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Ultimate composition analysis of municipal solid waste in Muscat

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ABSTRACT

Properly uncontrolled municipal solid wastes (MSWs) may affect public health and the environment. This study investigates the ultimate composition of the MSWs in Muscat, Oman. To achieve this, a set of 22 solid and leachate samples was collected in February 2015. The solid samples were screened according to their size fractions from less than 8 mm up to 100 mm. In addition, the fresh and old leachate samples were examined as well. The ultimate analyses were conducted for various physical and chemical characteristics of the MSW samples, e.g., composition of waste, moisture content (MC), volatile content (VC), loss on ignition, total oxides, elemental analysis, chemical content, heating value and energy content. Moreover, the leachates were analyzed for pH, electrical conductivity (EC), turbidity, total solid (TS), bacteriological analysis, biochemical oxygen demand (BOD), chemical oxygen demand (COD), total organic carbon (TOC), ammonia nitrogen, sodium and potassium, and major anions. From the study, it was found that more than 43% by weight of the disposed materials at the landfill consisted of biodegradable organic compounds. The results also showed that the main components of the total generated wastes were plastic wraps (24%), cardboard (14%) and food wastes (8%). This study also recommends a "waste-to-energy" program, because of the high-energy content of the MSWs (>15,000 kJ/kg). The chemical formulas of the MSW were obtained as $C_{215}H_{395}O_{120}N_2S$ with sulfur and $C_{125}H_{230}O_{70}N$ without sulfur element.

1. Introduction

The steep rise in population, economic, and industrial development have brought many changes in the quantity and quality of the generated municipal solid wastes (MSWs) in Muscat, Oman (Baawain et al., 2014a). The MSWs are defined as the materials managed traditionally by municipalities, which are categorized as unwanted and useless solids thrown from various activities (Liu and Liptak, 1999). These MSWs are classified as residential, commercial, institutional, and recreational as described in Table 1 (Baawain et al., 2014b).

The characteristic and quantity of the MSWs and their leachates vary from one place to another (Rong et al., 2017). These differences depend on the lifestyle and living standards, e.g., socioeconomic structure, income level, product consumption, local regulations related to waste, recoverability of waste and usage behaviors of people (Khan et al., 2016). The MSWs are usually sent to authorized and/or unauthorized disposal dumpsites. However, the chemically hazardous materials contained in the MSWs and their corresponding leachate can be mobilized to the environment through the wastes (Melnyk et al., 2014). Moreover, physical and chemical features of the MSWs are important parameters to discover, since the functioning of transportation facilities, studying on recyclable materials, and designing a proper disposal method relies on them (Fudala-Ksiazek et al., 2016). Therefore, understanding the negative impacts of MSWs in different area is a hot topic of interest. However, the absence of international standards for the characterization of MSWs has resulted in diverse approaches among different studies (Dahlén and Lagerkvist, 2008).

Recently, studies on the MSWs have gained growing interest (Jones et al., 2013). In the Nablus district – Palestine, Al-Khatib et al. (2010) suggested a strong recovery potential for production of animal feed or compost from the MSWs. From their study, source separation was recommended due to the high portion of recyclable wastes. Poll (2003) conducted a survey study in Wales to draw a comprehensive picture of the MSW composition across a constituent part of the UK. Paper and card, food waste, and garden waste were the largest categories with 21%, 16% and 14% by weight of the

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Table 1
Sources, types, and examples of MSWs (Chandrappa and Das, 2012).

Source	Discretion	Example
Residential	Wastes from the livelihood of the people in residential area, such as households, apartments or condominiums.	Food waste, vegetables, bottle, glass, plastic bag and leaf, paper, cardboard, textiles, metals, bulky wastes, electronic stuffs, batteries, and hazardous waste.
Commercial	Waste from the places of trade, transportation or services, such as offices, stores, markets, grocery shops, hotels and restaurants.	Food waste, cardboard, glass, metals, paper, plastics, electronics, batteries, hazardous waste, construction and demolition waste, and bulky wastes.
Institutional	Waste from schools, hospitals, government centers, post offices, and police stations.	Food waste, paper, cardboard, plastics, glass, wood, metals, electronics, batteries, hazardous waste, and bulky wastes.
Recreational	Waste from the recreational places, municipal service area and tourist attractions, such as dam, beach, lake, reservoir, and temples site.	Food waste, paper, cardboard, packaging, street refuse, tree trimmings, and dead animals.

