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Performances analysis of Treatment of Urban Wastewater at the Laboratory Scale by Activated Sludge

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Abstract

The aim of this study is to investigate the effectiveness of activated sludge in reducing the biological oxygen demand (BOD5), chemical oxygen demand (COD), and total suspended solids (SS) of urban wastewater. To determine the optimal operating conditions for the activated sludge pilot plant, an extended pilot purification test was conducted. The pilot plant operating conditions that corresponded to a low mass load were: flow rate of 0.5 liters per hour, oxygenation rate of 60%, 100% recycling of activated sludge, and aeration tank agitation speed of 100 rev/min. During the trial period, the pilot plant operated under low mass load and consistently produced effluent with BOD5, COD, and SS levels that were significantly lower than the Moroccan discharge standards, with reductions of 90.20%, 89.79%, and 97.67%, respectively. These findings demonstrate the potential of activated sludge as an effective wastewater treatment technology for urban wastewater.

Keywords: Wastewater Treatment, Activated Sludge, Performance.

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1. Introduction

During the second part of the twentieth century, the question of water pollution has taken worrying proportions, whereas at the same time, water consumption increased together with the demographic explosion [1-3]. In industrialized countries, the reduction and the control of water consumption are linked to the optimization of processes for industrial and domestic wastewater treatment. With regard to the improvement of the different wastewater treatment processes already existing, there is still a lot to do, particularly to attain a better understanding of the flow properties of wastewater and sewage sludge. Within this broader context, this paper presents a comprehensive literature review [4,5]. In Morocco, while the practice of treated wastewater reuse is still in its nascent stages, it has become a customary component of public utility water resources, employed for irrigation of golf courses, green spaces, and certain agricultural crops. In addition to this, population's growth and the excessive exploitation of water resources lead to a significant increase in the volume of wastewater discharges [6-8]. Thus, urban centers are constantly confronted with liquid sanitation problems and wastewater discharges in the receiving backgrounds (Valley, lakes, sea...) [9]. In a situation which necessitates an augmentation in water needs, the orientation towards new resources is increasingly becoming necessary. The reuse of treated wastewater is the first and main alternative of conventional resources, they represent a significant potential of about 500millions of m3 in Morocco, over 700ha are irrigated with wastewater near major urban centers where we practice market gardening, cereal... [10,11]. As a consequence of water shortage, the treated urban wastewater, commonly discharged to the sewer in the past, is nowadays being the reuse of treated wastewater in agriculture.

2. Material and Methods

It is essential to treat wastewater before discharging it into the environment to prevent harmful substances from entering our waterways and ecosystems. Wastewater treatment involves a series of physical, chemical, and biological processes to remove contaminants and pollutants from wastewater [12]. Our laboratory of process separation, to conduct research work in this domain, has a simple purification pilot plant wastewater by activated sludge.

2.1. Sampling Point

Samplings are made on domestic effluent. During sampling, the temperature, pH, conductivity, turbidity and dissolved oxygen were measured in the field. All samples were stored at 4°C and analyzed in the laboratory within 24 hours that follow [13]. The transport time between the source collection and laboratory never exceeded 2 hours.

2.2. Raw Water Characterization

The measured average parameters are presented in Table. 1.

2.3. Procedure and Treatment Methods

Before starting treatment, adequate pre-treatment is necessary. The latter is intended to extract the elements of nature or size which would be an embarrassment for subsequent processes. This sector should remove most of the carbon pollution. It consists of two main steps: Pretreatment (screening, grit removal, settling), and secondary treatment (the activated sludge) [14]. The activated sludge treatment was performed on a laboratory pilot whose principle and description are given in Figure 1. The pilot of treatment of wastewater is implemented in the laboratory and it includes an aeration tank fed by the aeration pump, and continuous agitation by an electric stirrer [15]. While the pump supplies aeration tank by oxygen. the quantity of oxygen adjusted by the flow meter. The purified water is stored in a of treatment water tank (Figure 1) [16].

3. Results and discussion

3.1. Optimization of Operating Parameters of the Pilot Plant Activated Sludge Treatment

The objective of this section is to optimize the operation of activated sludge pilot to set the operating conditions allowing the best results of disposal indicator parameters of pollution. First, the operating parameters of the pilot station (flow of feed and oxygenation rate) were followed and optimized. After that we can begin the treatment for eliminating pollution. Throughout the study, the stirring speed of the aeration basin was set at 100 revolutions (rev) / minute (stirring speed) and the rate of recycling of decanted activated sludge into the clarifier to the aeration basin was all the time 100%. During the study, the parameters of operation of were followed: sludge index, mass loading, volume load, turbidity, suspended matter, hydraulic residence time, pH, conductivity and temperature [17].

