, whereas that of the Hay Iraqui site was equal about 7. These values were in the range of those of wastewater met in Morocco[20].

3.2. Interpretation of adaptation tests results

The results of the adaptation tests for the two rejects were presented in the following Figures 4, 5, 6, 7 and 8.

The monitoring of COD during the first adaptations (on clean plastic packing media) showed that the necessary time to eliminate the quasi-totality of the COD depended on the reject initial concentration.

For the domestic wastewater of the EHTP site (900 mgO_2/L), the time corresponding to an abatement rate of 100 % was 7 days, whereas for the reject of Hay Iraqui (2300 mgO_2/L) this time was 19 days (Figure 4).

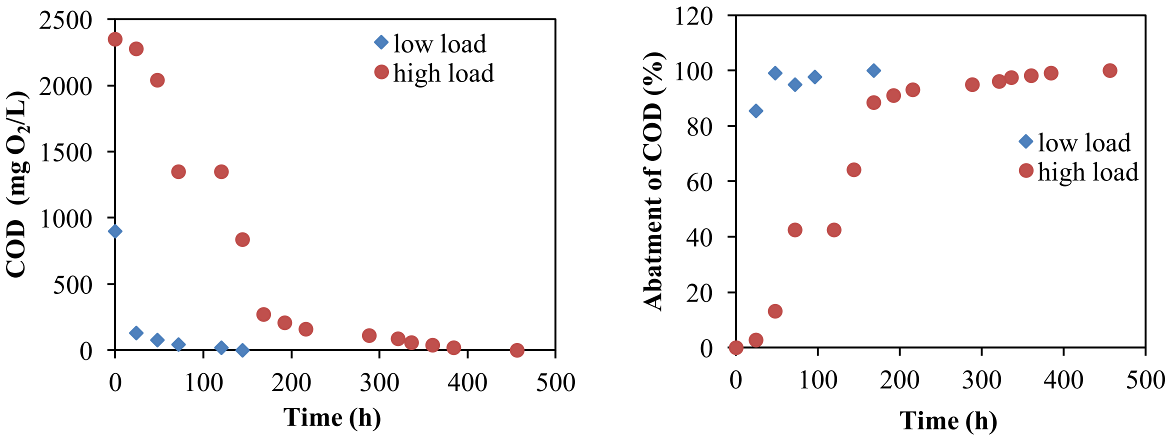

Figure 4: Evolutions of the COD and the abatement rate during the first adaptations of two sites

The advanced adaptation (Figure5)presented good COD elimination rates; the abatement occurred only during 8 hours; it reached values between 57 and 96%. The improvement of yields with low biodegradation times could be explained by the good acclimatization of the bacteria along successive adaptation tests, inducing a development of adapted bacteria cells to the nature of wastewater, in particular to their organic substrate, by forming a biofilm which could develop on the area of the plastic packing media, where the elimination of the dissolved matter was done by bioabsorption on the biofilm and then by their diffusion.This phenomenon is more favored in the case of the low concentration [13,29].

