Desalination and Water Treatment
www.deswater.com

doi: 10.5004/dwt.2017.20182

63 (2017) 69–77
February

Influence of the receiving of leachate from sanitary landfill on the sewage treatment in process of activated sludge with mobile biomedia

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Received 11 April 2016; Accepted 21 August 2016

ABSTRACT

In this research was investigated the performance of a hybrid system of the type integrated fixed-film activated sludge (IFAS), here called "activated sludge with mobile biomedia", in combined treatment of leachate from sanitary landfill and domestic sewage aiming at removing of organic substance and nitrogen. In order to assess the possible impact on treatment had been developed three experimental phases with contributions of leachate in the composition of the affluent: 5%, 10% and 20% of the total load of BOD. A system was used on a pilot scale, which useful volume of the bioreactor is equal to 1.0 m^3. Overall, the results showed that, even at the highest contribution of leachate, there were no significant changes in the behavior of the biological process, and were usually obtained efficiencies of BOD removal above 85% and TKN near 90%. Nevertheless, there was a small reduction in the specific growth rates of both autotrophic bacteria as in heterotrophic, increased with leachate load. In general, the process showed a good performance and operational stability throughout its operation, indicating that, from the point of view of removal of organic matter and nitrogen, the leachate contributions used in this study can be admitted to treatment plants sewer of this category.

Keywords: Leachate from sanitary landfill; Combined treatment of leachate and domestic sewage; Hybrid system; Removal of organic matter and nitrogen

1. Introduction

The leachate from landfills is a wastewater of difficult treatability, due to the presence of biodegradable organic matter in varying concentrations over time, recalcitrant organic matter, inorganic toxic compounds and high concentration of ammoniacal nitrogen. One solution adopted in many countries is disposing it into the sewage treatment plants as the dilution suffered by inhibiting substances allows the biochemical processes involved to occur in a more stable and efficient manner. However, if very high amounts or not equalized loads of leachate are introduced into the sewage treatment plant (STP), there may be irreversible commitments.

The low operating cost, as well as the use of a structure already existing, reinforces the use of this alternative. However, regarding the quality of the effluent generated by the combined treatment of leachate and wastewater, it is possible that the variables commonly used to characterize the efficiency imposed by the treatment to remove organic compounds, such as BOD, COD and TOC, do not allow exact distinction between biodegradable organic matter and the recalcitrant one [1].

Researchers conducted in four STP's in Sao Paulo concluded that further studies are needed for a complete understanding of the implications arising from the combined treatment of leachate and sewage, with respect to various aspects such as toxicity of biological processes, sludge quality and the effluent of the treatment [2].

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Experiments performed with activated sludge in batch, by varying the hydraulic retention time (HRT) with leachate doses ranging from 5% to 25% (v/v) in sewage, with a HRT of 2 d, obtained 97.5% of organic matter removal [3].

Researches treating leachate from the landfill of Gaziantep, Turkey, together with sewage by the activated sludge process in batch, in a ratio ranging from 5% to 20% (v/v), showed that when the percentage of leachate is over 20% of the treated affluent wastewater or equal to 50% of the initial COD load, will compromise the efficiency of the treatment [4]

Studies developed in laboratory with the activated sludge process, where the addition of leachate ranged 1%–16% in volume in the mix with sewage, showed increasing of BOD and COD values in the final effluent, with the boost of the proportion of added leached, possibly as a result of phosphorus deficiency and the addition of non-biodegradable organic load from the leachate [5].

The addition of leachate (BOD 2,000–4,700 mg.L^{-1}, COD 4,700–12,000 mg.L^{-1} and N-NH$_3$ 405–920 mgN.L^{-1}) in percentage of 10% in the mix volume with sewage, in the activated sludge reactor, operating in sequencing batch in the laboratory, resulted in removal efficiencies of 70%–98% BOD and 35%–50% total nitrogen [6].

Some authors recommended volume ratio between the leachate and wastewater below 2%. Large volumes of leachate added to sewage treatment system may further result in effluents treated with high concentrations of organic matter and ammoniacal nitrogen [7].

Seeking to study the removal of nutrients in the combined treatment of leachate and wastewater, it was demonstrated that a leachate with COD rates of up to 10,000 mg.L^{-1} can be handled in a mixture of 5% (v/v) with sanitary sewage, without changing the quality of the final effluent, through activated sludge process with extended aeration [8].

Among the new treatment technologies developed in recent decades, there is the hybrid process integrated fixed-film activated sludge (IFAS), which has not yet been fully exploited in the treatment of sanitary landfill leachate.

The IFAS process promotes the growth of biomass in the aeration tank of an activated sludge system, in order to increase its capacity and improve its performance. In this process, the concentration of active solids in the biological sludge can be significantly increased by the introduction of mobile biomedia in an activated sludge system. Inside the biomedia is developed a highly specialized biomass for each type of condition imposed on the reactor, regardless of the relative age of the sludge biomass in suspension. As the contribution of biomass that attached to the support environment, the required concentration of biomass in suspension in the reactor is lower, thus reducing the load of suspended solids to the secondary clarifiers, preventing damage on clarification of effluent [9].

The IFAS process can be considered a good alternative when the objective is to increase the treatment capacity of an earlier activated sludge system, or when it is desired to incorporate the removal of nutrients, particularly nitrogen, as nitrifying bacteria to remain, retained by the biofilm, allows the possibility of operating the system with low-age sludge [10], thus generating savings to the treatment.

