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Gaseous emissions of landfill and modeling of their dispersion in the atmosphere of Shahrekord, Iran

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ABSTRACT

Anaerobic biodegradation of municipal solid waste produces a large amount of air pollutants. Therefore, it is important to estimate the quality and quantity of emitted pollutants from landfills worldwide. The aim of this study is to predict the amount of methane, carbon dioxide, carbon monoxide and non-methane organic compounds emitted from the Shahrekord, Iran landfill. The LandGEM model, introduced by the US Environmental Protection Agency, was utilized to predict the amount of the above-mentioned gases. Additionally, the AERMOD View model was used to estimate the dispersion of emitted pollutants from the Shahrekord landfill into the atmosphere. Metrological data, the most basic requirement enabling the models to work, were collected from the Islamic Republic of Iran Meteorological Organization. Results showed that the maximum amount of methane, carbon dioxide, carbon monoxide and non-methane organic compounds will be emitted from Shahrekord landfill in 2021. It is also elaborated that 114 million m^3 of methane will be emitted between 1997 and 2023, with the potential to generate 188100 MW electrical energy. The modeling of pollutants' dispersion into the atmosphere shows that concentration of the pollutants emitted by the landfill was within permissible levels in the city of Shahrekord.

1. Introduction

Population growth and urbanization have led to the production of a huge amount of industrial and municipal solid wastes worldwide (Tisserant et al., 2017). Sanitary landfills are one of the most economic and important methods for disposal of municipal solid waste. Historical studies show that landfilling of solid wastes has been utilized for the past five thousand years (Goel et al., 2017). In the past, there was no certain provision to landfill municipal solid waste; landfills were fetid places with environmental issues (Soltani et al., 2015). With increasing production of municipal solid waste, certain rules regarding municipal solid waste landfills have been established by environmental protection agencies in different countries. Improper management of municipal solid waste landfills can simultaneously contaminate air, water and soil (Yadav and Samadder, 2017). Therefore, extensive studies must be carried out to clarify all aspects of solid waste landfill pollutants.

Biological reactions in landfills can convert organic compounds to several different gases, called biogas (Jonidi and Talaiekhozani, 2010; Talaiekhozani et al., 2016d). Biogas is composed of approximately 60% methane, 40% carbon dioxide and small amounts of water vapor, hydrogen sulfide, ammonium and halogenated hydrocarbons (Hegde et al., 2003; Ohimain and Izah, 2017). In addition

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to these gases, biogas contains less than 1% of non-methane volatile organic compounds, which are highly toxic and often carcinogenic (Chalvatzaki and Lazaridis, 2010). Although non-methane organic compounds are a small part of biogas, because of their toxicity their control is absolutely important (Talaiekhozani et al., 2016a). Methane is a well-known gas in landfills, which has been utilized for energy recovery. For unknown reasons, the concentration of methane in the atmosphere increased until 1998; it subsequently experienced a period of stability between 1998 and 2007 until recently, when the level of concentration level is again increasing (Talaiekhozani et al., 2016a). Several studies are underway to understand the exact reasons for the increase of methane in the atmosphere and potential methods for its control. Although there are many sources for methane emission into the atmosphere, such as wetlands, coal mines and rice fields, municipal solid waste landfills are the major source worldwide (Chalvatzaki and Lazaridis, 2010; Talaiekhozani et al., 2016a). Both carbon dioxide and methane contribute to global warming (Fortuniak et al., 2017). However, according to the Intergovernmental Panel on Climate Change (IPCC), methane is 28 times more powerful than carbon dioxide in terms of global warming potential (Stocker et al., 2013). Therefore; estimation of methane production in landfills has gained much attention from scientists (Aghdam et al., 2017; Xu et al., 2014). Studies carried out by the European Environment Agency showed that around 400 gaseous chemicals can be emitted from landfills (Jiménez-Rivero and García-Navarro, 2017). Methane is a flammable gas that in concentrations of 5–15% causes fire or explosion in the air at a landfill's surface (Beyler, 2016). Produced methane can be utilized for electricity generation. In the USA, more than 243 million tons of municipal solid wastes were produced in 2009, so that 1.95 kg/day waste was produced by every person that year (Virmond et al., 2012).

