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LEACHATE TREATMENT BY REVERSE OSMOSIS METHOD-REGIONAL SANITARY LANDFILL "ZELJKOVAC" CASE STUDY

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Abstract. *The purpose of this paper is to elaborate a plan for the leachate treatment at the "Zeljkovac" sanitary landfill in Leskovac city. Different processes occur over time at the landfill. The processes of infiltration and transpiration occur continuously, distributing the humidity and affecting the water balance within the body of the landfill. The landfill body acts as a giant sponge, in which water moves, and from which water can be released - both into groundwater and into the atmosphere in the form of water vapour or as a filtrate at the bottom of the landfill. In this paper, particular attention is given to the kind of waterwhich is actually filtrate from a landfill, often called leachate. The efficiency of the most commonly used methods will be presented, depending on the most prevalent pollutants in leachate. As there are many methods for treating this kind of wastewater, the reverse osmosis method will be presented as one of the most widely used . The technological process of a reverse osmosis plant will be described, as well as the result that shows the output quality of the leachate after the treatment process. The major finding of this paper reflects a clear justification for using this method to achieve the desired efficiency of leachate treatment.*

Key words: *leachate, environment, environmental protection, reverse osmosis method*

1. INTRODUCTION

The Republic of Serbia has a small number of wastewater treatment plants. Large urban centers such as Belgrade, Novi Sad and Nis do not have these types of plants, which entails a long line of problems in the field of wastewater treatment, waste management and environmental protection in general. The accession of our country to the EU requires the fulfillment of the conditions of Chapter 27 concerning sustainable development and environmental protection. According to official data from the Environmental Protection

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Agency of the RS, untreated and/or untreated municipal and industrial wastewater is a key source of surface and groundwater pollution in the Republic of Serbia. Another problem when it comes to wastewateris leachate that is generated in the landfill body (atmospheric precipitation to the active part of the landfill, from the moisture of the waste itself) [1].

Leachate represents the entity affected by the entire complex of factors, both within the landfill body itself (landfill age, waste morphological composition, temperature and moisture content, fluid migration, pre-disposal waste technologies, landfill thickness, waste decomposition stages), and outside of it (meteorological parameters, with emphasis on annual rainfall, change of seasons) [2].

The quantity of leachate during the year varies significantly depending on meteorological and hydrological conditions, and influences their quality and concentration of pollutants.

The total quantities of effluent are mainly generated from groundwater entering the landfill body and probably groundwater that may already be located below existing landfills or occur on site. Waters discharged into landfills are:

- atmospheric waters,
- surface waters,
- drainage waters,
- underground waters.

The main potential environmental impacts related to waste leaching at landfills are groundwater and surface water pollution. The risk of groundwater pollution probably the most significant when it comes to negative environmental impacts because most landfills have been built without drainage and sewage systems.

In more recent years, regulations in many countries have required the installation of lining and sewage collection systems and a wastewater treatment plant [3]. Leachate treatment can be considered as the most important problem of municipal infrastructure development and depends directly on the population and development of the country and the region.

In order to return wastewater to natural waters the recipients / it must be treated in accordance with legal regulations so that their quality does not impair the quality of the recipient. Water recipients can self-purify which reduces the concentration of pollutants.

However, this capacity is limited, so wastewater must be treated to such an extent that the intensity of the pollution does not exceed the recipient's assimilative (self-purification) capacity. Leachate is collected by the drainage system and can be treated together with the wastewater from the recycling plant, the municipal wastewater from the ancillary facilities of the landfill as well as the wastewater from the vehicle wash [4].

There are various methods for treating leachate, such as: mechanical (grating, sieves, precipitation), chemical (coagulation and flotation), biological (aerobic and anaerobic), as well as a mixture of these methods [5]. However, in recent years, the process of leachate treatment using reverse osmosis (RO) has been increasingly applied.

The range of technologies available for leachate treatment is very wide, and most of the technologies used, have been proven in many different cases. Processing technologies were applied as standalone solutions and as part of a combination of processes. The composition of the leachate plays a decisive role in selecting the appropriate technology [6].