The use of a combined MBR-MBBR system with 37.5% of the total filling of the tank regarding the MBBR, treating leachate from an old landfill of Northern Italy, was operated with the view to observe the occurrence of nitrification, obtaining about 90% of ammonia removal with application rates ranging 50–120 gN-TKN.kgSST^{-1}.d^{-1} [11].

A MBBR system with 60% of filling, operating with HRT ranging from 2 to 5 d and at 80% of DO saturation, in the treatment of leachate from the landfill of Hyllstofia (Sweden), in operation since 1975, obtained 98% of nitrification, with application rates up to 11 gN-NH$_4^+$.m^{-3}.h^{-1}. The researchers concluded that rates of up to 40 gN-NH$_4^+$.m^{-3} reactor^{-1}.h^{-1} could be applied without the risk of biomass loss or compromise the efficiency of the treatment [12].

This study aimed to evaluate the performance of a bioreactor operated by IFAS process, after the introduction of leachate load combined with the treatment of domestic sewage in the removal of organic matter and nitrogen, as well as evaluating the kinetic behavior of this treatment.

2. Material and methods

The research was conducted by means of an experiment on a pilot scale and was put into operation a bioreactor of activated sludge with mobile biomedia, made of acrylic sheet.

The aeration tank was divided into two compartments, the first with 270 L of useful volume, equipped with a mixer, which operated as an anoxic pre-denitrification chamber. The second compartment, with 800 L of useful volume, worked as an aerated chamber, with four diffusers of thin membrane bubbles installed in its bottom to distribute the air provided by the compressor, in order to maintain the DO concentration in the interval between 3.0 and 4.0 mg.L^{-1}.

The secondary clarifier had a circular section in plan, with a wall scraper driven by an electric motor, presenting a surface area of 0.785 m^2 and useful volume of 1.47 m^3.

The pilot plant had also two elevating sets, one for the sludge return from the secondary clarifier to the anoxic chamber, and the other to promote the internal recycling of the sludge from the aeration tank to the anoxic chamber.

Both chambers of the bioreactor received addition of biomedia. Was used the K1 product, manufactured by AnoxKaldnes® company, currently owned by Veolia Water group, with specific surface area (protected) of 300 m^2.m^{-3} of support material. The filling percentages with biomedia of anoxic and aerobic chambers were 30% and 50%, respectively.

Have been installed pH, DO, ORP and temperature sensors in the bioreactor. Fig. 1 shows a schematic section of the pilot plant.

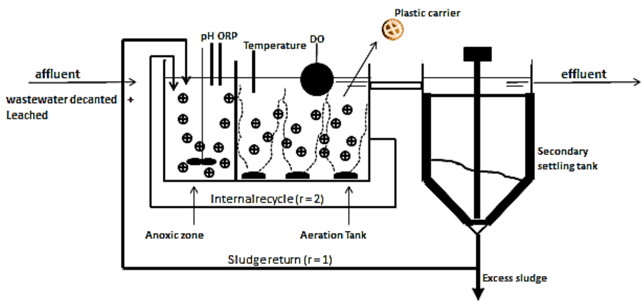

Fig. 1. System profile on a pilot scale.

Throughout the research was utilized the leachate from the landfill Caieiras (CTR-Caieiras), which has been in operation since 2002. The sewage came from the Residential Complex of the University of São Paulo/Brazil and received primary decanting before entering the pilot plant.

Three experimental phases were established, in which varied the BOD load percentage applied to the process due to the leachate contribution (5%, 10% and 20% of full load), keeping all other conditions constant.

The pilot unit operated discarding the excess of activated sludge in order to result in a 9-d-old sludge, based only on the concentration of suspended biomass expressed in terms of volatile suspended solids (VSS). The anoxic chamber occupied one-third of the useful volume of the reactor, resulting in a 6-d-old aerobic sludge. From the initial characterization of sewage, was settled the feed rate of 1.6 $m^3.d^{-1}$, corresponding to a ratio food/microorganisms of 0.2 $kgBOD.kgVSS^{-1}.d^{-1}$ and an HRT of 0.48 d.

Both the decanted sewage and the landfill leachate, as well as the effluent produced by the process, were characterized twice a week by determining the variables: total and soluble $BOD_{5.20}$, total and soluble COD, Kjeldahl nitrogen, ammoniacal nitrogen, nitrite, nitrate and total alkalinity. The sludge from reactor was characterized in terms of total, fixed and VSS, as well as monitoring by sensors.

To determinate the attached biomass concentrations, at first were separated, in a Falcon tube, 35 biomedia units occupying a volume of 40 mL; then was executed the release of all the biomass by scraping with a toothbrush. After this step, the mass of solids was determined by gravimetric analysis. Got that value, to obtain the concentration in terms of $mg.L^{-1}$, this mass was divided by the volume of biomedia (40 mL), and to obtain the concentration in terms of $g.m^2$, the mass was divided by the area of biomedia relating to these 40 mL (0.012 m^2).

All analytical methodologies followed the 21st edition of the Standard Methods for Examination of Water and Wastewater [13].

Aiming to evaluate the kinetic behavior of the process at each phase of the experiment, were performed respirometric tests with the sludge from aeration tank. For this purpose, it was used in the experimental research a device Beluga S32c, open-ended and semi-continuous, developed in the Department of Electrical Engineering of Federal University of Campina Grande (UFCG), Brazil [14].

The substrates ammonium chloride/sodium nitrite and sodium acetate were used in respirometric tests, for determination of kinetic coefficients concerning nitritation, nitration and denitrification, respectively.