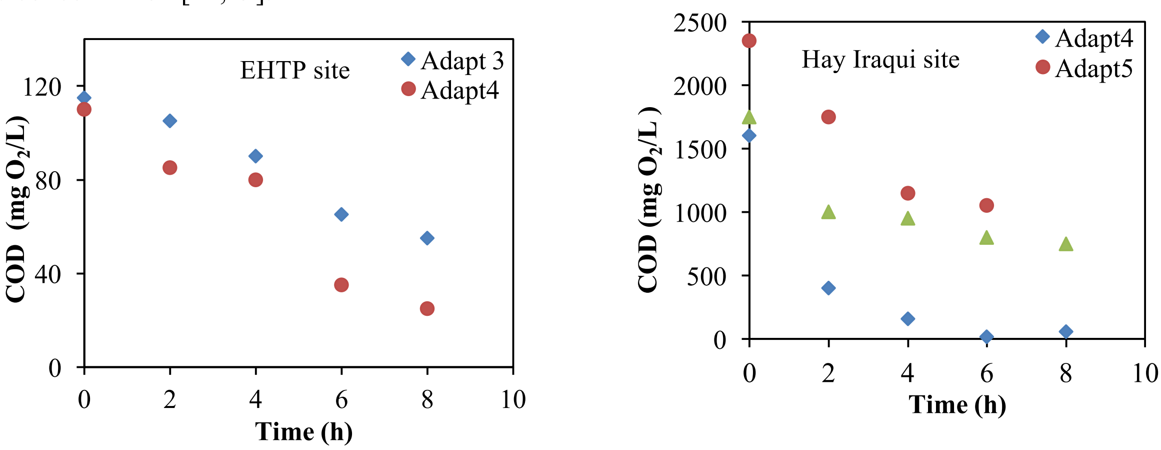

Figure 5: Evolutions of the COD after bacteria acclimatization

Figures 6a-b-c and d relative to the turbidity showed a decrease for all the tests, except that corresponding to the first bacteria adaptation, relative to the Hay Iraqui site wastewater; it increased in first and then decreased. Its increase (from 108 to 235 NTU)was probably due to the increasing of the bacteria population during their first adaptation (on clean plastic packing media). During this phase, the bacteria were isolated; they had no good conditions to aggregate in biofilm [30]. The other adaptations (2, 3, 4, 5 and 6 for Hay iraqui site and 1, 2, 3 and 4 for EHTP) showed a decrease. This decrease could be explained by the decantation of the dispersed non-adapted bacteria on the plastic packing media and their aggregation on biofilm by biofloculation, thanks to the extracellular polymeric substance EPS[31, 33].