Table 1 shows the available technologies that are most commonly used for leachate treatment and the applicability of the technology concerning individual parameters of leachate contamination.

Table 1 Process efficiency in leachate treatment [6]

Process	TSS	BOD5	COD	TN	NH4-N	Heavy metals	AOX	Salts
Biological purification	-	+	(+)	(+)	(+)	(-)	(-)	-
Adsorption by activated carbon	-	(-)	+	-	-	(-)	+	-
Sedimentation / flotation	(+)	(-)	(-)	-	-	(+)	(-)	-
Filtration / ultrafiltration	+	(-)	(-)	(-)	-	(+)	(-)	-
RO	(+)	+	+	+	(+)	+	+	+
Air stripping	-	(-)	(-)	-	+	(-)		-
Chemical oxidation	-	(-)	+	(-)	(+)	-	(+)	-
Evaporation	+	+	+	(+)	(-)	+	+	+

(-) Low efficiency
(+) Applicable with restrictions / additional requirements or hazard warnings

As can be seen in the table, the reverse osmosis method can be applied in the process of leachate treatment to reduce different pollution parameters like total suspended solids, biochemical oxygen demand, chemical oxygen demand, total nitrogen, adsorbable organic halides. Unlike the biological method, RO is the process of separating the flow of permeate and highly contaminated concentrate, which is recirculated into the landfill body or vaporized. The most common use of a reverse osmosis system is to purify water to a level that meets even the most demanding industrial criteria of the pharmaceutical and other process industries. RO devices change the natural direction of the osmotic process. The water that needs to be purified is directed, at a pressure greater than the osmotic pressure, through a semi-permeable membrane [7]. The membrane functions as a molecular filter, allowing the passage of water molecules through them, stopping the largest number of impurities present in the water.

In this paper, the method of reverse osmosis for leachate treatment will be presented on the example of “ Zeljkovac“ landfill, located in Leskovac city.

2. Description of the Regional Sanitary Landfill “Zeljkovac” Location

Landfill „Zeljkovac“ is the first regional sanitary landfill in the Republic of Serbia, built in 2009, on the territory of the Leskovac city by PWW Company [8]. The landfill accepts municipal waste from territories of 6 municipalities of the Jablanica District. Initially, waste was deposited without any pre-treatment. Today, after the construction of the Recycling Center, it performs primary and secondary selection of recyclable waste materials, before disposal. Location of regional sanitary landfill for municipal solid waste "Zeljkovac" has been designated so that it meets all requirements and criteria stipulated by the law regulations and by-laws [9].

2.1. Macro-location

The city of Leskovac (143.962 inhabitants and an area of 1.025 km^2) is located in the southeast of Serbia and belongs to the Jablanica District. It is administratively divided into 144 local communities and 140 cadastral municipalities. It is located on the most important road route in the Republic of Serbia (Corridor 10, Belgrade-Skopje) and the railway route (Belgrade-Athens).

The sanitary landfill with the facility for treatment and temporary storage of municipal and other waste is on location defined by the General Urban Plan of the City of Leskovac until 2010. The Detailed Spatial Plan of the City of Leskovac was prepared for the site, as well as the Study on the conditions for the development of landscaped sanitary municipal waste landfill of the city of Leskovac at the location of “Zeljkovac” [10].

2.2. Micro-location

The micro-location of the regional landfill complex "Zeljkovac" (managed by the company "PWW Deponija Dva" Ltd. Leskovac) is located in the southeastern part of the urban area of Leskovac, 6 km southeast of the city center.

The complex covers a total area of about 80 ha and extends to the northeast-southwest direction along the axis of the Bucan stream.

The” Zeljkovac” landfill consists of [10]:

- manipulative-service plateau with containers and truck wheel washer system: wire fence with entry gate, container personnel type facility, wheel scales and landfill laboratory,
- landfill body,
- internal roads,
- leachate lagoons,
- bottom channels for the collection of atmospheric clean waters,
- infrastructure facilities: transformer station, diesel generator and storage tank for sanitary and fire protection water.

