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REVIEW OF TECHNIQUES FOR LANDFILL LEACHATE TREATMENT

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Abstract: One of the basic problems of waste management, which is in practice encountered in landfills, is the collection and treatment of wastewater. Their production, and therefore quantity, depends on the age of the landfill, types of waste, climatic conditions, etc. These wastewater must not be discharged directly into the environment without prior collection and adequate treating. Water from solid waste, as well as water infiltrated into the landfill, forms a medium in which all soluble matter is dissolved and which causes the movement of unreacted material towards the bottom of the landfill. These waters are known as leachate water. The paper presents the production and composition of leachate landfills, and reviewed the technologies that are most often applied for their treatment. It can be concluded that leachate water due to its complex composition poses environmental risks and must be managed in an environmentally friendly manner.
Keywords: landfill, wastewater, treatment

1. INTRODUCTION

Disposal to landfills is one of the most common ways to manage waste materials safely in the human life and work environment. Well-designed landfills have systems for collecting and managing wastewaters and gases. By discharging untreated leachate from the landfill, surface and groundwater may be contaminated.

According to the chemical composition of the leachate, they belong to the group of the most polluted wastewater and therefore can have a detrimental effect on human health and the environment if they are not managed in an adequate manner. Therefore, their collection and treating is necessary in order to remove the present harmful compounds and reduce their concentrations to levels acceptable to the environment. For treating leachate landfill waters physico-chemical, biological and membrane processes are used.

In this work is comprehensively considered the way of formation, composition and possibilities of treating leachate landfill waters.

2. FORMATION OF THE WASTEWATER AT THE LANDFILL

Leachate waters are generated by the flow of water from atmospheric precipitation through the body of the landfill, in which extraction of soluble, colloidal and suspended matter from the waste occurs. In addition to the type of waste that is deposited, the compactness of the layers and processes taking place at the landfill, the quantity of leachate waters is influenced by other factors. The quantities of leachate water depend to a considerable extent on the location of the landfill, on the method of waste disposal, the collection and disposal system of leachate (filtrate) from the landfill.

The amount of leachate is affected by the outer waters that penetrate to the body of the landfill. The outer waters that penetrate to the body of the landfill are:

- groundwater,
- landfill surface water
- water caused by atmospheric precipitation.

The latest research in order to examine the problem of leachate from municipal solid waste landfills shows that these waters are one of the most complex sources of pollution in the environment.

ANNALS of Faculty Engineering Hunedoara – International Journal of Engineering
ISSN 1584 - 2665 (printed version); ISSN 2601 - 2332 (online); ISSN-L 1584 - 2665
Universitatea Politehnica Timişoara

The landfill leachate is a medium whose composition and quantity are significantly changing during the life of the landfill. From the point of view of toxicity, they are among the most polluted wastewater and are therefore extremely demanding for treating. Each landfill is a separate system where the composition and quantity of leachate water depends exclusively on the characteristics of the landfill. The main source of landfill leachate waters is the atmospheric precipitation coming to the surface of the landfill and flowing through the body of the landfill. A part of that water is running as precipitation water, the part is returned to the atmosphere by evaporation from the upper surface of the landfill or vegetation, and the remain is retained in the upper layer of the landfill, where moisture increases in the waste. When the waste is saturated with this moisture, the excess water flows through the layers of waste. Movement of water through waste depends on the permeability, porosity, humidity and thickness of the waste, the chemical reactions of the internal overhangs that form impermeable barriers and accumulation zones in the waste. Figure 1 shows the layout of the landfill with the collection system for leachate waters.

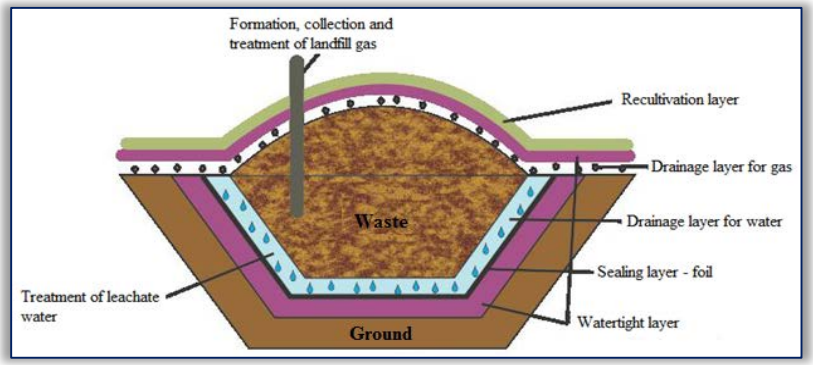

Figure1. Layout of the landfill with the collection system for leachate waters [1]