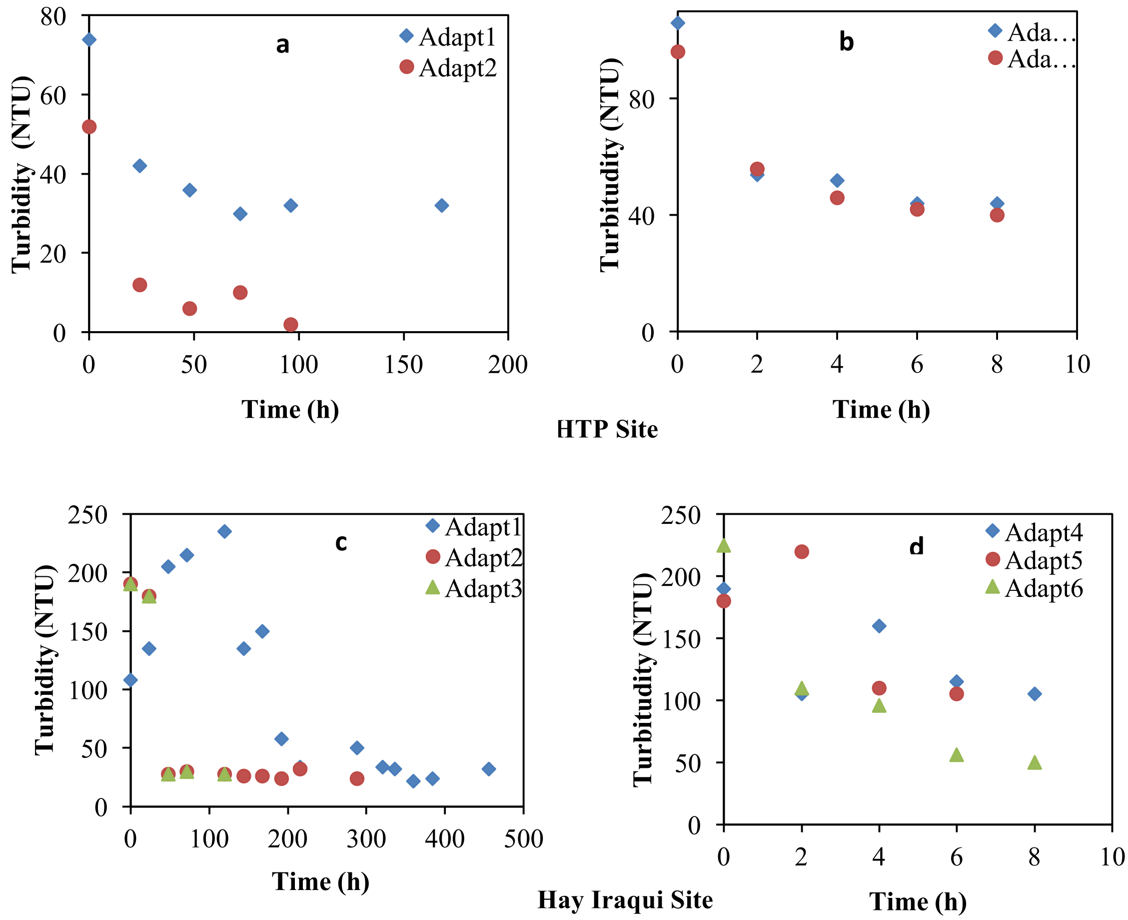

Figure 6: Evolution of turbidity of wastewater during different adaptation**.**

The Figures7a-b-c and d below presented the evolution of the dissolved oxygen concentration (DO) for all the tests. During adaptations 1, 2 and 3 for the EHTP site wastewaters and adaptations 2, 3, 4, 5 and 6 for the Hay Iraqui site wastewaters, the DO increased and then decreased. For the high pollution loads the initial DO (between 0.30 and 0.53 mg/L) increased and reached value varying between 3 and 13 depending on the adaptation degree. For the low pollution loads, the initial DO (between 2 and 6 mg/L) also increased at first and reached a value varying between 4 and 9, except adaptation 4 where the DO decreased from the beginning.
The increase could be explained by an improving oxygen transfer because of the progressive elimination of the organic matter, as well as that of the turbidity, and consequently by the decrease of the viscosity and the increase ofthe volume transfer coefficient k_La [25-26].
The DO decrease could probably be attributed to the adapted-bacteria which population increased and accelerated the catabolic process, and/or could probably be exacerbated by endogenous respiration phase inducing the solublization of extracellular materials and cellysis as noted by some authors[34-36], occurring when the substrate concentration became weak, resulting in the same time to mineralization of the solution which had a negative effect on the oxygen transfer. The same observations were noted in the fourth adaptation of the EHTP site wastewater, the DO decreased from the beginning because of the good bacteria adaptation (confirmed by the good rate abatement), promoting conditions of consumption of oxygen .For the Hay Iraqui site, at the first adaptation DO remained quasi-constant till 150 h. This was due to the high initial concentration of COD and turbidity which could not allow oxygen to dissolve. Then, it increased, inducing probably the elimination of a good part of the suspended solids, and dissolved substances.
Figures 8a-b-c and d showed variation of wastewaters pH between 6.5 and 8.5 during the tests of adaptations. It increased slightly (case of the reject of the EHTP site) and then significantly (case of the reject of the Hay Iraqui site).