3.1.1. Optimization of the feed flow

Table 2 shows the operating conditions for pilot optimization tests of the feed flow. Table 3. Presented the variations of operating parameters as a function of the feed flow of the aeration basin; the variations of these parameters are shown in figures 2, 3 & 4. Table 4 gives the influence of feed flow on purification performance of the treated water; the variations of these changes are shown in figure 5. The mass load and volume load decrease with decrease the feed flow. The pilot station for the mass loading of a high load to a low load and even at prolonged aeration as regards the slowest circulation rate [18]. As for the mass loading varies of a high load to a low load and even at prolonged aeration as regards the slowest circulation rate. This result is outcome by an amelioration of the performance wastewater treatment plant by moving from high speed to low-speed circulation rate (debit). Changes in the index of sludge are going in the same direction as the mass load. However, the index of sludge is excellent for all speed circulation rate indicating good settling sludge. The table 4 and figures 2 & 5 show that the performance of the pilot station ameliorates by going from the high load to the low load average. Indeed, the reduction in flow led to improved treatment rates of different monitored parameters. These results also show that the rate of reduction of turbidity and suspended matter are significantly better than those of COD, and BOD5. The reduction rate of suspended matter and turbidity exceed the 95% to 99% for the lower mass load. For high flow rates, so high specific load [19]. The reduction rate of COD and BOD5 remain low and below normal reduction rate of an activated sludge at high load [20]. European the quality standards are achieved with the lowest velocity to 0.5 l/h. So, the pilot works in the lower mass and volume loads. It is important to note that the sludge was not renewed during the whole step of optimizing the speed of circulation.

3.1.2. Optimization of the oxygenation rate

The optimization of the oxygenation rate was achieved at the lowest debit (0, 5 l/h) which gives the lowest mass loading. The table. 5. Exhibits the operating conditions of the pilot in the optimization tests of the oxygenation rate. Table 6 and figures 6 7 & 8 give the variations of the operating parameters of the aeration tank as a function of the oxygenation rate. Table 7 shows the changes in physical and chemical parameters of treated wastewater in terms of feed flows (BOD5, COD and suspended matter). Figure 9 shows the reduction of pollution parameters as a function of oxygen rate. Table 6 and figures 7, 8 & 9 show that the decrease of the oxygenation rate has no significant impact on the volume load, it had an effect on the mass load. All the results of the table and the figures show a slight influence of the variation of the oxygenation rate on the performance of this station and in the oxygenation range studied. The pilot works in the range of parameters imposed as a low load. The reductions of BOD5 and COD are higher than 88% [21]. Those of the suspended matter and turbidity exceed 98% (figure 9). European quality standards are met for various oxygenation rates. The quality of the water produced respect the Moroccan standards. The sludge age measured in this case was 14 days.

Table1: Composition of untreated domestic wastewater.

Parameters	Measures	Moroccan standards of wastewater
Temperature (°C)	24,1	< 30
pH	7,91	5,5<pH<9,5
Turbidity (NTU)	346	-
Dissolved oxygen (mg/l)	0,74	-
Conductivity (µS/ cm)	986	-
Total Suspended solids (TSS) (mg/L)	431,65	35< SS <100
Volatile Suspended Solids (VSS)(mg/L)	345,43	-
Biological oxygen demand (BOD_5) (mg/l)	246	40< BOD_5<80
Chemical oxygen demand (COD) (mg/l)	481	100< COD <200

Table 2: The optimization of operating pilot at different feed flow.

	Different debit of influent flow (l/h)			
Parameters	0.5 (l/h)	1 (l/h)	1.5 (l/h)	2 (l/h)
Oxygen rate (%)	100	100	100	100
Stiring velocity (ver/min)	100	100	100	100
Recirculation of the activated sludge (%)	100	100	100	100

Table 3: Variation operating parameters of the aeration basin as a function of the feed flow.

	Influent flow (l/h) the aeration tank by days			
Parameters	1st Day 0,5 l/h	2nd Day 1l/h	3th Day 1, 5 l/h	4th Day 2 l/h
Temperature (°C)	21,7	22,3	21,8	21
pH	8,16	8,15	8,46	8,22
Turbidity (NTU)	988	812	751	608
Dissolved oxygen (mg/l)	6,55	5,46	5,18	4,21
Conductivity (µS/ cm)	897	998	893	891
Total Suspended solids (SS) (mg/L)	5427,5	4461,5	2926,5	3339,5
Volatile Suspended Solids (VSS)(mg/L)	4343,8	3567,4	2340,4	2670,8
Food to Microorganism Ratio (F/M) ($kgBOD_5.kgMLVSS^{-1}.d^{-1}$)	0,063	0,16	0,34	0,52
Volumetric organic loading (VOL) ($kg\ BOD_5.m^{-3}.d^{-1}$)	0,27	0,55	0,81	1,37
Hydraulic detention time (h)	18	8.6	5,77	4,26
Sludge Volume Index (SVI) (ml/g)	42,38	42,61	70,85	53,93

Table 4: The influence of debit on purification performance.

-	Raw waste water	Treated water							
Days and influent flow (l/h) parameters		**1stDay 0,5 (l/h)**	**(%) Removal (R)**	**2nd Day 1 (l/h)**	**(%) (R)**	**3th Day 1,5 (l/h)**	**(%) (R)**	**4th Day 2 l/h**	**(%) (R)**
Temperature (°C)	23,22	21,61	--	18,92	--	20,6	--	20,8	--
pH	7,9	8,14	--	8,13	--	8,5	--	8,35	--
Turbidity (NTU)	346	5,1	98,56	8	97,6	12	96,5	10,9	96,8
Dissolved oxygen (mg/l)	0,72	5,25	--	4,24	--	4,51	--	4,74	--
Conductivity (µS/ cm)	927	921	--	952	--	926	--	912	--
Total Suspended solids (SS) (mg/L)	430,4	15	96,53	20	95,3	25	94,1	26	93,9
Volatile Suspended Solids (VSS)(mg/L)	345	12,5	--	16,2	--	20,1	--	20,7	--
Biological oxygen demand (BOD_5) (mg/l)	246	25,12	89,79	60,14	75,61	75	69,42	90	63,3
Chemical oxygen demand (COD) (mg/l)	480	45	90,63	100	79,2	130	72,9	185	61,5

Table 5: Optimization of the operating conditions of the pilot plant at various oxygenation rates.