The amount of collected water in the layers of waste up to the moment of achieving the degree of saturation of moisture represents the capacity of retaining moisture in the waste. At that stage, the moisture from the waste begins to form the leachate water at the landfill. The amount of water that occurs as a product of the biological and chemical processes of decomposition of waste is practically insignificant compared to other sources, except in areas with dry climate.

The quantity of leachate landfills can be calculated using various experimental methods and patterns, as well as using mathematical models and computer programs.

For the purpose of long-term control of the production of leachate water and reduction of purification costs, reducing the infiltration of atmospheric precipitation into the landfill body is one of the priority tasks. With the implementation of certain operational measures, the production of landfill leachate can be reduced to 0,02 to 0,2 mm / day. However, the reduction in the production of leachate has negative effects on the degradation of organic waste components in the landfill body. The lack of moisture in the landfill body leads to a decrease in the intensity of microbiological processes by which the organic components are broken down into waste, which causes an undesirable process of "dry stabilization" or "mummification" of organic waste components.

According to individual technical solutions and technical equipment of the landfill, controlled recirculation of leachate waters can be achieved in the body of the landfill. Recirculation of leachate water into the body of the landfill provides regulated dosing and their retention at the site of formation, and accelerates the degradation of deposited organic waste components.

3. COMPOSITION OF LANDFILL WASTEWATER

The quality of wastewater is conditioned by the physical, chemical and biological processes in the landfill body. The composition of wastewaters depends on a number of factors: the composition of waste, its pre-treatment, the stabilization and decontamination process at the landfill, the height and age of deposited waste, the charging technique and the degree of compression of waste, weather and hydrological conditions at the location. Landfill wastewaters are significantly different in composition. The real composition of these waters is very difficult to predict because it depends on a number of variables such as:

— waste composition,
— temperature and moisture content,
— the pathway of the fluid,
— thickness of the landfill,
— stages of waste decomposition,
— the ability of interlayers to absorb and remove pollution, and
— the quality of water infiltrating into the landfill.

So far the research carried out on the landfill leachate waters shows the following:

— the quality of the effluent is extremely variable, but partial or complete purification must be carried out before discharge into the recipient;
— assessment of the quality of the effluent water of the existing or future landfill, for the forthcoming period, can be orientated and bound to the experiential indicators from the literature;
— mathematical modeling, based on models and empirical relations, can be applied to the treating and application of specific conditions and characteristics of a specific landfill;
— the quality of the treated waters changes depending on the age of the landfill, and therefore the processing plant must be flexible and adaptable to monitor the changes in the quality of the treated water;
— the quality parameters of the effluent, in the treatment of leachate waste waters, should meet the legal regulations for industrial wastewater, and the obligatory quality indicators are the content of the suspended matter, the temperature, the pH value, chemical oxygen demand (COD), biologycal oxygen demand (BOD5), nitrogen content and total phosphorus.

Landfill wastewaters mainly contain dissolved organic matter, ammonium nitrate, sulfides, chlorides and other harmful substances. Their concentrations depend on the age of the landfill and the type of waste that is being disposed of, as well as the decomposition phase of the waste. The change in the composition of the effluent landfill depends on the phase of the decomposition of waste. The stages of decomposition of the waste at the landfill are the following: aerobic (phase I), acidic (phase II), the start of methane production (intermediate phase III), anaerobic intense methane production (Phase IV) and aerobic phase (phase V).

Based on the literature data, it is possible to illustrate the average composition of landfill leachate water depending on the age of the landfill (Table 1).

