Temperature Distribution Measurements in the Gyál MSW Landfil

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Abstract

Mixed municipal solid waste (MSW) landfills can serve as energy sources, because the temperature inside of them is high for a long time period. There are many mechanical, chemical and biological processes taking place simultaneously. Probably, there are aerobic and anaerobic biological decomposition taking place simultaneously because the average temperature can be higher than 40°C for decades. The inside operation of the heterogeneous MSW landfills is a really complex phenomenon. For the better knowledge about the operation of MSW landfills as bioreactors more measured data is necessary. For this reason a temperature, leachate and landfill gas monitoring system was installed into the Gyál (Hungary) MSW landfill. One hundred temperature sensors were installed into ten 16 m depth monitoring wells. Since two years temperature data has been red weekly. This data base is now available for analysis. The temperature monitoring wells were drilled into four different landfill sections. The deposition time of the waste is different in the different landfill sections. Exponential temperature increase can be observed at the young waste section and almost constant or decreasing temperature tendency at the older ones. Characterising temperature – time functions were determined by simple curve fitting. The vertical temperature distribution in the monitoring wells was also analysed.

Keywords: municipal solid waste, temperature distribution, decomposition heat generation, leachate, landfill gas

Introduction

Despite of the fact that disposal of waste by landfilling has become the final solution according to the hierarchy of waste management, in Hungary landfilling plays a significant role in handling processes because 4.2 million tons of mixed municipal solid waste (MSW) is landfilled every year. Although the energetical harness technology of the generating biogas in up-to-date landfills is elaborated yet, the utilization of the large amount of heat produced in waste by decomposition processes has not been solved. Appreciable quantity of this heat is stored by the material mass. Preliminary measurements showed that temperature can rise up to even 70°C. The knowledge of thermal properties is essential for estimation of the heat extraction potential, planning the technology and controlling the decomposition processes inside the landfills. We need to avoid undercooling because appropriate temperature is important for the decomposition processes and for the generation of methane. According to Coccia, C.J.R. et al. (2013) not only processes passing off inside the landfills can be controlled but the expected life service of landfill liner system can be also influenced. The elevated temperature in the bottom of the landfills makes great demands on the elements of the landfill liner system (HDPE geomembrane) resulting in the dehydration of the geosynthetic clay liners (GCLs). These harmful effects can be decreased by heat removal from the base of landfills. According to Viebke, J. et al. (1994) exposing to a maximum temperature of 20°C the service life of a typical HDPE geomembrane is expected to be approximately 600 years. The service life of HDPE geomembrane decreases to less than 50 years if exposed to temperatures around 50°C. This paper summarises the main achievements of the temperature monitoring system built into the Gyál MSW landfill.

Heat generation in MSW landfills

Heat, leachate and gas are the primary by-products of the decomposition of organic fraction in MSW landfills. The decomposition of organic waste fraction occurs in three different phases: an aerobic phase, a transient phase and an anaerobic phase (Tchobanoglous, G.et al., 1993; Daniel, D.E., 1993). Heat- and gas generation rates related to the decomposition phases are illustrated in Figure 1.

The generated heat results elevated temperatures within the waste body compared to the local air or ground temperatures (Yesiller, N. et al., 2015). Based on Figure 2, the heat generation reaches a peak value within a short time after the deposition by an exponential growth. After reaching the peak value, the curve is rapidly decaying. Figure 2 also represents that the heat generation is still significant after several years.