Parameters	**Oxygen rate (%)**			
	100	80	40	20
influent flow (l/h)	0.5	0.5	0.5	0.5
Stiring velocity (ver/min)	100	100	100	100
Recirculation of the activated sludge (%)	100	100	100	100

Table 6: Show the aeration tank operating parameters as a function of the oxygenation rate.

	Aeration Tank			
Days and Oxygen rate (%) parameters	**1st day 100 %**	**2nd day 80 %**	**3th day 60 %**	**4th day 40 %**
Temperature (T) (°C)	21	22	22	22
pH	8,15	8,66	7,97	8,25
Turbidity (NTU)	812	608	467	217
Dissolved oxygen (mg/L)	5,75	5,51	3,77	3,47
Conductivity (µS/ cm)	997	939	967	944
Mixed liquor suspended solids (MLSS) (mg/l)	4460,81	3338,6	2564	1189
Mixed liquor volatile Suspended Solids (MLVSS) (mg/L)	3568,51	2671	2051	952
Food to Microorganism Ratio (F/M) ($kgBOD5.kgMLVSS^{-1}.d^{-1}$)	0,096	0,16	0,17	0,38
Volumetric organic loading (VOL) ($kg BOD_5.m^{-3}. d^{-1}$)	0,35	0,33	0,34	0,35
Hydraulic detention time (HDT) (H)	17	17	17	17
Sludge Volume Index (SVI) (ml/g)	42,81	45,32	43,13	50,22

Table 7: The influence of oxygenation rate on purification performance.

	Raw wastewater	**Treated water**							
Days and Oxygen rate (%) parameters		**1st 100 (%)**	**(%) R**	**2nd 80%**	**(%) R**	**3th 60%**	**(%) R**	**4th 40%**	**(%) R**
Temperature (°C)	24	22	--	22	--	22	--	22	--
pH	7,9	8,14	--	8,45		8,6		8,21	
Turbidity (NTU)	346	6,5	98,3	5,8 5	98,34	7	97,95	9	97,38
Dissolved oxygen (mg/l)	0,72	5,25	--	4,35		4,13		3,86	
Conductivity (µS/ cm)	986	803	--	937	--	961	--	958	--
Total suspended solids (SS) (mg/L)	430,5	13	96,9	10	97,68	18	95,82	20	95,34
Volatile Suspended Solids (VSS)(mg/L)	344,6	10,5	--	8	--	14,5	--	16	--
BOD_5 (mg/l)	245	25	89,8	18	92,65	28	88,57	30	87,8
COD (mg/l)	480	48	90	32	93,34	45	90,61	63	86,84

Table 8: Percentage of the reduction of physicochemical parameters (pollution) of treated wastewater by activated sludge after optimized parameters the functional pilot station.

	Raw wastewater	**Treated water**									
Days parameters		**1st day**	**(%) R**	**2nd day**	**(%) R**	**3th day**	**(%) R**	**4th day**	**(%) R**	**5th day**	**(%) R**
Temperature(°C)	23,2	23,4	--	23,7	--	23,8	--	23,7	--	23,4	--
pH	7,8	8,03	--	7,85	--	8,1	--	7,93	--	8,00	--
Turbidity (NTU)	345	6	98,26	5	98,55	4,45	98,71	5,47	98,41	6,50	98,12
Dissolved oxygen (mg/l)	0,71	3,91	--	3,48	--	4,01	--	3,91	--	3,54	--
Conductivity (µS/cm)	985	956	--	958	--	986	--	990	--	985	--
SS (mg/L)	430,5	10	97,7	13	96,8	12	97,3	11	97,5	14	96,9
VSS (mg/L)	344,4	8	--	10,4	---	9,6	--	8,8	--	11,2	--
BOD_5 (mg/l)	246	25	89,8	30	87,9	24	90,4	32	86,8	30	87,9
COD (mg/l)	480	60	87,5	68	85,8	49	89,7	68	85,8	72	85

