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Membrane bioreactor performance in treating Algiers' landfill leachate from using indigenous bacteria and inoculating with activated sludge

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ABSTRACT

This study focuses on the treatment of both organic and metallic pollution in the Staoueli landfill leachate. This leachate contains a large amount of organic and inorganic matter and it must imperatively be treated before being released into the environment. Our work presents a comparative study between two membrane sequenced batch bioreactors (B2 contains indigenous leachate bacteria and B1 contains activated sludge). The purpose is to assess the best treatment to use, one that allows the reduction of the polluting load of the leachate and a reduction of membrane fouling. Performances were evaluated by measuring the chemical oxygen demand (COD) and the metal content of the leachate (zinc, iron). The results showed a similar COD removal efficiency in B2 (95%) and B1 (93%). Coupling the bioreactors with an ultrafiltration process allowed a notable reduction in zinc and iron concentrations: Fe of 35% and Zn of 78% for B1UF, and Fe of 71% and Zn of 74% for B2UF.

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1. Introduction

In Algeria, for some years now, under the impulse of exponential economic and demographic development, the problem of solid wastes is above anything else a constraint faced by local authorities. It creates direct and indirect negative effects that are linked to the amount of waste, its disposal and treatment. Landfilling remains the only solid waste management tool adopted by developing countries. A dump can be the source of several nuisances: odor emissions, production of biogas and especially of leachate. Landfill leachates are complex and heavily polluted waters resulting from the percolation of rainwater, through solid waste and also from biological, physical and chemical processes taking place within the landfill itself. Indeed, rainfall and decomposition of waste produces leachate at the bottom of the landfill (Francois et al., 2007; He et al., 2005; Liu et al., 2001). It presents high values of biological oxygen demand (BOD), total organic carbon (TOC), chemical oxygen demand (COD), ammonia nitrogen (NH_3-N), dark color, heavy metals and its composition depends on many factors: composition of the wastes, age of the landfill, meteorological conditions, and several more (Chu et al., 2008; Calabrò et al., 2010; Zhang et al., 2013). In most cases, it is made up from humic substances (Kang et al., 2002) and ammoniacal nitrogen, organochlorines and inorganic salts (Wang et al., 2002). Because of their composition, leachates are likely to contaminate the natural environment, particularly groundwater if not properly treated.

In order to limit the harmful effects of these leachates, different types of treatments can be applied to reduce their biological or chemical pollutant content. They must be treated before being released into the environment (Renou et al., 2008). Due to an increase in discharge standards, new treatment techniques have emerged in this area including membrane processes such as microfiltration, ultrafiltration, nanofiltration and reverse osmosis (Renou et al., 2008; Talalaj, 2015). The efficiency of these processes on an industrial scale is still limited, mainly because of the high polluting load of the leachate concerned.

Biological methods, including activated sludge, anaerobic filter, leachate recirculation, and sequencing batch reactor (SBR), are widely applied in the treatment of leachate to reduce the high values of BOD, COD, and NH_3-N (Lema et al., 1988).

This study presents a sequenced batch biological (SBR) reactor treatment, coupled with a membrane process in a second step. In order to simulate the treatment plant used in Algiers, activated sludge from a wastewater treatment plants was added. The objective of the study is to examine general parameters: pH, conductivity, suspended matter, volatile matter, organic compounds ((COD) and (BOD_5), total organic nitrogen, BOD_5/COD ratio), and inorganic compounds (nitrogen ammonia, Nitrite, Nitrate, phosphate, ferrous, cadmium, chrome, copper, lead) in order to find solutions for the pollution load from Staoueli's landfill leachate and to bring the remaining load to discharge standards.

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The aim is to compare the performance of a SBR which only contains raw leachate and in which indigenous bacteria already present inside will be responsible for the reduction of the organic load of the leachate, and another SBR in which activated sludge was added to the leachate, as it is done in leachate treatment plants in Algiers.

This would allow us to assess the necessity of adding sludge to the leachate. Indeed, if the difference in performance between the two bioreactors is low, it would imply that using non inoculated bioreactors would be preferable. This would lead to a reduction in the quantity of sludge generated at the end of the process, which therefore reduces the amount of solid waste that has to be treated.

2. Materials and methods

2.1. Samples

A volume of 60 L was taken from the catchment area of Staoueli's landfill (Algiers). In order to treat the leachate in SBR, a volume of 20 L of activated sludge was taken from the aeration tank of the wastewater's treatment plant in Beni Messous (Algiers).

The activated sludge (SS = 2.1 g/l, MSS = 57%) is put in clean water, stirred, and then submitted to decantation. The water is removed and the sediment (the activated sludge) is once again put in clean water. This operation is repeated 5 times and the whole process took about 2 h. Since the bacteria present in the activated sludge are aerobic, it is aerated at room temperature to preserve its quality (Yahiat, 2010). A pre-culture of the activated sludge was carried out before its use. A volume of 50% activated sludge is inoculated into 50% of the leachate for 3 days under aeration and stirring (Chemlal et al. (2014)).

