US MSW AND ITS BIODEGRADATION IN A BIOREACTOR LANDFILL

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SUMMARY: MSW samples were collected and characterized to assess the efficiency of a horizontal leachate recirculation system in terms of waste moisture content and biodegradation in a US bioreactor andfill. MODECOM protocol, developed by the French Environmental Protection Agency, was used to characterize size distribution and composition of fresh waste and landfilled waste collected from boreholes. Waste samples were collected at different depths in three boreholes and tested for moisture content and loss-on- ignition. Selected samples were also tested for biochemical methane potential (BMP). Even though the bulk waste is rather dry, MODECOM results show that the easily biodegradable and moderately biodegradable waste fractions possess the optimum moisture content for biodegradation. Even though the study has shown that the age difference between the fresh waste and the landfilled waste is too short to notice significant trends of biodegradation, following conclusions can be drawn: (1) the radius of influence of leachate recirculation system is at least 8 m; (2) either the cessation of the recirculation for even three months could lead to low moisture content of the biodegradable waste and slow biodegradation or the radius of influence is less than 12 m.

1. INTRODUCTION

Currently, bioreactor landfills are being designed on the premise that leachate recirculation provides an environment to enhance biodegradation of municipal solid waste (MSW), leading to shorter duration of post-closure monitoring, and earlier land reuse. The most critical aspect of a bioreactor landfill is the efficiency of the leachate recirculation system in order to reach a homogeneous moisture distribution inside the waste mass.

This study was conducted at Orchard Hills landfill in Davis Junction, Illinois, USA, which is owned and operated by Veolia Environmental Services. The site opened in 1988 and is expected to be completed by 2018. The total landfill area is approximately 135 ha with 71 ha currently permitted for waste disposal. The waste is placed in one lined cell at a time. In the study cell, waste has been placed from September 2004 to October 2005 at the rate of about 3,200 tons per day. The waste consisted of approximately 70% MSW, 17% construction and demolition debris

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(C&D), 11% soils and 2% special and other waste. Horizontal leachate recirculation lines (LRLs) were installed in the cell during filling; these consisted of 15 cm diameter perforated HDPE pipes in gravel-filled trenches spaced at 15-20 m center to center. Leachate was recirculated intermittently through the LRLs depending on the availability of leachate.

This paper evaluates the changes in composition and the extent of biodegradation of the landfilled waste under leachate recirculation operations compared to fresh waste.

2. METHODOLOGY

The landfill is a MSW landfill installed with a multi-level horizontal recirculation system. The landfill cell selected for this study was subjected to approximately 3,780 m^3 of leachate recirculated intermittently over a time period of approximately 8 months. The cell was closed in 2005 and the sampled landfilled waste is between 15 to 19 months old.

On this landfill, Gas Extraction Wells (GEW) have been drilled using bucket auguring method in the bioreactor landfill cell that was subjected to leachate recirculation. Thus it was the opportunity to use three GEW for waste sampling and characterization. Two GEW (GEW14 and 16) were located close to the recirculation lines (to study the influence of recirculation) (Table 1, see Figure 7 for more details). One borehole (GEW23) was located far from the recirculation lines (to serve as reference waste not influenced by the recirculation). In addition fresh waste samples were collected from the working face of the landfill

Both, the fresh waste and the landfilled waste, were analyzed for particle size distribution and composition using the method known as MODECOM™ developed by the French Environmental Protection Agency (ADEME, 1993). This method essentially involves sieving about 500 kg of fresh wet waste (or 100 kg of landfilled waste) through a set of three large sieves with opening diameters of 100, 50 and 20 mm. The waste retained on each sieve was sorted into 18 components (wood, cardboard, tetra-packs, textile, sanitary textile, disposable napkins, metal, plastic bottles, other plastics, domestic hazardous waste, glass, paper, cooking waste, garden waste, medical waste, inerts, other waste, and residual fines). Each component was weighed and its moisture content and organic content were determined.

Representative bulk (global) samples of fresh and landfilled wastes (respectively about 100 kg and 40 kg) were also tested for moisture content, organic content (loss-on-ignition) and biochemical methane potential (BMP).