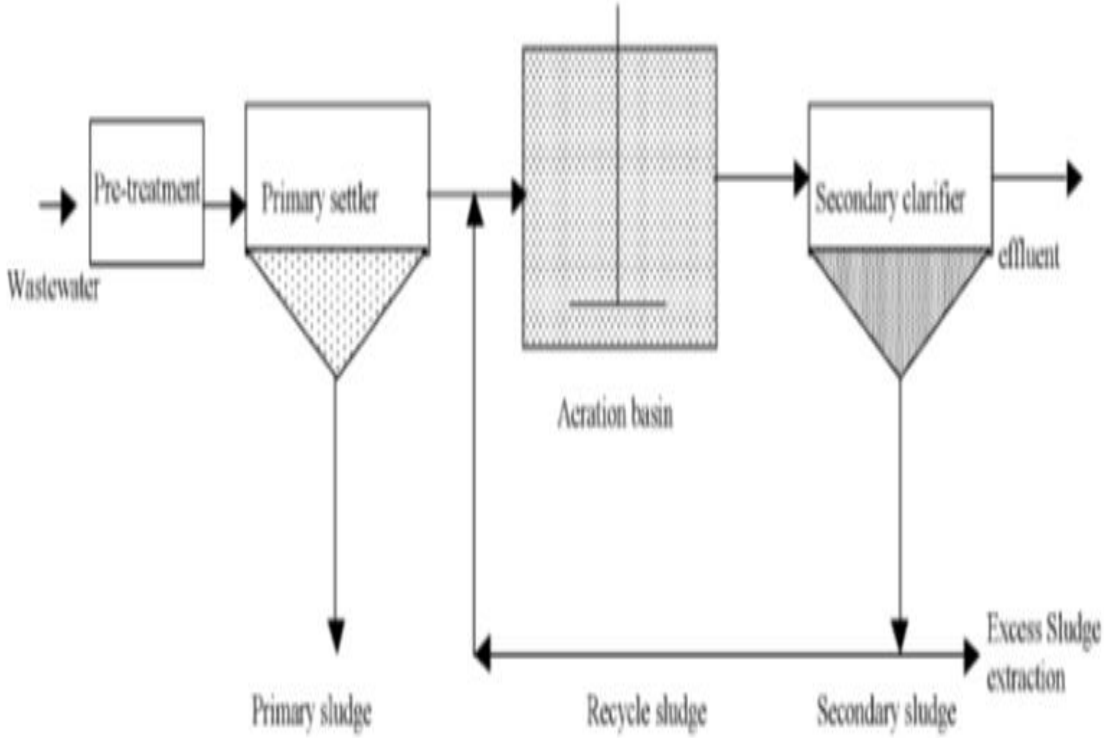

Figure 1: Description of pilot plant activated sludge.

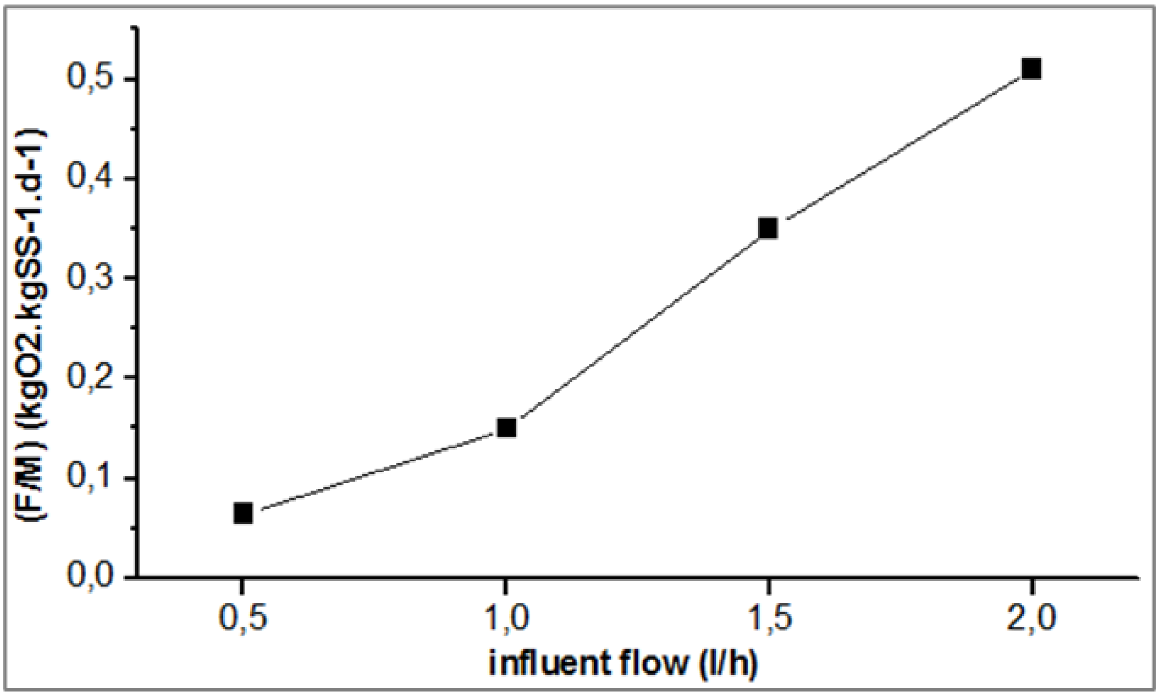

Figure 2: Variation of F / M as a function of feed flow.

