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Morphological characterisation of MSW landfills

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Abstract

Landfill characterisation has been carried out by analyses of waste samples collected from different depths in the municipal landfill of Torino. The main result has been that landfill drilling to collect samples can provide useful information about landfill morphology: e.g., inside a landfill, water lenses can form and their origin can strongly influence organic matter degradation rates and, therefore, biogas generation and composition. In addition, the investigation suggests that landfill behaviour and biogas production can be predicted in a more reliable way if very simple chemico-physical analyses of collected samples are performed.

Keywords: Landfill; Borehole; Biogas

1. Introduction

In the last decade much attention has been paid to municipal solid waste (MSW) landfills. These studies have mainly considered biogas and leachate production, barrier systems and environmental impact. Extensive literature on these aspects can be found. In spite of this, only limited data (and studies) on landfill waste characteristics are available, and the data have often been obtained from laboratory scale systems (lysimeters).

This paper presents data obtained from samples collected from various sites of the municipal landfill of Torino. A study was previously undertaken together with

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A.M.I.A.T. (Azienda Municipale di Igiene Ambientale Torinese) for the prediction of biogas production of the landfill. In order to ascertain the reliability of certain assumptions, some landfill drillings were done. Chemical and physical characteristics have been measured, in-situ and in the laboratory. The findings are reported in this work. They show that landfill behaviour can be well described by some parameters. Considered together, these parameters can give important information about the progress of biochemical processes inside a landfill. The data confirm some previous works.

2. Background

The study was carried out at the municipal landfill of Torino (whose metropolitan area has about one and half million inhabitants), with the technical support of the organisation providing the collection and disposal of wastes (A.M.I.A.T). The municipal landfill of Torino is worked on a cell basis and multilift filling. One cell (Fig. 1) was selected as test cell for this paper. This test cell contains about 500 000 tons

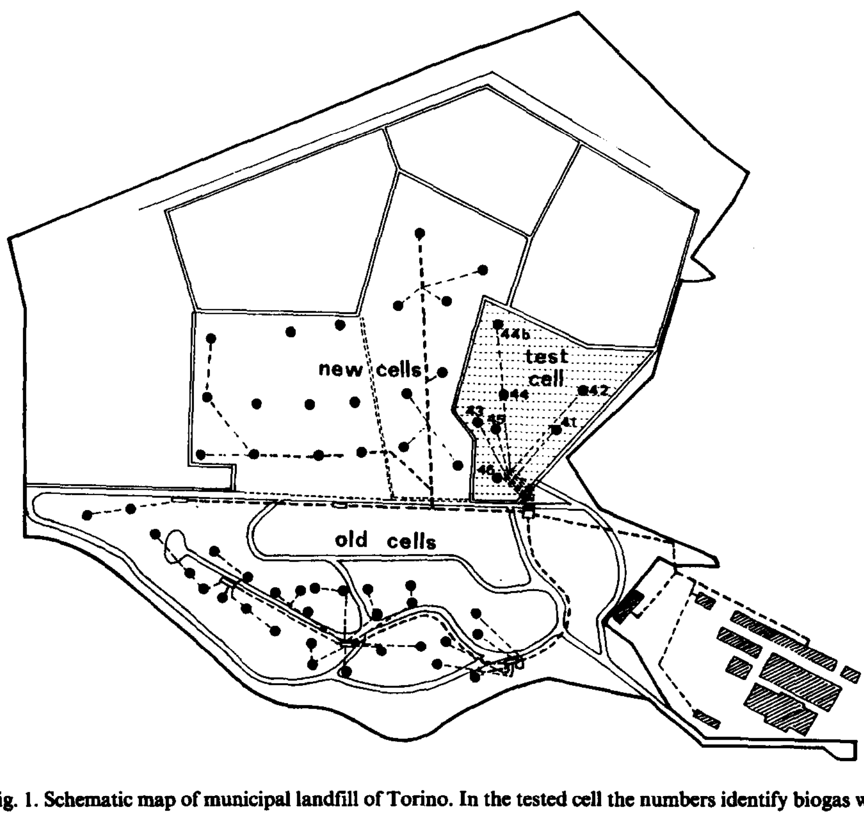

Fig. 1. Schematic map of municipal landfill of Torino. In the tested cell the numbers identify biogas wells.