In order to facilitate the interpretation of results, the waste components were grouped into different fractions depending on their biodegradability:

- easily biodegradable waste (EBW): cooking waste and garden waste;
- moderately biodegradable waste (MBW): paper, cardboard, food carton, sanitary textiles;
- hardly biodegradable waste (HBW): nappies and feminine hygiene products, wood and textiles;
- inerts: plastics, metal, glass, medical waste, other waste and special waste; and
- residual fines: particles below 20 mm, where plastics, glass, inerts and metal have been sorted.

Wood is biodegradable, but only under aerobic conditions, so it is included in the hardly biodegradable waste. Previous studies have shown that textile is hardly biodegradable in

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anaerobic or aerobic conditions (François, 2004). The residual fines contain both organic and inert components.

A comparison of the results for the landfilled waste with that of fresh waste revealed the effects of biodegradation on the size and component distribution, organic content and BMP of the waste. In addition, analyses of moisture content of the landfilled waste at different distances of the recirculation system also allowed assessing its efficiency.

Table 1: Landfilled samples description(LRL=Leachate Recirculation Lines)

	GEW14			GEW16			GEW23		
Samples	Depth (m)	Distance to the closest LRL (m)	Waste age (months)	Depth (m)	Distance to the LRL (m)	Waste age (months)	Depth (m)	Distance to the LRL (m)	Waste age (months)
M1	16.5	Above	15	14.6	7.5	15	2.2	> 50	17
M2	21.7	Above	17	19.8	7.5	17	7	> 50	19
M3	26.2	10	19	23.8	12	19	NA		

3. RESULTS AND DISCUSSION

3.1 Waste characterization

Leachate recirculation can enhance biodegradation, thus concerns the biodegradable waste categories: fines, EBW, MBW. HBW is very hard to degrade. Thus, this paper focuses on the fines, and easily and moderatly biodegradable waste fractions.

Loss-on-ignition (LOI) and Biochemical Methane Potential (BMP) are direct indicators of the state of waste degradation. Waste composition, particle size distribution and moisture content can give indirect indications, with additional information about biodegradation and its effect on waste. Generally biodegradation leads to a decrease of LOI and BMP, large-sized waste particles will also be reduced in size and the proportion of biodegradable fractions will be decreased.

The moisture content data is very important as this is a key parameter for optimal biodegradation with a target of 40%. Moreover, as the landfill is operated as a bioreactor landfill, moisture content data can assist with evaluating the efficiency of the recirculation system.

3.1.1 Composition

Waste composition analyses of the fresh waste allow comparing it to the typical US and French MSW. The composition of the fresh waste has been obtained by the Modecom protocol, which is a protocol developed by Ademe, the French Environmental Protection Agency. Thus it is interesting to compare the two data sets. For the US typical waste, no fines proportion is available. However it can be assumed that the fines are included in the EBW and MBW.
The proportion of fines, easily biodegradable and moderately biodegradable waste is relatively similar for the US and French MSW, about 60% of the total waste (Figure 1).

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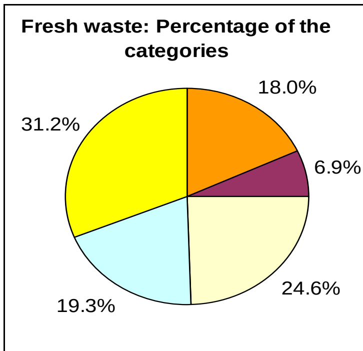	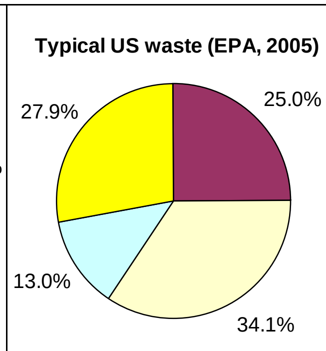	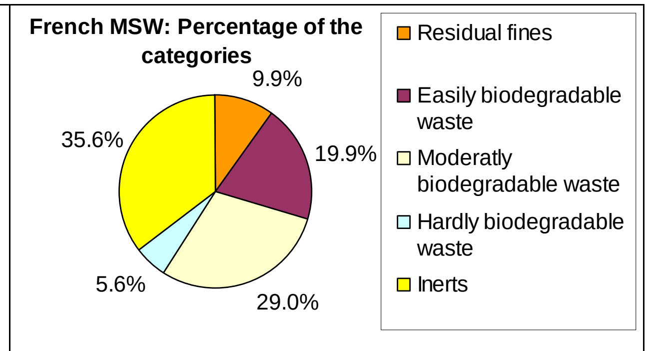
Composition of the fresh waste at Orchard Hills landfill	Composition of typical US waste (US EPA, 2005)	Composition of French waste (MODECOM 93 data)