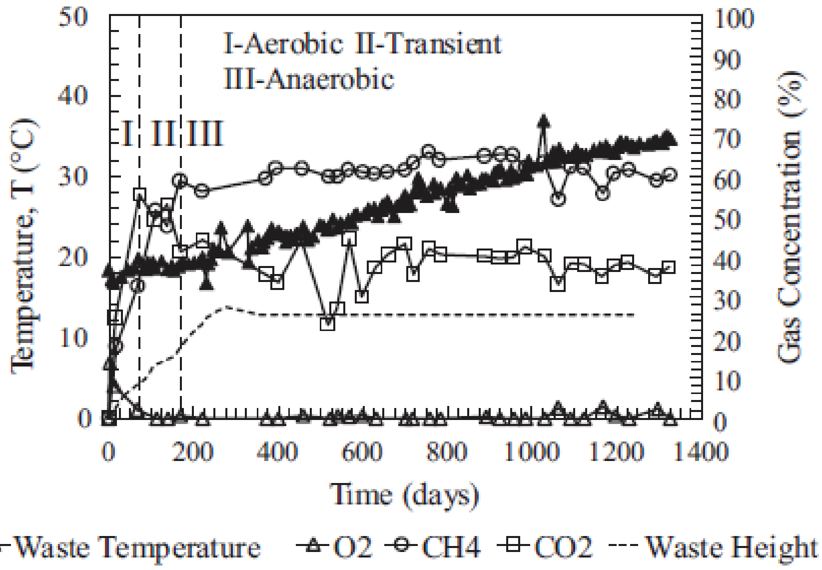

Fig. 1. Heat- and gas generation rates as function of time in a MSW landfill (Coccia, C.J.R. et al, 2013)

Rys. 1. Wydzielanie ciepła w funkcji czasu składowania odpadów komunalnych (Coccia, C.J.R. et al, 2013

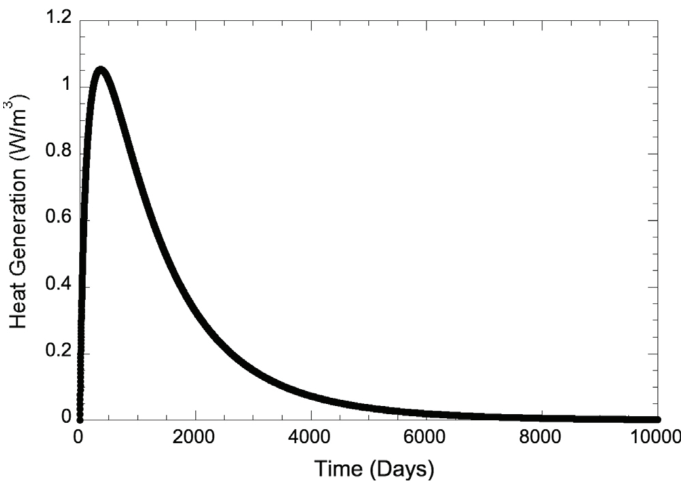

Fig. 2. Heat generation profile as function of time in a typical MSW landfill (Yesiller, N. et al., 2015)

Rys. 2. Rozkład ciepła w funkcji czasu w typowym składowiska odpadów komunalnych (Yesiller, N. i wsp., 2015)

According to Coccia, C.J.R. et al., 2013 the heat content of waste depends on not only the deposition (initial waste deposition temperature, waste deposition rate) – but also the climatic (precipitation rate, average yearly air- and earth temperatures) conditions.

Area description

The A.S.A. Hungary Ltd. operated landfill is located in Gyál – Hungary, where 100,000–150,000 tons of mixed municipal solid waste is landfilled every year. Up till now five landfill sections have been put into operation (Figure 3). Table 1 shows the geometric characteristics and the period of deposition time of the five different landfill sections.

Materials and methods

Temperature distribution monitoring system

A temperature distribution monitoring system was installed into the Gyál MSW landfill in June 2013 in order to characterize its functioning. As part of the monitoring system, 10 drilling points were selected in four different MSW landfill sections. Table 2 shows the quantity of installed temperature monitoring wells and the related range of waste ages for each landfill section. The temperature has been monitored in each meter in the boreholes from 6 m to 15 m referenced to the surface of the waste body.