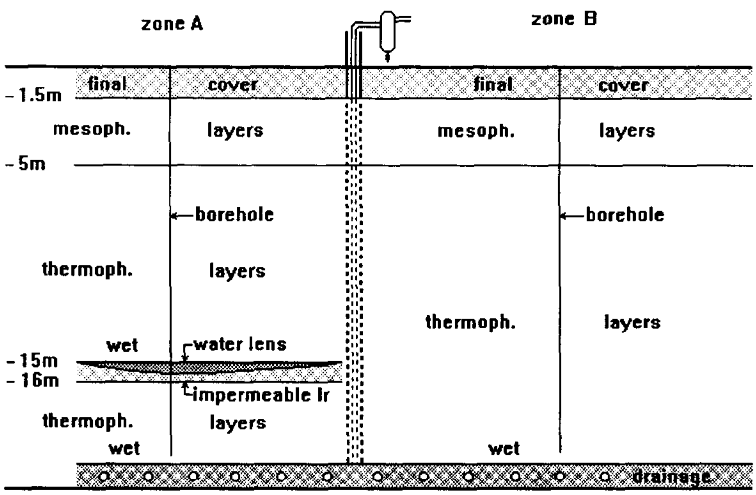

Fig. 2. Section of landfill as predicted in this study.

of MSW, has a height of about 20 m, and covers more than 42 000 m^2. It was closed at the end of 1990, after 9 years' filling. The average composition of waste is reported in Table 1, where a comparison between waste coming from Torino and from the surrounding zones is shown. Biogas is recovered by forced extraction by means of six wells. Each well has an influence radius of 47 m, corresponding to a surface of 6950 m^2. The scheme of a typical well is shown in Fig. 2. During the filling period, biogas was collected by exploiting its natural overpressure. Since 1991 it has been extracted applying a suction pressure of 0.08–0.12 m H_2O.

In 1993 it was decided to undertake a study of landfilled waste characteristics, and link them to previous studies on biogas production and landfill behaviour [1]. Two drilling series were carried out, one in November 1993 (zone A, Fig. 2) and another in May 1994 (zone B, Fig. 2) near well No. 43 (Fig. 1). Drilling was done in layers,

Table 1
Average composition of waste in Torino and surroundings

Fraction	Torino (%)	Surroundings (%)
Undersieve	19.5	27.1
Organic matter	25.8	29.8
Paper and cardboard	24.8	20.5
Wood	2.9	2.0
Textiles and leather	3.4	0.4
Glass, metals and inerts	14.4	11.0
Plastics	8.5	8.9
Dangerous fractions	0.7	0.3

at different landfill depths, and corresponding samples were collected and analysed in the laboratory (samples were stored in a refrigerator).

3. Results

3.1. In-situ measurements

3.1.1. Temperature

Biogas generation occurs in mesophilic (29–34°C) or thermophilic (49–55°C) conditions, i.e. waste is rather hot. Nevertheless, literature presents very few data on waste temperature [2]. In this study, during each run instantaneous temperatures in boreholes and of waste were measured at different landfill depths. A set of values from zone A is shown in Fig. 3, where, for comparison, the temperature measured in the neighbouring well is shown. It is evident that in the upper 6 m of waste the biogas generation process is mesophilic, whilst in the remaining waste is thermophilic. In a layer near the bottom, the measured temperature was very high. This layer was characterised by the presence of a thin lens of water followed by a sublayer of very thick mud. It is very likely, since biological activity was absent, that the local temperature rise reported in Fig. 2 was due to drilling friction. Owing to the intrusion of water on the borehole, drilling was suspended and started again later on. The layers below showed an almost normal thermophilic activity. Other water lenses were also found in the cell. As will be explained later on, some anomalies in biogas

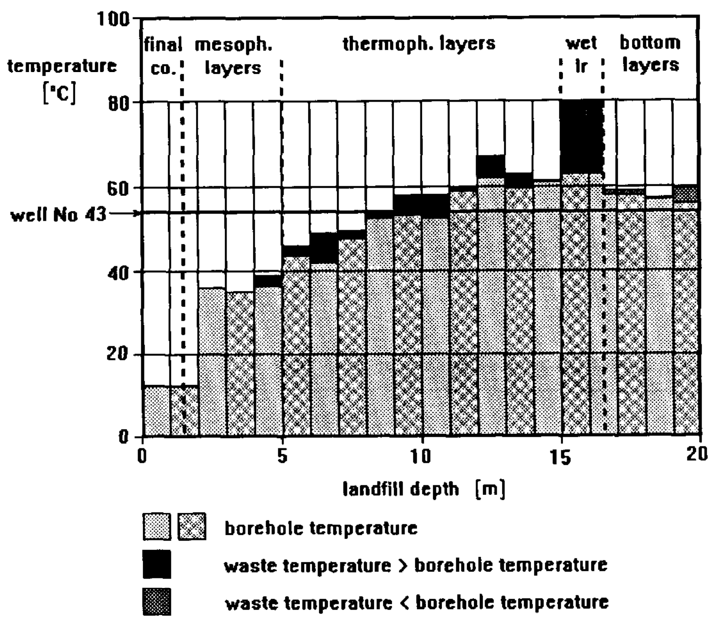

Fig. 3. Temperature profile in landfill.

generation can be ascribed to their presence. The temperature trend in zone B was very regular, increasing from 15°C to 50°C in the upper six meters of waste and then rather constant (50–60°C) to the bottom of the landfill.