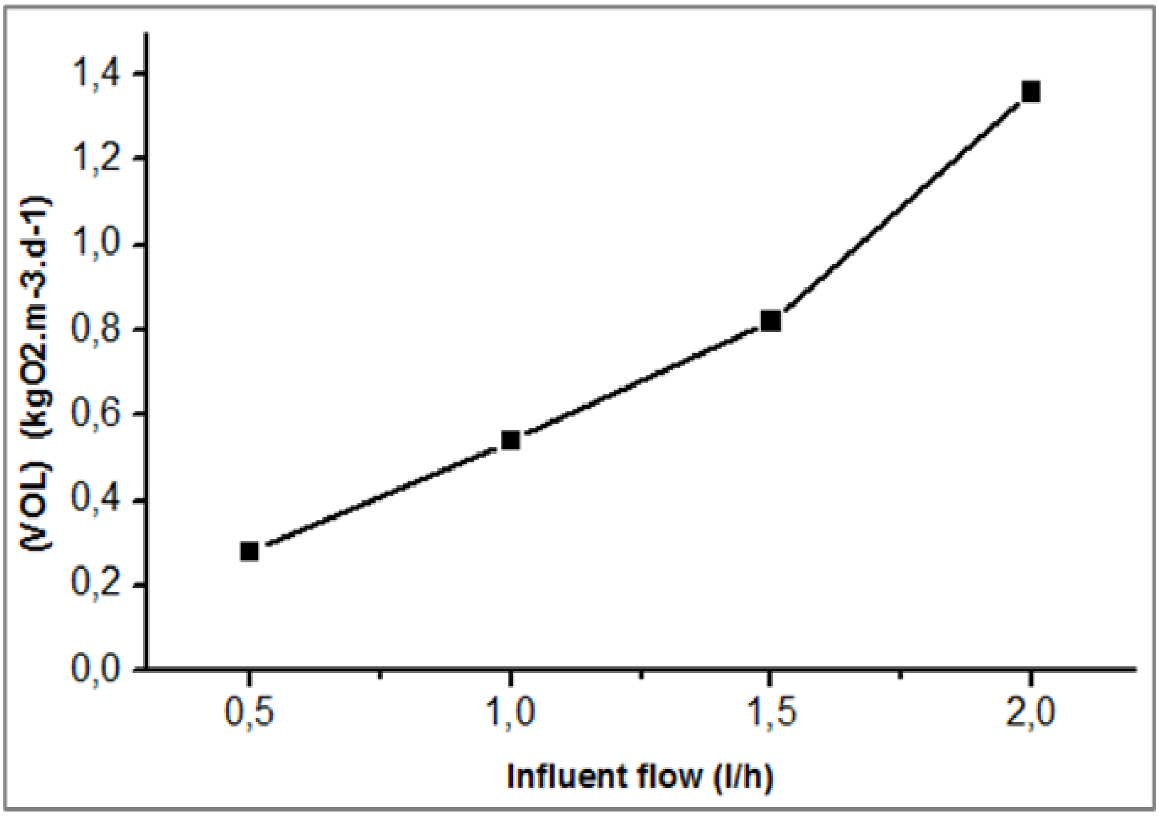

Figure 3: Variation of VOL as a function of feed flow.

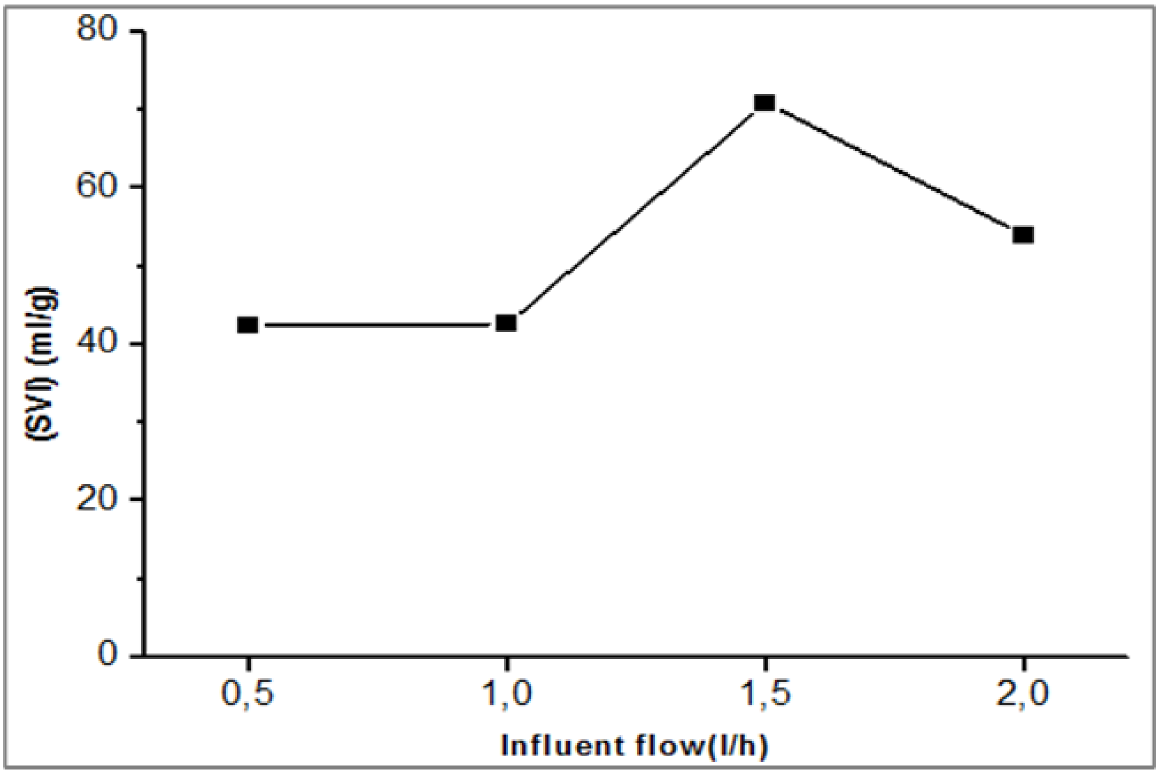

Figure 4: Variation of SVI as a function of feed flow.