The conception of the solution and organization of the “Zeljkovac” landfill complex is based on the implementation of technical, technological and organizational measures that ensure protection of the environment and health of the population and employees. The following separate sewerage networks have been set up at the complex [10]:

- for atmospheric water,
- for fecal water,
- drainage and
- technical water.

Leachate from the landfill body is collected by drainage sewage system and drained gravitationally to the collecting tank, from where it is pumped into the lagoon, a biological basin where the process of aeration and mixing of the leachate is taking place. In the second precipitate, the processes of water purification and separation of the activated sludge at the bottom of the precipitate, are performed. From the recirculation pump station, treated water returns to the landfill body. The decomposition of organic, dissolved and suspended matter is carried out by microorganisms floating in the water. Aeration replenishes the oxygen needed while mixing makes it better to contact the microorganisms with nutrients and the resulting products break down faster. The mobile wastewater treatment plant is located near the sewage collection and leachate treatment system (lagoon). It is a reverse osmosis plant - container type RO-IO 70. The RO unit is pre-assembled and shipped in a 12,192 m long container. RO system is fully automated and equipped with an easy-to-operate control system.

3. TECHNOLOGICAL PROCESS

The mobile water treatment plant operates on the principle of a semi-permeable membrane and high pressure to extract the pollution from water. The RO system is based on membrane technology including pre-treatment, conditioning and ancillary systems. Water can pass through the membrane, while organic substances and even small ions cannot. The process water is separated into pure water (permeate) and highly concentrated residue (concentrate).

The RO system has two passages, which means that the entire amount of wastewater entering the plant is filtered twice through semi-permeable membranes. After the first leak, permeate (purified water) is collected into an accumulation tank that serves as a reservoir for the second pass. The concentrate is a solution highly saturated with pollutants that must be returned to the landfill (Fig. 1).

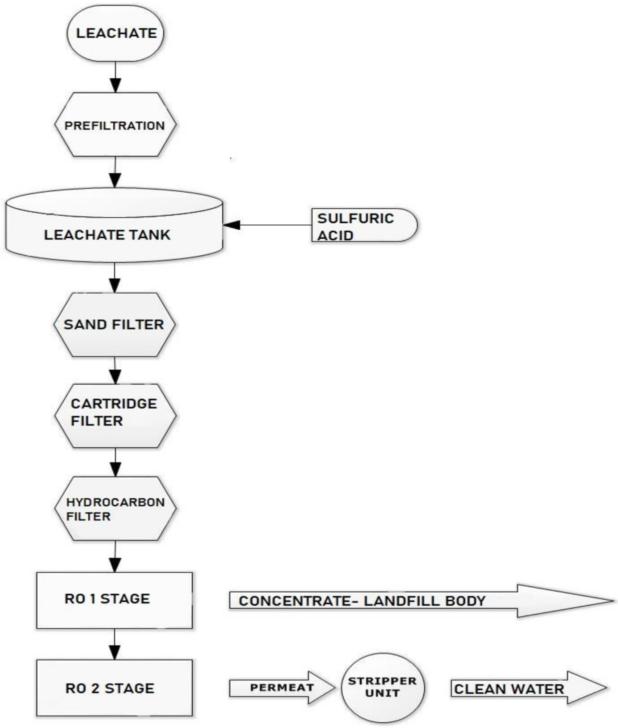

Fig 1 Technological process of leachate treatment by reverse osmosis method

Figure 1 shows that packed RO container has: two levels, sand filter with automatic cleaning, filter cartridges before the first level of membranes, automatic membrane cleaning, organic membranes with a spiral coil in the first phase, organic disc membranes in the second phase, maximum service pressure of 65 bar, and crude water tank. Also, the RO system has a panel display, PLC, 12 membranes for the first phase and 6 modules for the second phase.

