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Optimization Study and Treatment of Urban Waste Water at the Laboratory Scale by Activated Sludge Pilot Plant

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ABSTRACT

The aim of this study is to decrease the biological oxygen demand (BOD5), chemical oxygen demand (COD) and total Suspended solids (SS) of urban wastewater by activated sludge. To begin with, we need to focus on determining the best activated sludge pilot plant operating conditions in order to confirm the performance of the station and a long period of the pilot purification test has been carried out. The pilot operating conditions correspond in terms of mass load to a low load are: Flow 0.5 l/h; Oxygenation rate 60%; 100% recycling of the activated sludge; Aeration tank agitation 100 rev/min. Also, a sustained performance during the trial period, during which, the station operated in low mass load, producing water with BOD5, COD and SS, which is respectively (90.20%, 89. 79% and 97.67%) much lower levels in Moroccan discharge standards.

Keywords: Wastewater Treatment; Activated Sludge; Performance

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. In industrialised countries, the reduction and the control of water consumption are linked to the optimisation 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 sludges. In such a wide context, this article proposes a review of the literature [1,2]. In Morocco, although the reuse of treated wastewater is not really advanced, it is customarily used as part of the hydraulic resources of public utilities: irrigation of golf courses, public gardens and agricultural irrigation.

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. Thus, urban centers are constantly confronted with liquid sanitation problems and wastewater discharges in the receiving backgrounds (Valley, lakes, sea...) [3].

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 500 millions of m^3 in Morocco, over 700 ha are irrigated with wastewater near major urban centers where we practice market gardening, cereal... [3,4]. 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.

MATERIALS AND METHODS

The removal of harmful substances from waste water requires treatment before discharge. This treatment embodies the reduction of the pollution load rejection.

Our laboratory of process separation, to conduct research work in this domain, has a simple purification pilot plant wastewater by activated sludge.

Sampling Point

Samplings are made on domestic effluent. Pollution loads are assumed to be all of domestic origin. 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. The transport time between the source collection and laboratory never exceeded 2 hours.

Period and Sampling Frequency

Our study was spread over a period of 4 months (March, April, May, and June). The wastewater sampling was done weekly at the outlet of the sanitary sewer network.

The study of the physical and chemical quality is conducted during the whole period because it is strongly recommended to do the campaigns of analyzes in dry weather. In general, the period of the most appropriate study ranges between March and October [4].

Quality of the Raw Water

The measured average parameters are summarized in Table 1. Pollution loads are assumed to be all of domestic origin.

Table 1. The Quality of raw wastewater

Parameters	Measures	Moroccan standards of wastewater
Temperature (°C)	23.1	< 30
pH	7.8	5.5<pH<9.5
Turbidity (NTU)	345	-
Dissolved oxygen (mg/l)	0.71	-
Conductivity (µS/cm)	985	-
Total Suspended solids (TSS) (mg/L)	430.5	35<SS <100
Volatile Suspended Solids (VSS)(mg/L)	344.4	-
Biological oxygen demand (BOD5) (mg/l)	245	40<BOD5<80
Chemical oxygen demand (COD) (mg/l)	480	100<COD<200

Description of 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. The treatment process is summarized in Figure. 1.

Figure 1. Steps of the suggested treatment

This sector should remove most of the carbon pollution. It consists of two main steps: Pretreatment and secondary treatment.

- Pretreatment consists of a physical separation which aims to remove the raw wastewater of the coarsest solid pollutants (screening, grit removal, settling) [5-7].
- Secondary treatment selected in our case is the activated sludge.

The activated sludge treatment was performed on a laboratory pilot whose principle and description are given in Figure 2.

The pilot of treatment of wastewater is implemented in the laboratory and it includes an aeration tank fed by a peristaltic pump for sucking raw wastewater from sewage storage tank, and continuous agitation by an electric stirrer [5-8].

While the diaphragm pump supplies aeration tank by oxygen. We can adjust this quantity of oxygen by the flow meter.

