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Anaerobic treatment of sludge from a MSW landfill leachate treatment plant

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Abstract

A study was carried out of anerobic treatment in the mesophilic range (37°C) of sludge from a leachate treatment plant (Biomembrat system) at the MSW landfill of Asturias. The reactor chosen was of the UASB type, with a useful capacity of 9 litres, operating at an HRT of 9 days. The COD values of said sludge ranged between 10 000 and 19 400 mgO_2/l.

Start-up of the reactor was realized in 7 stages, beginning with sludge diluted with distilled water and progressively increasing the amount of sludge fed into the reactor (from 10% up to 100%). The study was carried out for a period of 224 days. With the aim of favouring the growth of methanogenic flora, different amounts of methanol were added to the feed, ranging between 6.75 and 1 ml/l of feed in the first and last stages, respectively.

In the two last stages, recirculation of the effluent was carried out (recirculation ratio: 2) with the two-fold aim of producing agitation in the reactor and of decreasing both the COD and the solids content of the reactor influent.

The biodegration of the organic matter achieved with the anaerobic treatment of the sludge was high, obtaining decreases in COD of 87% by the end of the process. Purging of the digested sludge represented approximately 16% of the volume of the treated sludge

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1. Introduction

Of the different alternatives for the disposal or treatment of MSW, sanitary landfilling is probably the most widely used up until the present day due to the economic advantages it offers. The degradation of the organic fraction of the waste in the landfill in combination with the percolation of rainwater [1, 2, 3] produce a liquid called "leachate". The values of COD, ammoniacal nitrogen, colour, odour, etc. of this leachate make treatment of this residue absolutely necessary in order to avoid serious damage to both surface and underground waters.

The Principality of Asturias is an Autonomous Community located in the North of Spain, with a population of approximately 1 100 000 inhabitants. The wastes generated are mainly managed by the Consortium for the Management of Municipal Solid Wastes (COGERSA, its Spanish acronym), to which all the Asturian municipalities belong, said wastes being disposed of at the Consortium's Central Landfill at La Zoreda. The landfill started functioning in January 1986, the amount of MSW eliminated having increased with time up to the present day level of around 550 000 t/year (1999). The volume of leachate generated has also increased with time, reaching levels of around 600 m^3/day during periods of heavy rainfall. The COD of the leachate has decreased with time from 80 000 mgO_2/l at the beginning, until values of around 3 000 mg O_2/l, with levels of BOD_5 of around 700 mg O_2/l, indicating that this is an "old leachate" with a large amount of refractory material. The leachates produced are collected at the bottom of the landfill and subsequently transferred to a treatment plant. The treatment system employed at the landfill consists of a pressurised aerobic biological process characterised by a large amount of volatile solids in the aerobic reactor, in the order of 14 g/l, and by increased solubility of the oxygen present, due to the system working under pressure (3 bars). The biomass (sludge) is subsequently separated by means of ultrafiltration. The plant is designed to treat a daily flow of 400 m^3. The COD of the leachate treated by means of this process presented values equal to or higher than 1 000 mg O_2/l. The quantity of sludge generated is around 30 m^3 per day [4].

Among the different methods that may be employed to treat sludge with a high content in organic matter, anaerobic treatment is currently being successfully used in different countries [5, 6, 7]

The main goal of this research work was to study the anaerobic treatment of this sludge at mesophilic temperature (37°C).

2. Experimental

2.1. Materials and Methods

Studies were carried out at laboratory scale employing a UASB reactor made of transparent PVC. The reactor consisted of two cylindrical sections, the lower one jacketed and separated from the upper one by a deflecting ring to facilitate phase

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separation. The upper part had a larger diameter and contained the gas collector as well as outlets for the effluent, recycling and other uses. Other side-outlets were arranged along the lower body for sample taking. The volume of the reactor up to the triphasic separator was 9 litres.

The gas collector is connected to a gasometer, which consists of a cylindrical recipient, 24.5 cm in diameter and 50 cm high. It is divided into two parts, the top part is totally airtight and the bottom part has a side opening or window that allows access to the control valve for the exit of the biogas.