Omrani et al. (2009) reported that 5.22 kWh of electrical energy can be generated from each cubic meter of biogas (Omrani et al., 2009). There are several methods to prevent biogas emission from landfills, such as incineration, chemical scrubbing, adsorption and biofiltration (Rabbani et al., 2015; Roshan et al., 2015; Talaiekhozani and Nasiri, 2016; Talaiekhozani et al., 2016e). Incineration of biogas can convert its methane and non-methane organic compounds to carbon dioxide and water vapor (Chai et al., 2016). Adsorption of organic compounds from biogas is another method to remove harmful compounds from biogas (Talaiekhozani et al., 2016f). However, adsorption of pollutants from a large amount of produced biogas is expensive. The best method to prevent methane emission is to recover its energy (Cieślik et al., 2015).

Talaiekhozani and Nasiri (2016) reported that in the year of 2028, carbon dioxide and methane production in the Jahrom, Iran landfill (with GPS coordinates of 28° 19′ N and 52° 45′ E) was estimated at 10,570,000 m^3 (Talaiekhozani and Nasiri, 2016). Estimation shows that by recycling the obtained methane in the Jahrom landfill, it would be possible to generate 8375 MW of energy per year by 2016. It is reported that only 24.18% of the produced waste in the city of Rodan, in southeastern Iran (with GPS coordinates of 27° 28′ N and 57° 11′ E), is biodegradable (Talaiekhozani et al., 2016b). Calculations indicate that the maximum biogas emission from the Rodan landfill is 420 tons per year, achievable by 2019. The production rates of carbon dioxide and methane in 2019 in the Rodan landfill would be equal to 308 and 112 tons per year, respectively (Talaiekhozani et al., 2016b). (Talaiekhozani et al., 2016e) showed that 2077×10^6, 7.569×10^5 and 3253×10^4 tons of carbon dioxide, methane and non-methane organic compounds will be emitted into the atmosphere from the landfill of the large city of Shiraz, in southern Iran (with GPS coordinates of 30° 25′ N and 37° 29′ E), during the years 1997 to 2029.

Since emission of methane, carbon dioxide and non-methane organic compounds is highly important, suitable systems for managing these emissions should be applied. To control landfill emissions, estimation of biogas production is necessary before selection of a suitable management system. Although there are many studies that have estimated emitted biogas from landfills worldwide, the Shahrekord landfill had not yet been investigated. Furthermore, only a few researchers have studied the distribution of pollutants emitted from a landfill into the atmosphere. Therefore, the aims of this study are 1) to estimate the amount of pollutants, including methane, carbon dioxide and non-methane organic compounds, emitted from the Shahrekord landfill by using the LandGEM model and 2) to model the pollutants' distribution, using AERMOD software.

2. Materials and methods

2.1. Prediction of population

In order to predict Shahrekord population in the future, Eq. (1) that has been introduced by (Lippman, 2013) was used.

$$P_n = P_0(1 + r)^n \tag{1}$$

where P_n is the population in year of n, P_0 is current population, r is population growth rate and n is the number of years. Based on the Iran National Population and Housing Census 2011, the population of Shahrekord is 315,980 persons. Eq. (1) predicted the population of Shahrekord for the years 2017–2021. The growth rates of population for the years between 1993 and 2016 were obtained from the Statistical Centre of Iran. It is assumed that the population growth rate from 2016 to 2021 will be stable, with a growth rate of 1.15%. The amount of produced solid waste in this period was calculated by multiplying the population by the rate of solid waste production. In this study, it is assumed that the rate of solid waste production will not change over time.

2.2. Determination of Shahrekord climate

Weather conditions are one of the most important environmental factors in landfill management (Talaiekhozani et al., 2016c). A portion of the input data for the LandGEM model must be determined based on Shahrekord's climate. Therefore, the climate of the city of Shahrekord was estimated using the de Martonne method (Eq. (2)).