3.1.2. Biogas composition

During temperature measurements, the biogas composition was measured by a portable infrared landfill gas analyser. Methane content was more or less constant along the borehole depth and was typical of anaerobic decomposition (52–55%). In zone A, near the water lens, a sharp decrease of biogas generation was observed and terminated suddenly, owing to the high water content. Afterwards, when drilling was restarted, underlying layers showed an almost normal biogas generation.

3.1.3. Discussion

MSWs are covered daily with a thin layer of soil; in order to enable collection vehicles to reach the working face of the cell, where wastes are unloaded, placed and compacted, on the fresh waste a pathway of thicker and compacted cover soil is built. Comings and goings of vehicles further compact the soil and make conditions for the origin of a water lens. The water lens was actually found near a buried pathway used in 1987.

During the placement of waste material, the layers above this intermediate, scarcely permeable cover, have a high moisture content and therefore decomposition is very fast. The content of biodegradable organic matter rapidly decreases. When moisture content becomes too high biological reactions stop. On the contrary, the layers under the intermediate cover are affected by a moisture content which is inadequate to support complete anaerobic digestion. Consequently the production of biogas is lower, and the content of biodegradable organic matter remains high. This phenomenon particularly affects the layer just under the scarcely permeable sublayer, since the bottom layers receive water from neighbouring zones. This interpretation is corroborated by laboratory findings and, since some meters of waste are concerned, can explain the anomalous behaviour of some wells which show unexpected variations of biogas production with time.

3.2. Laboratory investigations

Landfill drilling makes it possible to collect waste samples at different depths. Each borehole supplied 8–10 samples (20–30 kg each) at approximately 1- to 2-m depth intervals. These samples were transported to the laboratory and analysed.

3.2.1. Waste composition

Initially, the qualitative composition of each sample was determined. Plastics and inerts were rejected since they are not degradable materials. Table 2 shows the findings for a borehole (zone A), with the corresponding depth. It is possible to note, especially in bottom layers, the presence of large quantities of loam and mud, associated with degradation of organic substances.

Table 2
Qualitative composition of the tested landfill samples

Sample	Sampling depth (m)	Qualitative composition
1	3–6	Wood (not much) Magazines (a lot) Newspapers (not much) Loam (not much)
2	6–8.5	Wood (a lot) Loam Magazines (not much)
3	9.5–12	Loam Wood (not much)
4	12–13	Loam (a lot) Parcel paper (not much) Newspapers (not much)
5	15–16	Loam (a lot) Wood Water Mud (thick)
6	16–17	Loam Wood Mud
7	17–18	Loam (a lot) WET Wood (not much)
8	18–19	Loam WET Wood (not much)

In each sample construction and demolition debris, glass and plastics were eliminated.

3.2.2. Total solids (TS)

This parameter was determined for each sample. The runs were carried out in a stove, where samples were kept at 105°C for 24 h. Results are listed in Table 3. The result obtained for sample No. 6, characterised by a very high moisture value, is due to piercing of the impermeable layer of compacted soil that forms the bottom of the water lens mentioned above. The drilling was suspended after the collection of this sample and then started again some time after.

3.2.3. Volatile solids (VS)

This parameter is strictly related to the organic matter content: it is represented, more or less, by volatile solids. The analyses provided the values reported in Table 3. They were obtained by keeping the samples in a stove at 550°C for 60 h. The lowest VS content corresponds to the sample collected just above the water lens. Neglecting the possible, but statistically not probable, accidental presence of a large amount of rapidly decomposable material, the result can be attributed to the substantial moisture level of the waste. The corresponding rather high value of TS

Table 3
Chemico-physical characteristics of the tested samples

Sample	TS (g/kg waste)	VS (g/kg TS)	COD (g/kg TS)	TOC (g/kg TS)	TOC/VS	Redox potential (mV)
1	769	600	642	241	0.40	−400
2	786	278	293	124	0.45	−361
3	628	560	611	291	0.52	−380
4	860	136	110	57	0.42	−376
5	890	101	169	61	0.60	−341
6	488	555	521	255	0.46	−360
7	769	215	256	125	0.58	−340
8	896	126	261	55	0.44	−356

In each sample construction and demolition debris, glass and plastics were eliminated.

is mainly due to the presence of wood that, in spite of the difficulty of the decomposition of lignin, was clearly rather decomposed.

On the other hand, the layer just under the impermeable sublayer is characterised by a very high VS value. This confirms that biological decomposition was influenced by inadequate moisture. Unfortunately, the piercing of the impermeable sublayer altered the TS result. When drilling was restarted the new TS value was consistent with those of the lower layers. The findings of the analysis of the two following samples are in good agreement with the suggested interpretation. In fact, owing to water penetration from surrounding sides, VS values are rather low with an evident decrease with depth.

