Soil & Tillage Research 170 (2017) 130–135

Contents lists available at ScienceDirect

Soil & Tillage Research

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

A simulated column packed with soil-activated carbon for organic matter removal

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ARTICLE INFO

Keywords:
Carbon
Leachate
Natural organic matter
Water
Sorption process

ABSTRACT

A sustainable sorption process was developed for environmental protection of an area around a landfill without control. Different columns, acting as a simulated permeable barrier, packed with semi-wasted activated carbon (AC) and soil samples, were studied to remove natural organic matter (NOM). The AC was supplied from a deionized equipment; meanwhile, the soil was taken from a landfill, without any contamination control, located in Mexicaltzingo, México. These samples were taken at 3 and 12 m depth. NOM was represented by leachate samples (LS) taken from a landfill site, and laboratory prepared samples (LPS). NOM measured, like chemical oxygen demand, biochemical oxygen demand, nitrites and nitrates, was removed through packed columns. Two different packed columns were tested; in the first one, the AC was placed as upper support for the soil; meanwhile, in the second one, a homogeneous mixed AC-soil was used. It was demonstrated that there was an influence in the way the column was packed: a homogeneous mixture in the second column was more efficient than in the first column. Moreover, experiments showed that 60 min is an optimal time for a fast NOM removal in LPS, and the four indicated parameters decreased almost at 100% in the second column. In addition, it has been evidenced that there is no influence in soil depth for NOM removal, but actually, there is an influence for leachate since all columns were more efficient for LPS. In this work, NOM removal through packed columns was proposed, and it showed to be viable applying AC in a permeable barrier, in order to reduce the contamination risk due to leachate produced in the landfill area. Finally, the AC has been revalorized as waste, since it is possible to use it in a second process.

1. Introduction

Commonly, organic matter is used to describe a mixture of heterogeneous chemical fractions (Bieroza et al., 2009). Normally, the term "natural organic matter (NOM)" is used for the organic matter in a reservoir or natural ecosystem (Filella, 2014). NOM is formed by a wide variety of organic compounds that are mainly derived from the decomposition of both plant and animal residues, which contribute to its offensive taste and odors (Joseph et al., 2012). In a place of waste disposal or landfill, leaching is the process by which organic or inorganic contaminants, such as NOM, are released from the solid wastes into the liquid phase; and when those are exposed to aquifer for drinking water, they are transferred and pollute it (Agassi et al., 1998). Particularly, NOM formed in landfill leachates includes volatile fatty acids, refractory humic and fulvic-like compounds, proteins, lipids and carbohydrates. Their quantity is associated with the stage of waste degradation in the landfill (Hu et al., 2014; Joseph et al., 2012). As a result, NOM is one of the major pollutant materials in leached liquids. Therefore, the main risk detected by NOM, in leachate samples, is the totally or partially decreased amount of oxygen in water. Thus, the aquatic life and aerobic processes are limited in nutrients (Yang et al., 2014). As a result, NOM is one of the major pollutant materials in leached liquids. In lab tests, to measure NOM in synthetic conditions or some carbohydrates or hydrous metal oxides is used as standards to obtain an analytical signal to follow it (Filella, 2014).

In Mexico, more than 86,343 tons of garbage are collected every day. From these only 13% of the municipal solid waste (MSW) were disposed in a landfill; meanwhile, the rest 87% was put in open dumps (Hernández-Berriel et al., 2008; INEGI, 2016). In San Mateo Mexicaltzingo, which is a town located in central Mexico, there is a typical MSW disposal site located out of the Mexican environmental standards and regulations (SEMARNAT, 2014; GTZ, 2006). This county was chosen

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http://dx.doi.org/10.1016/j.still.2017.03.010
Received 3 November 2015; Received in revised form 15 September 2016; Accepted 20 March 2017
Available online 05 April 2017
0167-1987/

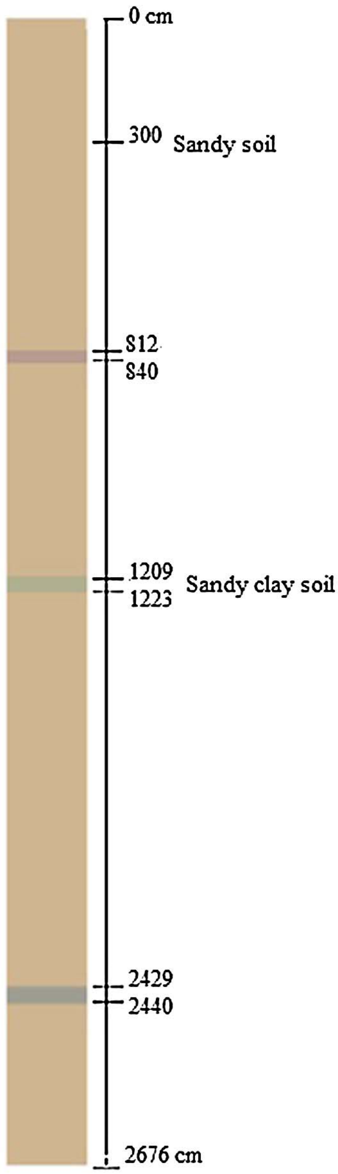

Fig. 1. Scheme of the piezometric well.