MSWs in Wales, respectively. Another study confirmed that food waste usually constitutes a major portion of any MSWs. A study by Hui et al. (2006) revealed that food waste accounts for about 59% of the total MSW in Chongqing, China. As discussed, high moisture content (MC) (64.1%) and low heating value (3728 kJ/kg) of the MSW were a hindrance for incineration. Finally, they concluded that pollution released by simple landfills and the absence of backup disposal landfills are the major problems in future years. Quaghebeur et al. (2013) found out that the amount of combustible materials in the excavated waste varied between 23 and 50% of the total weight with a large potential of energy content around 18 MJ per kg per dry waste. They also showed that a large amount (40–60%) of the total weight was fine grained materials (<10 mm). In case of industrial wastes (Baawain et al., 2015), the fines contained high amounts of heavy metals (e.g., Cu, Cr, Ni and Zn).

Landfill leachates were also proved as a significant source of hazardous pollutants to the environment (Li et al., 2012). Complex and heavy metal components in the leachates are certainly the most dangerous substances to the groundwater and soil (Aronsson et al., 2010). Therefore, assessment and control of the leachates has become a major focus of every landfill management plan.

Although Riber et al. (2009) reported ultimate waste analysis, a thorough MSW characterization is scarce and the reported data do not provide a clear picture about the MSWs. This is possibly because of the challenging and expensive procedures involved in the process. Hence, the main objective of this study is to characterize the MSWs of the first engineered landfill in Muscat. The ultimate composition of the MSWs and the corresponding leachates are also explored. Further, the potential of reusing, recycling and recovering of the MSWs for sustainable development is discussed and some of the inefficiencies in the management of the MSWs are explored. This study is important to help in future planning for better environmentally friendly society in Oman or similar countries located in the gulf cooperation council (GCC) area. Moreover, the outcome of this study will revamp the MSW management plans to ensure the safety of the environment in the years ahead.

2. Materials and methods

2.1. Site location and specifications

These days, the old dumping sites in Oman are located either close to the residential or the private and public drinking water catchment areas. Additionally, as the number of population increases every year, more than 1.2 kg per capita (or about 4700 t per day) of waste is generated on average every day (Zafar, 2013). Therefore, MSW is considered as a serious issue due to the limited availability of well-designed final disposal lands.

The first engineered landfill located in the capital city of Muscat was commissioned in 2011. The total landfill zone spreads over an area of 96,000 m^2 with total capacity of 10 Mm^3. The landfill includes five cells, which were designed to collect the resulted leachate (Zafar, 2013). This landfill is considered as the first step of the government's big plans for managing the MSWs in a controlled and environmentally friendly way.

2.2. Waste characterization methodology

2.2.1. Sampling method

The preparations of samples are schematically illustrated in Fig. 1. The sampling procedure was started with determining waste origins. For the MSW analyses, 22 samples were collected from different waste categories, e.g., wood, cardboard, textile, sanitary textiles, food, paper, plastic bottles, plastic wraps, other plastics, glass, and metals. Leachate samples were collected from the leachate pond and the leachate inlet. The wastes from six selected trucks (of three locations) were mixed and the mass of the final sample (300 kg) was used according to the percentage of each district. After the removal of big size elements (>300 mm), the sample constituted by mixed sub-samples was screened in three common size ranges (less than 8 mm, 8–20 mm, and 20–100 mm) (EN 14899). A fraction less than 8 mm was considered as fines. All of the fractions were hand sorted according to their waste categories and were weighted according to their size fraction.

2.2.2. Laboratory experiments

The MSW samples were analyzed for their physical and chemical characteristics. To determine the percentage of moisture in the MSW samples, MC analysis was conducted according to American public health association standard (APHA, 2005). The high MC of the MSW is regarded as one of the greatest concerns in the MSW plants. Because high MC poses some difficulties during incineration, such as increases in the volume of leachate in landfills and reduces the energy content of the MSW (Zhang et al., 2010). The volatile content (VC) was determined by heating the MSW sample to 550 °C under a controlled condition and measuring its weight loss, excluding the weight of moisture dried off at 105 °C (APHA, 2005). The VC is a useful approximation of the organic matters in

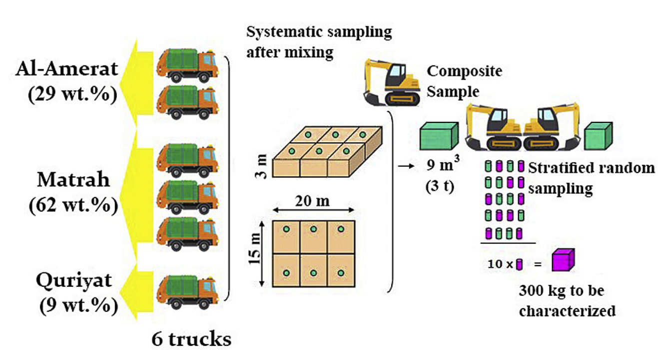

Fig. 1. The MSW sampling procedure adopted from Sita and Al-Bashaer environmental company (2015).