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ASPECTS REGARDING THE BASIC ELEMENTS OF THE GAS COLLECTION SYSTEM AT MUNICIPAL WASTE LANDFILLS

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Abstract: The efforts of the global scientific community to reduce methane emissions from landfills seem ridiculous and unimportant, especially in terms of investment costs, but, given the energy potential, it is of great interest to identify and efficiently exploit the widest possible range of potential energy sources. Landfill gas (Landfill Gas = LFG), due to its methane concentration that can reach over 50% in some cases, can prove to be a viable alternative in many applications, of local or even regional interest. At most landfills, in the maximum emission phase, landfill gas is composed of 45–60% vol. CH_4 and 40–55% vol. CO_2, the remainder consisting of oxygen, nitrogen, ammonia, hydrogen sulfide and other volatile organic compounds. The design of the entire system, from the capture of gas through wells to the energy recovery of this gas, where possible, necessary and/or feasible, shall consider the state of development of the deposit. In this paper, the types of collection wells are presented, which can be vertical or horizontal, long, or short, depending on the needs and peculiarities of the warehouse.
Keywords: ecological landfill, landfill gas, collection wells, waste

1. INTRODUCTION

The ecological challenges at the end of the twentieth century led to a reorientation of perceptions regarding the way in which "environment" and human society influence each other, the states of the world making joint efforts to cope with the new problems appeared: globalization, economic crisis, energy, climate change, loss of diversity of biological and ecological systems, deterioration of the quality of the abiotic environment (3R Waste Management Handbook).

According to generally accepted opinions, methane (CH_4) is thought to be responsible for about 30% of global warming on record. Although the residue of this gas in the atmosphere is much lower compared to carbon dioxide (CO_2), methane has a warming potential 80 times greater over a 20–year period. Recently, through high–precision instruments installed on the International Space Station (ISS), NASA identified more than 50 methane "super emitters" in regions of Central Asia, the Middle East, and the southwestern United States.

In Iran, south of Tehran, a methane cloud with a length of approx. 4.8 km, formed in the vicinity of a waste treatment complex. Researchers estimate that this complex emits approx. 8 500 kg of methane per hour. By comparison, an oil field in the New Mexico area (USA) emits approx. 18 300 kg per hour, and the infrastructure associated with oil and gas production east of the port city of Hazar (Turkmenistan), emits approx. 50.400 kg per hour.

Methane is a powerful greenhouse gas, second only to carbon dioxide in terms of global contribution to climate change. At the molecular level, methane is more potent than carbon dioxide. Methane, although it stays less time in the atmosphere (Intergovernmental Panel on Climate Change, 2014), has a significant effect on climate and contributes to the formation of ground–level ozone, a powerful local air pollutant that causes serious health problems (European Environment Agency, 2016).

Current non–CO_2 policies are expected to reduce methane emissions in the EU by 29% by 2030 compared to 1990 levels. However, the impact assessment of the 2030 Climate Target Plan identified methane as the main greenhouse gas after CO_2 in the EU (Impact assessment of the EU's 2030 climate target plan).

In this context, the efforts of the global scientific community to reduce methane emissions from landfills seem ridiculous and unimportant, especially in terms of investment costs, but, given the energy potential, it is of great interest to identify and efficiently exploit the widest possible range of potential

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energy sources. Landfill gas (Landfill Gas = LFG), due to its methane concentration that can reach over 50% in some cases, can prove to be a viable alternative in many applications, of local or even regional interest.

Landfill gas is an unavoidable by–product of any non–hazardous landfill accepting untreated biodegradable waste. It is the product resulting from the ordinary, natural anaerobic digestion of organic matter, a process that takes place under certain pressure and temperature conditions, characteristic of landfills. Usually, LFG is a mixture of methane, carbon dioxide and other decomposition gases. At most landfills, in the maximum emission phase, landfill gas is composed of 45–60% vol. CH_4 and 40–55% vol. CO_2, the remainder consisting of oxygen, nitrogen, ammonia, hydrogen sulfide and other volatile organic compounds.