Figure 1. Comparison of composition of US and French fresh waste

For the landfilled waste, the proportion of residual fines increases with depth and age of the waste at GEW14 and 23 (Figure 2). GEW16 has the highest proportion of residual fines, maybe because of the proximity of the LRL and the higher level of waste biodegradation compared to the other GEW. Independently of the moisture content, the easily biodegradable waste fraction is almost completely degraded in all boreholes, which shows that this fraction is rapidly biodegraded, considering the low age of the waste (15 to 19 months). The percentage of hardly biodegradable waste is not influenced by depth.

The proportion of inerts does not show any trend, but its proportion is almost always lower than that of the fresh waste. Indeed, with the degradation of waste, the proportion of inerts is expected to increase with time. This might be explained by the fact that the fresh waste collected from a different cell at the same landfill may not truly represent the waste disposed in the study cell.

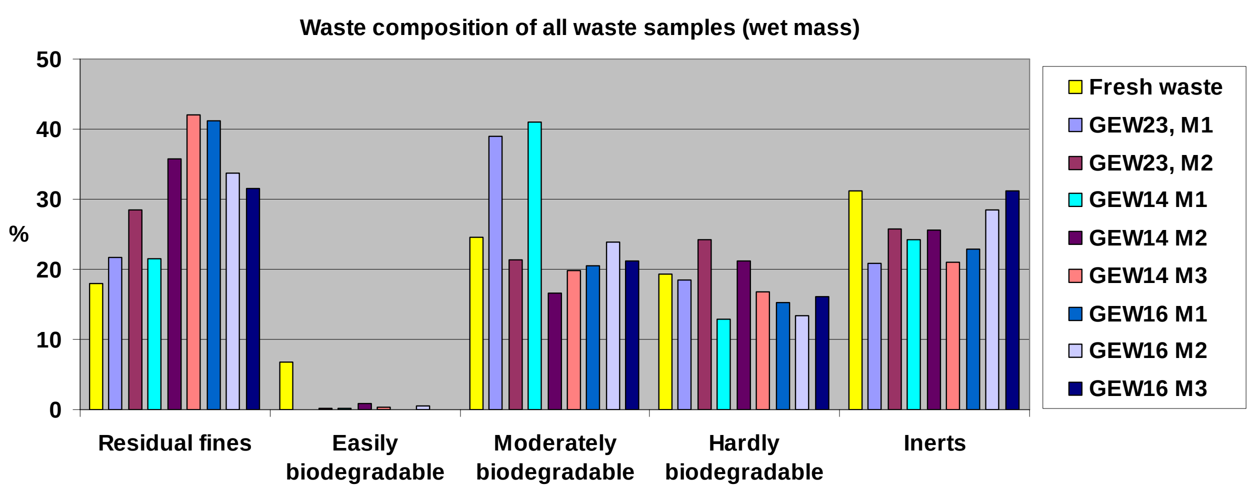

Figure 2. Waste composition of all the waste samples (% by wet mass)

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3.1.2 Particle size

Figure 3 presents the particle size evolution for each waste sample based on MODECOM. In general, the phenomenon of size decrease is observed for GEW23 and 14: as the larger particle size waste degrades, it will increase the proportion of smaller particle size. However, GEW16 M1 results do not show a consistent decrease in particle size with depth. The result for this sample GEW16 M1 may be due to errors during the sorting and/or the presence of a daily soil cover with significant fines rather than large particle sizes.