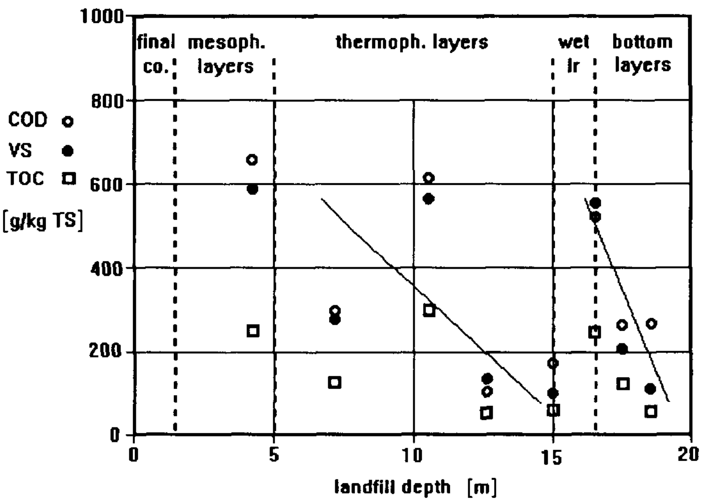

Fig. 4. Experimental results achieved in the present study versus landfill depth.

3.2.4. Chemical oxygen demand (COD)

Waste contains both inorganic and organic reduced matter. COD measurements give a cumulative indication of the oxygen required to oxidise both organic and inorganic matter. The experimental results are listed in Table 3. In Fig. 4 COD and VS are plotted versus landfill depth. It can be noted that:

(a) COD and VS values are in good agreement. The correlation between COD and volatile solids content can be given mathematically by a straight line (Fig. 5): COD (g/kg) = 0.92 VS (g/kg) + 62. A similar correlation has been achieved by Ehrig [3] from experimental runs carried out in a lysimeter.

(b) Zone A of the landfill shows a very peculiar behaviour since the water lens practically divides it into two independent parts. If this behaviour is compared with that of zone B which is characterised by a regular decrease of VS and COD values, the faster decomposition of the layer above the water lens and the slower one of the layer under the water lens are evident. Biological decomposition in zone A is strongly irregular, and it is necessary to take this into account in the estimate of biogas production and in the development of closure phase.

3.2.5. Total organic carbon (TOC)

Table 3 shows the quantities of organic carbon contained in the analysed samples and the ratio TOC to VS. The values of this ratio agree with the general estimate that organic carbon accounts for about half of the organic matter. The experimental results have been plotted versus landfill depth in Fig. 4, together with COD and VS.

3.2.6. Redox potential

Chemical elements have a different redox potential value depending on their oxidising or reducing power (taking the sign into account, a low redox potential means that the system is reducing). Measurements of this parameter can give information about chemical species in the considered system. Redox potential measurements have generated the data presented in Table 3. The values are negative (≤ -340 mV). The system is amenable to anaerobic digestion. Data reported in Table 3 indicate that the deepest samples, or rather, the matter contained in the deepest samples, are

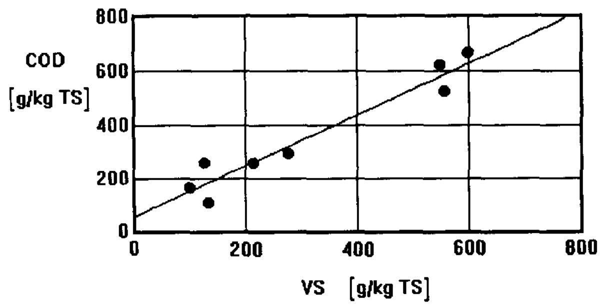

Fig. 5. Correlation between COD and VS for the samples collected.

more oxidised than that contained in the layers near the surface. The data confirm the findings for volatile solid content previously described.

4. Conclusions

Landfill waste sampling is difficult and somewhat expensive, but at the same time it is very useful for the characterisation of the landfill and for assessing biogas generation. This investigation has pointed out the presence of water lenses inside the landfill. This morphological characteristics is extremely important to recognise since the moisture level strongly influences the biodegradation rate of organic matter. In-situ temperature measurements and determination of the concentrations of the principal landfill gas constituents can give information about biochemical processes that are occurring inside the landfill. At the same time they can increase the reliability of the prediction of biogas production in postclosure management. Moreover, notwithstanding the extreme heterogeneity of waste, some easily determined physical and chemical parameters can provide indispensable support to in-situ findings. The results obtained in this work indicate the presence of water lenses in the landfill. This can explain irregularities observed in biogas generation.

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