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Multiphysical Modeling of the Activated Sludge Wastewater Treatment Process

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Abstract This work was the subject of the design of a multiphysics model of wastewater treatment by activated sludge in anaerobic and aerobic environments. These treatments are described the diffusion equations, and the equations of the ASM model (activated sludge model), thus making it possible to simulate the operation of the treatment system using the Comsol software. The first phase consisted of the characterization of the effluents treated in the wastewater treatment plant of an oil mill in Côte d'Ivoire. The second phase was the modeling and numerical simulations of anaerobic and aerobic digesters. These simulations gave respectively the performance of τ_1 = 21.1% and τ_2 = 71.7% for the anaerobic and aerobic treatment. It appears that aerobic treatments are more effective than anaerobic treatments. The third phase consisted of the coupling of the three processes which are the anaerobic, aerobic and settling treatment. To validate the model, the effluent parameters were determined experimentally. These experimental values were used to design the model. In addition, the experimental values of the COD and the quantity of sludge were compared with those of the model in order to validate the results of the model. The experimental and simulated results are almost identical, hence the validation of the model with a coefficient of performance of γ_G =98.53%.

Keywords Biological treatment/ multiphysics modeling/ simulation/ aerobic/ anaerobic

1. Introduction

The first stations, which initially had to meet immediate needs for the collection and treatment of industrial wastewater, now have to face new problems [1,2]. In a context of continuous improvement and sustainable development, human activity seeks to optimize its constructions as much as possible, to manage its resources responsibly and to minimize its impact on the environment by reducing the pollution resulting from its activity. Wastewater treatment plants are not excluded from this approach [3]. The main techniques used in water treatment are of a physical, chemical, physico-chemical or biological nature [4-6]. However, due to the high biodegradability of effluents from food factories, biological treatments remain the most widely used [7]. These treatments are based on the use of microorganisms that degrade organic pollutant. These treatments are generally carried out in bioreactors with aerobic or anaerobic conditions [9-12]. In order to understand the behavior of microorganisms in anaerobic and aerobic environments and to compare the performance of these two types of treatment, a multiphysics simulation is necessary. It is in this context that we carried out this study entitled: "Multiphysics modeling of the wastewater treatment process by activated sludge". This project to design a multiphysics model for the simulation of activated sludge treatment of wastewater will make it possible to monitor water quality control parameters such as COD, nitrogen and dissolved oxygen levels. This model will also make it possible to have a more in-depth knowledge of these processes, to always check the correct functioning of the treatment system set up in a wastewater treatment plant and to optimize it.

2. Materials and methods

2.1 Material

For the realization of this work, several materials were used. These include monitoring reports, data sheets, software, chemical reagents and equipment. This equipment makes it possible to perform analyzes of the various parameters sought. This is how the mixer (WARING PRODUCTS DIVISION) was used to homogenize the samples. The Sartorius balance was used for the weighing of chemical reagents. For the analyzes, the HACH DR 2800 spectrophotometer was used to determine the suspended solids and the turbidity. The pH meter for the hydrogen potential; Oxitop® (WTW) for BOD and the HACH DRB 200 spectrometer for COD. For the assays, conventional laboratory glassware was used. Thus, the characteristics of the effluents treated in the target station (SANIA-cie) are recorded in table 1:

Table 1: Average composition of wastewater from the SANIA treatment plant

ETP Running Daily Report															
Site	Collecting Tank			CAF1		CAF2		Anarérobic Tank		Clarifier	SBR1		SBR2		Remark
Date	PH	Flow (m^3/d)	COD(mg/L)	PH	COD(mg/L)	PH	COD(mg/L)	PH	SV_{30}%	COD(mg/L)	COD(mg/L)	SV_{30}%	COD(mg/L)	SV_{30}%	
SPEC															
2018/3/1	6,69		3290						0			36	155	32	
2018/3/2	5,89		3140						0			36		32	
2018/3/3	6,22		2960						0			36	160	31	
2018/3/4	6,68		3570						1			35		31	
2018/3/5	7,07		3840						0			35	310	32	
2018/3/6	6,63		6490						0			35		32	
2018/3/7	6,76		6470						1			35	140	31	
2018/3/8	6,77		9860						1			34		32	
2018/3/9	6,69		5710						1			34		32	
2018/3/10	6,31		5930	6,90	5730	6,17	2000		1	1990,00		34	230	32	
2018/3/11	6,18		3760						0			34		32	
2018/3/12	6,26		3760						0			34	430	31	
2018/3/13	6,39		7350						0			33	360	31	
2018/3/14	6,06		3445						0		185	33		31	
2018/3/15	5,85		3725	6,03	3610	5,57	1985		0	1605,00		33		31	
2018/3/16	6,8		3520						0			33	270	31	
2018/3/17	9,17		5484						0		170	33		32	
2018/3/18	6,11		3236						0			33	140	32	
2018/3/19	6,13		3431						0		190	65		32	
2018/3/20	6,2		3120						0			65		33	
2018/3/21	6,6		3200						0			65	335	32	
2018/3/22	6,59		5735						1		55	65		31	
2018/3/23	7,19		6700						1			65		32	
2018/3/24	6,79		5500						1		365	65		32	
2018/3/25	6,44		4430						0			65	355	32	
2018/3/26	6,15		3990						0		360	65		32	
2018/3/27	4,714		2590						0			63		33	
2018/3/28	5,26		3510	5,26	2460	5,13	2140	6,49	1	1780,00		63	530	32	
2018/3/29	5,9		3000						1			62	240	32	
2018/3/30	5,93		3980	5,55		8,00			0			62	390	32	
2018/3/31	6,1		4920						0		200	60		32	
Note:check local Gov specs by Lab weekly.															

In addition, Comsol multiphysics software was used for the simulation.

2.2. Phenomena to be modeled

This study consists first of all in modeling and then in simulating the sedimentation of particles suspended in water, the growth of biomass, the decomposition of biomass, the ammonification of organic nitrogen and the hydrolyses of particulate products [13].

The physics involved in the biological treatment of wastewater are:

- ✓ Laminar flow;
- ✓ Transport of diluted species;

2.3. Choice of model

The difficulty of this work lies in the fact that the COMSOL software used does not have a pre-established multiphysics system adapted to the phenomenon of biological treatment of water. We therefore need to find the equations that best describe the phenomena and reactions that take place during anaerobic and aerobic treatment of wastewater [14]. A bibliographic study carried out on empirical models describing activated sludge treatments revealed that, to date, the Activated Sludge Model (ASM) is the model that best describes the phenomena of biological treatment of wastewater, more specifically activated sludge treatment. The ASM models in general and in particular the ASM1 model provide the equations for phenomena such as carbon oxidation, nitrification and denitrification by quantifying the kinetics and stoichiometry of each reaction. The model has a total of: 13 state variables, 8 processes and 19 kinetic and stoichiometric parameters.