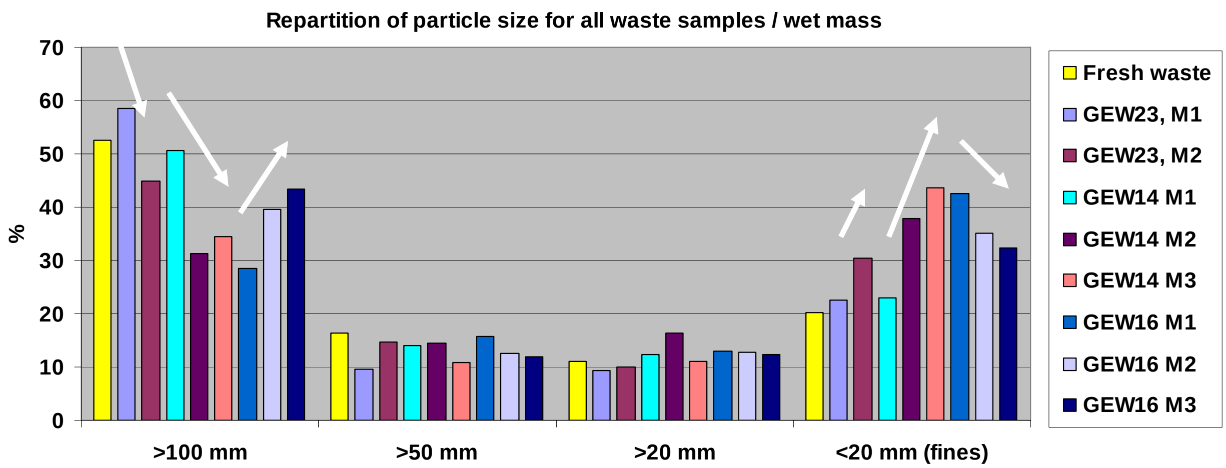

Figure 3. Repartition of particle size for all waste samples (% by wet mass)

3.1.3 Moisture content

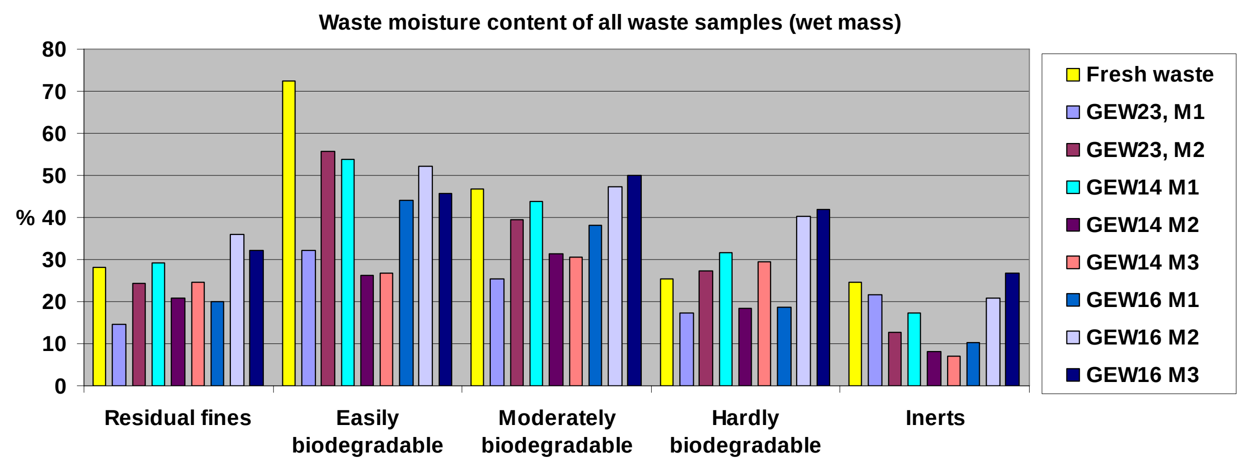

Figure 4. Waste moisture content of all waste samples (% by wet mass)

For the fresh waste, the easily and moderately biodegradable waste fractions, containing a

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moisture content of 40 to 70% (Figure 4), have the desirable moisture content for their degradation (approximately 40%). Except at GEW14, the samples moisture content is found to increase with depth at GEW23 and 16. The moisture content values are in the same range for both GEW23 and 14. GEW16, which is closer to the LRL and received significant leachate during the few weeks before the drilling, has high moisture content values, especially for GEW16M2 and M3. The moisture contents of easily biodegradable and moderately biodegradable waste fractions are at or very close to the desirable value for every sample, except for GEW14 M2 and M3. These two samples may have received less rainfall or leachate. This may be also due to heterogeneities of waste, which leads to permeability variations, of the initial waste moisture content, of liquid distribution and/or to the absence of recirculation during the year before the drilling.

