Journal of Environmental Management 170 (2016) 131–135

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Research article

Optimized evaporation technique for leachate treatment: Small scale implementation

Fatima Benyoucef [a], Abdelhadi Makan [b, c, *], Abderrahman El Ghmari [a], Aziz Ouatmane [d]

[a] Team of Applied Teledetection and SIG to Geosciences and Environment, Faculty of Sciences and Technics, 23000, Beni Mellal, Morocco
[b] Water and Environment Laboratory, Chemistry Department, Faculty of Science, University Chouaib Doukkali, 24000 El Jadida, Morocco
[c] ENQUAS Consulting, Environment Quality and Safety Consulting Office, 25000 Khouribga, Morocco
[d] Environment and Agro-resources Valorization Laboratory, Faculty of Sciences and Technics, 23000 Beni Mellal, Morocco

ARTICLE INFO

Article history:
Received 9 October 2015
Received in revised form
5 December 2015
Accepted 7 December 2015
Available online xxx

Keywords:
Evaporation technique
Convection
Thermal conduction
Leachate treatment
Evaporation rate

ABSTRACT

This paper introduces an optimized evaporation technique for leachate treatment. For this purpose and in order to study the feasibility and measure the effectiveness of the forced evaporation, three cuboidal steel tubs were designed and implemented. The first control-tub was installed at the ground level to monitor natural evaporation. Similarly, the second and the third tub, models under investigation, were installed respectively at the ground level (equipped-tub 1) and out of the ground level (equipped-tub 2), and provided with special equipment to accelerate the evaporation process. The obtained results showed that the evaporation rate at the equipped-tubs was much accelerated with respect to the control-tub. It was accelerated five times in the winter period, where the evaporation rate was increased from a value of 0.37 mm/day to reach a value of 1.50 mm/day. In the summer period, the evaporation rate was accelerated more than three times and it increased from a value of 3.06 mm/day to reach a value of 10.25 mm/day. Overall, the optimized evaporation technique can be applied effectively either under electric or solar energy supply, and will accelerate the evaporation rate from three to five times whatever the season temperature.

1. Introduction

The growing concern for environmental protection has led socioeconomic actors to focus on issues generated by household waste effluents, especially issues of leachate treatment. Leachates can be considered as toxic effluents by their complex composition and their temporal variations as reported in several studies (Zin et al., 2012; Torres et al., 2009; Del Borghi et al., 2003; Ahmed and Lan, 2012). These effluents have become very difficult to treat. The treatment difficulty itself carries actually an additional issue that threatens the environment and public health (Renou et al., 2008a,b). Studies carried out on leachates show that physicochemical characteristics of these effluents vary in both time and space and according to the waste type (Bernard et al., 1997). These leachates are enriched in non-biodegradable toxic compounds (Bejgarn et al., 2015), and conventional sewage treatment is not always possible to meet the discharge standards.

The leachate issue was investigated by many authors (Syron et al., 2015; Xue et al., 2015; Zhang et al., 2015; Amor et al., 2015). Leachate treatment technologies vary from biological treatment (Yabroudi et al., 2013; Zhu et al., 2013) to membrane technologies such as: microfiltration (Piatkiewicz et al., 2001), ultrafiltration (Pi et al., 2009), nanofiltration (Mohammad et al., 2004; Vogel et al., 2007) and reverse osmosis (Šír et al., 2012). The most common are biological treatments because of their reliability, simplicity and high cost-effectiveness (Peng, 2013). Nevertheless, they have shown their limits especially during the winter periods, where the treatment process seems to be affected by law temperatures (Peng, 2013; Renou et al., 2008a,b). Faced to this wide variety of treatment techniques, the choice of the most suitable and cost-effective technique is becoming more difficult. However, the evaporation technique has not received the expected focus especially in warm climate countries, because it can be performed as well as in a natural or forced alternative. The treatment of leachate using evaporation technique was lately mentioned by several authors, but usually coupled with other techniques such as reverse osmosis and ultrafiltration (Di Palma et al., 2002; Xu et al., 2006; Yamasaki

* Corresponding author. Water and Environment Laboratory, Chemistry Department, Faculty of Science, University Chouaib Doukkali, 24000 El Jadida, Morocco.
E-mail address: abdelhadi.makan@gmail.com (A. Makan).

http://dx.doi.org/10.1016/j.jenvman.2015.12.004
0301-4797/

et al., 1996).

Natural evaporation is, however, relatively slow and requires more space. Treating leachates using evaporation technique in conventional basin on the ground has been adopted and used in most landfills of Moroccan cities, but it was not satisfactory due to leachate excess facing the limited capacity of the basin storage (Smahi et al., 2013; Chofqi et al., 2004). Kasba Tadla city, where this study is conducted, is one of these cities which is characterized by a semi-arid climate with very high temperatures during summer periods. One among the objectives for choosing this technique is to exploit climatic conditions of the study area to avoid leachate discharge in wild nature. This experimental work was based on the design and implementation of a small scale forced evaporation tub models and their comparison to the natural evaporation tub model. Specific factors were tested, such as the effect of elevation of the evaporation tub and seasonal comparison. Then, energy optimization study was conducted through electrical energy substitution by solar energy in order to compare the operation of both systems and make environmentally-friendly model.