The upper tank is also coupled at the top to a valve that allows the gasometer to be filled with the liquid onto which the biogas is collected. This exit is also used to measure the composition of the biogas produced by means of its connection to a portable methanometer.

2.2. Chemical Analyses

The parameters analysed in the leachates were Chemical Oxygen Demand (COD), ammoniacal nitrogen, phosphate (PO_4^{3-}), total solids (TS), volatile total solids (VTS), volatile acidity (VA), total alkalinity (TA), gas volume, gas composition and metals. The standard methods were employed whenever applicable [8].

The metals were determined by atomic absorption on a Perkin Elmer Mod. 3110 spectrophotometer.

The volumetric composition of the biogas was determined by means of a Geotechnical Instruments portable methanometer.

2.3. Experimental Work

As mentioned above, the sludge used came from the leachate treatment plant that COGERSA has in the valley of La Zoreda. The samples, 5 in all, were supplied by the firm and transported to the laboratory in 25-litre plastic containers.

The sample was characterised on arrival at the laboratory, the following parameters being determined: COD (Chemical Oxygen Demand), pH, phosphates, TS (total solids), VS (volatile solids), VA (volatile acidity) and TA (total alkalinity), ammoniacal nitrogen ($N\text{-}NH_4^+$) and metals.

In the study, which was carried out in 7 stages over a period of 224 days, an HRT (hydraulic residence time) of 9 days was employed, the daily volume of feed being 1 litre.

The main difference existing between each stage was with respect to the percentage of sludge fed into the reactor, which ranged between 10 and 100% of the liquid to be treated. The sludge was diluted with distilled water and the feed was analysed periodically.

Once the analytical values of the samples exiting the reactor (effluent) showed that this had acclimatised to the feed, i.e. the COD presented more or less constant values, the next stage was initiated, with the subsequent increase in the percentage of raw sludge added to the feed.

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With the aim of favouring the growth of methanogenic flora, different amounts of methanol were added to the feed, ranging between 6.75 and 1 ml/l of feed in the first and last stage, respectively.

At the same time, other substances, such as bicarbonate, nutrients or hydrochloric acid were either added or not depending on the tendency of the remaining parameters evaluated.

In the last two stages, recirculation of the effluent was carried out (recirculation ratio: 2) with the two-fold aim of producing agitation in the reactor and of decreasing both the COD and the solids content of the reactor influent.

Table 1 presents the composition of the feed for each stage.

Table 1. Composition of the feed for each stage

.	1st STAGE	2nd STAGE	3rd STAGE	4th STAGE	5th STAGE	6th STAGE	7th STAGE
Days	1-26	27-40	41-72	73-94	95-125	126-160	161-224
% Sludge (Sludge No.)	10 (1)	20 (1)	30 (2)	40 (2)	55 (3)	75 (3)	100 (4, 5)
Methanol (ml/l)	6.75	6.75	5	4	3	1.5	1
Bicarbonate (g/l)	0.8	0.8/1.5	1.5	1.5	1.5	1	0
Phosphate (mg/l)	26	26	26	26	0	0	26
H Cl (ml/l)	0	0	0	0	0	0	1.5
$N\text{-}NH_4^+$ (mg/l)	61	61	61	61	0	0	0

The aforementioned parameters were determined in the sludge used as feed for the reactor and in the effluent from the reactor. The content of solids inside the reactor were likewise characterised, as well as the biogas generated in it.

3. Results and discussion

3.1. Sludge characteristics

The characteristics of the sludge used from the COGERSA leachate treatment plant are given in Table 2. Sample number 1 corresponds to the sludge used in the feed in the first and second stages, sample 2 corresponds to that used in the third and fourth stages, no. 3 to the fifth and sixth stages and 4 and 5 to the seventh stage. In view of the results obtained, it may be affirmed that there were important variations in COD, ranging between values of 10 000 and 18 400 mg O_2/l.

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The concentration of metals in the raw sludge was likewise determined. Table 3 shows the amount of metals present in samples 4 and 5. In general, the concentrations are low.