Table 1. Characteristics of landfill leachate water, depending on the age of the landfill [2]

Parameter	Unit	The age of the landfill		
		up to 1 year	from 1 to 10 years	from 10 to 20 years
pH value	-	5,4 ÷ 7,7	7,1 ÷ 8,7	7,3 ÷ 9,3
Suspended substances	mg/L	1875	386 ÷ 1950	159 ÷ 1150
Total suspended substances	mg/L	4,6 ÷ 6,8	848 ÷ 6786	767 ÷ 6786
Biologycal oxygen demand (BOD5)	mg/L	5000 ÷ 15000	280 ÷ 15000	207 ÷ 1800
Chemical oxygen demand (COD)	mg/L	-	640 ÷ 13040	5500 ÷ 17600
Chlorides	mg/L	-	420 ÷ 2875	119 ÷ 5860
Ammonium nitrogen (NH3-N)	mg/L	-	150 ÷ 2700	2 ÷ 47
Nickel (Ni)	mg/L	-	0,02 ÷ 1,56	0 ÷ 1,56
Cadmium (Cd)	mg/L	-	0 ÷ 0,13	0 ÷ 0,05
Lead (Pb)	mg/L	-	0 ÷ 3,25	0 ÷ 3,45
Chromium (Cr)	mg/L	-	0,05 ÷ 16,9	0,04 ÷ 1,16
Mercury (Hg)	mg/L	-	0,4 ÷ 1,70	-

Organic contaminants are organic compounds that are harmful to the ecosystem. They can be carcinogenic, toxic and mutagenic to living organisms. Organic pollutants are determined using mass spectrometry methods. Gas chromatography in combination with mass spectrometry (GS-MS) is the most commonly used method.

Heavy metals are present in leachate if heavy metal waste is deposited at the landfill. If the leachate contains colloids, then the greater risk is that heavy metals, such as cadmium, copper, lead and chromium, are transported outside the landfill.

Ammonia nitrogen (NH_3-N) represents the amount of ammonia, toxic pollutants in waste landfills, sewerage, liquid fertilizer and other liquid organic products. Ammonia nitrogen can directly disturb the balance of water systems. High concentrations of untreated ammonia nitrogen boost algae growth, reduce the performance of biological systems for water treatment, accelerate eutrophication, increase the consumption of dissolved oxygen in the water and increase the toxicity of surface waters.

4. PROCESSES FOR THE LANDFILL LEACHATE TREATMENT

All waters generated at landfills, according to the Waste Disposal Directive 1999/31 / EC, should be collected and refined before discharge into the recipient. Leachate water is collected by the drainage system and can be treated together with wastewater from the recycling waste separation plant, municipal waste water from the auxiliary objects of the landfill, as well as the waste water from the washing of vehicles that bring the waste to the landfill. The quantity of leachate water

during the year varies considerably depending on meteorological conditions, and therefore their quality, or concentrations of pollutants.

Selection and design of the treatment process of leachate waters are not simple. Important factors that significantly influence the selection and design of the treatment systems for the landfill leachate water are:

— defining the characteristics of leachate water (quantity and quality);
— analysis of the possibility of final discharge of leachate waters, and determining the appropriate level of treatment;
— the selection of a purification process or process that will ensure that the quality of the effluent meets the legal regulations and uninterrupted release into the recipient;
— cost analysis of different treatment processes depending on the choice of the final disposition;
— selection of the best treatment and disposition process from the aspect of cost, reliability, flexibility and other specific requirements.

Transfer of leachate waters includes processes such as recycling / recirculation and combined treatment with water from the public drainage system, i.e. public sewers. In the last few years, the solution has often been the treatment of leachate waters along with water from public sewerage systems in municipal wastewater treatment plants. This solution was popular due to low cost and relatively simple processing. One of the arguments in favor of the application of this treatment is the fact that nutrients for the growth of microorganisms in municipal wastewater treatment plants do not need to be added; nitrogen is fed to the leachate while phosphorus is introduced with sewage water. In addition to the nutrients of leachate water, organic compounds with low biodegradability are brought with them, as well as heavy metals, which can reduce the quality of the treatment and result in an increase in the concentration of metals in the effluent, which bring into questions process of treatment of leachate water using this procedure. There are different types of technologies for the treatment of leachate water and some of them are shown in Table 2. It is not appropriate to specify in advance what technologies are the best, and a general solution cannot be proposed. It is necessary to design a treatment plant for effluent water that can efficiently and economically respond to variations in the quality and quantity of wastewater, as well as the necessary degree of purification based on the required water quality in the recipient.