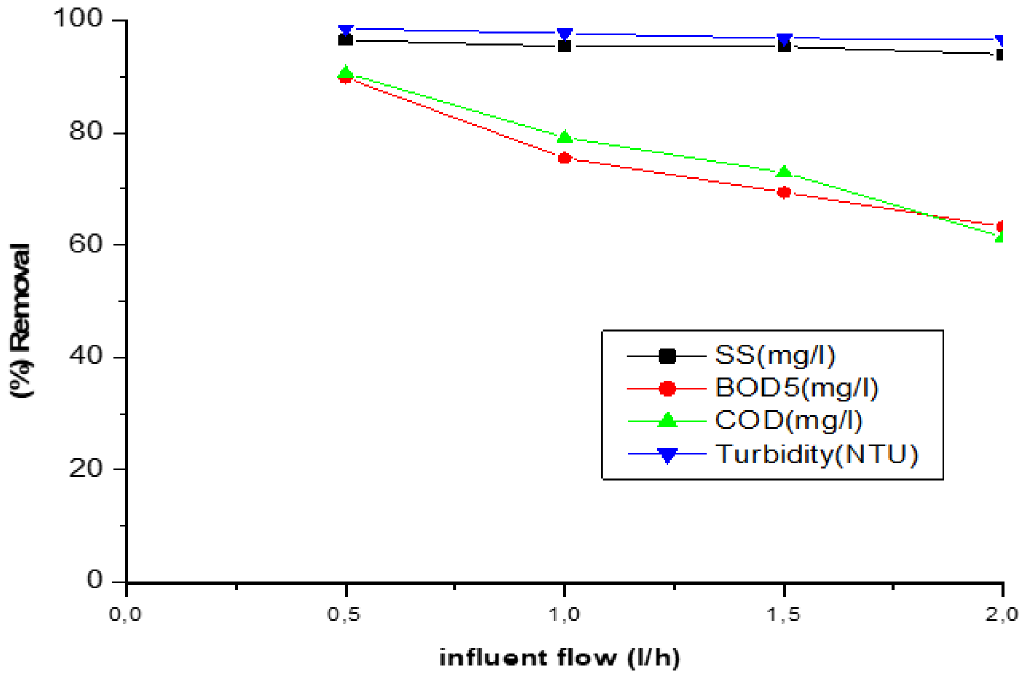

Figure 5: Reduction of pollution parameters as a function the feed flow.

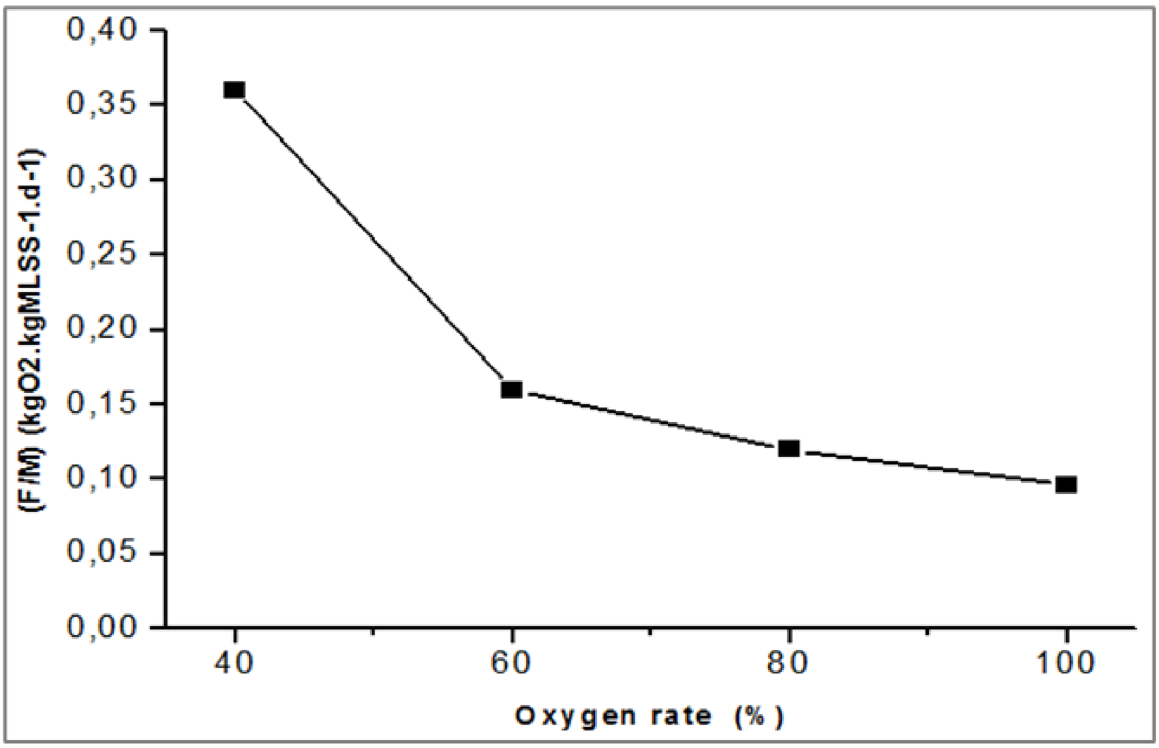

Figure 6: Variations in F/M as a function of oxygen rate.