3.1.4 Loss on Ignition

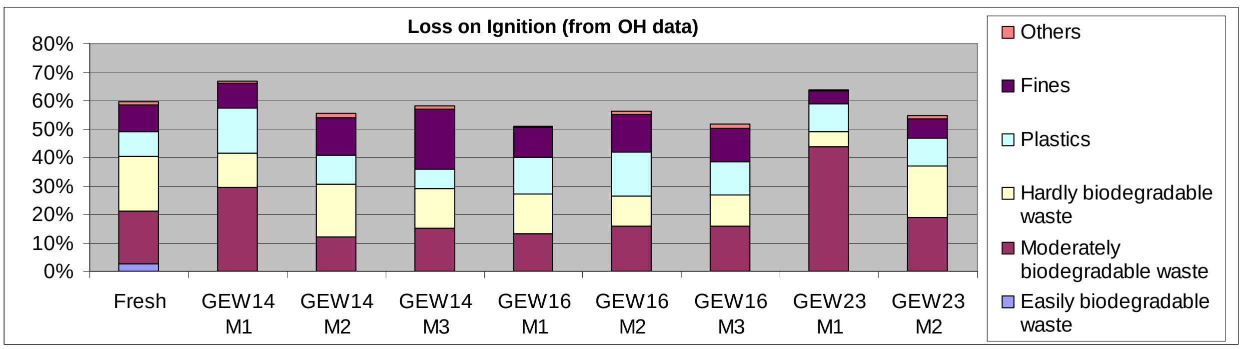

Figure 5. Loss-on-Ignition (LOI) of all waste samples (% by dry mass)

The loss-on-ignition calculated from the fractions of the MODECOM samples may not be very accurate considering that the LOI of the fresh waste is lower than some of landfilled samples which are supposed to be more degraded (so with less organic matter) (Figure 5). This may be due to the fact that the LOI from the "other" waste category was not considered. The LOI for the global samples seems more realistic in this aspect (Figure 6). However, the variations between the LOI values (Figure 5) are not large enough and the waste not old enough to see significative trends. Figure 5 shows the major waste categories that contribute the most to the organic content. These results also reflect the waste heterogeneity: GEW14M1 and GEW23M1, which contain more moderately biodegradable waste, also have a large part of their organic content constituted by this category. The main categories contributing to LOI are usually the fines and the moderately biodegradable waste.

3.1.5 Analyses on global samples

For each MODECOM, a global sample of about 30-40 kg is analysed for its moisture content, LOI, and BMP (Figure 6). The LOI values are usually lower for landfilled waste than for fresh waste. However, there is no obvious influence of the depth, the moisture content or the distance to the LRL on the LOI values.

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The BMP and LOI are correlated: a sample with a high BMP value will also have a high LOI value (Figure 6). Both parameters are linked to the waste biodegradation, as well as the percentage of wet fines. Clear trends in the waste degradation are not evident due to relatively young age of waste as well as waste heterogeneity.

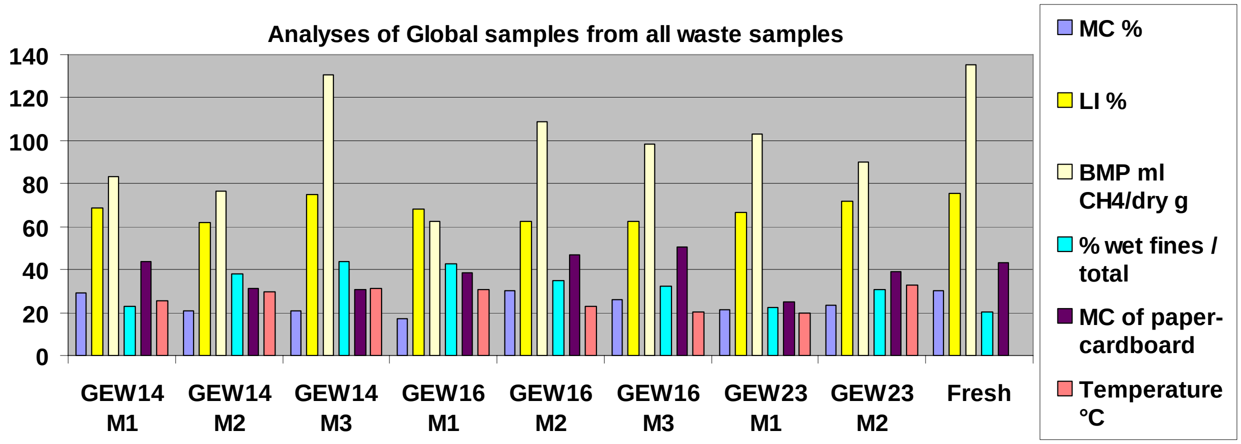

Figure 6. Waste moisture content of all waste samples (% by wet mass)