The type of LMN35C temperature measuring sensor was selected for the measurements. The sensor is calibrated, 10 mV change in voltage cor-

Tab. 1. Geometric characteristic and period of deposition time of different landfill sections

Tab. 1. Geometria składowiska i czas składowania w różnych sekcjach składowiska

Identification number of landfill section	Geometric size [m^3]	Period of deposition time
I.	377.596	1999 - 2003
II.	426.322	2003 - 2006
III.	593.059	2006 - 2009
IV.	400.000	2009 - 2012
V.	423.900	2012 - 2014

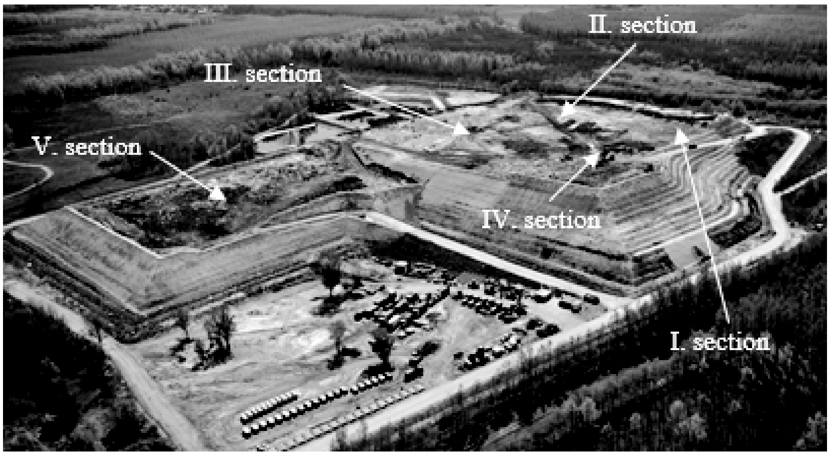

Fig. 3. The municipal solid waste landfill in Gyál

Rys. 3. Składowisko odpadów komunalnych w Gyál

Tab. 2. Quantity of installed temperature monitoring wells and the related range of waste ages for different landfill sections

Tab. 2. Ilość zainstalowanych studzienek dla monitorowania temperatury i wpływ czasu składowania dla różnych sekcjach składowisk

Identification number of landfill section	Quantity of installed temperature monitoring wells	Waste age in years
I	2	12-16
II	3	9-12
III	2	6-9
IV	3	0-6

responds for a unit temperature change in case of 0.1 Ω output electrical impedance. The measuring range of the sensor is between -40°C and +110°C, the accuracy is guaranteed by the manufacturer from ± 1 to 1.5°C. Consequently, special equipment is not necessary to obtain the measured data. The measured data can be read easily by a digital multimeter, because the measured voltage corresponds the numerical value of the temperature (Figure 4). A normal 9 V battery is appropriate for the power supply, thereby the problem that there is no available power source on the landfill can be solved in this way.

The temperature measuring sensors have to be protected against the harmful effects of the forming leachate and biogas due to the decomposition processes. Because of the aggressive media, close-ended HDPE tubes were inserted into the boreholes and the probes – which contain 10 temperature measuring sensors – were let down into it. Each sensor was also protected by a plastic housing equipped stuffing box to avoid the influence of the heat transport in the borehole. The diameter of the HDPE tube and the plastic housing fits well to each other, their thermal inertia is not problem during the monitoring, because the temperature changes slowly inside the waste body, there is enough time to take over the temperature from the surrounding waste.

Results

A long-term temperature distribution monitoring has been performed at the Gyál MSW landfill. In this chapter, a monitoring well was selected

Fig. 4. Temperature reading at a monitoring well (left) and evolving of a borehole for installation of a temperature monitoring well (right)