Table 2. Characteristic analysis of the sludge (freshly collected sample)

Sludge	COD (mgO_2/l)	TA ($mgCaCO_3/l$)	VA (mg/l)	TS/VS (g/l)	pH
1	10 000	2 720	1 080	-	7.5
2	12 000	3 200	920	-	7.3
3	15 000	3 400	960	17.96/11.3	7.8
4	16 000	3 150	940		7.5
5	18 400	4 300	1 600	32.51/23.61	7.4

Table 3. Metals concentration in the sludge (samples 4 and 5)

Sludge	Cd (mg/l)	Pb (mg/l)	Ni (mg/l)	Mn (mg/l)	Zn (mg/l)	Cu (mg/l)	Fe (mg/l)
No. 4	0.06	0.20	0.63	0.40	0.72	0.07	5.4
No. 5	0.19	1.34	1.16	-	3.11	0.64	1.32

3.2. Performance of the UASB digesters

Figure 1 shows the COD of the influent, diluted sludge (in all cases except for the last stage) + methanol and the COD at the exit (effluent). In the first stage, the COD of the influent presented values that ranged between 8 618 mg O_2/l and 8 768 mg O_2/l, the values of the COD of the effluent reaching 1 200 mg O_2/l. Once the COD had stabilised, the following stage was initiated with a higher percentage of sludge and the same amount of methanol. Thus, for entry CODs of 8 468 mg/l, the exit COD started to rise initially, due, as will be seen below, to an increase in the volatile fatty acids content and thus in the pH of the reactor, giving rise to an inhibition of the process. To avoid this, a greater amount of bicarbonate was added, resulting in a decrease in the COD, which finally fluctuated around values of 2 200 mg O_2/l. Biogas starts to be produced during this stage; hence in the following stage, the third, the amount of raw sludge in the feed was increased and the percentage of methanol reduced to 5 ml/l. The influent COD ranged between 9 293 and 10 118 mg O_2/l, the exit CODs ranging between values of around 3 000 mg/l and 597 mg/l. The percentages of raw sludge continued to be increased and those corresponding to methanol to be reduced, so that in the fourth stage the values of the influent COD ranged between 9 293 and 9 893 mg O_2/l, reaching COD values in the effluent of around 1 000 mg O_2/l. In the fifth stage, the influent COD ranged between values of around 10 669 to 11 219 mg O_2/l, achieving exit values of less than 500 mg O_2/l.

In the sixth stage, the influent COD increased to values of around 11 200 mg O_2/l, the COD values of the effluent being 2 300 mg O_2/l. Although the COD values in the influent in this stage are only slightly higher than those of the prior

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stage, the fact that the amount of added methanol (an easily biodegradable substance that favours the growth of methanogenic bacteria) had decreased and the amount of sludge (much less biodegradable) in the feed had increased may justify these effluent values, which are much higher than in the prior stage.

In the seventh stage, the influent COD was 18 173 mg O_2/l when using sludge no. 4. When using sludge no. 5, which has higher COD values, the influent COD increased to values of around 20 573 mg O_2/l. The effluent COD presented values of around 2 500 mg O_2/l, similar to those obtained in the sixth stage.

At the end of the seventh stage, the methanol was eliminated This gave rise to the COD removal percentages decreasing to values of 57.7%, possibly due to the fact that in the presence of methanol, the methanogenic bacteria undergo increased growth, being able to assimilate the other substrate at the same time. This fact, together with the fact that the COGERSA leachate plant uses methanol to carry out denitrification of the leachate (as a source of easily biodegradable organic matter), leads to the consideration of the convenience of adding 1 ml of methanol/litre of feed to the reactor.

The determination of the volatile solids shows how the biomass begins to grow; appreciably at first, while in the final stages, this growth is much greater. This meant that the reactor had to be purged, removing amounts of 200 ml/week in the first weeks of the sixth stage and 400 ml/week in the last weeks of the sixth stage and the first weeks of the seventh stage, reaching volatile solids concentrations of around 29 g/l. The biomass growth reached its maximum level from day 198 of the study onwards, corresponding to the seventh stage, and around 800 ml had to be purged every 5 days so as to impede this mass overflowing into the settling funnel and contaminating the exit, which would have meant that the samples taken were not really representative of the purification achieved.