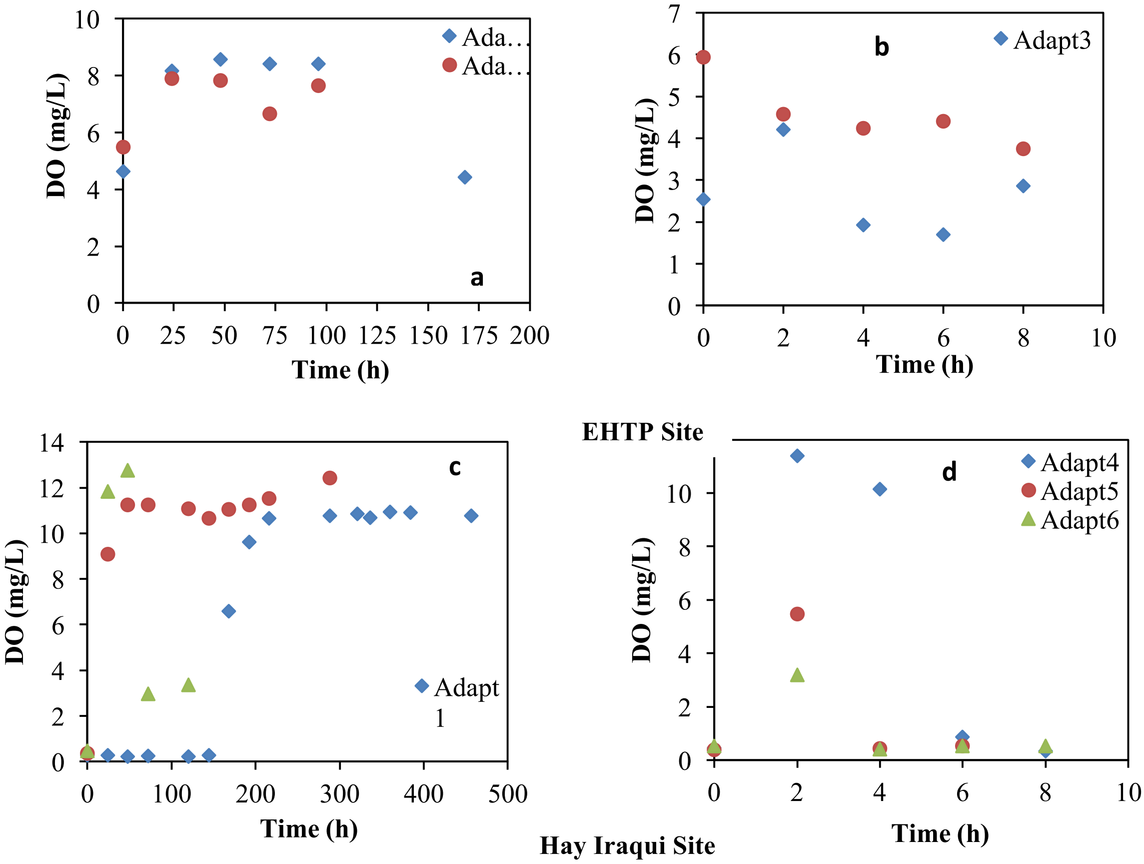

Figure 7: Evolution of DO of EHTP site and Hay Iraqui during different adaptations

