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OPTIMIZING THE OPERATION OF MUNICIPAL SOLID WASTE LANDFILLS

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Abstract
Despite of the fact that the disposal of municipal solid wastes by landfilling has become the final and least preferable solution according to the hierarchy of waste management, in Hungary landfilling plays a significant role, because 4.6 million tons of municipal solid waste was still landfilled in 2013. Therefore, the operation and management of municipal solid waste (MSW) landfills are still really important. There are lots of different processes (decomposition, heat transfer, leachate forming and transfer, landfill gas generation, etc.) arising in landfills, and only a few tools are in our hand by with the operation of landfilling can be controlled, such as the leachate liquid system, the landfill gas extraction system, the method of landfilling and compaction, covering technologies and so on. A possible new tool might be an installed heat exchanging system by with part of the decomposition heat can be extracted and the operation might be influenced.
The partners of the “DEPOHO – KMR 12-1-2012-0128” research project are working on the development of heat exchanging, extracting and utilisation technologies. So far a temperature (100 sensors) and landfill gas (30 points) monitoring system, a horizontal (800 m^2) - and four vertical pipe heat exchangers with pumps which circulate the working liquid have been installed in the Gyál – Hungary landfill. The extracted heat will be utilised for the heating of a small greenhouse with vegetables (winter mode) and for the intensification of leachate liquid evaporation (summer mode). Our measurements showed that the temperature in the landfill body can rise up to even 70 ^{o}C.
Great advantage if someone has an installed heat exchanger system that the operation and the inside landfill processes can be controlled. 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 the landfill liner system can also be influenced. If high temperature is forming in the bottom of a landfill, it 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 reports about the mentioned results of the DEPOHO project, and summarizes the inside effects and processes in a landfill as well as the tools for the operators to control them.

Keywords: *municipal solid waste landfills, decomposition heat extraction, landfills operation optimization.*

Introduction

Modern life of mankind is inherent with waste generation. Enormous research work is focused on waste management, especially to use wastes as secondary raw materials. However, in Hungary landfilling of municipal solid wastes (MSW) is still the largest volumic applied waste treatment technique. Not to mention the many existing and closed landfills. Therefore, the proper operation of MSW landfills is still very important especially for the Hungarian economy. There are some tools in the hands of the landfill operators by with the processes inside the landfill can be influenced depending on the actual aim. A new tool might be an installed heat exchanging system. We think that this idea is new and useful, that the operation of a landfill can be carried out in a planned manner depending on the final aim. In the following the aims and the tools will be described, particularly the developed decomposition heat exchanging system for the .A.S.A. Gyál MSW landfill.

Aims

Obviously the first aim of an MSW landfill is the disposal of the waste itself. By the safe storage of the waste the hazardous effect of it can be significantly reduced. The safe long life storage is the minimal requirement; all MSW landfills must accomplish this task.
The second most important aim of MSW landfill operators is the landfill gas energetical utilisation. There are installed landfill gas extraction systems and gas motors at the up-to-date MSW landfills worldwide. In many cases the operators of the landfill and the landfill gas energetical system are different. Their interests are different as well. This second aim is the maximisation of methane yield from the landfill, so the quality and the quantity of the forming landfill gas are equally important. Typical problem with the landfill gas motors, that the generated electrical power is utilised but the heat content of the cooling or flue gas of the motors is not. The reason is that the MSW landfills are generally situated far from urban areas and therefore, there are