Rys. 4. Wyniki monitorowania temperatury w otworach i w głąb otworu

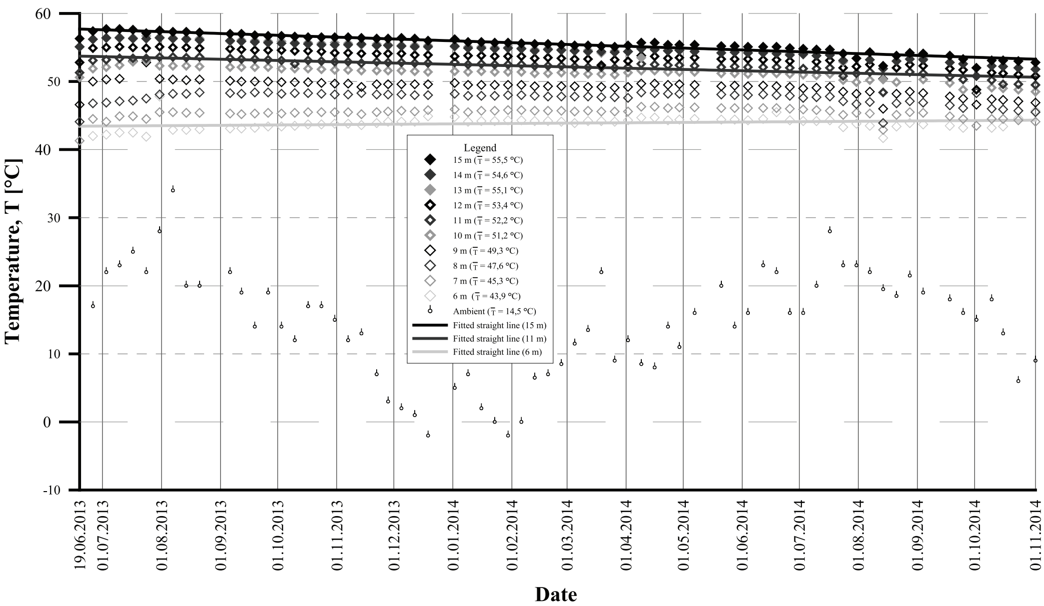

Fig. 5. Results of temperature monitoring well II/2

Rys. 5. Wyniki monitorowania temperatury w otworze II/2

from an old MSW landfill section (II/2) as well as a relatively fresh one (IV/3) to present and compare their temperature distributions. In both cases, the average temperature was calculated in each meter for each well. The values of ambient temperature are also indicated in the graphs. In order to obtain a comprehensive view, the average temperature was illustrated in each depth for both wells divided into seasons.

Temperature distribution of an old MSW landfill section

As Figure 5 indicates, the tendency of measured temperatures does not change significantly during the examined period, the ambient temperature has no influence on the measuring sensors. The highest temperature values can be observed in the deepest monitoring depth (15 m). As the depth increases the average temperature increases as well.

The deposition was started at 2003 and finished at 2006 in landfill section No. II, therefore the age of waste is between 9–12 years. In this landfill section the aerobic degradation phase is

Tab. 3. The applied parameters of the fitted straight lines for temperature monitoring well II/2

Tab. 3. Aproksymacja liniowa temperatury w otworze II/2

Depth [m]	A	B
6	-0.001756	43.4375
11	0.006170	53.7300
15	0.008810	57.7052

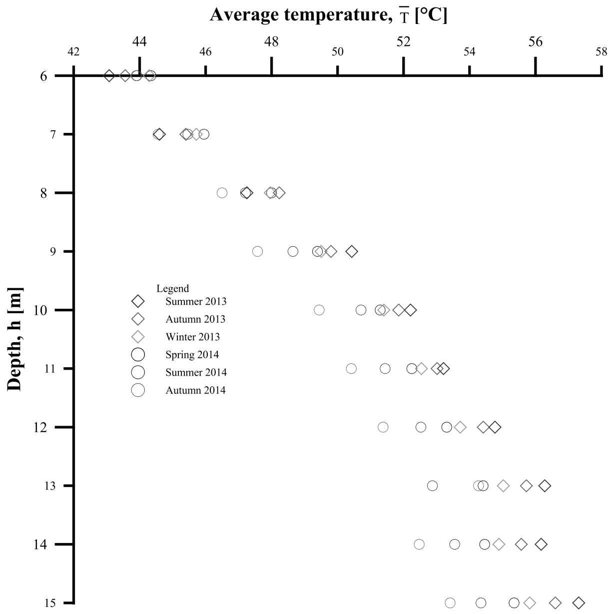

Fig. 6. Average temperature values of monitoring well II/2 divided into seasons

Rys. 6. Średnie wartości temperatur w monitorowanym otworze II/2 (podzielone na sezony)

