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Low Energy Technology for Leachate Valorisation

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***Abstract*—**Landfills present long-term threats to soil, air, groundwater and surface water due to the formation of greenhouse gases (methane gas and carbon dioxide) and leachate from decomposing garbage. The composition of leachate differs from site to site and also within the landfill. The leachates alter with time (from weeks to years) since the landfilled waste is biologically highly active and their composition varies. Mainly, the composition of the leachate depends on factors such as characteristics of the waste, the moisture content, climatic conditions, degree of compaction and the age of the landfill. Therefore, the leachate composition cannot be generalized and the traditional treatment models should be adapted in each case. Although leachate composition is highly variable, what different leachates have in common is hazardous constituents and their potential eco-toxicological effects on human health and on terrestrial ecosystems. Since leachate has distinct compositions, each landfill or dumping site would represent a different type of risk on its environment. Nevertheless, leachates consist always of high organic concentration, conductivity, heavy metals and ammonia nitrogen. Leachate could affect the current and future quality of water bodies due to uncontrolled infiltrations. Therefore, control and treatment of leachate is one of the biggest issues in urban solid waste treatment plants and landfills design and management. This work presents a treatment model that will be carried out "in-situ" using a cost-effective novel technology that combines solar evaporation/condensation plus forward osmosis. The plant is powered by renewable energies (solar energy, biomass and residual heat), which will minimize the carbon footprint of the process. The final effluent quality is very high, allowing reuse (preferred) or discharge into watercourses. In the particular case of this work, the final effluents will be reused for cleaning and gardening purposes. A minority semi-solid residual stream is also generated in the process. Due to its special composition (rich in metals and inorganic elements), this stream will be valorized in ceramic industries to improve the final products characteristics.

***Keywords*—**Forward osmosis, landfills, leachate valorization, solar evaporation.

I. Introduction

ANNUALLY in the European Union, 16 tonnes of materials are used by each person and 6 tonnes of it are converted into waste. Solid waste can be disposed in various ways, such as incineration (with or without energy recovery), landfilling, recycling and composting [1].

Due to the economic and industrial growth that Europe has been through in the last decades, the resources have been consumed at a highly accelerated rate. Since resources are not infinite, they are facing the risk of shortage. Therefore, European authorities enforce that the member states implement policies to lessen the stress created on the resources and the amount of waste created and to extract the value from the waste.

Landfills and waste treatment centres generates atmospheric emissions (greenhouse gases) and also a very polluting liquid fraction called leachate (Fig. 1).

Fig. 1 Leachate generation in waste accumulation areas

Leachate is the liquid fraction of the already existing moisture/liquid within the solid waste, and the continuously formed liquid with dissolved and suspended solids extracted from the waste while rainfall percolates through it. Not only during their useful life, but also 50 years after their closure, landfills keep on producing leachates. Approximately, 10 m^3 of leachate is generated per 115 tonnes of solid waste.

Leaching is also a process that is industrially used to prepare elixirs, hence its name, and so the connotation of this word has not always been so negative. An elixir is a concentrate of different substances with beneficial properties. And why not convert a leachate into an elixir? This approach is not new. It falls within the philosophy of the "Circular Economy", which seeks, among other things, to stop considering waste as waste and to consider it as a new source of wealth.

Leachate composition cannot be generalized because depends on factors such as the type of waste, climatic conditions, age of the landfill, etc., so a unique treatment option cannot be suggested [2].

Although leachate composition varies from one waste storage to another, what they have in common is hazardous constituents and their potential polluting effect on the environment.

In the absence of treatment, leachate is recycled back to the waste to maintain the biological activity in the composting pile or it is sent to sewer or to a wastewater treatment plant (WWTP) for off-site treatment.

The recirculation of leachate creates a more concentrated liquid that worsens the odour and attracts flies, which can transpose germs and diseases. This creates a bigger potential risk for human and environment and unpleasant working

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conditions.

When the leachate is not treated on-site, the most common disposal method is to transport to sewer systems or WWTPs and mixing it with the municipal sewage. However, due to its high organic and ammonium concentrations, leachates cause extra loading in the biological sewage treatment plant. This needs extra chemical addition, energy consumption and advanced operational skills to comply the effluent limits. Moreover, due to the high metal content in leachate, the sludge generated during the treatment may be discarded for its use in agriculture applications. In smaller size WWTPs, the handling of leachate is more difficult since its dilution with the municipal sewage is much less than in big WWTPs. The removal efficiency of polluting substances in the WWTP can range between 15% and 90%, depending on the contaminant in question [3]. Nowadays, leachate treatment has relatively high operation and maintenance costs, which constitute 40-60% of the total investment, operation, and maintenance costs per cubic meter. The cost of leachate treatment falls in the range of 7.5-30.0 €/m^3 leachate [4].