no heat consumers nearby. Huge quantity of heat is wasted worldwide this way. Possible new research area regarding the landfill gas energetical utilisation is the anaerobic bacteria treatment of the landfill to intensify methane forming.
The third fundamental aim of MSW landfilling might be the fast decomposition of the filled waste. There are two reasons why fast decomposition might be good. The area of a consolidated and recultivated MSW landfill can be utilised for various purposes, the area can be get back by this way. Another and recent idea is, that the fertilised material of the landfill, after many years retention time can be re-mined and reprocessed to gain secondary raw materials.
A novel approach might be the fourth aim of MSW landfilling, the extraction and utilisation of the decomposition heat that the mass of the landfill stores. If during the landfilling a heat exchanging pipeline is installed into the waste body, by circulating a working liquid in this pipe system heat can be extracted or introduced. The heat exchanging pipe system can be installed afterwards of the operation, in closed or filled MSW landfills as well. The heat transported by the extracted warm working liquid can be utilised, but the earlier remark, namely few heat consumers are located near the MSW landfills is valid here also. However, being able to control the temperature of the waste body is really advantageous, because by this way the inside processes can be controlled as well. 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 the landfill liner system can also be influenced. If high temperature is forming in the bottom of a landfill, it 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.

Conventional tools

So far the fundamental four aims of MSW landfilling were discussed. Let's go through the basic tools which are available to the operators.
Processing before landfilling. Generally in Hungary the collected MSW is landfilled without any processing, however a simple comminution to cut the plastic bags greatly increases the biological decomposition.
Landfilling technology. Landfilling of MSW can be achieved by different technologies. Every landfilling technology includes compaction and some inert material covering. The purpose of compaction is to decrease the volume of waste; thereby the volumetric storage capacity of MSW landfills increase. The compaction of waste is also advantageous in order to improve the stability of MSW landfills. The bulk density of the original waste (landfilled waste without compaction) is in the 0.15-0.25 t/m^3 ranges, depending on its own composition. This value can be significantly increased (2 … 4 times) by using different compacting machines (compactor, crawler machine). The volume of the waste can be further decreased by applying shredding technologies. Covering of waste by an inert layer is necessary to prevent the environmental pollution and to minimize the amount of the forming leachate inside the waste body. The safe storage and the minimisation of hazardous effects of waste can be solved by applying landfilling technologies (Hungarian Ministry of Environment and Water).
The leachate handling system. The disposal of leachate can be performed in two different ways. The most common way is to spray back the leachate into the waste body. Another option is the leachate pre-treatment according to its own qualitative characteristics. Pre-treatment can be pH adjustment, intensive oxidation, precipitation of metals, sedimentation or filtration. The leachate back spraying has significant effect on the inside landfill processes.
The landfill gas extracting system. Passive and active type of gas wells are also used for the extraction of landfill gas. In the case of passive wells the gas pressure is enough for the extraction of landfill gas, while vacuum is necessary for active wells. Active gas wells have higher safety and efficiency. The applied suction head influences not only the landfill gas yield, but indirectly the decomposition and the methane forming as well.

The developed new tool, the heat exchanging and utilisation system

This is a considerably new idea in the literature. If during landfilling heat exchanging pipelines are installed, later for a long time some of the decomposition heat might be extracted. When the landfill is partly empty (under cultivation) the pipeline installation is evidently easier, but after filling a landfill up (after cultivation) it is still possible. The partners of the "DEPOHO – KMR 12-1-2012-0128" research project are working on the development of heat exchanging, extracting and utilisation technologies. At this time a complete industrial size technology has been installed and put into operation. Systematic tests have been started. This paper reports about the main elements of this technology. The main elements of the installed technology are:

- I. Heat exchanger in “under cultivation” MSW landfill parts (horizontal heat exchanger) for heat extraction.
  a. “slinky” type heat exchanger (4 x 40 m)
  b. “ladyfinger” type heat exchanger (16 x 40 m)
- II. Heat exchanger for “after cultivation” MSW landfill parts (vertical heat exchanger) for heat extraction (4 heat exchanger wells and 1 gas monitoring well).
- Thermally insulated pipeline system with fittings.
- Mechanical engineering equipments (main pipelines, pumps, fittings, etc...) in a metal container.
- I. Heat exchanger for heat utilisation (greenhouse – winter mode).
- II. Heat exchanger for heat utilisation (leachate pond – summer mode)
- Computer and manual data acquisition system

Figure 1 shows the design of the horizontal heat extracting system with two heat exchanger pipelines (“slinky” and “ladyfinger” types).