The aeration tank communicates with a final settling tank. The purified water is stored in a tank of treatment water. Activated sludge which is formed is recirculated by using a pump to the aeration tank as shown in Figure 2 [5-11].

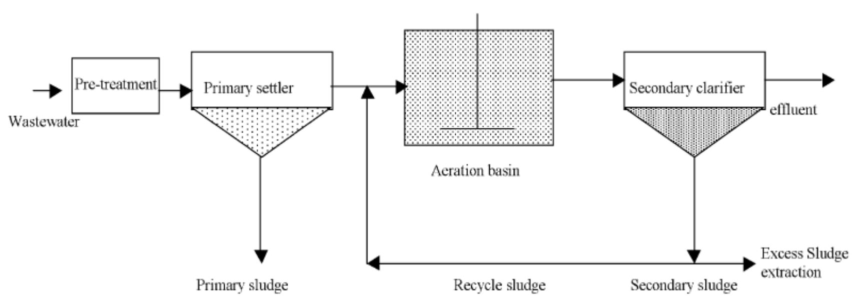

Figure 2. Station pilot of activated sludge

The Operation Forming Activated Sludge

For launching a biological activated sludge treatment, we must sow the aeration tank by activated sludge. To form sludge, raw wastewater is allowed to circulate in the closed circuit station for a week in order to recover sufficient sludge, then the jars are emptied and washed, the sludge recovered for subsequent reuse trying to treat biologically.

RESULTS AND DISCUSSION

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 start 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 conventional parameters of operation of an activated sludge were followed: sludge index, mass loading, volume load, turbidity, suspended matter, hydraulic residence time, pH, conductivity and temperature (Table 2).

Optimization of the Feed Flow

Table 3 gives the variations of operating parameters as a function of the feed flow of the aeration basin; the variations of these changes are shown in Figures 3-5.