Landfill gases are produced when bacteria break down organic waste. The amount of these gases depends on the type of waste present in the landfill, the age of the landfill, oxygen content, moisture content and temperature. For example, gas production will increase if the temperature or moisture content increases. Although production of these gases generally peaks in five to seven years, a landfill can continue to produce gas for over 50 years (U.S. Environmental Protection Agency).

The general interest in landfill gas capture is an environmental interest and is given by the objective of reducing greenhouse gas emissions, responsible for global warming. Interests in implementing landfill gas capture projects can range from reducing air quality complaints to reducing current operating costs or post–closure monitoring (Xu, L., X. Lin, J. Amen, K. Welding, et D. Mc Dermitt, 2014).

Landfill gas can be a renewable source of energy (since biodegradable waste will continue to be produced). Partial or full coverage of the heating or electricity energy needs of the warehouse and related facilities is a matter of economic common sense if it can be achieved efficiently and technically feasible.

Since the construction and operation of a landfill is carried out in stages, on cells and/or compartments, it goes without saying that landfill gas capture must also be subject to the same rules. From this point of view, at most medium and high–capacity landfills, the landfill gas capture project must be designed, carried out and put into operation in stages, with the development of the landfill and the stage in which it is at a certain moment.

The design of the entire system, from the capture of gas through wells to the energy recovery of this gas, where possible, necessary and/or feasible, must take into account the state of development of the deposit, in terms of the amount of untreated organic matter contained, the geometric and volumetric dimensions of the storage compartments, the length of time that will elapse until the onset of landfill gas emissions, the location and weather conditions of the landfill site and a multitude of other contractual and institutional factors (Qi–Teng, Z., Rowe, R. K., & Shi–Jin, F., 2018).

Capturing methane from landfills is a net climate benefit but, depending on the region and technologies used, could entail higher costs due to the need to install gas–to–electricity technologies in landfills.

2. MATERIALS AND METHODS

During the lifetime (operation and subsequent post–closure monitoring) of a warehouse, the configuration of the collection system requires changes and adaptations, depending on the development of the deposit, changes in gas composition, actual recovery possibilities, etc.

In Romania, the legislation in force, implemented based on European directives, is quite rigorous and does not accept too many deviations from the basic concept, most likely due to the lack of effective control.

According to Romanian legislation (Ministry of Environment and Water Management, 2004), a gas collection system consists of the following components:

- gas collection wells, which also include transmission pipelines for collected gas;
- gas collection stations;
- main gas transmission pipeline;
- condensate separators;
- gas controlled combustion plant / gas recovery plant;
- safety components.

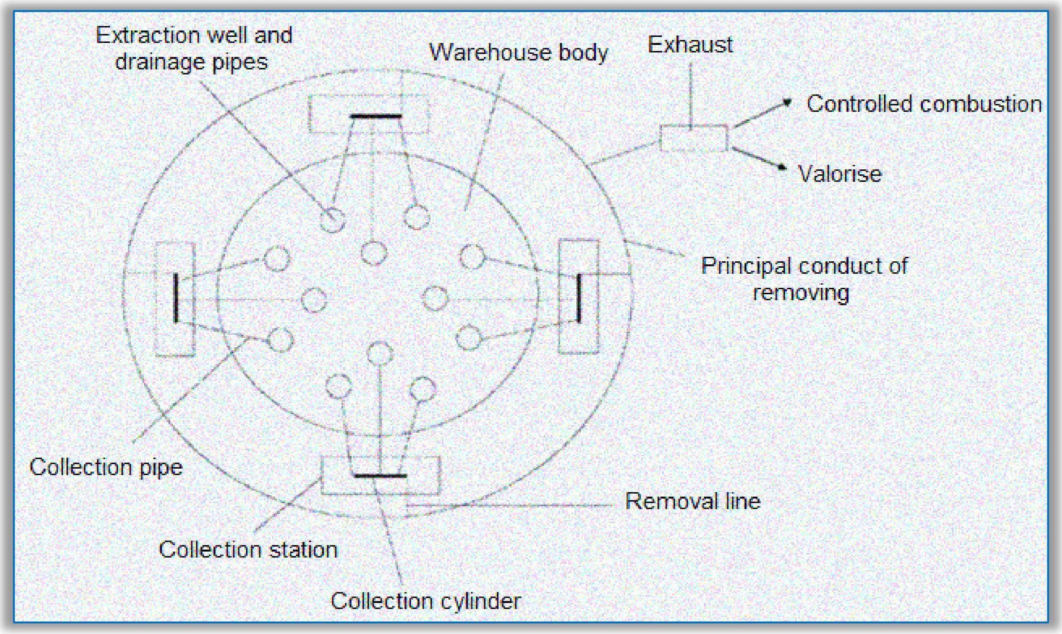

Figure 1 – Structure of the gas collection system within an ecological deposit (McKendry, P., 2018)

One of the main components of an ecological deposit is the gas collection well, which can be built in different constructive versions that will be presented below.

