Health Science Monitor
2023; 2(4): 233-237
Published online (http://hsm.umsu.ac.ir)

Original Article

Determination of environmental impact and energy recovery from municipal solid wastes in the Northwest of Iran

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Abstract

***Background & Aims*:** Unsuitable management of municipal solid waste (MSW) is one of the main factors in environmental degradation, particularly in developing countries. This study aimed to analyze the quantitative and qualitative properties of MSW for energy recovery in the city of Mahabad, located in the West Azerbaijan Province, Iran.

***Materials & Methods*:** Sampling from MSW was taken during the four seasons in 2014. Quality and quantity analyses included chemical composition, moisture percentage, dry weight, ash percentage, and heat value, which were performed in the lab as per the American Society for Testing and Materials Method D 5231-92. The experience modeling was used to extract chemical composition and heat value.

***Results*:** The results showed that MSW was composed of 75% food waste, 12% ash, and 61% moisture. In the MSW organic fraction ($C_{28.7}H_{43.6}O_{15.3}N_1S_{0,065}$), carbon/nitrogen and heat values were found at 28.7 and 2.1×10^4 Kj Kg^{-1}, respectively. Also, in the MSW biodegradable organic fraction ($C_{23.7}H_{37.7}O_{14.69}N_1S_{0.069}$), heat value and produced methane were calculated to be 10077 Kj Kg^{-1} and 207 liters (148 g), respectively. Any carbon dioxide added to the atmosphere will hang around for a long time, between 200 and 200 ton day^{-1}, which contributes to trapping heat and warming the atmosphere.

***Conclusion*:** This study shows energy recovery from MSW is a good option, due to the high heat value. However, it is not an eco-friendly method as it will produce more greenhouse and poison gases and needs control systems.

***Keywords*:** Chemical composition, Carbon/nitrogen, Energy recovery, Heat value, Municipal solid wastes, Incineration

Received 03 December 2022; accepted for publication 28 December 2022

Introduction

Population increase, economic development, urbanization, consumption pattern change, and living standard promotion have raised the generation rate of municipal solid waste (MSW) in developing countries (1). Poor management of MSW is a major cause of environmental degradation, particularly in these countries (2). MSW management includes the collection, processing, transport, and disposal of solid waste, affecting both the environment and public health. MSW may release several toxic substances, mostly in small quantities and at deficient levels in the environment. Due to a wide range of pollutants, different pathways of exposure, long-term exposure, and the potential for synergism among the pollutants, there are concerns about the potential health effects of MSW (3).

In Iran, like other developing countries, MSW management is one of the most critical challenges in environmental issues, particularly in urban areas. Due to varying types and qualities, MSW in Iran is different from other countries in the world (4). Failures in the composting process and non-cost-effective methods in the collection and disposal of MSW in many cities of Iran justify using engineering methods in MSW management. Burning MSW in landfills can produce pollutant gases such as carbon dioxide, ammonium, oxide carbon, hydrogen, methane, hydrogen sulfide, nitrogen, and oxygen. Methane and carbon dioxide constitute the leading gases arising from anaerobic decombustion of organic biodegradable compounds, which form more than 90% of produced gases. The release of methane in the atmosphere needs to be controlled due to the contribution of methane to global warming (5). Carbon dioxide is denser than air and methane; therefore, it tends to move toward the bottom of the landfill. It can also penetrate into groundwater and increase groundwater hardness in landfill areas. Thus, energy and materials recovery from MSW could be the best choice for protecting the health and environment (6).

To manage collection, recovery, and disposal of MSW, it is essential to analyze the chemical components of these wastes, including hydrogen, carbon, oxygen, nitrogen and sulfur, carbon/nitrogen (C/N) ratio, ash percentage, heavy metals, pH, electrical conductivity, phosphorous, calcium, potassium, and micronutrients, the content of moisture and ash and density (7). The aim of this study was to analyze the quantitative and qualitative properties of MSW for the recovery of energy in Mahabad City, West Azerbaijan Province, Iran.