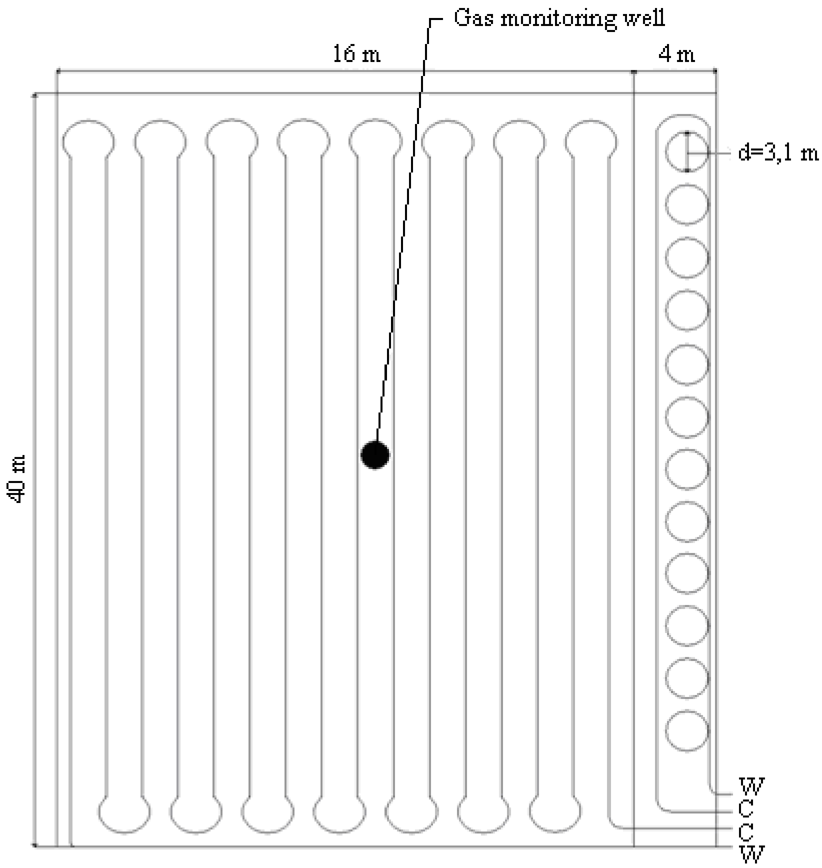

Figure 1. Plan of the horizontal heat exchanger pipelines (W – warm, C – cold).

800 m^2 of horizontal landfill surface was divided into two parts. The “slinky” type heat exchanger pipeline was placed near the side slope of the landfill (4 x 40 m) and the “ladyfinger” type one was laid to the remaining surface (16 x 40 m). The pipelines were laid on sand bed, where a flat surface was established firstly (Figure 2 and 3).

Figure 2. The preparation of the area before laying down the horizontal heat exchanger pipelines.

Figure 3. The “ladyfinger” (left) and the “slinky” (right) types of heat exchanger pipelines.

Electrofittings were used on site to connect HDPE pipes. The network of pipeline was configured in such way that the highest point was reached on the slope. The height of pipeline is monotonically decreasing in the direction of the heat exchanger and the pump.

The vertical heat exchanger wells were made by 800 mm diameter drilling (Figure 4).

Figure 4. The drilling of vertical heat exchanger wells. In the foreground, the closure of a finished monitoring well can be seen.

Previous temperature monitoring showed us, that the temperature is low in the upper 6 m depth from the landfill surface and below that the temperature increases. Drillings were 16 m depth. In the 800 mm diameter hole, both the downward and the upward pipe sections have to be installed. The inevitable heat exchange between the pipe sections is not good for the heat extraction. Figure 5 shows the concept of the planned vertical heat exchanger.