3. RESULTS

Collection wells can be vertical or horizontal, long, or short, depending on the needs and particularities of the warehouse. In general, in most projects, vertical wells are preferred, especially since they are also "approved" by national regulations.

Vertical wells have the advantage of being quick to build, can be put into operation quickly and give noticeably favorable results in a very short time after commissioning.

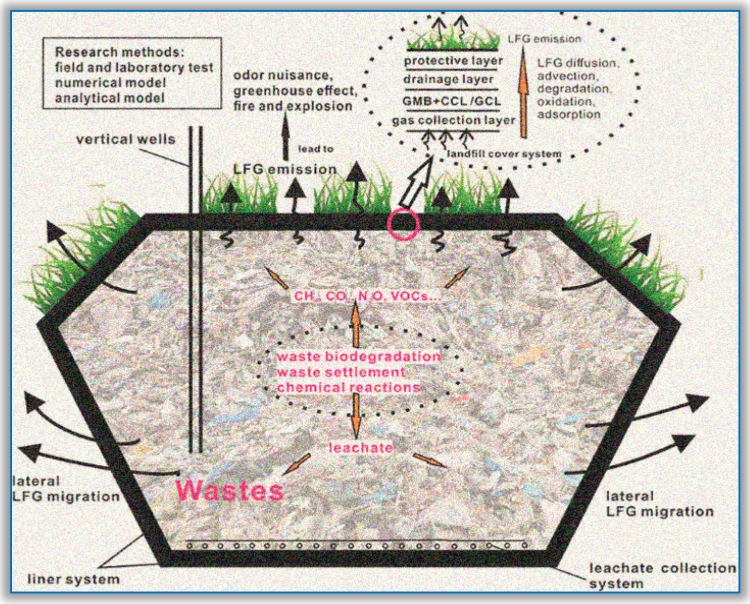

Figure 2 – Structure of the gas collection system within an ecological deposit (Qiao, W., Xiting, G., Suqin, T., Arif, M., Devendra, N. S., Haijian, X., Yun, C., & Xinru, Z., 2022)

The general diagram of a vertical well is illustrated in Figure 3, provided that this configuration is specific to the period after the final closure of the deposit. In the period of current operation, the constructive configuration of the well is different.

Although they have undeniable advantages, vertical wells also have several disadvantages, such as, but not limited to:

- are directly affected by deposit settlements. It is worth mentioning that the settlements in the body of the warehouse are not only in the vertical direction, but also in horizontal directions, impossible to control and predict accurately. For this reason, in the medium and long term some of the vertical wells within a system are abandoned and/or replaced;
- the absorption pressure of the gas, so the composition of the extracted gas varies quite a lot along the length (depth) of the well, which creates difficulties in correctly estimating the quality and quantity of extracted gas;
- are affected by the variable level of leachate in the body of the deposit, which can clog the active portion of the well and create leachate–saturated areas in influence of the well, thus affecting the amount of gas extracted.