Table 2. The operating conditions for pilot optimization tests of the feed flow

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

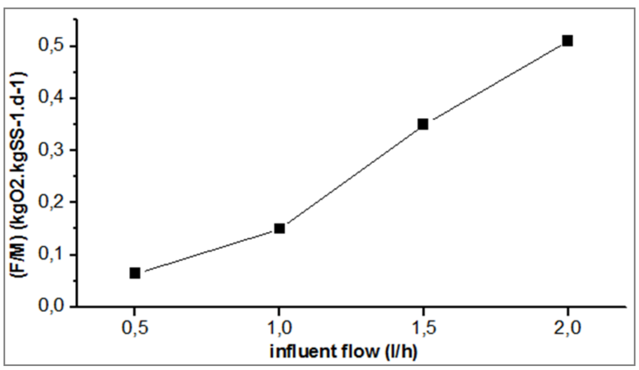

Figure 3. Variation of F/M as a function of feed flow

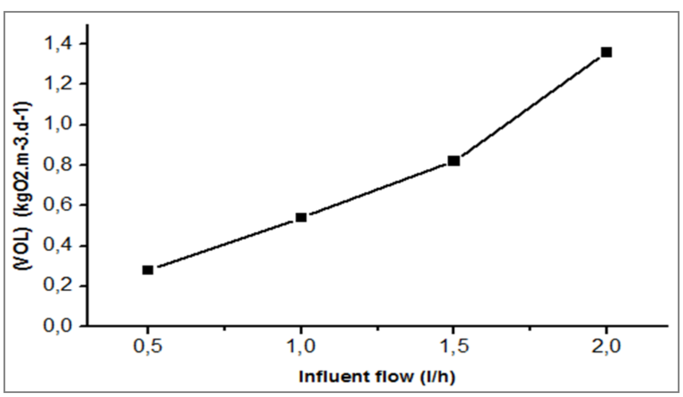

Figure 4. Variation of VOL as a function of feed flow

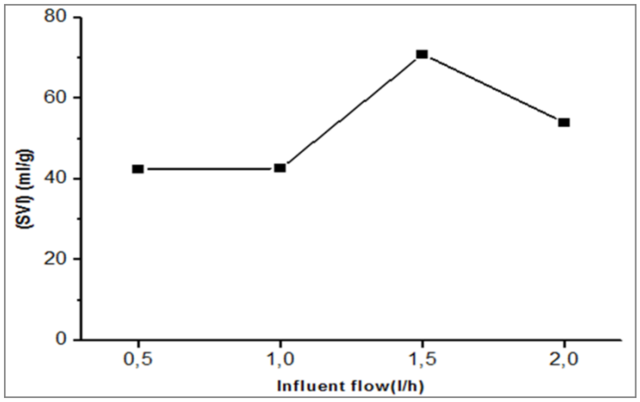

Figure 5. Variation of SVI as a function of feed flow

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

Parameters \ Days and influent flow (l/h)	Aeration Tank			
	1st Day 0.5 l/h	**2nd Day 1 l/h**	**3th Day 1.5 l/h**	**4th Day 2 l/h**
Temperature (°C)	20.7	20.3	20.8	21
pH	8.15	8.12	8.44	8.20
Turbidity (NTU)	987	811	750	607
Dissolved oxygen (mg/l)	6.54	5.47	5.17	4.20
Conductivity (µS/cm)	897	998	893	890
Total Suspended solids (SS) (mg/L)	5428.5	4460.5	2925.5	3338.5
Volatile Suspended Solids (VSS)(mg/L)	4342.8	3568.4	2340.4	2670.8
Food to Microorganism Ratio (F/M) (kg BOD5.kgMLVSS^{-1}.d^{-1})	0.064	0.15	0.35	0.51
Volumetric organic loading (VOL) (kg BOD5.m^{-3}.d^{-1})	0.28	0.54	0.82	1.36
Hydraulic detention time (h)	17	8.5	5.66	4.25
Sludge Volume Index (SVI) (ml/g)	42.37	42.60	70.84	53.92

Table 4. Influence of feed flow on purification performance

Days and influent flow (l/h) parameters	Raw wastewater	Treated water							
		1st 0.5 l/h	**(%) Removal (R)**	**2nd 1 l/h**	**(%) (R)**	**3th 1.5 l/h**	**(%) ®**	**4th 2 l/h**	**(%) ®**
Temperature (°C)	23.1	20.6	--	19.9	--	20.5	--	20.6	--
pH	7.8	8.12	--	8.07	--	8.4	--	8.34	--
Turbidity (NTU)	345	5	98.55	8	97.68	12	96.52	10.90	96.84
Dissolved oxygen (mg/l)	0.71	5.24	--	4.20	--	4.50	--	4.73	--
conductivity (µS/cm)	926	920	--	950	--	925	--	911	--
Total Suspended solids (SS) (mg/L)	430.5	15	96.51	20	95.35	25	94.19	26	93.96
Volatile Suspended Solids (VSS)(mg/L)	344.4	12	--	16	--	20	--	20.8	--
Biological oxygen	245	25	89.79	60	75.51	75	69.38	90	63.26

demand (BOD5) (mg/l)									
Chemical oxygen demand (COD) (mg/l)	480	45	90.62	100	79.16	130	72.91	185	61.45

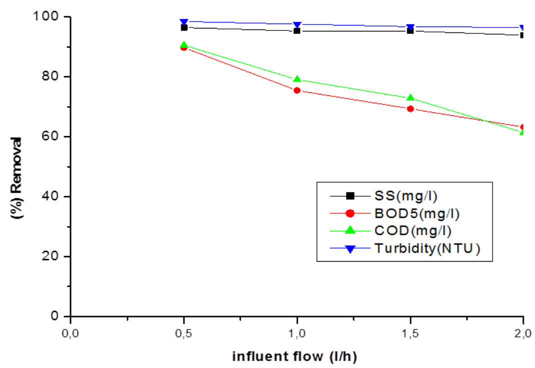

Figure 6. Reduction of pollution parameters as a function the feed flow

The decrease in feed flow resulted in a decrease in the mass load and volume load. 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. While the operation of treatment is taking place, 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 translated 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 generally 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, Figures 3 and 6 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, the reduction rate of COD and BOD5 remain low and below normal reduction rate of an activated sludge at high load.