3.2 Effectiveness of leachate recirculation system

During the drilling of each borehole, waste samples (between 20 and 30 kg) were collected at 3 m depth interval in order to measure their moisture content and LOI to assess the influence of the recirculation system on the waste moisture content and degradation.

3.2.1 Waste moisture content, BMP and LOI

Figure 7 presents the wet moisture content, BMP and LOI values for each sample collected in the boreholes. The relative locations of leachate recirculation lines (LRLs) to the borehole locations are also shown in this figure. GEW23 is at least 50 m away from any LRL, as it is considered as a reference location not influenced by the recirculation. GEW14 is located at 10 m from LRL19 and 26 m from LRL26. GEW16 is located at 8 and 12 m from LRL29 and 26, respectively.

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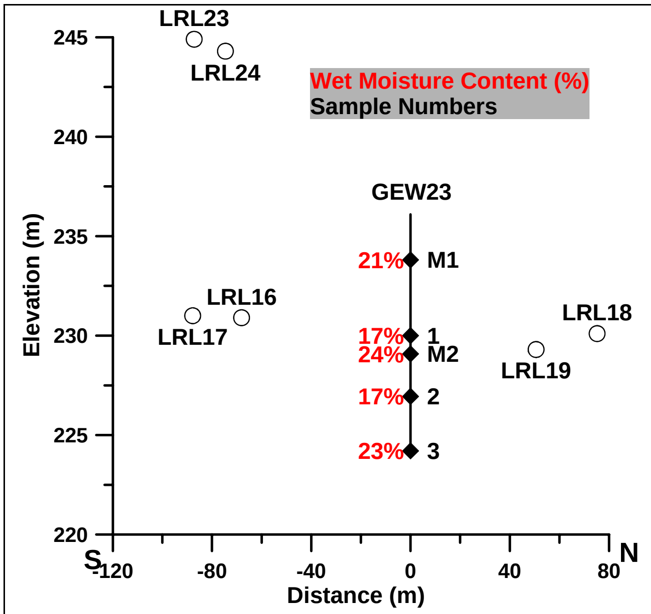
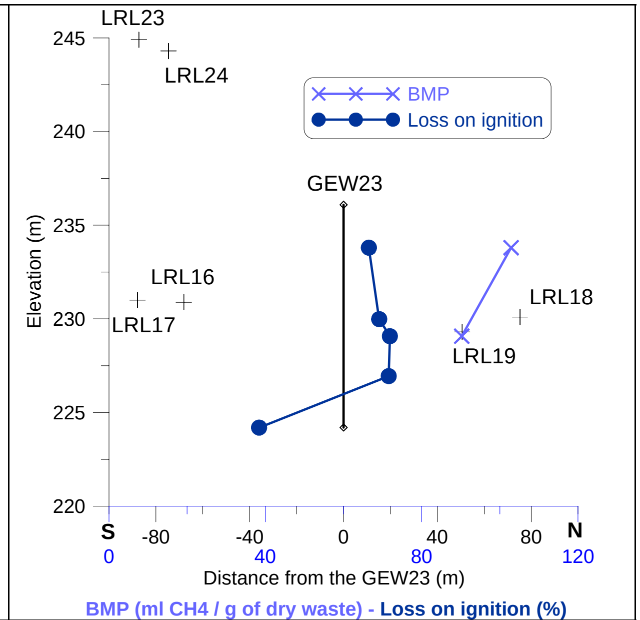
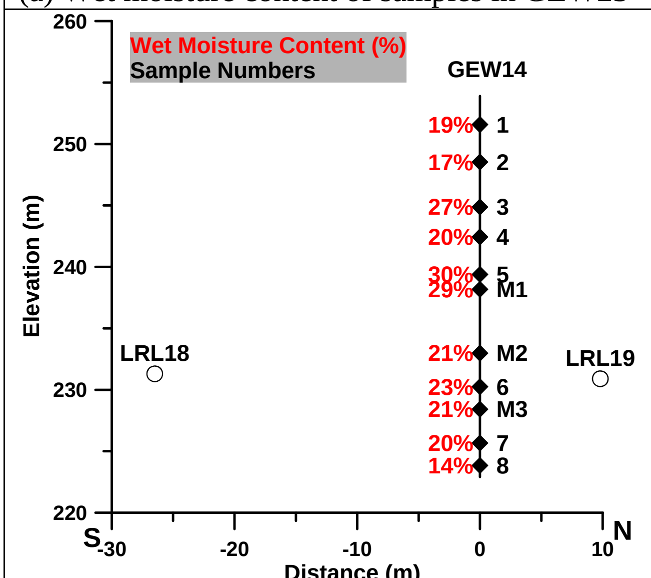