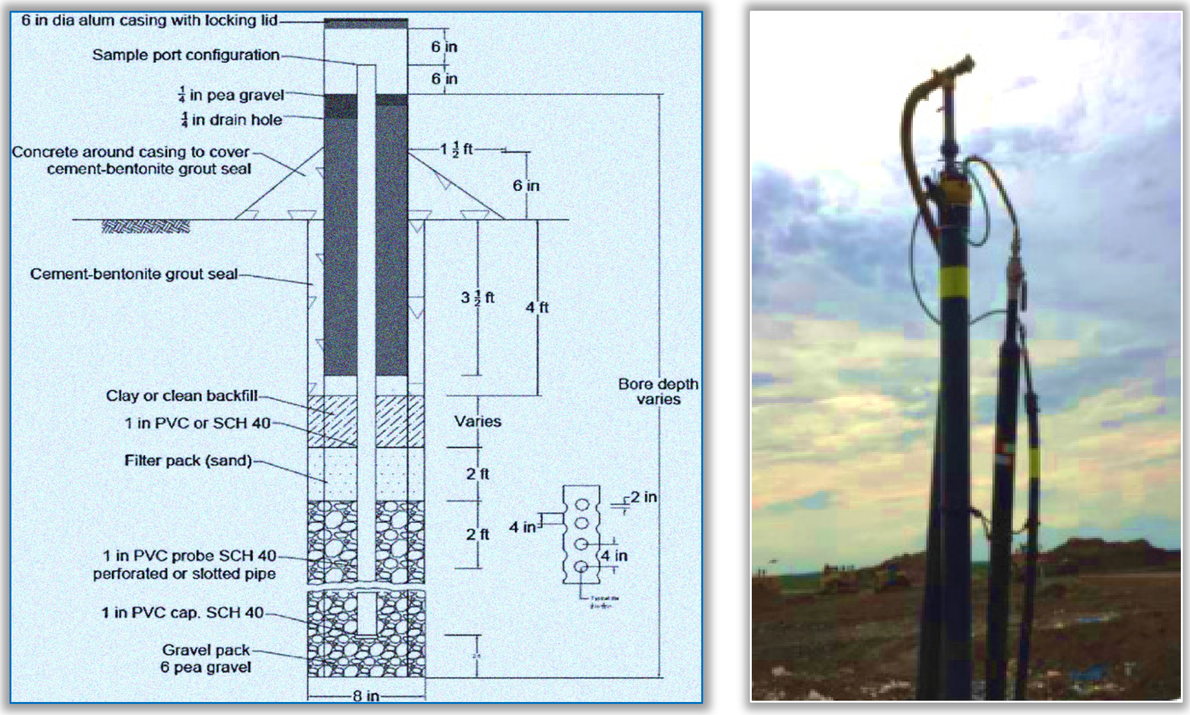

Figure 3 – The structure of a vertical well for collecting landfill gas (Jay, N. M., Hiroshan, H., & Hettiaratchi, J. P., 2016)

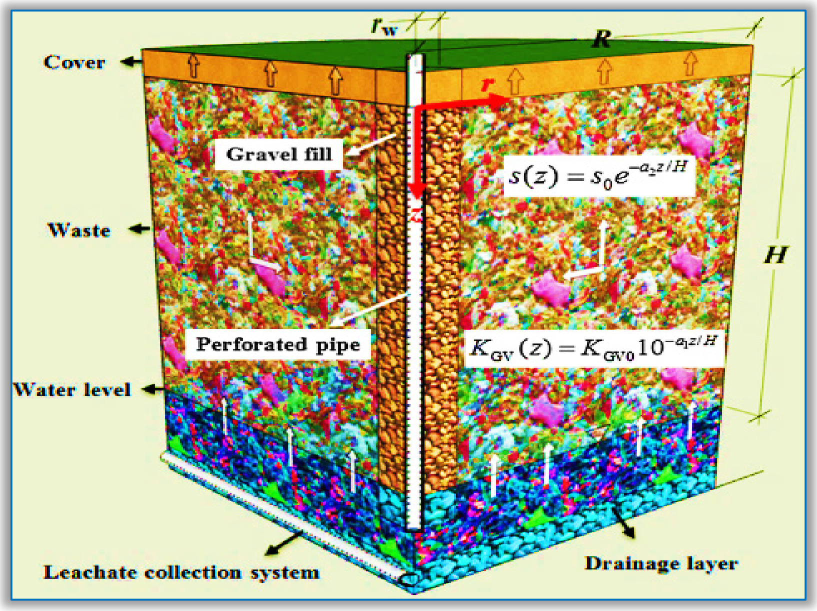

Figure 4 – Diagram of the waste field around a vertical LFG collection well (Qi–Teng, Z., Rowe, R. K., & Shi–Jin, F., 2018)

Vertical wells have a diameter of from 20 to 90 cm and include pipes with a diameter of 5 to 15 cm. A minimum drilling diameter of 30 cm and a pipe diameter of 10 cm are recommended. Larger diameter boreholes and larger pipes usually increase LFG collection because of increasing surface area. Figure 4 shows a diagram of the waste field around a vertical LFG collection well with a horizontal distance of 2R (m).