The main transformations translated into mathematical equations in our multiphysics model are:

- ✓ Aerobic growth of heterotrophic biomass
- ✓ Aerobic growth of autotrophic biomass;
- ✓ Mortality of heterotrophic and autotrophic biomasses
- ✓ Hydrolysis of particulate organic matter
- ✓ Ammonification of organic nitrogen:

The equations describing the digestion of the substrates are collated in Table 2.

Table 2: The equations for the degradation of organic matter in ASM1

Composante / Processus	S_I	S_S	X_I	X_S	$X_{B,H}$	$X_{B,A}$	X_P	S_O	S_{NO}	S_{NH}	S_{ND}	X_{ND}	Cinétiques ρ_j [$ML^{-3}T^{-1}$]
Croissance aérobie des hétérotrophes		$-\frac{1}{Y_H}$			1			$\frac{-1-Y_H}{Y_H}$		$-iX_B$			$\mu_H \frac{S_S}{S_S+K_S} X_{B,H}$
Croissance hétérotrophe anoxique		$-\frac{1}{Y_H}$			1				$\frac{-1-Y_H}{2,26Y_H}$	$-iX_B$			$\mu_H \frac{S_S}{S_S+K_S} \cdot \frac{S_{NO}}{S_{NO}+K_{NO}} \eta_g X_{B,H}$
Croissance des autotrophes						1		$\frac{-4,57-Y_A}{Y_A}$	$-\frac{1}{Y_A}$	$-iX_B-\frac{1}{Y_H}$			$\mu_A \frac{S_S}{S_S+K_S} X_{B,A}$
Mortalités des hétérotrophes				$(1-f_p)$	-1		f_p					$iX_B - f_p iX_P$	$b_H X_{B,H}$
Mortalités des autotrophes				$(1-f_p)$		-1	f_p					$iX_B - f_p iX_P$	$b_A X_{B,A}$
Ammonification											-1		$ka.S_{ND} X_{B,H}$
Hydrolyse de la MOP		1		-1						1			$kH \frac{\frac{X_S}{X_{B,H}}}{K_X+\frac{X_S}{X_{B,H}}} X_{B,H}$
Hydrolyse de l'azote organique											1	-1	$\rho_2(X_{ND}/X_S)$

3. Results and Discussion

The parameters used in this simulation are: the speed of the effluent, the pressure, the COD, the rate of nitrogen and oxygen.

Several simulations have been carried out from different values. However, we will present some simulations and the results obtained then the interpretations and discussions of these results.

3.1. Variations in the speed and pressure of the basins

The speed and pressure variations of the anaerobic and aerobic basins are given by Figures 1 and 2.

Figure 1 presents a slight increase in the speed at the exit of the anaerobic basin. The speed varies from 0.6 m/s to 0.8 m/s. In the figure, there is a drop in pressure along the pelvis. This pressure drop is explained by the formation and settling of sludge due to the activity of the purifying biomass.

Figures 3 and 4 present the variations in speed and pressure along the processing chain.

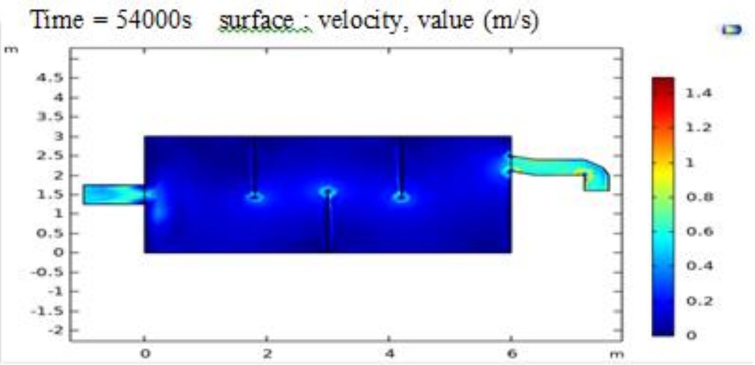

Figure 1: Variation of speed in the basin

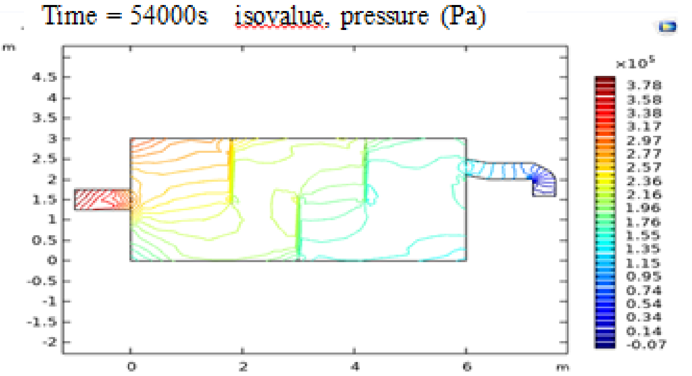

Figure 2: Pressure variation

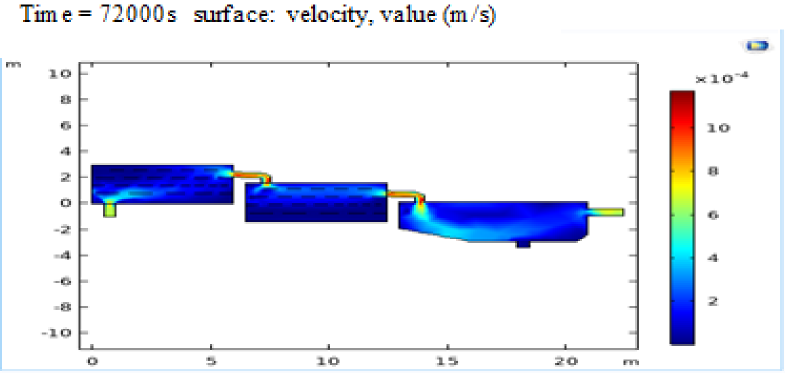

Figure 3: Variation of speed in the basin

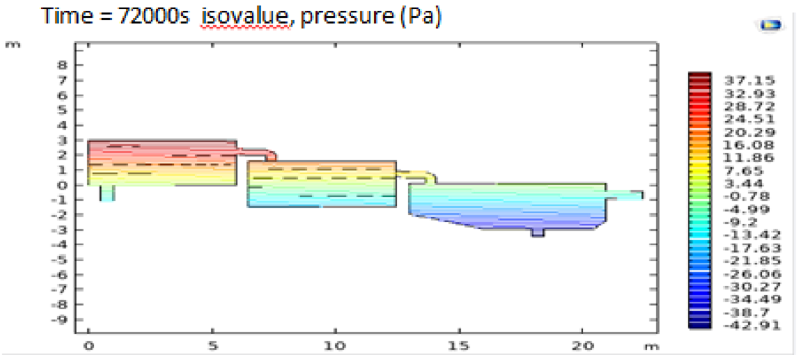

Figure 4: Pressure variation

The analysis of figure 3 shows that the flow of the effluent is at constant speed ($6 * 10^{-4}$ m/s) along the treatment chain. In addition, there is a drop in pressure along the processing chain. This pressure drop is explained by the formation and settling of sludge due to the activity of the purifying biomass.