Table 1 presents the equations used for determining the kinetic coefficients concerning the growth of heterotrophic bacteria, and Table 2 concerns the autotrophic bacteria.

To determine the constant of half-saturation (K_n), was considered the Monod Kinetics, in which, through respirograms, at the moment where $\mu = ½ \mu_m$ or $OUR_n = ½ OUR_{n\,Max}$, is calculated the ratio between the area equivalent to the concentration of residual substrate (ammonia or nitrite) and its stoichiometric coefficient of oxygen: 4.57 for ammonia and 1.14 for nitrite.

Table 1
Equations for determining the kinetic coefficients of heterotrophic bacteria

Symbol	Equations	Eq. No.
OUR	$\text{OUR} = \frac{dO}{dt} = \frac{DO_{\max} - DO_{\min}}{t_1 - t_0}$	(1)
X_a	$X_a = \frac{\text{OUR}_{\text{end}}}{[f_{cv} * (1-f) * b_h]} * 24$	(2)
K_{ms}	$K_{ms} = 3 * \frac{\text{OUR}_{\text{exo}}}{X_a} * 24$	(3)
$\mu_{\max}$	$\mu_{\max} = Y_h * K_{ms}$	(4)

Note: OUR = oxygen uptake rate ($mgO_2.L^{-1}.h^{-1}$); OUR_{end} = oxygen uptake rate in endogenous phase ($mgO_2.L^{-1}.h^{-1}$); OUR_{exo} = exogenous oxygen uptake rate ($mgO_2.L^{-1}.h^{-1}$); f_{cv} = COD conversion factor for active material (adopted: 1.5 $mgCOD.mgVSS^{-1}$); f = activated sludge fraction that remains as endogenous residue (adopted: 0.2); b_h = endogenous decay coefficient (adopted: $0.24*1.04^{(T-20)}$); K_{ms} = specific speed of substrate utilization ($mgCOD.mgX_a^{-1}.d^{-1}$); X_a = activated sludge concentration ($mgVSS.L^{-1}$); Y_h = coefficient of cellular synthesis (adopted: 0.45 $mgX_a*mgCOD^{-1}$); and K_{ms} = specific speed of substrate utilization ($mgCOD.mgX_a^{-1}.d^{-1}$).

Table 2
Equations for determining the kinetic coefficients of nitrifying bacteria

Symbol	Equations	Eq. No.
OUR_n	$\text{OUR}_n = \text{OUR}_{\max} - \text{OUR}_{\min}$	(5)
r_n	$r_n = \frac{\text{OUR}_n}{4{,}57} * 24$	(6)
N_l	$N_l = \frac{0{,}1 * X_v * V_r}{R_s * Q_{\text{afl}}}$	(7)
N_c	$N_c = TKN_a - TKN_e - N_l$	(8)
X_n	$X_n = \frac{Y_n * N_c * SRT}{(1 + b_n * R_s) * HRT}$	(9)
$\mu_{m\,n}$	$\mu_{mn} = \frac{Y_n * r_n}{X_n}$	(10)

Note: OUR_n = oxygen uptake rate ($mgO_2.L^{-1}.h^{-1}$); r_n = specific speed of substrate utilization ($mgN.mgX_n^{-1}.d^{-1}$); N_l = Nitrogen concentration in excess sludge ($mgN.L^{-1}$); V_r = reactor volume (L); X_v = VSS concentration in the aeration tank ($mg.L^{-1}$); SRT = solid retention time (d); Q_{afl} = affluent flow ($L.d^{-1}$); N_c = nitrification capacity ($mg.L^{-1}$); TKN_a = TKN concentration in the affluent ($mg.L^{-1}$); TKN_e = TKN concentration in the effluent ($mg.L^{-1}$); X_n = Concentration of active nitrifying organisms in the volatile biomass ($mgVSS.L^{-1}$); HRT = hydraulic retention time (d^{-1}); Y_n = coefficient of cell synthesis for nitrifying bacteria (adopted: 0.1); b_n = decay constant of the nitrifying organisms (adopted: $0.04*1.03^{(T-20)}$); $\mu_{m\,n}$ = maximum specific growth rate for nitrifying bacteria (d^{-1}).

3. Results and discussion

3.1. Characterization of the affluent and application rates

Table 3 shows the characteristics of the affluent over the bioreactor, after mixing the decanted sewage with landfill leachate, with the specific proportions provided for the three experimental phases.

Taking into account the operating conditions imposed at each phase of the research, as well as the affluent characteristics, it was possible to work within the typical values for the application of organic and nitrogenous volumetric load, ranging from 0.4 to 0.9 kgBOD.m^3.d^{-1} and 0.32 to 0.7 kgN.m^3.d^{-1}, respectively.

Fig. 2 presents the historical series of the volumetric organic load (VOL) throughout the research, highlighting the contribution of each component part of the load applied to the process (decanted and leached sewage).

3.2. Characterization of suspended and attached biomass

It was possible to work with desirable values of VSS in the sludge aeration tank, due to operating conditions imposed on the process in most of the study [15], observing the average values of 2,319, 2,225 and 3,099 mg.L^{-1} to VSS in the 1st, 2nd and 3rd phases, respectively. In relation to the sludge from return line, was obtained average values between 3,000 and 6,000 mg.L^{-1}. This fact shows that the introduced leachate load did not affect the formation of the suspended biomass in all experimental phases.

