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Evaluation of emission inventory for the emitted pollutants from landfill of Borujerd and modeling of dispersion in the atmosphere

Amirreza Talaiekhozani[a,*], Mahshid Dokhani[b], Amin Aleebrahim Dehkordi[b], Zeinab Eskandari[b], Shahabaldin Rezania[c]

[a] Department of Civil Engineering, Jami Institute of Technology, Isfahan, Iran
[b] Department of Chemical Engineering, Jami Institute of Technology, Isfahan, Iran
[c] Department of Civil and Environmental Engineering, Seoul National University, Seoul, Republic of Korea

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ABSTRACT

Nowadays, air pollution is a serious problem in big cities, since municipal solid wastes contain high amounts of organic compounds. The aim of this study is to evaluate the emission inventory of the pollutants emitted from the municipal solid wastes landfill of the city of Borujerd, the capital of Borujerd County, Lorestan Province, in western part of Iran. First, all the necessary information, such as the amount of disposed solid waste in the landfill, analysis of the municipal solid wastes and the metrological data were collected. Then, the information was analyzed by the LandGEM model to estimate the amount of carbon dioxide, methane, and non-methane organic compounds emitted into the atmosphere from the Borujerd landfill. Next, the distribution of the pollutants emitted from the landfill was modelled using AERMOD software. The results showed that the majority of biogas is generated between 2015 and 2025. The maximum amount of biogas generation will be observed in 2020, which would be 12,900, 4600 and 200 tons for carbon dioxide, methane, and non-methane organic compounds, respectively. The Borujerd landfill has the potential to generate 4035 MW electricity in 2020.

1. Introduction

Nowadays, industrial and municipal solid wastes are viewed as environmental pollutants that have created significant issues for human health. Although part of municipal solid wastes is recoverable, another part is non-recoverable and should be disposed in an effective manner. Sanitary landfilling is one of the most common methods to dispose of municipal solid wastes worldwide (Bingemer and Crutzen, 1987; Uyguner-Demirel et al., 2017).

Waste disposal can lead to environmental disaster when strict health standards are ignored (Talaiekhozani et al., 2016c). After disposal, organic compounds are decomposed by chemical and biochemical reactions, and large volume of gases are produced and released into the atmosphere. Gases produced by landfills are called biogas or landfill gas. The major part of biogas contains carbon dioxide, methane, and non-methane volatile organic compounds (NMOCs) (Omar and Rohani, 2017; Talaiekhozani et al., 2016b).

Methane, one of the most important gases produced in landfills, contains 60 to 70% of total biogas, and contributes to global warming 30 times more than carbon dioxide. Methane is a nontoxic greenhouse gas that has the explosion potential of about 35,310,000 μg/m^3 (Talaiekhozani et al., 2016c). Various studies have shown that 5% of the greenhouse gases are released from the landfills worldwide (Broun and Sattler, 2016; Zuberi and Ali, 2015). In developed countries, waste disposal is based on energy

* Corresponding author.
E-mail address: amirtkh@yahoo.com (A. Talaiekhozani).

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renewal from biogas, while in developing countries, such standards have not been employed (Talaiekhozani et al., 2016a). Although the amount of organic compounds released from landfills is low, this category of compounds is highly toxic and most of them are carcinogenic (Chalvatzaki and Lazaridis, 2010). Usually, about 250 kg biogas is produced from each ton of waste and can be consumed through extraction (Talaiekhozani et al., 2016b). Recovery of methane is one of the best ways to prevent the emission of biogases. In several landfills in Los Angeles, USA, the produced methane is used to launch a 50 kW generator (Themelis and Ulloa, 2007). Methane produced in landfills is higher than the methane produced in rice farms and wetlands. The amount of humidity of the disposal area as well as pH level of the disposed wastes influences the level of biogas. (Alexander et al., 2005) reported that the produced biogas in a humid environment is 3.85 times greater than that in a dry environment.