Table 2. Technologies for the treatment of wastewaters [3, 4]

Technology and processes	Advantages	Disadventages
Physical-chemical processes: flotation, coagulation / flocculation, precipitation, chemical oxidation, adsorption, aeration and evaporation	Low investment	Low level of purification efficiency
Biological processes: aerial lagoons, suspended activated sludge, sand irrigation filters, anaerobic (anaerobic lagoons and anaerobic digestion), rotating biological reactor	Efficient and economical removal BOD and ammonia	Complex system maintenance
Membrane technologies: microfiltration, ultrafiltration, nanofiltration and reverse osmosis	High level of purification efficiency	High investment, wastewater initial treatment, waste sludge problems

Physical and chemical processes for the treatment of leachate waters include the removal of suspended particles, colloids, floating materials, dye and toxic compounds by flotation, coagulation / flocculation, adsorption or stripping processes. Physico-chemical processing is used as an additional treatment in the line of treatment of leachate water, most often as a previous treatment or last treatment, i.e. post-purification.

Methods of biological treatment are carried out using microorganisms capable of converting unwanted products to biomass and gas. However, the main reason for the use of biological treatment is not just the removal of organic pollutants, because biological treatment in the removal of organic matter can remove parts of organic pollutants. Biological methods of treatment can be divided into: aerobic and anaerobic processes. Aerobic processes are more commonly used primarily because of their efficiency and ease of use. Biological anaerobic treatment methods involve the degradation of organic content by the action of microorganisms in the absence of oxygen and the formation of biogas. In contrast to aerobic, anaerobic processes produce small amounts of sludge, while the process, as well as in the case of aerobic degradation, can be carried out with suspended or immobilized microorganisms on the biofilm.

By increasing the demand for quality of treated water before discharge it into natural recipes, conventional methods of treatment are not sufficient to achieve a high level of treatment especially of leachate waters of older landfills, because the pollutant components in them are more stable and

hardly biodegradable. In the past twenty years, methods of treatment based on membrane technologies have been developed which can meet the new more stringent regulations regarding the quality of treated leachate landfill water.

The purification system using membrane technologies can be divided into two groups:

— nanofiltration and reverse osmosis: In these systems are used pressure membrane modules with a high degree of purification and recirculation of the concentrate,
— ultrafiltration and microfiltration: Such plants are based on modules and cassettes completely submerged in biological reactors called membrane bioreactors.

The difference in these processes is in the nature of the matter and the size of the particles that can be extracted. In general, an indicator of the efficiency of membrane processes is the size of the particles separated from the water being processed. The size of the separated particles by individual processes is as follows: by reverse osmosis is extracted from 0.01 to 0.00015 μm, and by nanofiltration from 0.001 to 0.01 μm. Ultrafiltration extract particles in the range of 0.1 to 0.003 μm, and microfiltration of 3 to 0.05 μm.

5. CONCLUSIONS

When designing facilities for treating leachate water it is difficult to accurately determine the quantity and composition of the water to be processed. Their quantity and composition depend on the age of the landfill, types of waste, disposal technology, microclimate parameters, etc. Due to all of this, it is very important to choose a technology that is flexible for treatment these types of wastewater to achieve the required quality of purified water.

Conditions for purification of leachate waters are prescribed by law, and the application of treatment technology depends on the quantity, composition and conditions of discharging the treated water into the recipient. The paper gives a brief overview of the production and composition of leachate landfill waters. The technologies that are most often applied for their purification are presented. The presence of organic, inorganic and microbiological loads, as well as the low biodegradability of leachate water requires a combination of different treatment processes to meet the criteria to environmental discharge.

Due to the complex composition in comparison with other types of industrial wastewater, the landfill leachate is the most demanding for treating. Therefore, it is necessary to combine treating methods in order to achieve the prescribed quality of treated landfill water.

Note: This paper is based on the paper presented at IIZS 2019 – The 9th International Conference on Industrial Engineering and Environmental Protection, organized by Technical Faculty "Mihajlo Pupin" Zrenjanin, University of Novi Sad, in Zrenjanin, SERBIA, in 03–04 October, 2019.

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ANNALS of Faculty Engineering Hunedoara – International Journal of Engineering
ISSN 1584 - 2665 (printed version); ISSN 2601 - 2332 (online); ISSN-L 1584 - 2665