With respect to the attached biomass, using the methodology developed for its quantification, and considering the specific surface area of the Kaldnes® holders of type K1 (300 m^2.m^{-3}), were obtained, throughout the study, VSS values of 12.9, 7.2 and 12.6 gVSS.m^{-2} of biofilm, respectively, to the three experimental phases, which are within the range found in the literature: 2–44 gVSS.m^{-2} [16–19].

Fig. 3 shows the historical series of VSS concentrations in both suspended and attached biomass.

It is possible to realize, according to Fig. 3, there was no clear correspondence between the behaviors of the concentrations of suspended and attached VSS along the study. In 1st phase, attached biomass increase while aeration tank sludge decrease. In 2nd phase, attached biomass is constant and the aeration tank sludge decreases, while in 3rd phase, both increase.

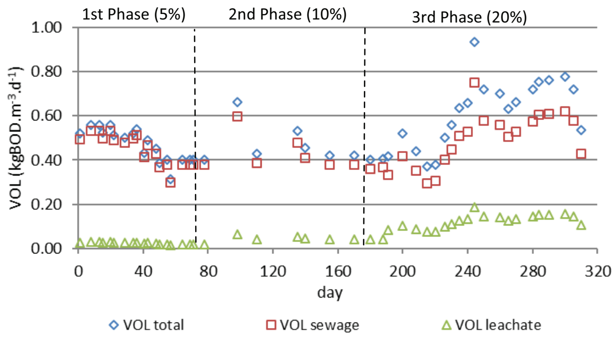

Fig. 2. Historical series of applied BOD volumetric loads.

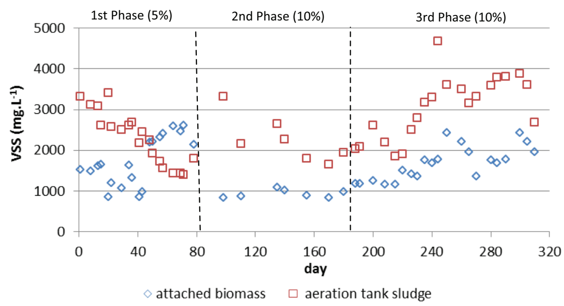

Fig. 3. Historical VSS series referring to suspended and attached biomass.

Table 3
Affluent characterization (sewage + leachate) and effluent

Variable	1st phase N = 19 (5% leachate)				2nd phase N = 8 (10% leachate)				3rd phase N = 20 (20% leachate)			
	Affluent		Effluent		Affluent		Effluent		Affluent		Effluent	
	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD
COD total (mgO$_2$.L^{-1})	522	93	55	17	531	51	66	15	614	95	108	26
COD sol (mgO$_2$.L^{-1})			20	9			29	9			82	19
BOD$_{5,20}$ total (mgO$_2$.L^{-1})	220	22	26	10	216	6	28	6	286	51	57	19
BOD$_{5,20}$ sol (mgO$_2$.L^{-1})			9	4			14	3			26	8
DOC (mgC.L^{-1})	59	9	13	5	71	11	16	6	84	25	28	9
TKN (mgN.L^{-1})	107	18	13	7	157	17	13	7	214	48	33	14
N-NH$_4^+$ (mgN.L^{-1})	82	5	6	4	108	11	7	6	125	28	25	12
N-NO$_2^-$ (mgN.L^{-1})			0.1	0.1			0.21	0.11			0.29	0.27
N-NO$_3^-$ (mgN.L^{-1})			12	2.7			26.2	15.5			6.1	5.1
Alkalinity (mgCaCO$_3$.L^{-1})	228	50	47	27	369	26	59	45	568	154	268	157
pH			7.2	0,1			7.4	0.4			7.1	0.5
Temp. °C			18	2.6			17	0.7			18	2.1

The VSS contribution from the attached biomass has resulted in a percentage increase of 75%, 43% and 55%, respectively, for each phase of the study, concerning the biomass in suspension. It should be noted that the biomedia had a specific surface area of 300 m^2/m^3, and there are currently available material with values two or three times higher; furthermore, the filling percentage may be higher too. Thus, the ratio between the biomass attached and the suspended one may be so high about to allow effective operation as MBBR, i.e., without sludge recirculation.

As regards the determination of the composition of biomass attached, in terms of nitrogen (TKN) the values obtained were very close to those typically observed in biomass in suspension of activated sludge systems, i.e., about 10% of the mass of VSS.

The evaluation of hybrid systems, such as IFAS process, must comprehend the individual participation of the contribution shares allocated to each fraction of biomass, attached or in suspension, in the treatment process. To estimate the substrate consumption by biofilm area, were used the values suggested by literature, whose development was based on the kinetic model of the process [20]. Thus, by linear interpolation, to 6-d-old aerobic sludge, we reached up to the fractions applied on the attached biomass: 12.5% for COD and 35% to ammoniacal nitrogen. Assuming these fractions, were calculated the application rates by area of COD biofilm and ammoniacal nitrogen.

We can observe the increase of surface application rate of ammoniacal nitrogen over the three experimental phases, due to the increase of percentage contribution of the leachate, which has a higher concentration of this constituent than the sewage. The COD application rate, although it should remain constant, showed higher values, especially in the third phase.

3.3. Removal of organic matter

Regarding the removal of organic matter, it can be said that the system was kept under stable operation in three phases of research.

With respect to the average removal efficiencies, it was possible to obtain 85% to BOD_{total} and 90% to COD over the three experimental phases.