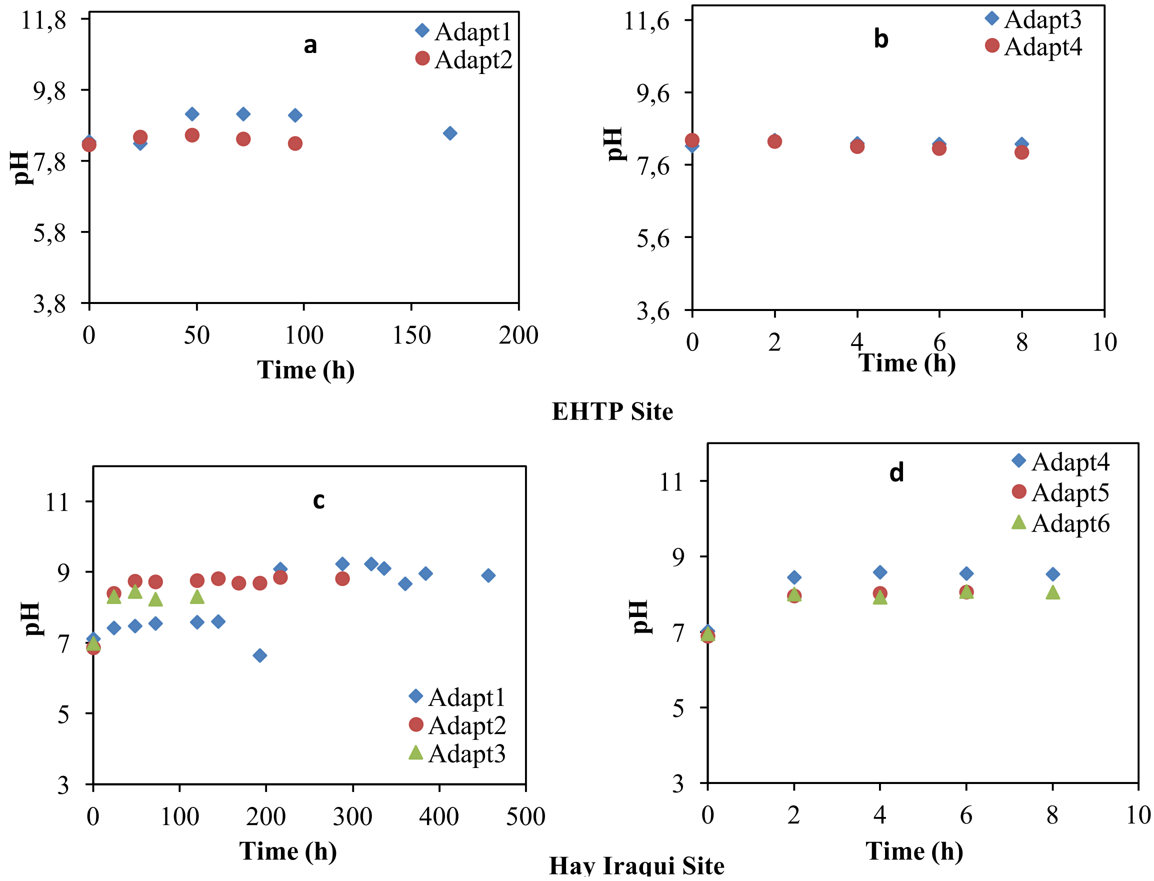

Figure 8: Evolution of the pH of EHTP site and Hay Iraqui site during different adaptations

In this pH range bacteria could metabolize organic substrate. Indeed, species produced during biological treatment affected the wastewater pH [37-38]; so, its increase, despite of the formation of CO_2 like metabolite, was probably associated with the production of alkaline, such as alkaloids, ammoniac, etc. by hydrolysis of some molecules present in organic pollution[39]. Denitrification phenomenon could also occur inside the biofilm (anoxic area), as reported by some authors[27, 40]. It was more accentuated in the case of high loaded effluents (Iraqui site), where the biological degradation reaction led to the formation of a thick biofilm. Then, the pH stabilized, probably because of the buffering effect due to the dissolution of CO_2 issued from the biodegradation.

Conclusion

In this work, tests were carried out on two domestic wastewater loads (low from the campus of the Hassania school of Public works and high from a suburban site), with a range of the COD values corresponding to those of the domestic wastewaters in Morocco. The aim of this study was to verify if the Biological Aerated Filter could efficiently treat these domestic wastewaters. The conducted tests showed that the adaptation depended upon the initial COD value. The necessary time to reduce the quasi-totality of the organic matter was longer for higher load than for the lower load, because it was easy for the bacteria to adapt when the substrate concentration was low. When the plastic packing media were clean (first adaptation), the adaptation takes more time; the bacteria issued from catabolic process were isolated and could not aggregated in a biofilm. The turbidity decreased when the bacteria adapted. However, in the case of the high loaded wastewater it increased at first, before decreasing. The turbidity decrease was due to its retention on the plastic packing media and their aggregation on the biofilm by biofloculation, due to the extracellular polymeric substance. The dissolved oxygen concentration was correlated with COD and the turbidity; it increased when COD and turbidity decreased. However, it was noted that it decreased because of the anabolic process and the mineralization occurred when the exogenous substrate decreased. The pH increased at first and then stabilized.

The obtained results showed excellent performances and revealed that BAF constituted a process with better provisions, compared 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 wastewater of rural cities which were not connected to a sanitation network.

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