European emission 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. The sludge age was followed and experimentally determined in the order of 11 days.

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 shows the operating conditions of the pilot in the optimization tests of the oxygenation rate.

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 and Figures 7-9. Give the variations of the operating parameters of the aeration tank as a function of the oxygenation rate.

Table 6 shows the changes in physical and chemical parameters of treated wastewater in terms of feed flows (BOD5, COD and suspended matter). These variations are shown in Figure 10.

Table 6. Variations in the aeration tank operating parameters as a function of the oxygenation rate

Days and Oxygen rate (%) / Parameters	Aeration Tank			
	1st 100%	**2nd 80%**	**3th 60%**	**4th 40%**
Temperature (T)(°C)	20.3	21.2	21.8	21
pH	8.12	8.63	7.93	8.23
Turbidity (NTU)	811	607	466	216
Dissolved oxygen (mg/L)	5.74	5.50	3.75	3.45
Conductivity (µS/cm)	998	938	966	943
Mixed liquor suspended solids (MLSS) (mg/l)	4460.5	3338.5	2563	1188
Mixed liquor volatile Suspended Solids (MLVSS) (mg/L)	3568.4	2670.8	2050.4	950.4
Food to Microorganism Ratio (F/M) ($kgBOD5.kgMLVSS^{-1}.d^{-1}$)	0.096	0.12	0.16	0.36
Volumetric organic loading (VOL) ($kg\ BOD5.m^{-3}.d^{-1}$)	0.34	0.32	0.32	0.34
Hydraulic detention time (HDT) (H)	17	17	17	17
Sludge Volume Index (SVI) (ml/g)	42.80	45.3	43.11	50.20