due to its accessibility and to its commercial activity. Originally, this place was a sand mine, and for the last 20 years, it has been used as a final disposal site, and it is still operating. The site covers 8705 m^2, and approximately 5600 m^2 of them are still used. In addition, in this place have been found pork meat residues and some other animal-derivatives. These disposed materials have augmented the NOM content, which mainly is composed of humic-like materials, according to the age of the landfill (Joseph et al., 2012). The stratigraphic profile showed that the soil in Mexicaltzingo is sandy, as illustrated in Fig. 1 by García-Maya et al. (2011). So NOM could filter through the soil into the phreatic zone, where drinking water is extracted, becoming a risk to it and life around it (Yang et al., 2014; Renou et al., 2008). Unfortunately, in Mexico there are many sites without any kind of contamination control where no real action is taken to decrease the generated pollution (GTZ, 2006).

Many studies focus on the removal of NOM by different methods, such as ion exchange, membrane filtration, coagulation and adsorption in several materials (Joseph et al., 2012). From them, activated carbon (AC) is the primary adsorbent used for water and treated wastewater with heavy metals, phenols, dyes and organic matter (Bieroza et al., 2009; Bullinger-Weber et al., 2014). The main disadvantage of organic matter removal with AC is the large molecular size of the NOM, which sometimes blocks carbon pores. Nevertheless, organic matter is highly attracted to adsorption sites on the AC (Hu et al., 2014; Zietzschmann et al., 2014). This last characteristic is a disadvantage in some processes; however, for NOM removal is an advantage, such as its low cost, its availability, environmental kindness (Yang et al., 2014) and also, that can be regenerated by temperature or UV-radiation (An et al., 2015).

An additional alternative for NOM removal are permeable reactive barriers (PRB), that have been used successfully to treat a wide range of pollutants (Suk et al., 2009). A PRB consists of making a long trench around the soil and filling it with a reactive material, they are no toxic for humans and, at the same time, are functional to adsorb dangerous chemical compounds present in groundwater. Moreover, the system can be used with any type of soil. The chief limitation for PRBs is their slowest, since they depend on the natural groundwater flow and are difficult to construct (Hunter, 2003; Korfiatis et al., 1984).

Laboratory assays using packing columns are one option to establish the best operating conditions for pollutant control (Tirado-Corbalá et al., 2013), including NOM, through the future use in PRBs (Rodríguez-Cruz et al., 2007), where the results from assays in packed columns with AC will allow the design of PRB for the landfill site in Mexicaltzingo town in a long term.

The purpose of this work was to study the reduction of organic matter through lab columns, using a mixture of packed AC intercalated with a sandy and sandy-clay soil from the Mexicaltzingo disposal site (DS), similar tests has been proposed in other works (Foo and Hameed, 2009; Rodríguez et al., 2004; Li et al., 2010). Also, we suggest a sustainable treatment: first, using a semi-wasted AC from a water treatment device and, second, testing in columns the decrease of NOM in a DS of Mexicaltzingo town. Two leachate samples were used: 1) a natural one was taken from the DS and 2) a synthetic one was prepared in the lab. The semi-wasted AC coming from the deionized water equipment was replaced every 6 months, after this time, it has no other use. AC was not regenerated because it is very expensive. Finally, it was important for this work to revalorize the wasted AC by looking for an additional use after its employment in these devices.

2. Method and materials

2.1. Soil and leachate sampling

A stratigraphic profile of Mexicaltzingo soil was determined in a previous study and it was made from a profundity of 60 m (García-Maya et al., 2011), data for 3 and 12 m of this profile are shown in Table 1. Up to a depth of 12 m the predominant soil is sandy, and the clay content is higher than in the rest of the sample. Thus, in this research two types of soil samples (60 g) were collected at 3 and 12 m deep, a simple scheme is in Fig. 1. The collected soil samples were air dried. Based on their textural classes, described by the United States Department of Agriculture (USDA), there are two soil types in this landfill: the first located at a depth of 3 m, which is sandy and the second at a depth of 12 m, which is sandy-clay.

A leachate sample (LS) was taken from a mentioned piezometric

Table 1
Characteristics of natural soil (García-Maya et al., 2011).

Soil depth (m)	Texture	pH	E.C. (dS/m)	C.E.C. (cmol/Kg)	Clay (%)	Silt (%)	Sand (%)
3	Sandy	5.9	1.42	7.52	**5.94**	**12.62**	**81.44**
12	Sandy clay	7.4	1.79	7.57	**14.31**	**0.07**	**85.62**

E.C. Electric conductivity.
C.E.C. Cation exchange capacity.