3.2. Evolution of COD during anaerobic treatment

Several simulations were carried out in order to visualize the variation of the COD as a function of time and during the anaerobic treatment. The results of the simulations carried out on the evolution of the COD are presented in Figures 5, 6 and 7. These simulations were carried out over a treatment period of 7 hours. This corresponds to the actual processing time of the plant. Indeed, the complete treatment takes place in 24 hours as indicated, however the anaerobic phase lasts 7 hours.

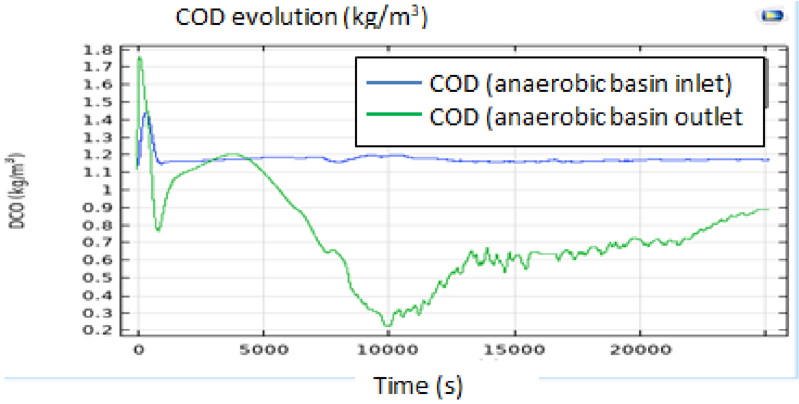

Figure 5: Evolution of COD during anaerobic treatment (COD input = 1.12 kg/m^3)

The figure 5 highlights the variation of COD over time and at two points in the anaerobic pool (at the inlet and at the outlet). An effluent that enters the anaerobic basin with an initial COD of 1120 mg/L or 1.12 kg/m^3, leaves the basin with a COD of 0.9 kg/m^3.

The yield is $\tau = \frac{COD_{extracted}}{COD_{inlet}} = \frac{1.12-0.9}{1.12} = 19.6\ \%$ at the level of anaerobic treatment.

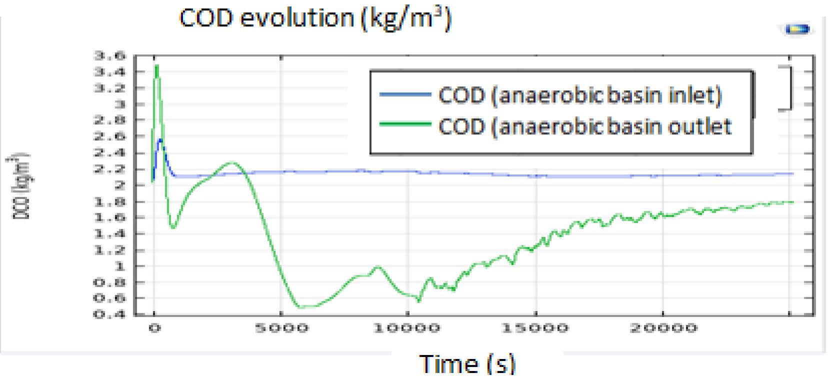

Figure 6: Variation of COD during anaerobic treatment (COD input = 2.1 kg/m^3)

For this simulation, the input COD is 2.1 kg/m^3 and the COD of the outgoing effluent is 1.8 kg/m^3. Let a yield of $\tau = \frac{2.1-1.8}{2.1} = 14.3\ \%$.

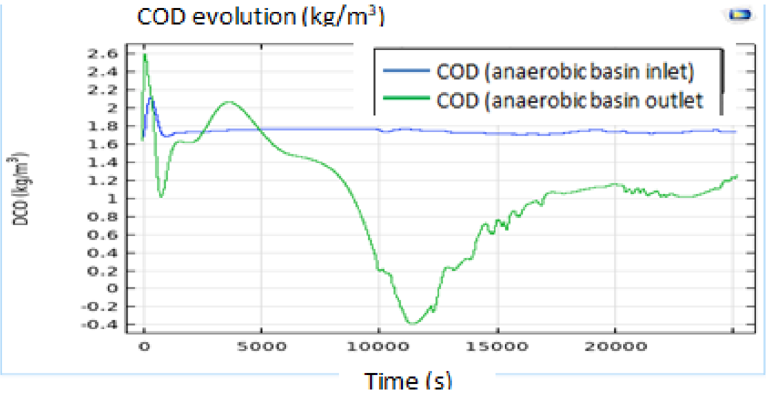

Figure 7: Evolution of COD during anaerobic treatment (COD input = 1.7 kg/m^3)

For this simulation, the input COD is 1.7 kg/m^3 and the COD of the outlet effluent is 1.2 kg/m^3. Whence $\tau = \frac{1.7-1.2}{1.7} = 29.4$ %. For each input value, the returns were calculated and then grouped together in Table 3.

Table 3: Treatment performance according to the input load

Inlet COD (kg/m^3)	Outlet COD (kg/m^3)	Performance
1.12	0.9	19.6%
1.7	1.2	29.4%
2.1	1.8	14.3%

The overall efficiency of the anaerobic treatment is given by $\tau_1 = \frac{\sum \tau_i}{3}$. So the real yield of the land is $\tau_1 = 21.1\%$.

3.3. Evolution of the nitrogen rate during anaerobic treatment

Figure 8 shows the change in the nitrogen rate over time and at two points in the basin (at the inlet and at the outlet).