Tab. 4. The applied parameters and the calculated values of coefficient determination of the fitted exponential curves for temperature monitoring well IV/3

Tab. 4. Aproksymacja wykładnicza temperatury w otworze IV/3

Depth [m]	T	A	B	R^2
6	57.750760	0.405046	0.006772	0.9920
11	64.538319	0.441505	0.005820	0.9761
15	65.831160	0.372177	0.006184	0.9559

already completed, the decomposition process is in the anaerobic degradation phase currently. The temperature trend refers to steady state conditions which can be characterized by straight lines in the monitored period. The straight lines are fitted for the measured temperatures at the depths of 6 m, 11 m, 15 m (top-, middle- and bottom of the waste body). The equation of the fitted straight lines in general form is:

$$Y = -A \times x + B \quad (1)$$

where: A – is the slope of the fitted straight line; B – is constant (y-intercept)

The applied parameters of fitted straight lines are given in Table 3.

Figure 6 shows the average temperature values as function of depth divided into seasons. The highest average temperature values can be observed in summer-, the lowest in the winter period. As the depth increases, the temperature difference increases among the seasons in each depth.

Temperature distribution of a relatively fresh MSW landfill section

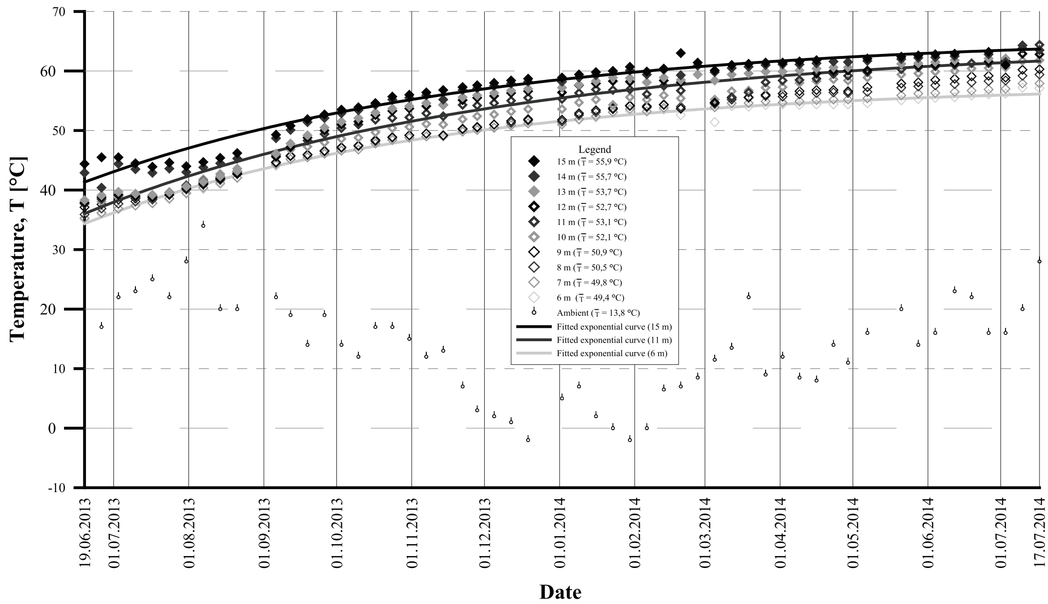

Fig. 7. Results of temperature monitoring well IV/3

Rys. 7. Wyniki monitorowania temperatury w otworze IV/3

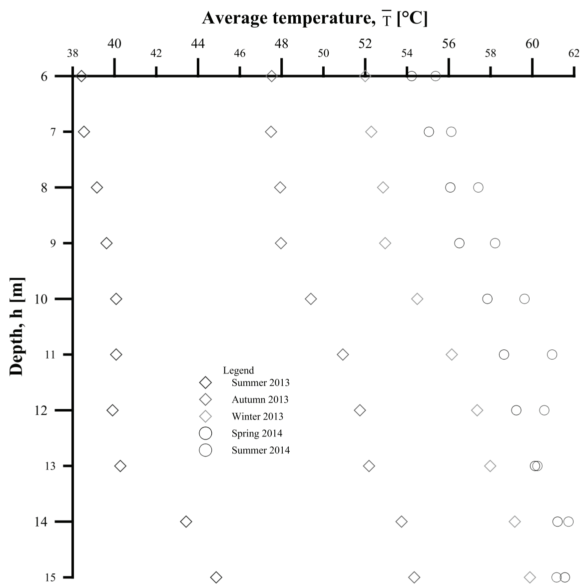

Fig. 8. Average temperature values of monitoring well II/2 divided into seasons

Rys. 8. Średnie wartości temperatur monitorowane w otworze II/2 (podzielone na sezony)

In case of monitoring well IV/3, elevated temperature values can be observed in Figure 7 compared to Figure 5. The tendency of measured temperature data is increasing as time goes by in the examined period. Landfill section IV is a relatively fresh one where the supply is continuously provided by the incoming fresh waste which is actually deposited there. The decomposition process is in the aerobic degradation phase at shallow depth, generating a large amount of heat. The temperature is started to increase at the beginning of the monitoring from the value of approximately 40°C and reaches the maximum temperature to approximately 65°C in the end of the observed period.

Based on Figure 7, the temperature trend refers to warming-up period, which can be characterized by exponential curves. The exponential curves are fitted at the same depths like in the former case. The equation of the fitted exponential curve in general form is:

$$Y = T \times (1 - A \times EXP(-B \times x)) \quad (2)$$