Fig. 5 shows the historical data regarding BOD_{total} and COD_{total} of both raw and treated sewage over the three experimental phases.

The removal efficiency of BOD was lower than expected, due in good part to the drag of suspended solids, because of operational problems with the scraper in the secondary clarifier, in the pilot scale unit. The analysis of the $BOD_{soluble}$ in the effluent allowed estimating the conclusion of effective colloidal organic matter removal, since the mean values were 10 and 40 $mgO_2.L^{-1}$.

Regarding the COD, the relatively high values present in the effluent in the 3rd phase are due to the fact that a greater proportion of leachate in the composition of the affluent organic load, causing the concentration of recalcitrant organic compounds.

Fig. 6 presents the historical series and the Box-Whiskers plots concerning the COD removal efficiency.

However, the ratio BOD_{total}/COD remained at around 0.49 over the three experimental phases, showing the prevalence of a condition of good biodegradability, despite the increase in the share of leachate. This condition did not affect negatively the overall efficiency of the process, so that it can be inferred that the introduction of leachate together with decanted sewage did not cause harm to the biomass nor to removal efficiency of organic compounds, even at its maximum contribution (3rd phase). Fig. 7 shows the correlation between the amount of VOL due to the leachate contribution and the removal efficiency of organic matter, expressed in terms of BOD_{total} and COD_{total}.

It was observed that there is not a clear correlation, as were obtained higher removal efficiencies at lower application rates, having after occurred lower efficiencies for intermediate rates, and again an increase of efficiency when were applied higher loads of leachate. Apparently, other factors

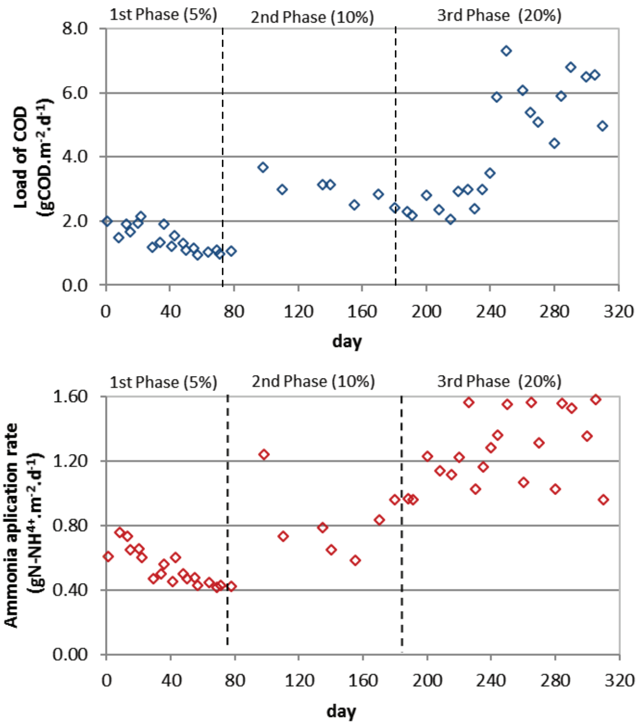

Fig. 4. Application rates of COD and ammoniacal nitrogen by biofilm area.

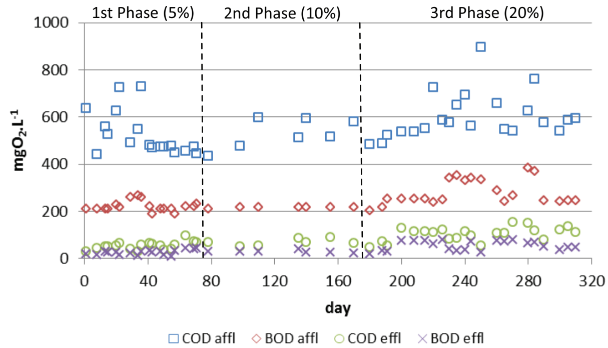

Fig. 5. Historical series of the results of affluent/effluent BOD_{total} and COD_{total}.