As acidic components cross the membrane much more easily than alkaline components, the pH of the RO plant must be reduced. The pH is adjusted to approximately 5.5. - 6.5. and sulfuric acid (H_2SO_4) with a concentration of 96%, is used for this purpose. From the pH adjustment tank, the leachate is fed to a sand filter to remove any suspended matter that may be present in the leachate.

During the reverse osmosis filtration process, membrane coating is contaminated due to the presence of organic compounds and salts in the leachate. When the permeate flow is reduced due to the clogging of the membrane sheath, it is necessary to clean and remove this layer in order to restore membrane performance.

The entire process is automatically controlled via the PLC and the control panel. The process is presented through a series of flowcharts showing the following information:

- process variables such as pH, flow, pressure and temperature,
- valves, on or off,
- alarms, and
- process direction.

The main parameters of leachate, permeate and concentrate are: temperature, pressure, conductivity and pH value. The desired pH level is maintained within a certain range, automatically by means of dosing pumps.

4. Results and Discussion

Leachates are most often contaminated with organic matter (BOD, COD, TOC), nitrogen compounds, heavy metals and other salts. Because all of these compounds have a negative impact on the environment, the leachates are treated through a reverse osmosis unit before being discharged into a river or sewer (as a recipient).

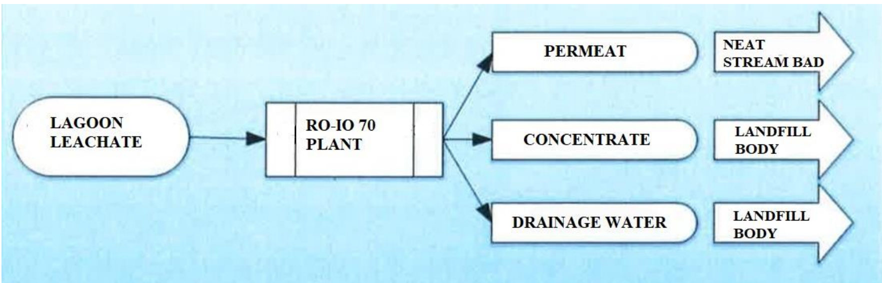

Fig 2 Block diagram of a leachate treatment plant [10]

The mobile plant is designed to treat a maximum of 3 m^3 of wastewater per hour. The plant design is organized in such a way that the operating parameters are adjusted based on the input characteristics of the wastewater and the required output parameters of the water. Operating parameters, based on which the performance of the RO plant is determined, arepH value, conductivity, temperature and pressure. Also, individual flows of permeable liquid of each pressure vessel and laboratory analysis of inlet liquid are recorded. Other operating parameters (pump operating condition, tank level) are measured continuously, registered and monitored separately from the quality monitoring of the above-mentioned parameters [11].

Input characteristics of wastewater and required output parameters are derived from the summary table of the Report PWW Deponija dva, Ltd. Leskovac – Monitoring voda 2013-2019 [12]. The report presents the sums of all laboratory tests from 2013 to 2019. which were performed in accordance with the Regulation on limit values of pollutants in surface and groundwaters and sediments and deadlines for achieving them , "Official Gazette of the RS", No 1/2016 and Rulebook on the Waste Categories, Examination and Classification "Official Gazette of the RS", No 93/2019. [13,14].

According to the Regulation on limit values of pollutants in surface and groundwaters and sediments, and deadlines for achieving them, "Official Gazette of the RS", No 1/2016, there are requirements for the discharge of wastewater into the recipient shown in Table 2 [12]. Emission limit values are given in this table, and they are only observed on wastewater where pollution originates primarily from the disposal of waste.

