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Analysis of parameters for leachate treatment in a greenhouse system

Ana Laura Gómez Blasco [a], Constantino Gutiérrez [b], Andrés Armando Sánchez Hernández [c], Margarita Teutli León [a,*]

[a] *Facultad de Ingeniería, Benemérita Universidad Autónoma de Puebla, Mexico*
[b] *Universidad Nacional Autónoma de México, Mexico*
[c] *Facultad de Arquitectura, Benemérita Universidad Autónoma de Puebla, Mexico*

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Abstract

In this paper is presented an approach for landfill leachate treatment using enhanced natural evaporation. Experimental set up considered using a greenhouse pilot prototype placed into the municipal landfill of Puebla city, México. The greenhouse was built with a basement surface enough to place 9 trays with leachate. Treatment follow up was done through the following parameters: air temperature inside and outside the greenhouse; leachate temperature at surface and middle liquid height. Results of the first set of experiments defined a minimal initial liquid height of 20% in respect to the tray height; the 2nd set allowed defining optimal evaporation rate conditions evaluated in respect of a tray placed outside, considered as reference of 100% efficiency (blank), obtained results showed that morning and night processes provided efficiencies up to 2 times the reference; otherwise, afternoon measurements showed similar temperature values inside and outside. In general collected data at winter season provided efficiencies between 82% and 147%, in periods of 24 h, it was observed that higher liquid reductions took place at North, and lower ones at the South positions. Based on these results it was proposed a 20 days experiment, using stagnant (E) and recharge (R) conditions referred to the blank (L), the R process showed greater efficiency (168%) than the stagnant one (158%). Leachate chemical characterization indicates that pH is highly stable; while total solids, chemical oxygen demand, sulfate and chloride exhibit an increase in concentration reaching values of 1.2–2.5 times the initial concentration, phosphate was the only parameter exhibiting a decreasing trend ending with 40% of its initial concentration.
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Keywords: Landfill; Leachate; Evaporation; Greenhouse; Tray position

1. Introduction

Actually urban solid wastes are disposed in landfills, where the inherent organic matter decomposition produce leachate liquids, and their amount is enhanced by liquids input into the confining cells; liquids come from external sources like runoff. Wrong actions in handling leachate liquid usually represent a contamination risk and a source of infections, therefore it is mandatory to implement actions to improve efficiency of applied treatment.

There are reports about applied methods for leachate treatment, which at first approach operate under aerobic or anaerobic conditions (Cleber et al., 2014; Ismail and Tawfik, 2016), in treatment design facilities it has been con-

* Corresponding author.
E-mail address: teutli23@hotmail.com (M. Teutli León).
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sidered using natural systems like ponds and artificial wetlands (Ogata et al., 2015; Mojiri et al., 2016), while other systems accounted for leachate recirculation and evaporation (Huang et al., 2016; He et al., 2015).

Research to improve leachate treatment has made use of membrane bioreactors, reverse osmosis, (Sanguanpak et al., 2015), electrocoagulation (Contreras et al., 2009), and flocculation (Raghab et al., 2013). Recent research approaches have explored applying Advance Oxidation Process (AOP) which involves generation of strong oxidants addressed to reduce the chemical oxygen demand (Silva et al., 2015; Hassan et al., 2016; Hilles et al., 2016; Zhou et al., 2016), also there are reports of treatments that use more than one technique (Amor et al., 2015; Wallace et al., 2015; Liu et al., 2015; Wu et al., 2015), some treatment options, based on unit operations, ranges from primary to tertiary treatment (Oulego et al., 2015; Kumari et al., 2016), while others have made incursion on nanotechnology (Hu et al., 2016; Zhang et al., 2016).

From above mentioned reports it becomes evident that choosing a methodology for leachate treatment usually is a process defined by factors like: leachate chemical characteristics, site location, local weather, available land space for infrastructure, and the effluent final use, easiness in operation as well as inversion, operation and maintenance costs.

There is a recent report of Beyouncef et al. (2016) in which they mention that evaporation (natural or forced) has not received the expected attention, especially in warm climate countries; they reported the design and implementation of a small scale forced evaporation tub and its comparison to a natural evaporation tub. They mention that key factors to accelerate leachate evaporation are the surface exposure to sunlight, stirring effect and aeration, but also they recognize that one of their minuses is the electric power consumption to operate both the agitator and aeration fan.

Use of natural or induced evaporation should result in a reduction of leachate liquid volume, providing a sludge rich in salt and organic matter, which can either be returned to a final disposal cell or receive alternative treatment. Therefore, landfill operation should be favored since a concentrated sludge is easier to handle and it requires less space; so far, these actions imply an economical benefit.

Research work reported in this paper was developed in México, for the Puebla city landfill, which is located at 2018 m above sea level, this is a site with an estimated area of 916,826.747 m^2, whose UTM coordinates are between 590,578.4389-590,665.3343 East, and 2,098,706.7971-2,098,818.2245 North. Actual leachate production of 75 m^3 per day is treated in 3 evaporative ponds (3000 m^3 of installed capacity), 33% of treated leachate is recirculated to the active cells to provide humidity, and the rest (67%) are sent to a Waste Water Treatment Plant furnished with biological treatment for both sludge and liquid.

Typical weather at Puebla is mild and semi humid, with an average of 5–40 mm daily precipitation during rainfall season (from May to October), average temperatures range between 12 and 18 °C, with a minimum of 2 °C (at winter nights) and a maximum of 33 °C (at noon in spring). Also, official reports of wind patterns for Puebla city mention that there is presence of katabatic winds between 5 and 11 h running from North and North East to the South, these winds provide fresh and dry air; otherwise anabatic winds are present from 11 to sunset running from south to the north providing wet and warm air: additionally from sunset to sunrise there is presence of a light wind coming from the East. About solar intensity, there is a report (Ramos and Aguilar, 2005) which estimates that Puebla receives solar energy at the high atmosphere level with an estimated solar constant of 2 cal cm^{-2} min^{-1} obtained by correlating isotherms and isohyects data obtained in June 2004.

Main goal in this project is to take advantage of weather conditions at Puebla to propose a leachate treatment at the landfill site, in which the leachate could be concentrated by enhanced evaporation. An experimental greenhouse was built at the landfill area with the purpose of evaluate how much leachate evaporation is increased by using a greenhouse installation. The first stage considered short time experiments to get enough data for defining optimal operating conditions, and the second stage was a long period experiment (20 days) to evaluate how the optimal conditions work for enhancing evaporation.

2. Materials and methods

For designing and operating a greenhouse, the following external parameters should be accounted: amount of leachate to be treated, available space, site meteorological factors including latitude and altitude, solar radiation, temperature, relative humidity, presence of cloudiness, fog, evaporation, precipitation, as well as speed and direction of wind. These external factors will determine the greenhouse internal surface, roof slope and materials to be used; as well as optimal design to get the best conditions for internal climatic factors temperature, evaporation, humidity and ventilation.

2.1. Selection of materials for greenhouse construction

Experimental greenhouse prototype construction should consider recommendations like the following ones: (a) walls and roof should be made of high transmittance materials (Szantó et al., 2011); (b) the slope of the roof should be designed according to the site latitude, since the maximum solar radiation intensity is captured with a perpendicular plane to the incident ray (García-Badell, 2003); accounting for this recommendation the pilot greenhouse lower height wall was placed in the South position, and the higher at North, the last wall required been furnished with an aluminum cover, and the floor with a geomembrane which represents a black body, by which the bottom temperature in the greenhouse should be increased. Imple-

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