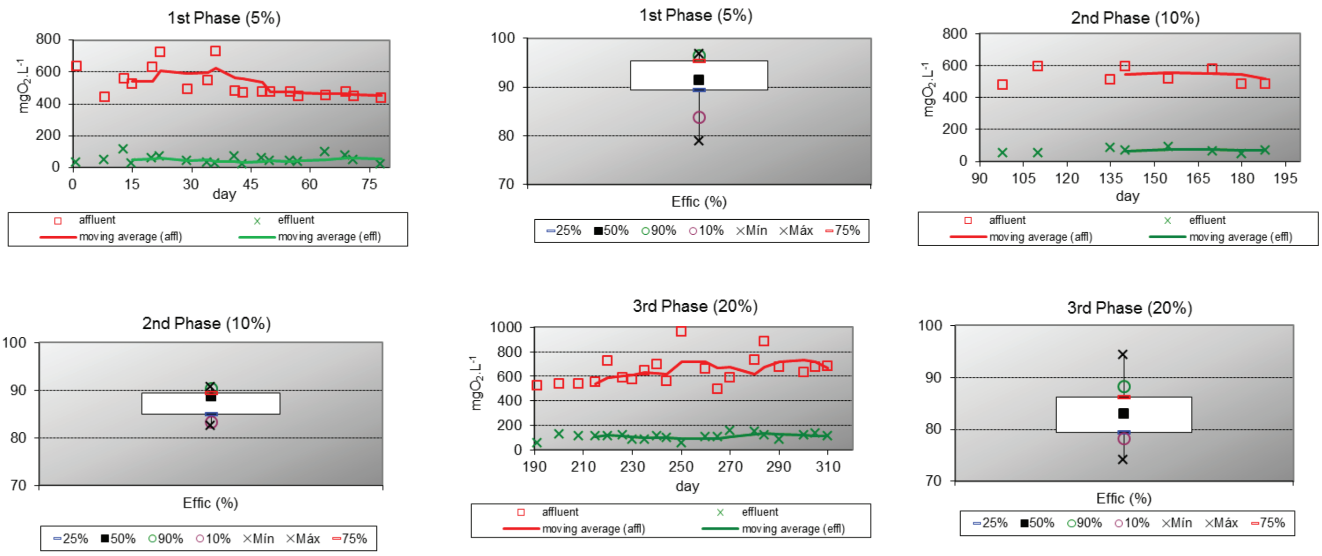

Fig. 6. Historical series and Box-Whiskers plots of COD_{total}.

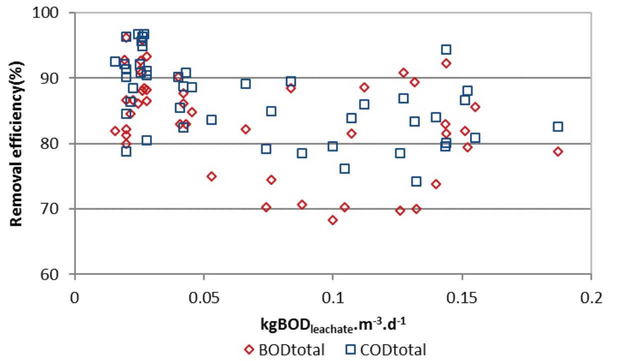

Fig. 7. Correlation between the VOL from leachate and the removal efficiency of BOD_{total} and COD_{total}.

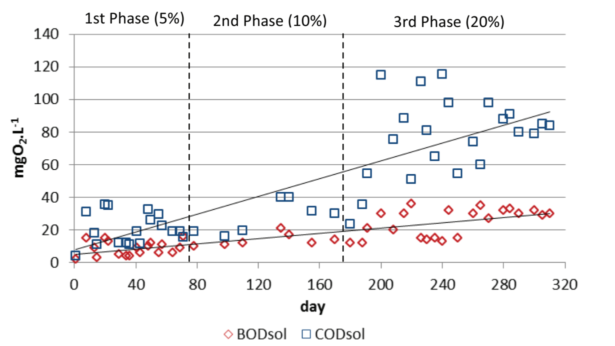

Fig. 8. Historical series and trend lines of the results of soluble COD and BOD.

have been shown more relevant than the leachate added in the three experimental phases.

The effect of the presence of leachate in organic matter removal becomes more evident when we evaluate the results of soluble COD and BOD in the final effluent (Fig. 8).

We note the rising trend of soluble COD and BOD from the effluent generated by the process, by increasing the contribution of landfill leachate, which is rich in recalcitrant organic compounds.

3.4. Removal of nitrogenous compounds

In relation to the removal of nitrogenous compounds, in regard to process efficiency, it was possible to obtain values around 90% of TKN and NH_4^+ conversion, in the first two phases, and approximately 80% in the 3rd phase.

Figs. 9 and 10 illustrate the values of the historical behavior related to nitrogenous series of both raw and treated sewage over the three experimental phases, whereas Figs. 11 and 12 present the Box-Whiskers plots relating to the conversion efficiency of these variables, respectively.

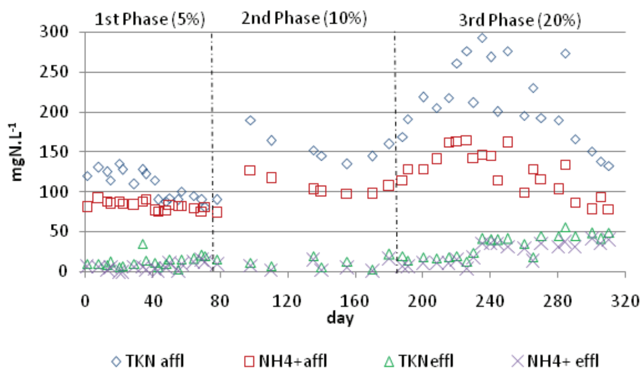

Fig. 9. Historical behavior of nitrogenous affluent/effluent series (TKN, NH_4^+).

Based on the values shown in Table 4 for the TKN variable, in the composition of the affluent applied to the pilot unit, it can be seen that the process was able to reduce TKN concentrations above the commonly found in sewage concentrate throughout the study, reaching levels around 250 mg.L^{-1} of converted ammonia.

Importantly, however, the results in the third phase of the study, where the effluent presented average values of 26 mgN-NH_4^+.L^{-1}, indicate that the leachate load of 20% has possibly influenced the decrease in system performance, indicating that this condition can be restraining for the process.

Fig. 13 illustrates the nitrification rates applied to the process throughout the study, which shows that were reached higher values than proposed by literature, in MBBR type systems [21].