Horizontal wells are often installed in the active areas of the landfill. They cannot disrupt landfilling operations as substantially as vertical wells because they are located at or below the surface of a waste elevator (layer). In general, horizontal wells are constructed in the same way as vertical ones, vertical, but can be built using standard earthmoving equipment instead of using a specialized drill, specialized drilling.

They are often used as an interim solution to allow collection of LFG from a landfill, shortly after completion of filling and possibly while still to be filled. In the case of horizontal wells, they must be efficient, it is necessary to place suitable waste (up to 30 feet) above them to allow operation without

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significant air ingress from the surface of the landfill. The frequency, length and location of horizontal wells are usually selected according to collector installation objectives, such as minimizing off–site migration issues.

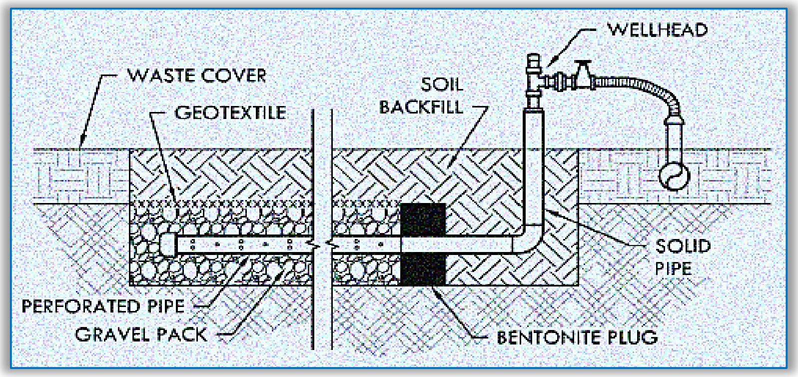

Figure 5 – The structure of a horizontal well for landfill gas collection (LFG Energy Project Development Handbook, 2020)

The optimal distance between the wells is 15 m (Manzur, S., Hossain, M., Kemler, V., & Dugger, D., 2012), both horizontally and vertically. They can also be used as a leachate recirculation system (in the case of deposits operated as bioreactors). Due to the inhomogeneity of the waste, the effective distance of leachate distribution (and gas capture) is 11 – 16 m (Shahed, R. M., Sahadat, H., Vance, K., & Mohammad, S. K., 2016).

Due to the longer collection length (which can even be a closed loop), horizontal wells have a higher absorption capacity than vertical ones. Their installation cost is much lower (at less than 50%) compared to vertical ones, because they do not require specialized machinery for installation. Horizontal wells can also be placed in active storage areas because they are functional even under machine traffic, with minimal protection.

In the case study, data show that 4 horizontal wells with a length of approx. 1.25 km each captured approx. 50% of the total amount of gas, the remaining 50% being collected through 83 (more than 20 times more) vertical wells. As an added advantage, horizontal wells can be installed and start capturing gas at an early stage of storage, whereas vertical wells are usually installed later at final closure, when the final shares of the deposit are almost reached (Samuel, A. D., David, R. H., P.G., & Bechte, J.D).

In order to benefit from the most consistent gas quality for as long as possible, it is beneficial that the well placement project considers the spatial development of the deposit, so that the cumulative gas mixture from several wells is usable for its intended purpose.

Depending on the area where the deposit is located and the applicable legislation, the use of landfill gas for useful purposes may start already in the current operation phase of the deposit, which requires more rigorous well construction measures or, conversely, only after the closure of the deposit, meaning that significant amounts of gas are not used and wasted.

4. CONCLUSIONS

The general interest in landfill gas capture is an environmental interest and is given by the objective of reducing greenhouse gas emissions, responsible for global warming. Interests in implementing landfill gas capture projects can range from reducing air quality complaints to reducing current operating costs or post–closure monitoring.

One of the main components of an ecological deposit is the gas collection well, which can be built in different constructive versions that will be presented below.

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