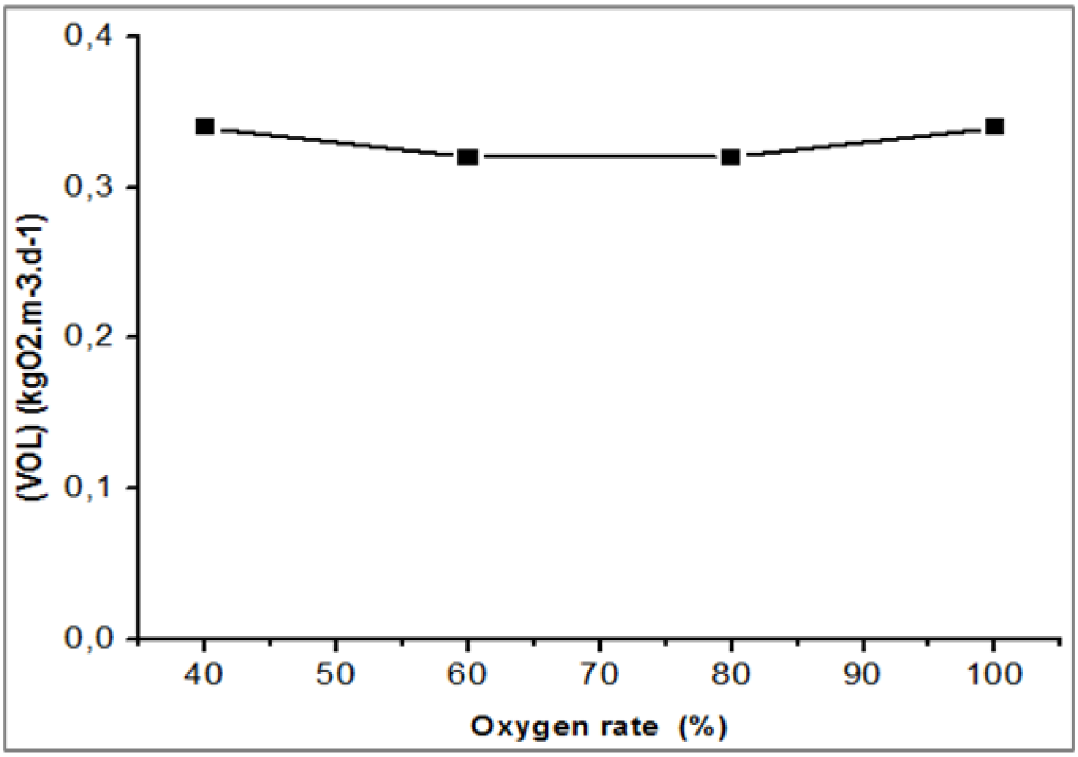

Figure 7: Variations in VOL as a function of oxygen rate.

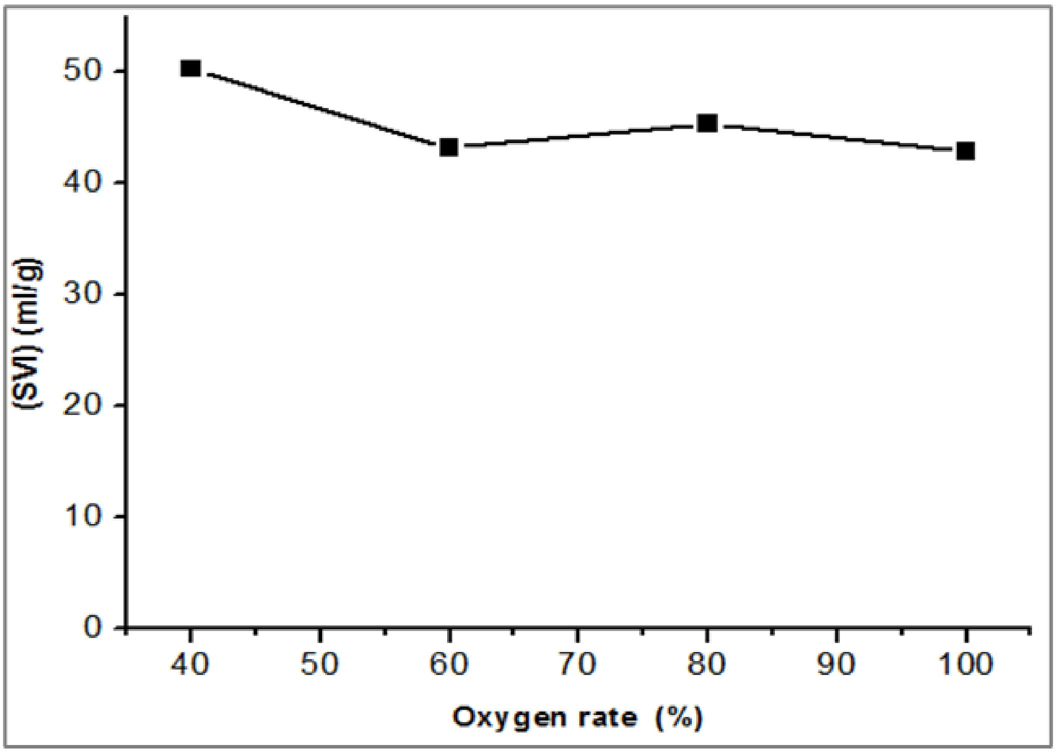

Figure 8: Variation of SVI as a function of oxygen rate.