There are various methods to estimate the emission of methane, including site evaluation, field testing, and mathematical modeling (Knapp et al., 2014). LandGEM model is an automatic instrument that provides the possibility for the estimation of annual emissions from landfills based on a first-order decomposition rate equation. This model has been developed by the Control Technology Development Center of the Organization for Environmental Protection of America (Talaiekhozani, 2015). LandGEM estimates two main gases (carbon dioxide and methane) and predicts the emission of NMOCs in landfills (Bruce et al., 2017; Saqqur et al., 2007; Yadollahikhales et al., 2016). For example, (Talaiekhozani et al., 2016a) reported that in Najafabad, Iran, 100% of the collected wastes have been recycled and no disposal occurs. They assumed that no recycling could be observed in this city and all wastes are landfilled. The results of (Talaiekhozani et al., 2016a) showed that if the wastes are not recycled over 20 years, 107,206 tons of carbon dioxide and 39,074 tons of methane could be released into the atmosphere. Additionally, based on their study 95 tons of harmful non-methane gases were released in the atmosphere of Najafabad; by recycling 100% of the wastes and sanitary landfilling, these harmful gases are not released into the atmosphere (Talaiekhozani et al., 2016a). (Omrani et al., 2009) modelled the produced pollutants in Shiraz, showing that $1.5 \times 10^6 m^3/year$ methane and $9.6 \times 10^5 m^3/year$ carbon dioxide are released from the landfill of Shiraz annually. Safari et al. (2010) reported that 538.8×10^7 ton biogas and 3.21×10^7 ton carbon dioxide during 40 years of landfill activities in Rasht, Iran, will be released to the atmosphere (Safari et al., 2010). A similar study showed that a large amount of gases that resulted from anaerobic decomposition of solid wastes are released to the atmosphere in Mashhad, Iran, each year (Safari, 2012). Pazoki et al. (2015) estimated the released gases from the landfills of Tehran. According to their estimations, during 2000 to 2100, each hour about 558 cubic meters of methane will be produced at Tehran landfills, which equals 2354 MW energy. Furthermore, they specified that during a 100-year period, 93,700,000 tons of carbon dioxide will be released to the atmosphere (Pazoki et al., 2015). In 2006, the US Environmental Protection Agency, with the aid of LandGEM, estimated the production capacity of methane in different parts of Central America at between 78 and 101 M^3 for each ton of wastes (Allen et al., 2013; Saqqur et al., 2007).

AERMOD is used for understanding the dispersion of pollutants over the chosen area, and requires hourly surface and upper air meteorological observations (Dey et al., 2017). This software can simulate the dispersion of atmospheric pollutants from point and aerial source emissions (Asadi et al., 2017; Esbrí et al., 2015).

Although numerous studies have been conducted on the production and emission of pollutants from landfills but, no study has been conducted on the disposal area of Borujerd, located at latitude 33.867, longitude 48.833. Therefore, this study determines the emission rate of carbon dioxide, methane, and 48 non-methane compounds in the landfill of Borujerd. Several types of information were collected, including the first and last years of landfill operation, landfill capacity, the amount of wastes disposed in the landfill, and the meteorological conditions of the city of Borujerd. Then, the amounts of methane, carbon dioxide, and non-methane organic gases were estimated using the LandGEM model. Finally, with the help of AERMOD, the distribution of the produced gases in Borujerd's atmosphere was investigated.

2. Material and methods

2.1. Determining the quality of wastes in Borujerd

The amount of the disposed solid wastes in landfill was determined from the recycling organization of Borujerd. In the first step, several samples were taken from Borujerd's municipal solid waste. For sample preparation, four garbage trucks were used for which the waste container had a specific volume. The discharged wastes were weighed according to the specified volume, and their density was quantified. This was repeated monthly for a year. Combined samples were taken from the garbage and their components' qualitative and quantitative characteristics were analyzed based on the standard method (Pazoki et al., 2015).

2.2. Estimation of population and the production of future wastes in Borujerd

Accurate understanding of population is necessary to estimate the future amounts of wastes to be produced. The population of Borujerd was determined to be 326,452 between 2015 and 2016 from the Statistical Center of Iran. Then, the population of this city was estimated from 2017 to 2020. Eq. 1, predicts the population for future waste production. According to the provided statistics, the average population growth rate of Lorestan Province equals 0.07% per annum. The following equation was used with assumption of stable population growth rate during 2017 to 2020.

$$P_n = P_0(1 + r)^n \quad (1)$$

In Eq. 1, Pn parameter is the population in year n, P0 is the population at the first year, r is the average population growth rate, and n is the number of years. To estimate the rate of solid waste production in 2016, total produced wastes in this year was divided by