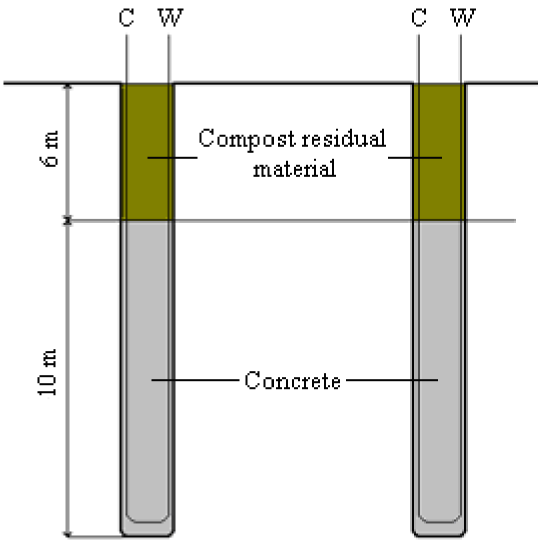

Figure 5. The concept of the planned vertical heat exchangers.

The method is based on two principles. The downward and the returning pipe sections are located at the edge of the borehole, providing the maximum distance among them. Between the waste and the heat producing section good thermal contact should be provided for which filling with concrete is suitable. The filling of concrete makes the system mechanically stable as well. The thermal conductivity of concrete is 1.09 W/mK which is twice better compared to waste or HDPE pipe. Thermally insulating material must be used on the upper section. The thermal conductivity of wood is 0.14 W/mK, this value is approximately a quarter of the wastes one. There is a compost residual material (rougher than 2 cm) with high proportion of wood on the landfill. This compost residual material is suitable for filling the upper 6 meters layer.

The metal container is functioning as engine-house and ensures the flexibility of the system, because each incoming (from “slinky” and “ladyfinger” type of heat exchangers as well as from vertical wells) and passing (to greenhouse and leachate pond) pipeline pairs were connected to the main pipes laying in the engine-house (Figure 6). The operation of each pipe system can be controlled by the taps and valves.

Figure 6. The engine-house and the installed mechanical engineering equipments.

Several hundreds of meters of HDPE pipe were used to connect the three heat exchanger systems to the engine-house. The connecting pipes were thermally insulated with matching size of poly foam. The protection of poly foam against precipitation and leachate was solved by wrapping nylon around the thermal insulation.

The three forwarding and returning pipelines of the heat exchangers (6 pipes) and a protective tube for the power and signal cables of data acquisition system were transferred under the service road near the side of the Gyál MSW landfill. Work shafts were established both side of the service road then a 250 mm diameter liner tube was inserted into the borehole made by horizontal drilling. The gaps were filled with sealing material by using insufflations technique on both sides of the borehole.

We developed two different alternatives for the utilisation of the extracted heat. The heat transported by the working liquid will be utilised for heating of a greenhouse in winter mode, while in summer mode the extracted heat will be used for making the evaporation of leachate liquid from the pond more intensive (Figure 7).

Figure 7. The built greenhouse, the container functioning as engine-house and the leachate pond.

A floating coiled pipeline was designed into the leachate pond with similar arrangement to the "ladyfinger" type of heat exchanger. This pipeline consists of 4 x 20 m long straight sections with three 2 m diameter reversing parts. The tubes were held by cross rods made by stainless steel with 4 m spacing. The hubs were equipped with buoys in 0.5 m long distance chains so the heat exchanger pipeline filled with working liquid can be sink in maximum 0.5 m depth in the leachate pond. The built greenhouse was equipped with a conventional heating system with radiators.

Conclusion

Landfills and landfilling of municipal solid wastes are still very important for the state of the art economies worldwide. Main aims and the conventional tools of MSW landfilling were shortly summarised to support the idea that the inside processes can be influenced by a planned manner, therefore the operation of MSW landfilling can be optimised. A new tool at the hand of the operators might be an installed decomposition heat extracting system. In Gyál, Hungary an industrial size system has been installed and put into operation. Two horizontal extractors ("slinky" and "ladyfinger") and four vertical extractor wells with the necessary auxiliary equipment were installed. The extracted heat is utilised in a built greenhouse (winter mode) and for leachate evaporation intensification (summer mode).

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