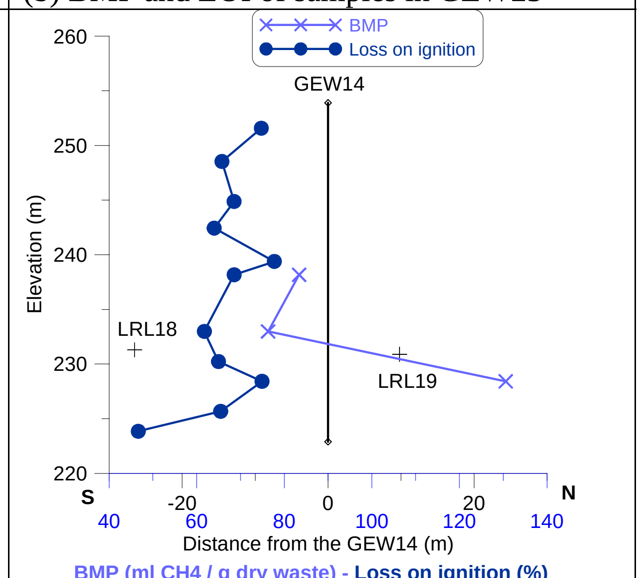
(a) Wet moisture content of samples in GEW23



(b) BMP and LOI of samples in GEW23



(c) Wet moisture content of samples in GEW14



(d) BMP and LOI of samples in GEW14

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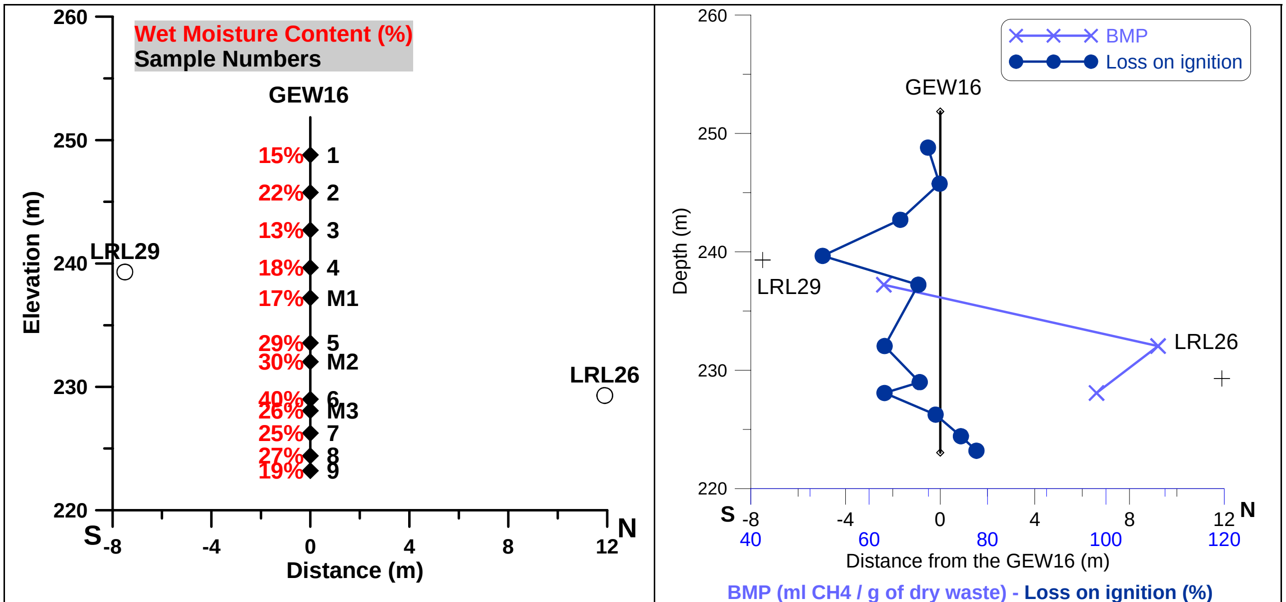