Table 2 Wastewater emission limit values from waste landfilling at the point of discharge into surface water [13]

Parameters	Unit of measure	Emission limit value(I)
Temperature	°C	30
pH		6,5-9
Suspended matter	mg/l	35
Biochemical oxygen demand BOD	mgO_2/l	20
Chemical oxygen demand COD	mgO_2/l	200(II)
Total inorganic nitrogen (NH_4-N, NO_3-N, NO_2-N)	mg/l	70(IV)
Total phosphorus	mg/l	3
Total organic carbon (TOC)	mg/l	10(III)
Toxicity to fish		2

(I) Values from the ratio of the two-hour sample.

(II) The case of wastewater considered to have a chemical oxygen demand (COD) before treatment exceeds 4000 mgO_2 / l, the COD level in the effluent in a representative random sample or a two-hour composite sample is equivalent to a 95% reduction in COD. COD reduction refers to the relationship between the amount of pollution in effluent and the amount of pollution in effluent at a wastewater treatment plant for 24 hours. Plant utilization capacity defines the number of pollutants in the effluent. The extent of the reduction was estimated based on the sizing and operation of the wastewater treatment plant.

(III) The requirements for the TOC are applied to the sample cases and does not apply to wastewater from municipal waste disposal.

(IV) The requirements for total nitrogen are applied to wastewater at a temperature of 12°C and above in effluent from the biological reactor of a wastewater treatment plant. Higher concentrations of up to 100 mg / l for total nitrogen may be allowed in the water discharge permit, if a nitrogen load reduction of up to 75%, is provided. The reduction is separated by a ratio between the nitrogen loading in the effluent and between the effluents after a representative period not exceeding 24 hours. Total nitrogen (organic and inorganic) will be used as a basis for load calculations.

The RO plant adjusts operating parameters based on the input characteristics of the leachate and the required output water parameters. The relevant discharge parameters are shown in Table 3.

Table 3 shows the output parameters of leachate treated by the reverse osmosis method, recorded during the plant testing period, conducted in accordance with Regulation on limit values of pollutants in surface and groundwaters and sediments, and deadlines for achieving them, "Official Gazette of the RS", No 1/2016.

Table 3 Leachate output parameters values [10]

Landfill "Zeljkovac" Parameter	Min mg/l	Max mg/l	Output values mg/l	Emission limit value
Temperature °C	12,85	25	30	30
pH	8,09	8,55	6,5-8,5	6,5-9
Suspended matter	57,3	6880	25-35	35
Biochemical oxygen demand BOD, mg O_2/l	1040	3434	5-20	20
Chemical oxygen demand COD, mgO_2/l	2067	8130	15-200	200
Total inorganic nitrogen (NH_4-N, NO_3-N, NO_2-N) mg N/l	734,67	1129,00	2-8	70
Total phosphorus mg P/l	28	57,67	0,5	3
Total organic carbon (TOC) mg/l	538	4092,67	6-15	10
Toxicity to fish	nd	nd	2	2

Nd - no data

The minimum values of the parameters presented in the table were obtained by calculating the mean values of all obtained minimum values in the period from 2013 to 2019. The maximum values of the parameters were obtained by calculating the mean values of all obtained maximum values in the period from 2013 to 2019 [12]. These values are not explicitly required in the abovementioned regulation but are given for a reason of a more detailed presentation of the treatment process.

After treatment, the suspended matter is in the range of 25-35 mg / l which is absolutely in accordance with the Regulation.

Biochemical oxygen demand is one of the basic indicators of the influence of polluted water on the recipients as it leads to a decrease in the content of dissolved oxygen. BOD reaches the defined maximum allowable value but does not exceed it.

The COD value has been developed analogically to the BOD measurement. Since there are many organics that are rather hard or not possible to decompose biologically, a parameter has been defined indicating the amount of oxygen which would be needed when all organic ingredients would be oxidized completely. The same situation, as BOD value, applies to COD where the output values also reach a limit of 200 mg/l but also do not exceed it.

Based on these data, it can be concluded that the treatment of the leachate has reduced the total inorganic nitrogen. After treatment, total inorganic nitrogen has an output of 8 mg/l which is far below the permissible values (70 mg/l).