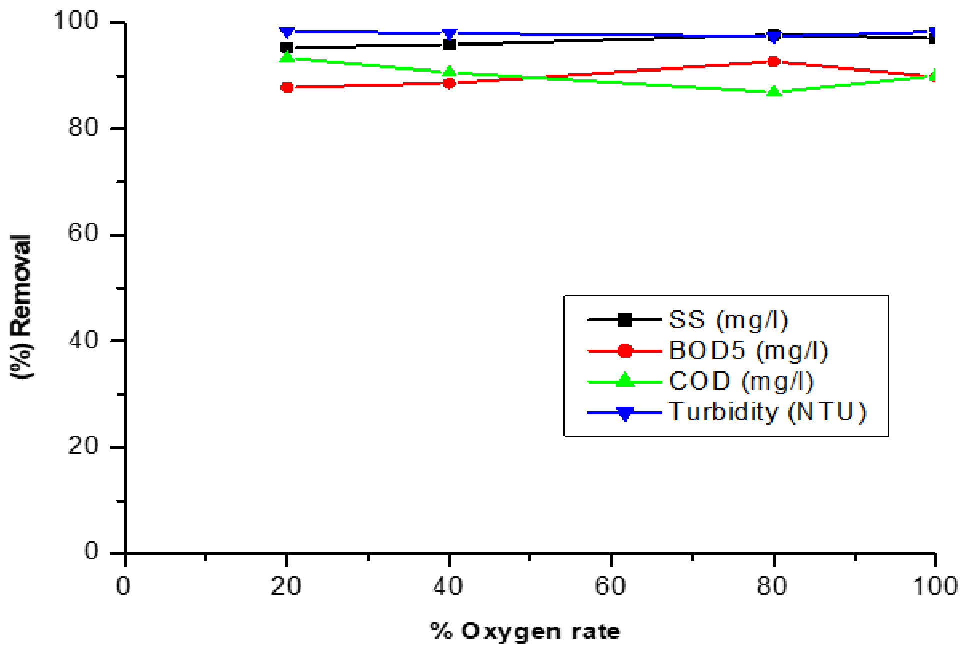

Figure 9: Reduction of pollution parameters as a function of oxygen rate.

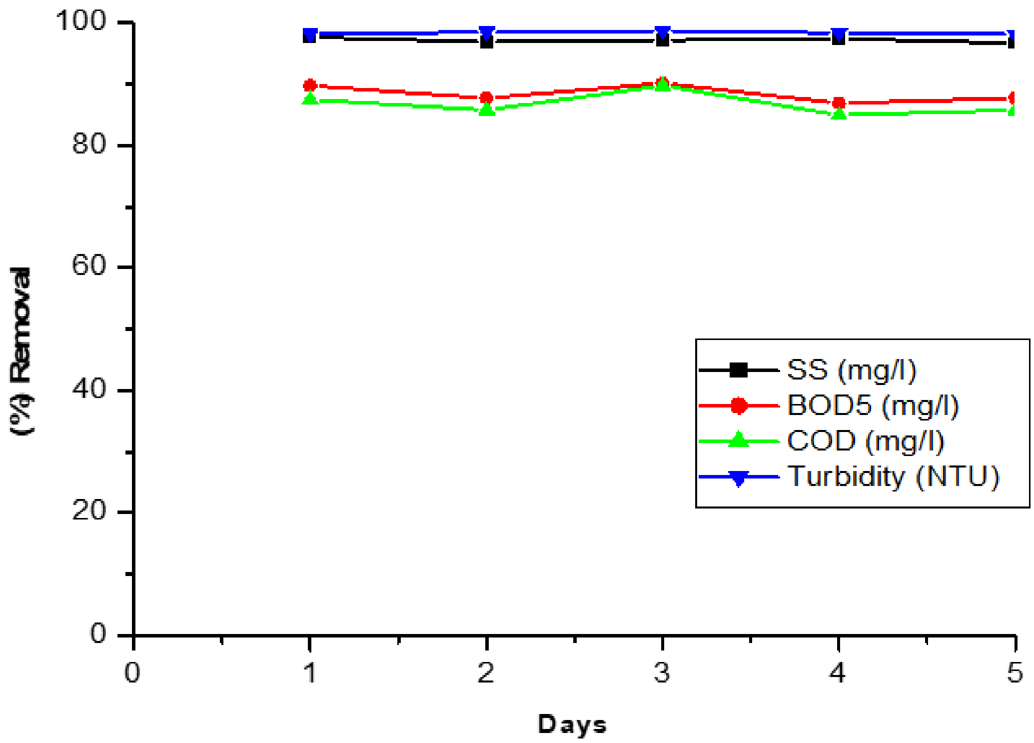

Figure 10: Reduction of pollution parameters as a function of the day after optimized.

3.2. Trials treating wastewater by optimized parameters

In order to confirm the performance of the station, a long duration of the pilot purification test was carried out. The pilot operating conditions correspond in terms of mass load to a low load are: Flow 0.5l / h; Oxygenation rate 60%; 100% recycling of the activated sludge; Aeration tank agitation 100 rev/min [22]. The table 8 shows the performance of the wastewater treatment station for five days of continuous operation. The variations of these parameters are given in figure 10. These results indicate the higher performance of the station in the purification of the treated wastewater. These results also show the consistency of the performance for five consecutive days during which the station operated in low mass loading, and a flow rate of 0.5 l/h and a 60% oxygen, producing water with much lower levels in European and Moroccan discharge standards

4. Conclusions

The results of this study showed a reduction of pollution load BOD5, COD and suspended matter which is respectively (90.20%, 89. 79% and 97.67%) and an improved quality of treated water. These results confirm the good performance of the station in the purification of wastewater. Also, a sustained performance in the trial period during which the station operated in low mass load, producing water with much lower levels in European and Moroccan discharge standards. The final treated wastewater could be reused water for agricultural irrigation after disinfection.

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