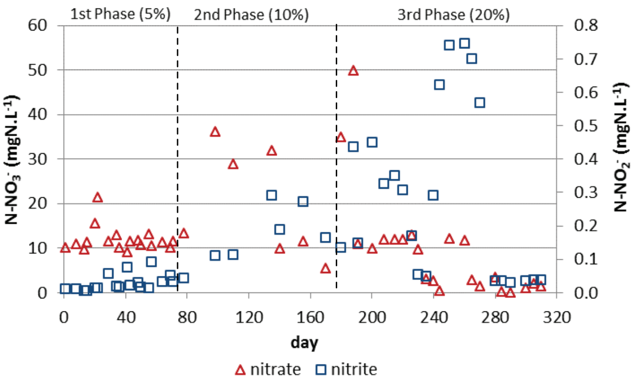

Fig. 10. Historical behavior of nitrogenous effluent series (NO_3^-, NO_2^-).

As seen in Fig. 13, the results tended to a linear behavior with a good adherence of all points, generating a single slope, indicating that, at any phase of the study, there was no reduction in the nitrification rate with the proportional increase of leachate into the composition of applied loads.

After recalculating the nitrification rates and the surface charge of ammonia, following the premises already mentioned concerning the fraction applied to the attached biomass in terms of ammoniacal nitrogen [20], was obtained the chart shown in Fig. 14.

The results of nitrification depending on the biofilm area, obtained by the pilot system, are similar to those presented by literature [23], indicating good efficiency of removal in COD loads of about 8 gCOD.m^{-2}.d^{-1}.

With regard to the denitrification phenomenon observed in the process, the nitrite and nitrate values remained within the acceptable during much of the 1st and 2nd phases of the experiment, whereas in the last phase occurred peaks in the nitrate, at concentration levels higher than the desired 10 mg.L^{-1}, returning to acceptable levels only at the end of the study, as can be seen in Fig. 10.

Throughout the experiment was observed nitrate consumption in the denitrification phenomenon, very near of concentration theoretically generated, indicating that,

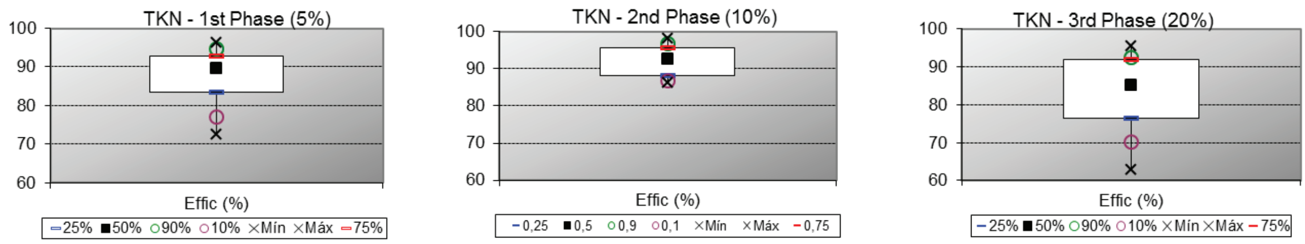

Fig. 11. Box-Whiskers plot of TKN conversion efficiency.

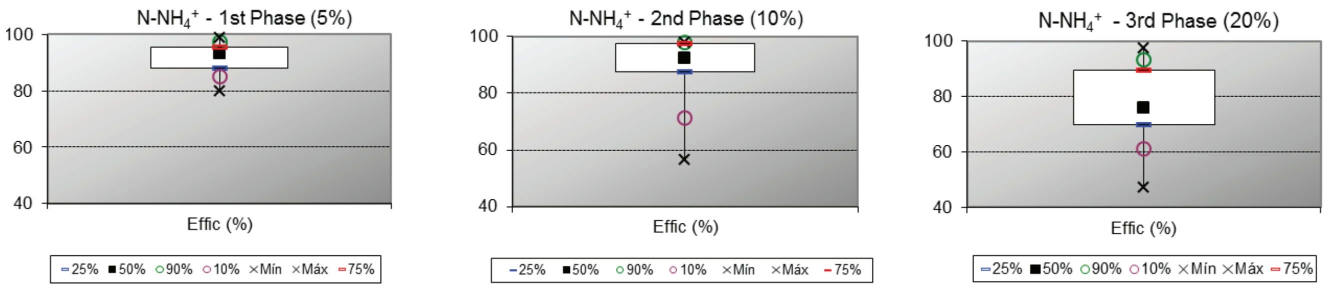

Fig. 12. Box-Whiskers plot of NH_4^+ conversion efficiency.

Table 4
Average values obtained in the respirometric tests

Phases (%)	Suspended biomass			Total biomass		
	μ_{max}, d^{-1}	r_{max}, mgCOD.mgX$_a$.d^{-1}	X_a, mg.L^{-1}	μ_{max}, d^{-1}	r_{max}, mgCOD.mgX$_a$.d^{-1}	X_a, mg.L^{-1}
5	1.6	3.5	1,002	2	4.4	1,541
10	1.1	2.4	1,000	1,5	3.3	1,387
20	1.3	3	1,310	1.6	3.6	1,600

overall, the introduction of leachate did not harm this phase of treatment.

3.5. Respirometric tests

In order to evaluate the metabolic behavior of autotrophic and heterotrophic bacteria active in the process, present in both attached and suspended biomass, were carried out tests with biomedia (total biomass) and without the presence of biomedia (suspended biomass).

Table 4 shows the average values of the kinetic constants of growth and utilization of organic material. And Tables 5 and 6 show the kinetic values for the autotrophic bacteria.

Based on the analysis of the results, it can be seen that the μ_{max} constant is reduced by approximately 20% in the suspended biomass and 25% in total biomass.