The parameter total phosphorus (TP) defines the sum of all phosphorus compounds that occur in various forms. Total phosphorus and nitrites also after treatment are released at much lower values than recommended by regulation.

In the end, the leachate that is being treated by RO is returned to the landfill for three reasons:

1. for fire protection;
2. for better compaction of waste and to save landfill space;
3. to prevent dust and light waste from spreading.

Before treatment, the leachate is a cloudy with dark brown color. As a result of treatment, clear water without visible impurities is obtained. The visual appearance of a sample of water from a sedimentary lagoon before and after its treatment at the treatment plant is shown in Figure 3.

Fig 3 Leachate sample before and after treatment in the purification facility [15]

The obtained values of the leachate quality parameters before and after the treatment by the reverse osmosis method of the examination are within the reported limits. There are no unexpected results and major deviations.

5. Conclusion

Environmental care and pollution control are one of the key contributors to the preservation and promotion of human health. Understanding leachate composition is critical to making projections of long-term landfill impacts. Even after the landfill ends its operation and disposal, the waste will still be decomposing. Although leachate production decreases significantly with the installation of the final cover, there is little data on their production over long periods of time.

In recent years, the issue of wastewater treatment plants (with or without wastewater fractions) has been raised as the most favorable variant in the environmental and economic criteria.

This paper examines the efficiency of leachate treatment by reverse osmosis method through the results that do not exceed the permitted values in any segment. A very high level of purification efficiency can be noted as an advantage of this treatment method. The reverse osmosis method can be applied to any type of leachate regardless of which pollutant is contaminated, which is not the case with other methods.

The disadvantages of this method are that it requires very high investment, pre-treatment of wastewater, and there are special problems with waste sludge.

It is not appropriate to specify in advance which method is best applied; therefore, no general solution can be proposed. Consideration should be given to the design needs of the effluent treatment plant which is capable of efficient and economical choices with variations in the quality and quantity of wastewater, as well as with the required degree of purification based on the required water quality in the recipient.

The "Zeljkovac" landfill represents a closed system and only experimental work is being carried out on it at the moment. It is still in the pilot phases because the leachates are very heterogeneous and it remains unknown what to expect after the treatment.

In the end,there is a potential plan for the treated water to start being discharged into the recipients once the conditions are met for an extended period of time.

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TRETMAN PROCEDNIH VODA METODOM REVERZNE OSMOZE NA PRIMERU REGIONALNE SANITARNE DEPONIJE "ŽELJKOVAC" U LESKOVCU

U radu je predstavljen akcioni plan za tretman procednih voda na sanitarnoj deponiji "Zeljkovac" u Leskovcu. Tokom vremena u telu deponije se dešavaju različiti procesi. Procesi infiltracije i transpiracije neprestano traju, uzajamno distribuirajući vlagu i utičući na bilans vode na deponiji. Materijali u deponiji ponašaju se kao veliki sunđer u kome se kreće voda i iz koje se može ispuštati voda - kako u podzemne vode tako i u atmosferu u obliku vodene pare ili procuriti kao filtrat na dnu deponije. U ovom radu je posebna pažnja posvećena upravo tim vodama, koje se izdvajaju kao filtrat sa deponije otpada a koje se nazivaju procednim vodama. Predstavljena je efikasnost najčešće korišćenih metoda tretmana, u zavisnosti od toga koje su zagađujuće supstance najzastupljenije u procednoj vodi. Obzirom da postoji mnogo metoda za tretiranje ovakve vrste voda, metoda reverzne osmoze je analizirana kao jedna od trenutno najčešće korišćenih. Opisani su tehnološki sastav postrojenja za reverznu osmozu, kao i rezultati koji pokazuju izlazne vrednosti tretirane procedne vode nakon procesa tretmana. Osnovni zaključak ovog rada opravdava korišćenje metode reverzne osmoze u cilju dostizanja zahtevane efikasnosti tretmana procednih voda.

Ključne reči: *procedne vode, životna sredina, zaštita životne sredine, metoda reverzne osmoze*