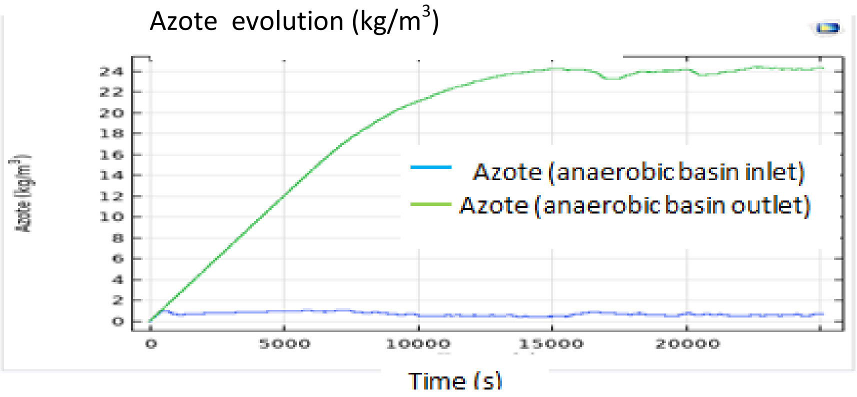

Figure 8: Variation in nitrogen content during anaerobic treatment

It emerges from the analysis of these graphs that an effluent which enters the anaerobic basin with an almost zero dissolved nitrogen content (0.1 kg/m^3), following the activity of the anaerobic heterotrophic purifying biomass leading to the denitrification of the nitrate molecules contained in the effluent to be treated, approximately 24 kg/m^3 of gaseous nitrogen is generated. This quantity of nitrogen is released at the outlet of the anaerobic basin in a basin called the degassing and clarification zone before starting the aerobic treatment.

3.4. Evolution of COD during aerobic treatment

Several simulations were carried out in order to visualize the variation of the COD as a function of time and during the anaerobic treatment. The results of the simulations carried out on the evolution of the COD are presented in figures 9, 10 and 11. These simulations were carried out for treatment duration of 15 hours. This corresponds to the actual processing time of the plant. Indeed, the complete treatment takes place in 24 hours as indicated [15]. However, the aerobic phase lasts about 15 hours.

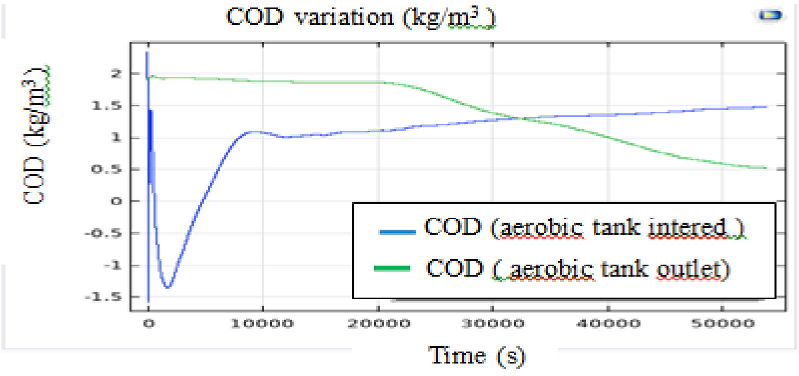

Figure 9: Evolution of COD during aerobic treatment (COD input = 2 kg/m^3)

The figure 9 present highlights the variation in COD over time and at two points in the aerobic pool (at the inlet and at the outlet). In the Sania-cie treatment plant, the outlet of the anaerobic digester is directly connected to the inlet of the aerobic digester. Thus, the input COD of the aerobic treatment constitutes the output COD of the anaerobic basin. An effluent which enters the aerobic basin with an initial COD of 2000 mg/L, amounts to 2 kg/m^3, leaves the basin with a COD of 0.5 kg/m^3, amounts to $\tau = \frac{DCO_{extracted}}{DCO_{entered}} = \frac{2-0.5}{2} = 75\ \%$ at the level of aerobic treatment

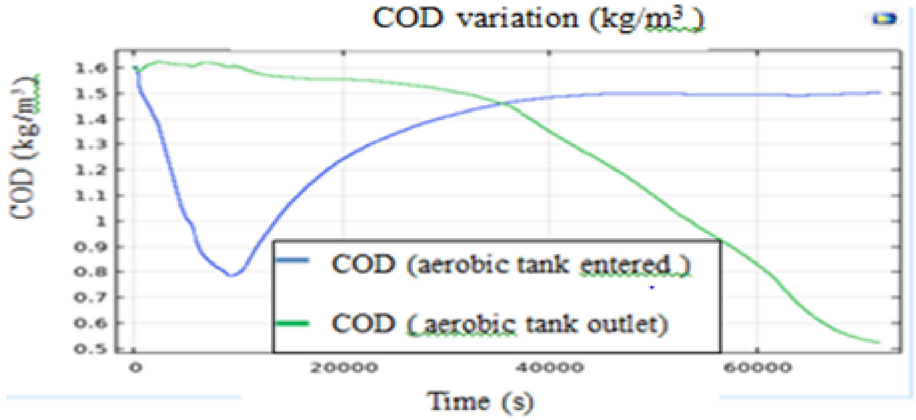

Figure 10: Evolution of COD during aerobic treatment (COD input = 1.6 kg/m^3)

For this simulation, the input COD is 1.6 kg /m^3 and the COD of the outlet effluent is 0.5 kg/m^3. Whence a yield of$\tau = \frac{COD_{extrated}}{COD_{initial}} = \frac{1.6-0.5}{1.6} = 68.75\ \%$.

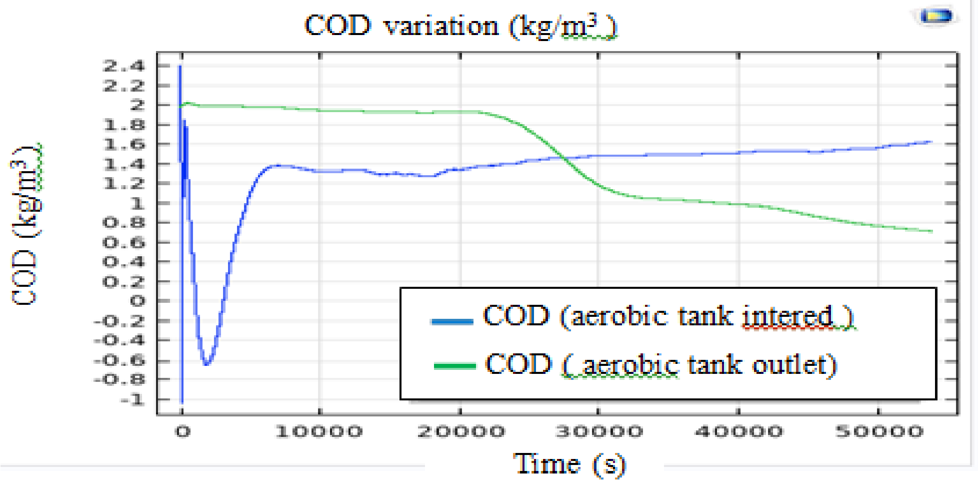

Figure 11: Evolution of COD during aerobic treatment (COD input = 2.1 kg/m^3)

For this simulation, the input COD is 2.1 kg/m^3 and the COD of the outgoing effluent is 0.6 kg/m^3. Whence a performance of$\tau = \frac{\text{COD}_{\text{extracted}}}{\text{COD}_{\text{initial}}} = \frac{2.1-0.6}{2.1} = 71.2\ \%$.