(e) Wet moisture content of samples in GEW16	(f) BMP and LOI of samples in GEW16

Figure 7. Waste wet moisture content, BMP and loss on ignition of samples

3.2.3 Interpretation

GEW14 is close to LRL 18 (at 26.5 m) and LRL 19 (at 9.8 m) oriented in east-west direction. The LRL18 is too far from the borehole location to influence the moisture content of the waste. The presence of the LRL 19 does not seem to affect the moisture distribution, maybe due to small amounts of injected leachate in this LRL (232 m^3), and that the last leachate injection occurred one year before the drilling this borehole.

GEW16 is close to LRL26 (at 12 m) and LRL29 (at 7.5 m), oriented in east-west direction. It seems that LRL26 may not have significantly affected the moisture content of the waste. The last leachate recirculations before the drilling of the borehole occurred about three months earlier for LRL26. The reason for the decrease of the moisture content below the LRL26 could be either that the elapsed time between the recirculation and the sampling is too long (all the leachate had been drained down) or that the radius of influence of the LRL is less than 12 m. At the depth of the LRL 29, the wet moisture content is higher (15 and 22%) than just above the LRL29 (13%). With increasing depth, the wet moisture content increases (from about 17.5% at the depth of the LRL29 to 40% at 10 m below the LRL29). The leachate recirculation on LRL29 has increased the moisture content of the waste below the LRL. The wet moisture content of the samples is decreased from 40% to 20% at deeper depths to the bottom of the borehole. The last leachate recirculation before the drilling of the borehole occurred only 12 days earlier for LRL29.

The profile of moisture content along GEW23 does not show any strong trend. The LRLs are too far to have an influence on the waste moisture content.

In general, the LOI and BMP values of landfilled waste are lower than that of fresh waste, presumably due to degradation. However, there is no obvious influence of the leachate recirculation on the waste biodegradation. This may be attributed to the young age of the waste and short duration of recirculation.

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The moisture distribution within the several boreholes suggests that it is important to recirculate leachate on a regular basis, with a minimum frequency, to maintain higher moisture content inside the waste mass.

4. CONCLUSIONS

The MODECOM results highlight the difficulty of analysing waste because of the heterogeneous nature of waste and the accuracy of the sampling. Some samples possess anomalous quantities of certain waste categories (GEW14 M1, GEW23 M1), and GEW16 M1 does not follow the expected trend of particle size decrease with depth. Nevertheless, some important trends have been observed: (1) the easily biodegradable and moderately biodegradable waste fractions are usually at a higher moisture content than the one of the total waste; (2) the waste biodegradation is in progress even if the waste is less than 2 years old (the phenomenon of particle size decrease is generally observed; the easily biodegradable waste fraction has almost disappeared, even on 15 months old waste, and independently of the depth and the age of the waste or the proximity from the recirculation system; (3) the LOI and BMP values are lower than for the fresh waste.

The waste sampling at every 3 m depth interval in three boreholes provided complimentary information about the efficiency of the recirculation system: (1) the radius of influence is at least 8 m; (2) during the cessation of the recirculation for even three months, the leachate may be drained out, this could lead to a low moisture content of the biodegradable waste and slow down the biodegradation; (3) the age difference between the fresh waste and the landfilled waste is too small to notice significant trends of biodegradation.

A bioreactor landfill aims at increasing the moisture content of the waste in order to reach the desirable value to enhance the waste biodegradation. Considering that only the biodegradable waste (especially the easily biodegradable and moderately biodegradable waste fractions) is concerned by this desirable moisture content, and based on the results of GEW16, it seems that even with a low regular recirculation leachate flow (like the one close to GEW16, affected by the recirculation), this purpose can be achieved. However, the leachate recirculation has to rotate with time between the various LRLs in order to distribute the leachate regularly through the entire waste mass.

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