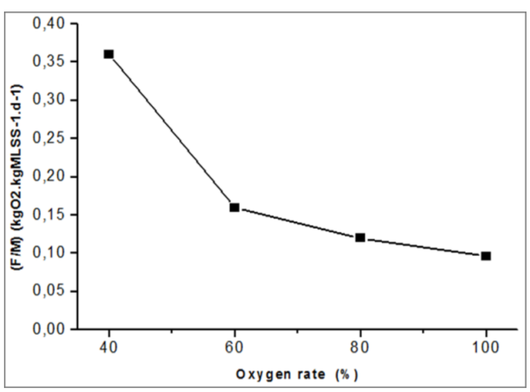

Figure 7. Variations in F/M as a function of oxygen rate

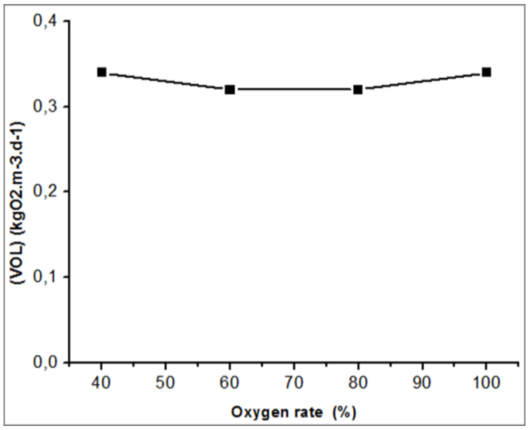

Figure 8. Variations in VOL as a function of oxygen rate

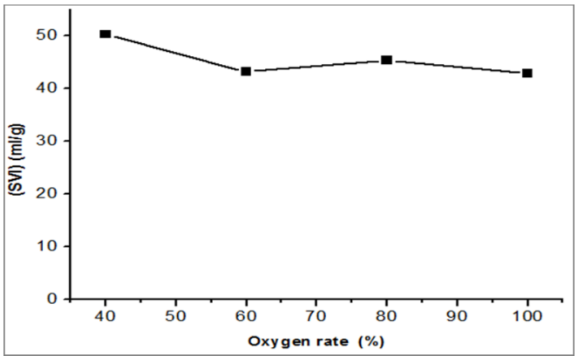

Figure 9. Variation of SVI as a function of oxygen rate

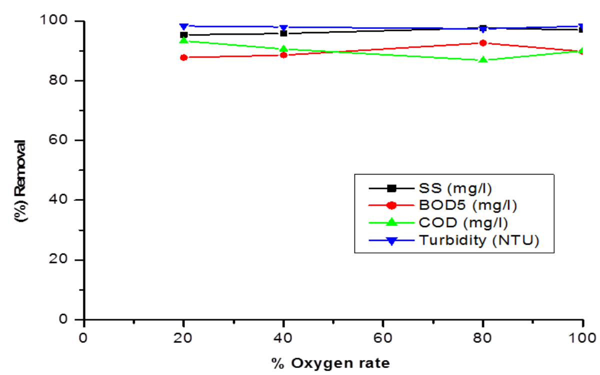

Figure 10. Reduction of pollution parameters as a function of oxygen rate

Table 6 and Figures 7-9 shows that the decrease of the oxygenation rate has no significant impact on the volume load. However, 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%. Those of the Suspended matter and turbidity exceed 98% (Figure 10).

European emission standards are met for various oxygenation rates.

The quality of the water produced is greatly better than that imposed by the Moroccan standards. The sludge age measured in this case was 14 days.

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 0.5 l/h; Oxygenation rate 60%; 100% recycling of the activated sludge; Aeration tank agitation 100 rev/min.

The following Table 7 shows the performance of the wastewater treatment station for five days of continuous operation. The variations of these performances are given in Figure 11.

Table 7. Percentage of the reduction of physicochemical parameters (pollution) of treated wastewater by activated sludge after optimized parameters the functional pilot station.

Days and parameters	Raw wastewater	Treated water 1st day	(%) R	2nd day	(%) R	3th day	(%) R	4th day	(%) R	5th day	(%) R
Temperature (°C)	23.1	23.3	--	23.00	--	23.9	--	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	98.11
Dissolved oxygen (mg/l)	0.71	3.90	--	3.47	--	4.04	--	3.90	--	3.53	--
Conductivity (mS/cm)	985	956	--	958	--	986	--	990	--	985	--
Total suspended solids (SS) (mg/L)	430.5	10	97.67	13	96.98	12	97.21	11	97.44	14	96.74
Volatile Suspended Solids (VSS)(mg/L)	344.4	8	--	10.4	---	9.6	--	8.8	--	11.2	--
Biological oxygen demand (BOD5) (mg/l)	245	25	89.79	30	87.75	24	90.20	32	86.93	30	87.75
Chemical oxygen demand (COD) (mg/l)	480	60	87.5	68	85.83	49	89.79	68	85.83	72	85

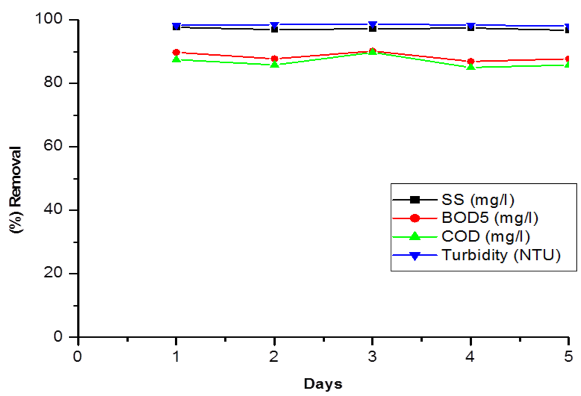

Figure 11. Reduction of pollution parameters as a function of the day after optimized parameters

These results confirm 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.

CONCLUSION

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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