For each input value, the returns have been calculated and grouped in Table 4.

Table 4: Treatment performance according to the input load

Entered COD (kg/m^3)	Outlet COD (kg/m^3)	Efficiency
2	0.5	75%
1.6	0.5	68.75%
2.1	0.6	71.2%

The overall efficiency of the model is given by$\tau_G = \frac{\sum \tau_i}{3}$. Thus the efficiency of the model is $\tau_G = 71.65\%$ whether $\tau_G = 71.7\%$. In fact, in the absence of oxygen, the growth and proliferation of microorganisms is slowed down, unlike the aerobic basin where the presence of oxygen stimulates and makes it possible to accelerate the development and proliferation of purifying biomass.

3.5. Evolution of the nitrogen rate during aerobic treatment

The figure 12 shows the evolution of the nitrogen rate as a function of time and at two points in the basin (the inlet and the outlet). The entrance to the aerobic pool corresponds to the exit from the anaerobic pool.

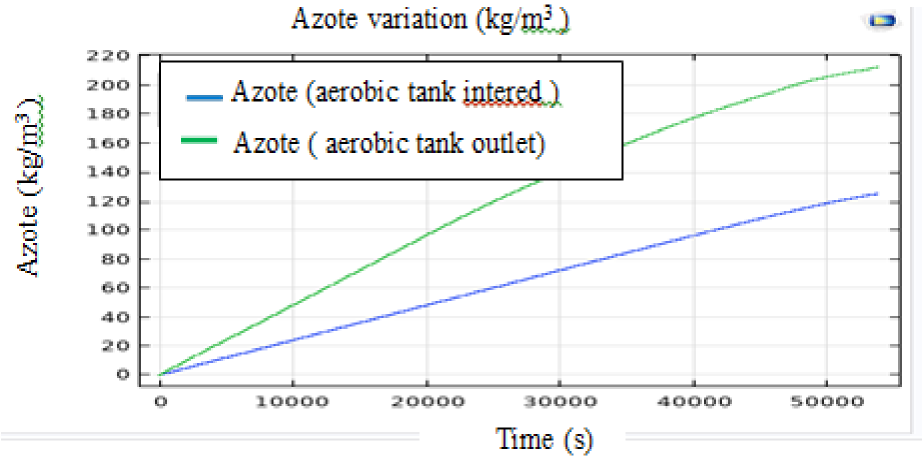

Figure 12: Variation in nitrogen content during aerobic treatment

It emerges from the analysis of these graphs that an effluent which enters the aerobic basin with an almost zero dissolved nitrogen content (0.1 kg/m^3), following the activity of the aerobic autotrophic purifying biomass, approximately 220 kg/m^3 of nitrogen gas is generated. This amount of nitrogen is released into the atmosphere as it leaves the aerobic pond.

Indeed, during the reaction phases the bacteria will use the oxygen available in free form in the effluent to degrade the carbonaceous pollution and the nitrogen which arrives in the NH4 form and transform it into NO_3. It is only during the phases of stopping the aeration, once the bacteria have consumed all the oxygen (O_2) available in free form, that they will use the oxygen available in bound form in the bacteria nitrates (NO_3) to ensure their activity and respiration. They will in fact by this means degrade nitrogen in its $N\text{-}NO_3$ form into gaseous nitrogen (N_2).

3.6. Evolution of the oxygen level during aerobic treatment

The variation of the amount of oxygen during treatment is shown in figure 13.

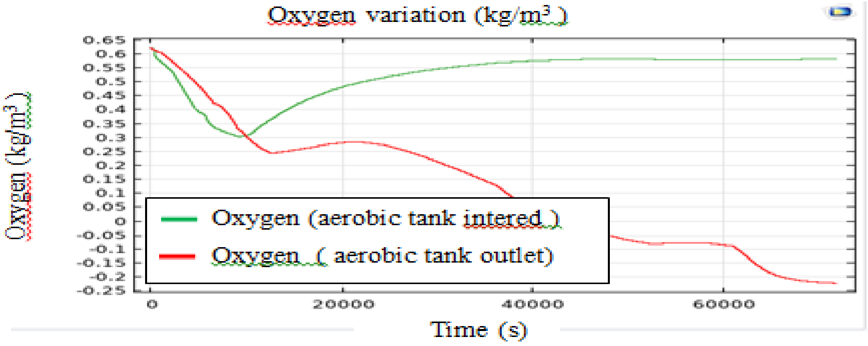

Figure 13: Evolution of the amount of oxygen during aerobic treatment

The amount of oxygen drops from 0.65 kg/m^3 to -0.25 kg/m^3.

Indeed, microorganisms use the oxygen available in free form in the effluent to degrade carbon pollution according to the following reaction:

Mast. Organic + micro-organism + O_2 + N + P $\longrightarrow$ micro-organism + CO_2 + H_2O + non-biodegradable solid residue

The negative values observed for the quantity of oxygen are evidence of a lack of oxygen in the reaction medium.

3.7 Evolution of the quantity of sludge

The variation in the fraction of sludge at the end of treatment (secondary settling) is presented in figure 14.

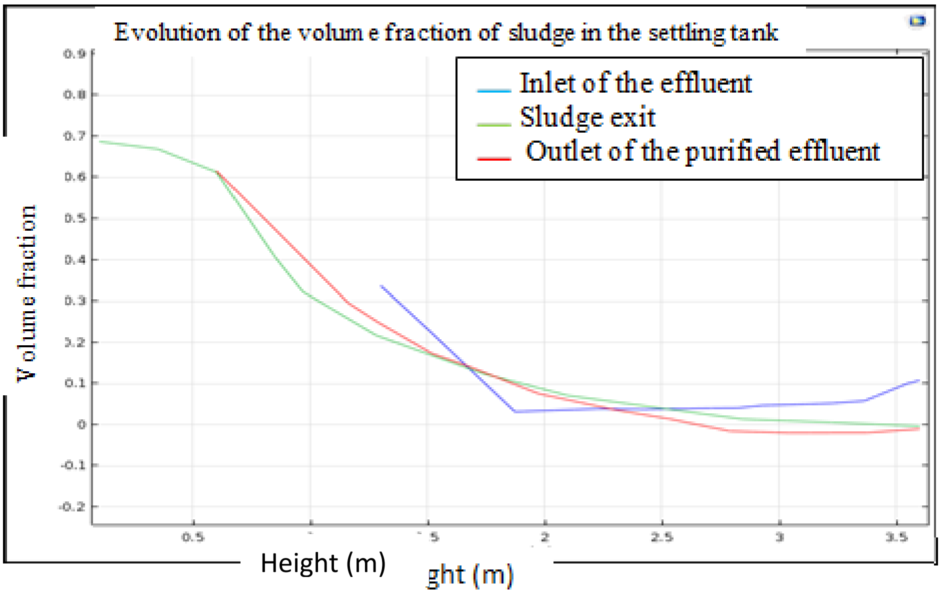

Figure 14: Evolution of the sludge fraction in the settling tank

The secondary settling takes place at the end of the treatment and makes it possible to visualize the volume fraction of sludge as a function of the height of the basin. This settling makes it possible to know the quantity of sludge contained in the treated effluent before it is released into the environment. The simulation visualized in Figure 4 was performed with an effluent whose volume fraction of sludge at the inlet of the treatment system is 0.4. The volume fraction of sludge is 0.7 instead of purging and is almost zero for the settled effluent (about 0.01). The yield of the model relative to the quantity of sludge is given below: $\tau = \frac{0.4-0.01}{0.4} = 97.5\%$.