Figures 2 and 3 show the variation in total volatile acidity and the alkalinity of the effluent from the reactor.

Acidification of the reactor took place during the third stage, the pH decreasing from values of above 7 to values of around 5.2. Due to the danger of entering into an acidic phase, which would destabilize the reactor, greater amounts of bicarbonate were added, concretely 1.5 g/l.

One consequence of acidification manifested itself as an increase in volatile acidity (VA) to values of 450 mg/l and 500 mg/l (Figure 2), a situation in which the ratio VA/TA reached values of 0.57; greater than 0.3, which is considered the maximum value for a good operation in anerobic processes

As well as values of around 500 mg/l in the third stage that caused a certain amount of alarm, higher values were observed than in subsequent stages. However, given that the values corresponding to alkalinity (Figure 3) fluctuate around 4 000 mg TA/l, the ratio VA/TA was around 0.15, lower at all times than the value of 0.3.

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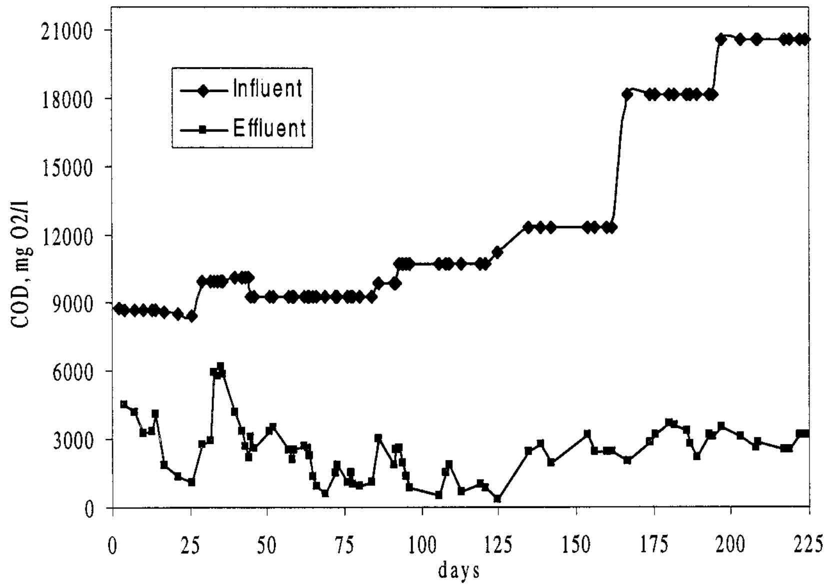

Figure 1. COD of the reactor influent and effluent.

Therefore, the danger of entering an acidic stage does not exist; the pH of the effluent corresponding to these points of high VA is also high, around 8.3.

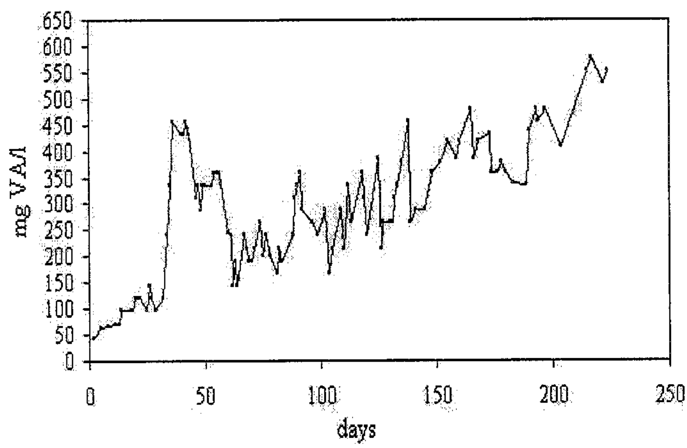

Figure 2. Variation of the total volatile acidity of the reactor effluent with time

In the seventh stage, the exit pH reached excessively high values of 8.7. Given that recirculation of this effluent is carried out, it is necessary to neutralise

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the influent so as to decrease its pH. The influent pH was reduced to values of 7.2 by the addition of HCl, thus avoiding a very high pH, which would impede the correct functioning of the reactor.