However, comparing the results of Table 4 with those of VSS arranged in Fig. 3, it is not possible to justify the behavior of the μ_{max} constant in the 3rd phase, since the elevation of the VSS concentration occurred without the oxygen consumption or the substrate to increase proportionally.

So, we can assume that the presence of recalcitrant compounds derived from the contribution of leachate load during each phase, may have caused this reduction in kinetic constant values, due to bioaccumulation on biomass; however, it should be noted that the values obtained are consistent with those found in the literature.

In general, comparing the kinetic behavior (total biomass) with the organic matter removal efficiency, there is no evidence that the influence of the leachate load has caused any significant change in the treatment processes.

The results shown in Tables 5 and 6 allow observing the same decrease in the maximal growth constant (μ_{max}) in each phase of the study, for both nitritating and nitratating bacteria groups; however, it is not observed among the other constants, which remains stable throughout the study.

However, in a global vision of the process, when we compare the average values of heterotrophic and autotrophic maximum growth constants (μ_{max}) with the average values of $BOD_{5.20}$ and TKN removal efficiencies, respectively, it is found that this decrease did not cause negative impacts in the process. Fig. 15 illustrates this fact.

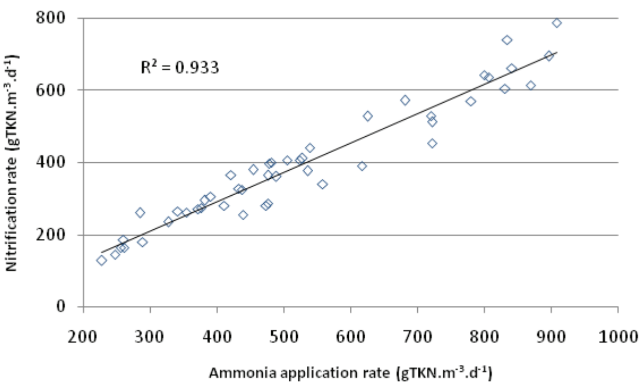

Fig. 13. Nitrification rates obtained throughout the study.

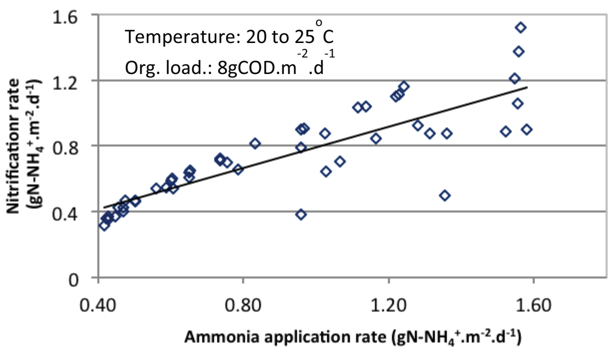

Fig. 14. Nitrification rate by biofilm area.

Table 6
Average values of the kinetic constants of nitritating bacteria

Phases (%)	Total biomass		
	μ_{max}, d^{-1}	r_{max}, mgN.mgX$_n^{-1}$.d^{-1}	K_n, mg.L^{-1}
5	0.25	1.85	9.9
10	0.22	2.11	10.2
20	0.14	1.97	10.2

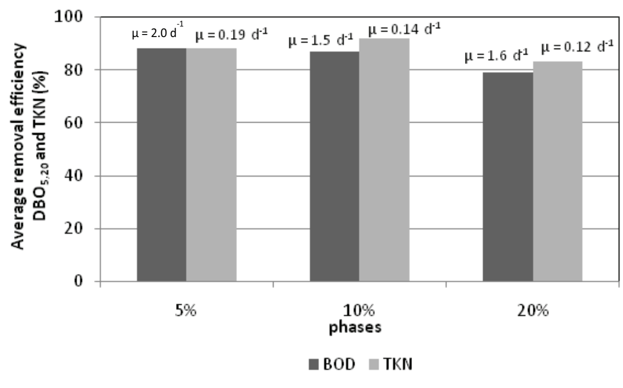

Fig. 15. Correlation between $BOD_{5.20}$ and TKN removal efficiencies with the respective μ_{max}.

Table 5
Average values of the kinetic constants of nitritating bacteria

Phases (%)	Suspended biomass			Total biomass		
	μ_{max}, d^{-1}	r_{max}, mgN.mgX$_n^{-1}$.d^{-1}	K_n, mg.L^{-1}	μ_{max}, d^{-1}	r_{max}, mgN.mgX$_n^{-1}$.d^{-1}	K_n, mg.L^{-1}
5	0.19	9.1	1.12	0.25	10	1.39
10	0.14	9.8	0.54	0.18	10.5	1.12
20	0.12	9.2	1.0	0.26	10.4	1.12

4. Conclusion

The results of this experimental investigation showed that the addition of leachate loads together with domestic sewage is a viable alternative for proper stabilization of this type of wastewater, and showed also that the operational control of the treatment plant is critical to the performance process.

The study showed that the activated sludge process with mobile biomedia seems promising and stable, in the presence of recalcitrant organic compounds and high nitrogenous load arising from the landfill leachate; also presenting stability and operational robustness, most likely due to the presence of attached biomass.

In general, it was possible to receive up to 20% of landfill leachate load without prejudice to the removal of organic matter or to the processes of nitrification and denitrification. The kinetic coefficients concerning the removal of organic and nitrogenous matter obtained throughout each phase remain stable, with minimum reduction and without negative impacts on the efficiency of treatment – reinforcing the conclusion that the leachate load caused neither inhibition nor significant changes in heterotrophic and autotrophic metabolic processes.

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