3.8 Evolution of COD

Several simulations were carried out in order to follow the evolution of the COD during the biological treatment. The results of three (3) simulations carried out on the evolution of the COD are presented in Figures 15, 16 and 17. These simulations were carried out for treatment duration of 20 hours. This corresponds to the actual duration of the biological treatment of the plant.

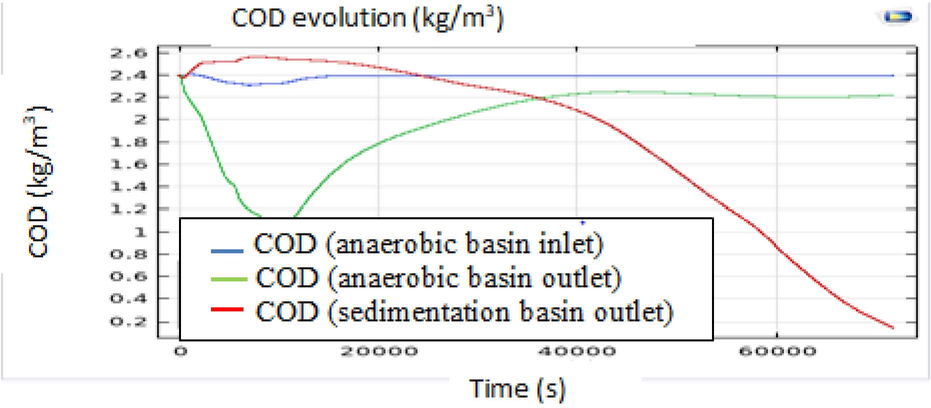

Figure 15: Evolution of the COD during the treatment (input COD = 2.4 kg/m^3)

Figure 15 shows the change in COD in each basin as a function of time. This simulation was carried out for a residence time of 20 hours in accordance with the duration of the plant's biological treatment. The effluent at the entrance to the biological treatment system (entrance to the anaerobic pond) has a COD of 2.4 kg/m^3. On leaving the anaerobic reactor, the effluent has a COD of 2.2 kg/m^3. The activity of the purifying biomass is not intense in an anaerobic environment (absence of oxygen). This explains the small decrease in COD at the outlet of the anaerobic reactor. In addition, the outlet of the anaerobic basin is directly connected to the inlet of the aerobic basin, hence the value 2.2 kg/m^3 for the COD entering the aerobic reactor. After aerobic digestion, the COD of the effluent decreases to 0.18 kg/m^3. After passing through the entire biological treatment system, the inlet effluent with a COD of 2.4 kg/m^3 exits with a COD of 0.18 kg/m^3. The yield of the model relative to the chemical oxygen demand (COD) is given by the following relation$\tau = \frac{2.4-0.18}{2.4} = 92.5\%$.

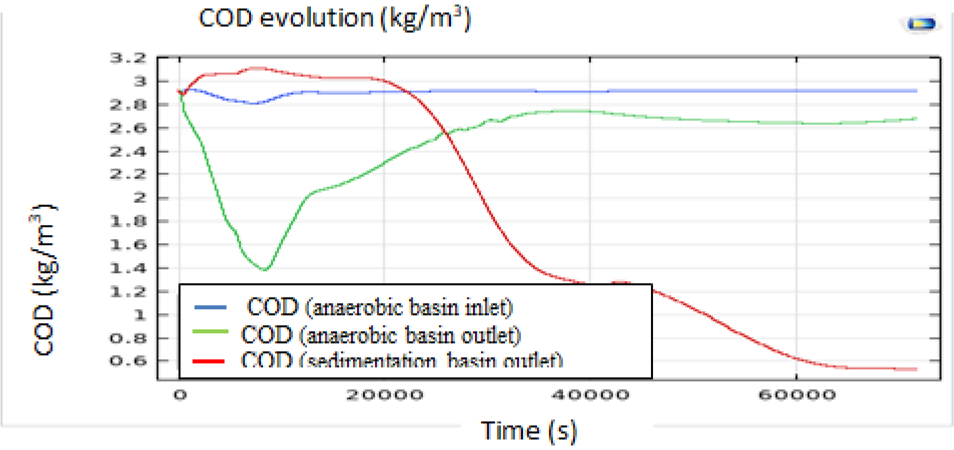

Figure 16: Change in COD during treatment (input COD = 2.9 kg/m^3)

For this simulation (Figure 16), the input COD is 2.9 kg/m^3 and the COD of the outgoing effluent is 0.5 kg/m^3. Hence a yield of $\tau = \frac{2.9-0.5}{2.9} = 82.76\ \%$.

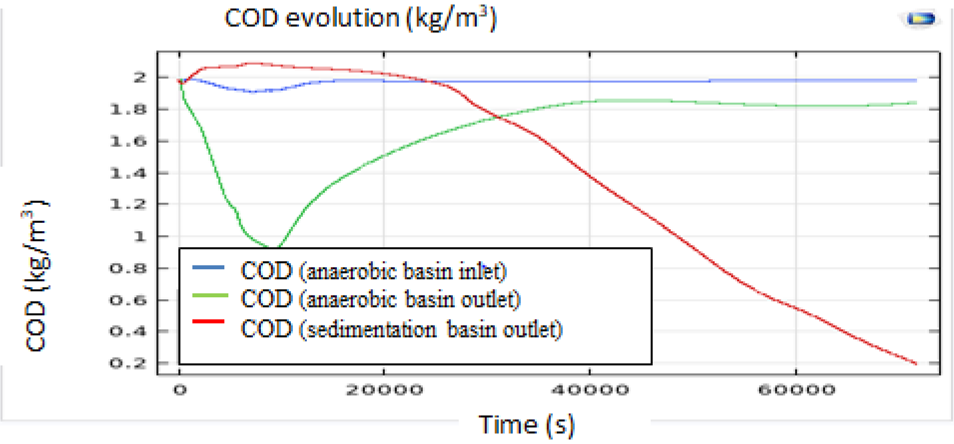

Figure 17: Evolution of COD during treatment (input COD = 2 kg/m^3)

For this simulation (Figure 17), the input COD is 2 kg/m^{3}and the COD of the outgoing effluent is 0.2 kg/m^3. That is, an efficiency of $= \frac{2-0.2}{2} = 90\%$. For each input value, the returns have been calculated and grouped in Table 5.