This paper presents the leachate treatment model proposed in the LIFE LEACHLESS project (LIFE15 ENV/ES/000530). This project proposes not only to solve the traditional environmental problem associated with the management of leachates from landfills and waste treatment centres using innovative technology and low operating costs, but valuing these residual streams in an integral way with the ultimate objective of generating value instead of destroying it.

II. Leachate Treatment Model

This work will demonstrate the feasibility of an innovative in-situ treatment process for leachates generated in landfills and waste treatment plants, addressing the environmental problems associated with its current management and providing the relevant environmental and socioeconomic values. This project proposes a sustainable management composed of specially designed solar panels, which reach to very high temperatures to evaporate the leachate. Then the vapour is condensed to follow its path through forward osmosis (FO) step. FO requires less energy than the reverse osmosis (RO) and has less fouling problems. This work will also show an economic system that is easy to replicate on any site where the solar radiation is sufficient with the objective to prevent the above-mentioned impacts of leachate on the environment. The proposed system is a universal solution independent of the leachate composition and is capable of eliminating the chemical and biological constituents, making it very practical for its use in any landfill or waste treatment site and easy to operate and maintain. This system (Fig. 2) will be placed in two containers, each with dimensions 12 m x 2.4 m x 2.9 m, for the easy portability between the demonstrations sites in Spain and Greece. On the demonstration sites, the top parts of these modules will be linked with a roof where the solar panels will be placed. The prototypes will be designed with a maximum capacity of 15 m^3/day.

When the solar energy is not enough, another renewable energy source (biomass) will be used as support. By providing biomass, the replication of the technology will be also possible in central and northern Europe countries. In these countries the solar radiation is lower than southern Europe countries, but they have a lot of biomass available.

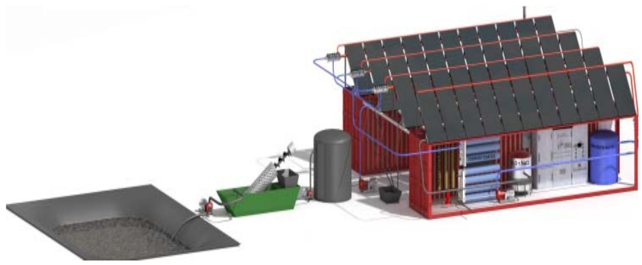

Fig. 2 LEACHLESS prototype

After treatment, the effluent quality is projected to comply with the effluent standards determined by RD 1620/2007, the legislation for the reuse of treated waters in Spain and the common Ministerial Decision No. 145116, the legislation for the reuse of treated waters in Greece. Therefore, the effluent is foreseen to be used as the backwash water to clean the filters, general cleaning of the treatment system and irrigation of the green areas in the treatment plant and landfill.

Apart from the effluent, the sludge extracted from the system will be also valorized. Leachates consist of high concentrations of metals; therefore, the leachate treatment method selected has the objective to eliminate the metals from the water fraction. This leads to generation of sludge with high concentrations of metals, and as it is toxic for agricultural use, it will be valorized in ceramic processing plants. The metal content in the sludge gives structural integrity and resistance to the ceramic products. Therefore, it is projected to incorporate the sludge in the production process of bricks or low-grade porous construction ceramics.

III. Comparison of the Leachate Management by Type of Technology

The most common methodology used for leachate treatment is biological treatment (nitrification-denitrification) due to the high organic and nitrogen content in the leachate composition. The biological treatment can be done in aerobic or anaerobic conditions with a post-treatment to separate the biological sludge via a filter or sedimentation [5].

Anaerobic treatment has low energy requirements due the absence of oxygen, but it is a sensitive method. The effluents of leachate treatment do not reach the discharge limits and so post treatment steps are required. Moreover, they are less effective in the treatment of old leachates due to the decrease in the BOD_5 concentrations within a time.

Activated sludge treatment requires very careful pH control and advanced management to obtain necessary effluent levels. Due to the need of aeration, significant energy consumption is inevitable.