2.2. Experimental device

Two batch bioreactors (B1 and B2), each with a capacity of 8 L are installed and compared to the control. The control was composed of 100% leachate maintained throughout the treatment period without agitation nor aeration to assess the growth of the leachate's indigenous microorganisms. The first bioreactor (B1) consists of 90% leachate where 10% of activated sludge preculture was added (Chemlal et al., 2014). The second bioreactor (B2) consists of 100% leachate with oxygenation. We used an air pump for aquarium, model, MARINA Air pump 50:50 L/h.

The bioreactors B1 and B2 were stirred at 200 rpm during the treatment time, with aeration, at ambient temperature (25 °C). Samples were taken every 2 h during the treatment period. Nutrients were added to adjust the C/N/P ratio to 100/5/1. This allows an optimization of the microorganisms' activity. To attain this ratio, 1.88 g/8 L of Urea and 0.375 g/8 L of K_2HPO_4 were added to the leachate.

To improve the general performances of the treatment, we coupled the bioreactor with an ultrafiltration device using the ultrafiltration membrane (Carbosep M5) with 10 kDa molecular weight cut-off (Fig. 1).

During this study, we followed the evolution of the experimental parameters: pH, COD and microbial biomass OD600 (samples were diluted prior to analyses when necessary) (Norme ISO 7218: 1996 (F).

The pH of the samples was measured using a HANNA pH meter, model pH 211.

A SOLAAR UNICAM M series Atomic absorption spectrophotometer was used to analyze heavy metals (Fe, Pb, Cu, Zn) according to the method described in Standard Methods (3030 G. Nitric Acid-Sulfuric Acid Digestion- APHA, Standard Methods for the Examination of Water and Wastewater. 22rd Edition 2014). The suspended matter (MES) were measured following the French AFNOR standards (NF T90-AFNOR, 1983).

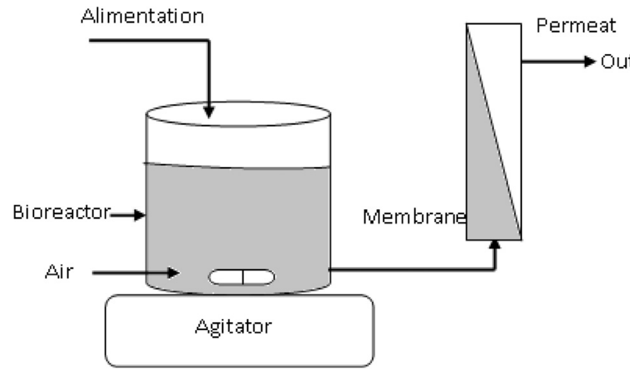

Fig. 1. Experimental bioreactor device in batch mode.

The membrane permeability (Lp) was determined experimentally using Darcy's relation:

$$Lp = \frac{Jv}{\Delta P}(\mathrm{L \cdot h^{-1} \cdot m^{-2} \cdot bar^{-1}}) \quad (1)$$

where Jv and ΔP are respectively the permeate solvent flux and the transmembrane pressure.

The transmembrane pressure (ΔP) is obtained by calculating the mean between the inlet pressure and the outlet pressure of the ultrafiltration module.

The variation of the membrane permeability may be calculated by the Poiseuille law (Eq. (2)):

$$L_p = \frac{N_p \cdot \pi \cdot r_p^4}{8 \cdot \mu \cdot e}(\mathrm{L \cdot h^{-1} \cdot m^{-2} \cdot bar^{-1}}) \quad (2)$$

L_p: Membrane permeability
N_p: Number of poresr_p: Average pore radius
μ: Dynamic viscosity
e: Thickness of the active layer

2.3. Statistical analysis

The principal components analysis (PCA), the representation of trio's size, correlation analysis and variance analysis (ANOVA) were performed by STATISTICA 7 (Dell software 2004) to analyze the experimental data obtained.

3. Results and discussion

3.1. Sequenced batch bioreactors treatment

After analyzing the landfill leachate, we obtained the results that are summarized in the Table 1.

In this study, the approximate initial leachate pH value was 7. With the digestion of organic matter, the leachate pH increased rapidly and reached 9–9.5 in B1 and B2 after 5 days (Fig. 2). The recorded pH values favor the development of neutrophilic microorganisms during aerobic biological treatment. The biological treatment has the advantage of accelerating the process of degradation of organic matter by the self-purification process (Wang et al., 2010).

We recorded the same pattern of pH evolution for B1 and B2 during the treatment period. At the end of the 5th day of treatment, alkalization of the medium was achieved. However, the pH change in B2 is greater than that one observed in B1. This is probably due to the development of the indigenous microorganisms of the leachate, which are denser in B2 compared to B1, and that are

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