Table 5: Summary of the yields calculated according to the input load

Inlet COD (kg/m^3)	**Outlet COD (kg/m^3)**	**performance**
2.4	0.18	92.5%
2.9	0.5	82.76%
2	0.2	90 %

The overall efficiency of the model thus calculated is $\tau_G = 88.42\%$

3.9 Evolution of the nitrogen rate

The change in the amount of nitrogen during the biological treatment is shown in Figure 18:

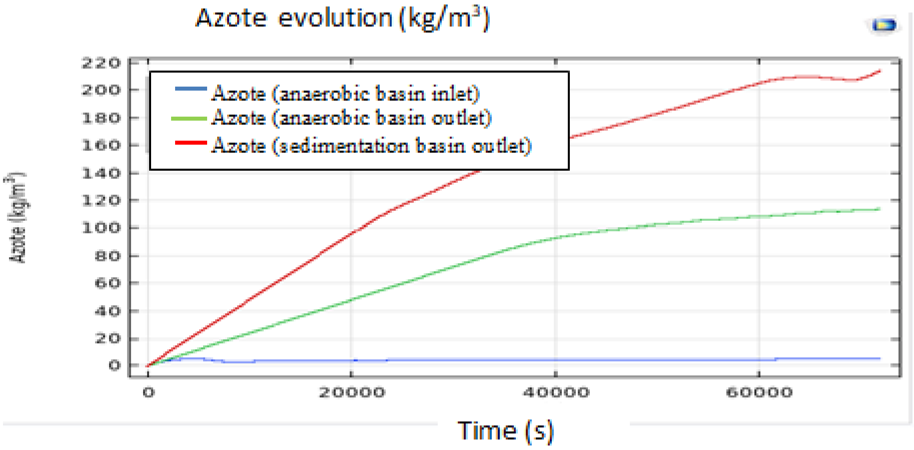

Figure 18: Evolution of the quantity of nitrogen during the treatment

Figure 18 shows the change in total nitrogen at three points chosen respectively at the entry of the anaerobic basin, at the exit of the anaerobic basin and finally at the exit of the aerobic basin as a function of time. An effluent in which the quantity of nitrogen gas entering the treatment system is almost zero leaves the anaerobic reactor with a quantity of 110 kg/m^3 of nitrogen N_2 released. After passing through the entire treatment chain, the treated effluent leaves the aerobic basin with a gaseous nitrogen content of 220 kg/m^3.

We notice that the amount of nitrogen gas increases as time passes. There has certainly been denitrification (transformation of nitrates into gaseous nitrogen) of nitrates formed during biological degradation. The residual organic nitrogen obtained comprises the nitrogen included in the suspended matter entrained, the “fines” discharged with the purified water, and the non-ammonifiable soluble organic nitrogen or soluble “refractory” or even soluble organic nitrogen. "Hard". This latter fraction will not ammonify or will ammonify extremely slowly in the natural environment.

3.10 Model validation

The validation of the model consists in comparing the values obtained by simulation with those measured in situ, by means of the coefficient of performance. This is made by the relation$\gamma = \frac{\tau}{\alpha} \times 100$with τthe yield of the model and α: the yield of the land. This validation is done for each parameter (COD, fraction of sludge and nitrogen rate).

- ✓ **Chemical oxygen demand (COD).**

The COD values of SANIA effluents before and after their treatment are shown in Table 6.

Table 6: Summary of field yields according to COD

Inlet COD (mg/L)	Outlet COD (mg/L)	Efficiency (α_i)
2000	230	88.5%
1985	185	90.68 %
2920	240	91.78 %

The real yield obtained in the field is$\alpha = \frac{\sum \alpha_i}{3} = 90.32\%$. The yield of the model obtained ($\tau_G = 88.42\%$) is close to that obtained in the field which is α = 90.32%. This makes it possible to calculate the coefficient of performance γ of the model establishes. $\gamma = \frac{\tau_G}{\alpha} = \frac{88.42\%}{90.2\%} = 97.90\%$. The model thus established is considered to be efficient relative to the COD since it reflects the real case well.

- ✓ **Quantity of sludge**

The quantities of sludge from the wastewater treatment plant effluents before and after their treatment are shown in Table 7.

Table 7: Quantities of sludge from plant effluents before and after treatment

	Effluent to be treated	**Treated effluent**
Sludge quantities (mg/L)	2000 - 4000	≈50

The average load of effluents treated in said plant is 3000 mg/L. The treated effluent is discharged with an average quantity of sludge of 50 mg/L. We therefore obtain a yield of $\alpha = \frac{3000-50}{3000} = 98.33\%$.The yield of the model being τ = 97.5% and that of the land α = 98.33%, the coefficient of performance γ of the model established was calculated. The results of the calculation gave$\gamma = \frac{97.5\%}{98.33\%} = 99.156\%$ or $\gamma = 99.16\%$. The model established is efficient in relation to the quantity of sludge.

✓ **Global coefficient of performance $\boldsymbol{\gamma_G}$ of the model.**

The overall coefficient of performance of the model $\boldsymbol{\gamma_G}$ is obtained from the arithmetic mean of the two (2) relative performance coefficients$\gamma_G = \frac{\sum_{k=1}^{N} \gamma_k}{N}$. Thus, the overall coefficient of performance of the model is$\gamma_G = \frac{99.16\%+97.90\%}{2} = 98.53\%$.

The overall coefficient of performance (98.53%) being very close to 1, the result is that the model established is efficient.

4. Discussion

This study has shown that several parameters (COD, nitrogen rate, quantity of oxygen, residence time, etc.) can be used to evaluate the effectiveness of biological treatments in anaerobic as well as aerobic environment. The treatment is as effective as when the residence time for the management of the substrates and the time to sediment almost all the suspensions is small [16]. A well carried out digestion leads to a good yield of the biological treatment process (activated sludge). To do this, the effluent entering the reactor must be in laminar flow. Thus [17] argued that the photo catalytic degradation of a pollutant in a reactor is greater at low flow rates. However, a slight increase in speed and pressure is observed at the exit of the basin. This is due to the formation and accumulation of mud at the bottom of the basin. The efficiency of the aerobic digester is much higher than that of an anaerobic digester. Indeed, the presence of oxygen stimulates and accelerates the development and proliferation of purifying biomass. This is not the case for anaerobic treatment. In fact, in the case of an anaerobic pond, as it is not oxygenated, the activity of anaerobic microorganisms depends on the nitrogenous organic matter load [18]. Anaerobic treatment is all the more effective than when nitrogen pollution is significant in the effluent to be treated. Then, conversely, an effluent with a low biodegradable nitrogen compound content provides a low yield. The reaction of organic matter assimilation by heterotrophic bacteria in the absence of dissolved oxygen and the presence of nitrates (NO_3) can be represented by the following reaction:

Organic matter + bacteria → New Bacteria + N_2 + H_2O + CO_2

This reaction is called "denitrification" because it results in the reduction of nitrates to molecular nitrogen (N_2), a gas which returns to the atmosphere. This transformation is also called dissimilative reduction [19, 20].