where: T – is the peak value of temperature in the observed period; A and B are the shape factors.

The applied parameters and the calculated values of coefficient of determination (R^2) of the fitted exponential curves for temperature monitoring well IV/3 are summarized in Table 4.

On the basis of the obtained values of R^2, it can be concluded that the applied exponential curves fit well on the measured temperature values. The average temperature values in Figure 8 represent the same continuously increasing tendency (warming-up period), according to which, the waste body becomes warmer and warmer in every season.

Conclusion

MSW landfills, especially those which are operated as bioreactors can be utilised as heat sources. To test the heat extraction potential a temperature, leachate and landfill gas monitoring system was installed into the Gyál (Hungary) MSW landfill. The temperature distribution inside of the landfill has been monitored for two years. Almost stable temperature time distribution was found in an older landfill section (age of deposited waste is about 6–10 years) and exponentially growing temperature was found in a new landfill section (0–2 years old).

Acknowledgements

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Pomiary rozkładu temperatury na składowisku odpadów Gyál (Węgry)

Zmieszane stałe odpady komunalne (MSW) zdeponowane na składowisku mogą służyć jako źródło energii, ponieważ temperatura wewnątrz składowisku utrzymuje się przez dłuższy czas na wysokim poziomie. W składowisku zachodzi jednozcesnie wiele procesów mechanicznych, chemicznych i biologicznych. Procesy rokładu biologicznego tlenowe i beztlenowe mogą zachodzić równocześnie gdyż średnia temperatura może być wyższa niż 40°C przez dziesiątki lat. Zjawiska zachodzace wewnątrz skladowisk odpadów zmieszanych są bardzo złożone. W artykule przedstawiono wyniki badań nad funkcjonowaniem składowiska odpadów komunalnych Gyál (Węgry). Zainstoalowano system monitoringu temperatury, odcieków i gazu wysypiskowego. Sto czujników temperatury zainstalowano w dziesięciu studiach o głębokości 16 m rozlokowanych w czterech sekacjach składowiska. Monitoring prowadzono w ciągu dwóch lat zbierając dane raz na tydzień. Uzyskana baza danych została poddana analizie. Czas składowania jest różnych dla różnych sekcji składowiska. Obserwuje się gwałtowny wzrost temperatury na początku składowania, przedstawiono krzywe zmiany temperatury w czasie a także zmiany temperatury z głębkokością studzienek.

Słowa kluczowe: stałe odpady komunalne, rozkład temperatury, wytwarzanie ciepła rozkładu, odciek, gaz wysypiskowy