Rotating biological contactors (RBC) and trickling filters are methods that are more appropriate for older leachates. They require less energy due to the natural oxygen take-up of the microorganism. Due to the high concentration of the leachate, clogging may be observed.

Physical-chemical treatment of leachates has been developed in recent years. Especially, reverse osmosis (RO) has been used in leachate treatment; however, the biggest disadvantage of the RO systems is the high-energy requirement. They also have issues in ammonium rejection, and high amount of reject and fouling of the membranes [4].

A comparison of the leachate management costs by type of technology can be observed in Table I.

TABLE I
LEACHATE TREATMENT PROCESSES COMPARATIVE COST [6]

Treatment technology	Cost (€/m^3)
Aerobic process with nitrogen removing	15.00
Two steps reverse osmosis	7.50
Biologic process+carbon activated carbon+precipitation	18.75-26.25
Biologic process+reverse osmosis+concentrate evaporation	26.25-30.00
LIFE LEACHLESS technology (solar evaporation+ forward osmosis)	4.75

IV. EXPECTED RESULTS

LIFE LEACHLESS will try for achieving the following results:

Treatment up to 15 m^3/day of leachate in a prototype introduced in containers for easy transport and installation, that allows flexibility in operating conditions.

- To obtain a high quality final effluent, 100% free of pathogens and xenobiotic compounds that can be reused or discharged into watercourses.
- To reduce the cost of leachate treatment over 80% when comparing with a traditional leachate treatment plant, by using solar radiation and biomass as energy sources. Nowadays, leachate treatment has relatively high operation and maintenance costs, which constitute 40-60% of the total investment, operation, and maintenance costs per cubic meter. The cost of leachate treatment falls in the range of 7.5-30.0 €/m^3 leachate [4].
- To reduce by 80% to 90% the environmental impact associated with leachate streams proceeding from waste disposal in landfills or waste treatment centres.
- To eliminate the need of leachate transport to municipal wastewater treatment plants (WWTPs), and thereby, to eliminate the associated transport costs and the risk of emerging pollutants from leachate entering the overall water circuit and carbon footprint.
- To have a technology applicable in those countries with the highest volume of municipal waste sent to landfill, which are also those, which most leachate generate. These countries (Spain, Greece, Italia, Italy, Portugal, Malta, etc.) are themselves the ones with the higher number of sunlight hours, which favour the operation of such technology.
- Improving the operation of landfills and reducing the associated environmental impact (contributing to the increased number of landfill adapted to the Waste Disposal Directive, 1999/31/CE).
- 100% valorization of the by-products generated in the process. The amount of sludge generated as a by-product is very low (1-3% of the total volume of leachate). However, the sludge generated can be valorized, since it is interesting for the ceramic industry.
- 60% reduction of the leachate storage reservoir size in landfills and waste treatment plants. Pollution removal at the source.
- Two replication studies for transferring the project findings in two "follower facilities" (one in Spain and one in Greece) and one in Pordenone’s landfill in Italy, when the project is completed.
- LIFE LEACHLESS will allow the authorities to increase the competitiveness and improve environmental legislation by better management of leachate.

V. CONCLUSION

The treatment proposed by the LIFE LEACHLESS project for effluents containing high polluting leachate and emerging pathogens is simple, from a technological point of view, with low costs associated to the treatment (both process and energy) and it would be carried out "in-situ" (thus, preventing mixing with common urban effluents in sewage treatment plants).

On the other hand, the obtained effluent would be suitable for industrial use, if required. Thus, loss of water, energy and resources would be avoided in the industrial production.

The LEACHLESS process for leachate treatment, mainly consisting of three steps (solar evaporation-condensation, forward osmosis and solar evaporation-condensation, provides a high quality final effluent for industrial consumption (depending on the processes) and other utilities (gardening, cleaning, etc.), which implies an obvious decrease in the consumption of other water resources, thereby reducing the environmental impact of human activity. This will promote the fulfilment of important directives and EU priorities, such as the Water Framework Directive 2000/60/EC, the Directive 1999/31/EC on the landfill of waste, Directive 2008/1/EC on the integrated prevention and pollution control (IPPC) and Directive 2009/28/EC on the promotion of the use of renewable energies in the European Union. Furthermore, the sludge extracted from the system could be also valorized in the ceramic industry.

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