5. Conclusion

This work has been the subject of the modeling and simulation of effluent treatment by activated sludge in anaerobic and aerobic environments in order to compare the efficiencies of these two types of treatment. In this document, we have presented a model of the treatment of industrial wastewater by activated sludge, more precisely the anaerobic and aerobic treatments. These models are described as the diffusion equations, and the ASM (Activated Sludge Model) model equations, thus making it possible to simulate the operation of the treatment system using the Comsol software. The first phase of this study consisted of the characterization of the effluents treated in a target plant (Sania-cie). The second phase of this study was the modeling and numerical simulations of anaerobic and aerobic digesters. These simulations gave the following results: yield of anaerobic treatment τ_1= 21.1% and yield of aerobic treatment τ_2 = 71.7%. It therefore appears that aerobic treatments are more effective than anaerobic treatments. It appears that aerobic treatments are more effective than anaerobic treatments. The third phase consisted of the coupling of the three processes which are the anaerobic, aerobic and settling treatment. To validate the model, the effluent parameters were determined experimentally. These experimental values were used to design the model. In addition, the experimental values of the COD and the quantity of sludge were compared with those of the model in order to validate the results of the model. The experimental and simulated results are almost identical, hence the validation of the model with a coefficient of performance of $\gamma_G = 98.53\%$.

References

[1]. K.L. Kouamé et N.E. Assidjo. Simulation du traitement par boues activées des effluents industriels en milieu anaérobie : cas de Sania-cie en côte d'ivoire, Rev. Ivoir. Sci. Technol., 35, 97 - 110 97 (2020).

[2]. R. Ghezli, N. Belarif. Contribution à l'évaluation de la qualité des effluents industriels et déchets solides au niveau de l'entreprise nationale des industries de l'électroménager ENIEM de tiziouzou, Université Mouloud Mammeri. (2017).

[3]. Zalaghi, F. Lamchouri, M. Merzouki. Traitement par le procédé SBR (Sequencing Batch Reactor) des lixiviats de la décharge publique non contrôlée de la ville de Taza (Maroc), International journal of invention and appliedstudies 23 (3), 299-309 (2018).

[4]. Boukerroucha. Modélisation des stations d'épuration à boues activées cas de la station de Baraki (Alger). Thèse de l'Ecole Supérieure d'Agronomie EL HARRACH ALGER. (2011).

[5]. J. Koné. Optimisation du process de traitement des effluents de SANIAcie, mémoire de fin d'étude, École Supérieure d'Industrie, 94p (2015).

[6]. E. Ghammat, T.Riffi., H. Zerrouk.A study of the performance of a sequential bioreactor plant for the treatment of dairy effluents, LARHYSS journal, 7-21 (2019).

[7]. Gil-Pulido, E. Tarpey, E. Almeida, W. Finnegan. Evaluation of dairy processing wastewater biotreatment in an IASBR system: Aeration rate impact on performance and microbial ecology, Biotechnology reports 19, e00263 (2018).

[8]. S. Heddam. Contribution à la modélisation de la qualité des eaux. Thèse de doctorat, ÉcoleNationalePolytechniqued'Alger, 210 P(2012).

[9]. M. Benneouala, Y. Bareha, E. Mengelle, M. Bounouba. Hydrolysis of particulate settleable solids (PSS) in activated sludge is determined by the bacteria initially adsorbed in the sewage, revue water research, 400-409 (2017).

[10]. Imen. Caractérisation de la taille des particules et de leur vitesse de chute en décantation primaire, Maîtrise en génie des eaux, Université de Laval, 249p. (2013).

[11]. K. L. Kouamé, N. E. Assidjo. Simulation en régime temporel de la sédimentation de particules en suspension dans l'eau a Sania-cie (Abidjan-cote d'ivoire), Revue Ivoirienne de Géographie des Savanes, Numéro Spécial Janvier, 174-186(2019).

[12]. M.Machkor. Modélisation et optimisation du taux du sulfate d'aluminium dans la station de traitement des eaux de barrage BAB LOUTA par la méthodologie du plan surface de réponse, Mémoire de fin d'études, Université Sidi Mohammed Ben Abdellah, 59p (2013).

[13]. Nidhal. Modélisation et simulation numérique de la dégradation photocatalytique d'un polluant modèle dans un microréacteur. Thèse de doctorat, Université de Lorraine, 169p (2012).

[14]. L. Amel. Amélioration des procédés de clarification des eaux de la station Hamadi-Kroma de Skikda. Mémoire de Magister, Université de Skikda Faculté des Sciences, Département des Sciences Fondamentales, Spécialité : Chimie ; Option : Pollutions Chimiques & Environnement, 120p (2009).

[15]. S. Moulin. Traitement des eaux usées. Centre d'Enseignement et de Recherches sur l'Environnement et la Société EnvironmentalResearch and Teaching Institute (2013).

[16]. Oumar et al.Utilisation des procédés électrochimiques et leurs combinaisons avec les procédés biologiques pour le traitement des lixiviats de sites d'enfouissement sanitaires, Revue des sciences de l'eau/ Journal of water science 29 (1), 63-89 (2016).

[17]. V. Rocher, C. Join, S. Mottelet, J. Bernier. La production de nitrites lors de la dénitrification des eaux usées par biofiltration-stratégie de contrôle et de réduction des concentrations résiduelles, Revue des sciences de l'eau/Journal of water science 31 (1), 5 61 (2018).

[18]. Dan. " Evolution des paramètres biochimiques et physico-fonctionnels des baies de SolanumanguiviLam récoltées en Côte d’Ivoire au cours du mûrissement", Thèse unique, Université NanguiAbrogoua, Abidjan 188p (2015).

[19]. H. Cabana. La coagulation, la floculation et l’agitation, GCI 720 -Conception: usine de traitement des eaux potables. 94p (2015).

[20]. J. Vaxelaire.Étude et modélisation de l’aération des stations d’épuration des eaux usées urbaines par agitation mécanique de surface, Thèse de Doctorat à l’Institut National Polytechnique de Lorraine, 193p (1994).