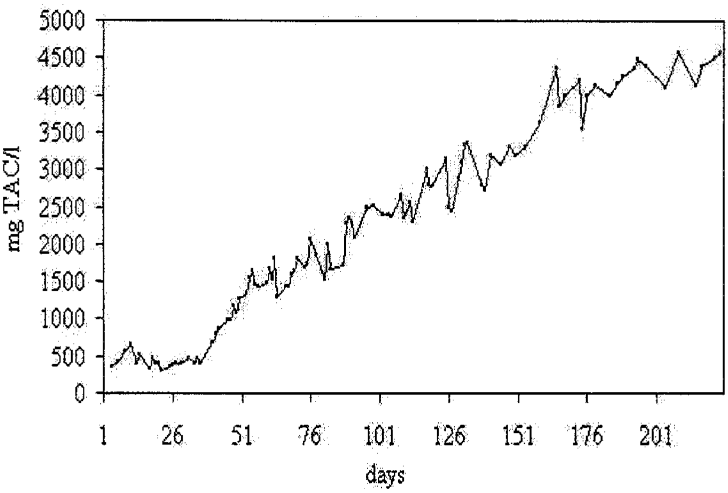

Figure 3. Variation of the total acidity of the reactor effluent with time

The production of biogas (Figure 4) varies according to the stage and was clearly influenced by the decrease in the amounts of methanol, ranging in general, though with a few exceptions, from volumes of biogas of 4 500 ml/day to values of around 1 000 ml/day. In the last stage, the amount of biogas produced increased with the increase in the COD of the sludge to be treated.

At the end of this last stage, the production of biogas was approximately 0.11 l CH_4/g COD removed, its composition for this stage varying around values of 72.5 % methane.

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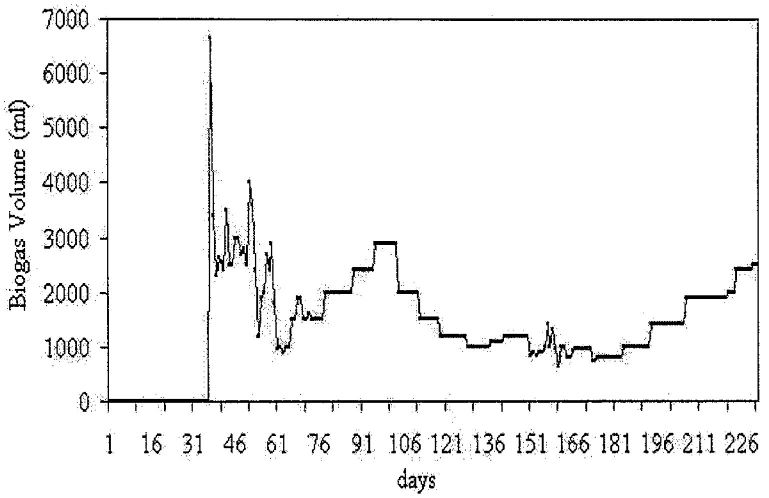

Figure 4. Daily production of biogas.

In anaerobic processes, the content of metals in the effluent of the reactor decreases due to precipitation as sulphides. This fact can be seen in Table 4.

Table 4. Metals contents in the influent, sludge in the reactor and effluent (seventh stage)

	Cd (mg/l)	Pb (mg/l)	Ni (mg/l)	Zn (mg/l)	Cu (mg/l)	Fe (mg/l)
Sludge N° 5	0.19	1.34	1.16	3.11	0.64	1.32
Sludge purged from inside the reactor	0.21	2.14	1.54	4.45	2.42	1.38
Effluent	0.03	0.23	0.36	0.61	0.13	0.87

4. Conclusions

The sludge produced in the biological treatment of leachates from sanitary landfills needs to be treated. This sludge, which has a high content of organic matter, can be treated by anaerobic digestion. The biodegradation of the organic matter achieved via anaerobic treatment of the sludge generated in the leachate treatment plant at the La Zoreda landfill was high, obtaining decreases in COD of 87% by the end of the process. This degradation was found to be favoured by the addition of small amounts of methanol (1 ml/l sludge).

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Purging of the digested sludge represented approximately 16% of the volume of the treated sludge. The biogas produced contains around 72.5% of methane.

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