2. Materials and methods

2.1. Characteristics of generated leachate

From previous studies, organic matter (OM) is the dominant class in Kasba Tadla household wastes, which also include unclassified wastes, by a percentage of about 74%. This later varies according to consumption, nature and composition of dumped wastes (Tabet-Aoul, 2001). It should be mentioned that the high content of OM in the produced waste influences the volume of generated leachate during transportation. This volume will be more important in hot season due to leaching process (Ye et al., 2011). However, high temperature intervals may be suitable for water evaporation which, then, can be condensed in contact with any less hot materials. Moreover, moisture content of household wastes in Kasba Tadla city is about 61.71%. As high temperature intervals, high moisture content influences the amount of leachate produced during waste transportation to the landfill. However, achieving a very high volume of leachate is then predictable. Raw leachate, used in this study, was collected from the leachate tank within the collection packer truck and was characterized by acid pH of about 5 with high organic load exceeding 20 g O_2/L. Monitoring these effluents shows that the daily production during collection and transportation is about 2500 L/day. Additional physicochemical characteristics of raw leachate are given in Table 1.

2.2. Experimental setup

In order to study the feasibility and measure the effectiveness of forced evaporation, leachate treatment experiments were performed using three cuboidal steel tubs with dimensions of 0.93 m length, 0.75 m width, and 0.3 m height. The first control-tub was installed at the ground level in order to monitor natural evaporation with no agitation effect. Similarly, the second and the third tub, models under investigation in this study, were installed respectively at the ground level (equipped-tub 1) and out of the ground level (equipped-tub 2). They were directly exposed to solar rays and were provided with special equipment to accelerate the evaporation process. The equipment includes: **(1)** inclined glass plates 2 mm thick to increase incident solar radiation absorption and prevent water droplets to return back into the tub; **(2)** an agitator to prevent occurrence of lipid layer at leachate surface, which slows the evaporation progress; **(3)** an aeration fan to permit mixing ambient air upon the evaporating surface; and **(4)** the main tub. The system was operating under electric power supply of 220 V (Fig. 1).

The operating conditions are the same for both equipped-tubs. Experiments were performed by evaporating a quantity of 80 L of leachate in each tub. The evaporation monitoring was performed by periodic measurement of evaporated leachate quantity using a graduated rule to measure liquid height in the tub. Tests were performed during the winter and summer periods.

Table 1
Physicochemical characteristics of raw leachate.

Parameter	Value	Unit
Temperature	22	°C
Electrical conductivity (EC)	26,930	μs/cm
pH	4.88	–
COD	23,500	mg/L
Turbidity	2890	NTU
Total solids (TS)	27,444	mg/L
Total suspended solids (TSS)	5552	mg/L
Total dissolved solids (TDS)	25,502	mg/L
Volatile solids (VS)	1012	mg/L
$[NH_4^+]$	1990	mg/L
$[Cl^-]$	2570	mg/L
Heavy metals	75	mg/L

3. Results

3.1. Treatments during the winter period

Since most leachate treatment techniques have shown their limits, especially during winter periods (Peng, 2013), this article addresses a simple and cost-effective technique even during the winter periods. It is about the treatment using evaporation technique with a developed experimental protocol. Fig. 2 shows the cumulative amount of evaporation during the winter period for different cuboidal tubs.

The obtained results show that the evaporation rate at the equipped-tubs is much accelerated with respect to the control-tub. The evaporation time for an amount of 80 L of leachate in the control-tub is about 5 months and 17 days with an average temperature of 19 °C during this period, and with an exhibition area to the sunrays of about 0.7 m^2. Results in the control-tub show a two-phase curve. The first phase is characterized by a very low evaporative power during the winter period as a result of downpours and low temperatures. After four months, the second phase begins to appear just after absence of rain and temperature increase, which promotes the evaporation process. However, the evaporation time of leachate at the equipped-tub 1 becomes about 4 months, while it becomes 2 months and 12 days at the equipped-tub 2. The evaporation time undergoes a decrease of 30% and 55% respectively at the equipped-tub 1 and 2. In addition, the evaporation rate has increased to five times. It passes from a value of 0.37 mm/day in the control-tub to 0.97 mm/day in the equipped-tub 1 and finally reaches a value of 1.50 mm/day in the equipped-tub 2.

However, the critical factor that differentiates between the three tubs is the quantity of absorbed sunrays. It is noted that this amount is higher in the equipped-tubs than that absorbed in the control-tub. Exposure to sunrays is the driving force of the evaporation process that helps to increase evaporating surface temperature. Moreover, the inclined glass plates limit and avoid intake of rain during downpour periods, which is the major problem encountered in the case of natural evaporation tub (control-tub). Rising the equipped-tub 2 above the ground also increases the evaporation rate by collecting more sunrays and increasing sun exposure surface. The evaporation rate is, thus, an increasing function with the increasing surface of exposure to sunrays.