Materials & Methods

This research was conducted as a cross-sectional, descriptive study on the MSW of Mahabad City in the West Azerbaijan Province of Iran (Fig. 1). MSW was sampled during the four seasons in 2014, and chemical composition, moisture percentage, dry weight, ash percentage, and heat value were analyzed as per the American Society for Testing and Materials Method D 5231-92 [9]. The MSW was manually categorized into the following physical components: food waste, plastic, paper, and cardboard, yard waste, textile, glass, metals, and others. To determine moisture content, each component was weighed and placed in an oven at 105 °C for 24 hours. Ash percentage of samples was measured by burning MSW in an oven at 770 °C for one hour. All the experiments were performed in triplicate. Samples were weighted using a digital scale with decimal precision (8). MSW chemical composition was calculated to determine the quantity of produced biogas and heat value. Biogas production and heat value were separately calculated and then compared. Dolang formula was used for the calculation of heat value (Btu lb^{-1}) as Eq. 1):

Heat value = 145C + 610 (H-1/8O) + 10N + 40S (1)

Where C, H, O, N and S show the percentage of carbon, hydrogen, oxygen, nitrogen, and sulfur in the MSW.

Fig. 1. Map of the study area.

Results

The results demonstrated that 75% of MSW was made up of food waste with 12% ash and 61% moisture. The chemical composition of organic MSW for the studied city, Mahabad, was calculated as $C_{28.7}H_{43.6}O_{15.3}N_1S_{0,065}$ containing a heat value of 2.1×10^4 Kj Kg^{-1}. The heat value and produced methane for the biodegradable organic MSW, with the chemical formula $C_{23.7}H_{37.7}O_{14.69}N_1S_{0.069}$, were determined as 10077 Kj/Kg of MSW and 207 L, respectively (148 g).

Table 1 shows the weight percentage of the components and their wet weight (ton per day). Ash and wet percentage of organic fractions are shown in Table 2, and the molar mass of each component and element are depicted in Tables 3 and 4, respectively. The chemical formula for organic and biodegradable fractions of the MSW are represented in Tables 5 and 6, respectively. The heat values for 1 Kg of MSW is given in Table 7.

Table 1. Composition of daily MSW in Mahabad city

Component	Wet weight (ton day^{-1})	Weight (%)
Food waste	99	75
Plastic	13	10
Paper and cardboard	5	4
Yard waste	1	0.75
Textile	3	2
Glass	3	2.04
Metals	5	3.8
Others	3	2.41
Total	131.7	100

Table 2. Wet and ash percentage of MSW organic fractions

Component	Wet (%)	Ash (%)
Food waste	61	11.5
Plastic	4.06	9
Paper and Cardboard	10	8.4
Yard waste	6.18	76

Table 3. Molar mass of each element in MSW organic fractions (g)

Component	C	H	O	N	S
Food waste	14.04	1.87	10.99	0.76	0.12
Plastic	4.08	0.49	1.55	0.00	0.00
Paper and Cardboard	2.22	0.31	2.25	0.015	0.010
Yard waste	2.29	0.29	1.82	0.16	0.014

Table 4. Molar mass of the MSW organic fractions

Organic fractions	C	H	O	N	S
Molar mass, g mol^{-1}	1.8	2.9	1.03	0.06	0.004

Table 5. Chemical formula for the MSW organic fractions

C	H	O	N	S
28.7	43.6	15.3	1	0.065

Table 6. Chemical formula for biodegradable organic fractions of the MSW and methane production

C	H	O	N	S
23.7	37.7	14.69	1	0.069
Methane production : 148 (g)				

Table 7. Heat value for organic composition and methane production for 1 Kg MSW

Heat value (Kj Kg^{-1}) for MSW organic combostion	Heat value (Kj Kg^{-1}) for methane production from biodegradable MSW
$C_{28.7}H_{43.6}O_{15.3}N_1S_{0,065}$ 21843.72 Kj Kg^{-1}	$C_{23.7}H_{37.7}O_{14.6}N_1S_{0.069}$ 10077 Kj Kg^{-1}

In this study, MSW was sampled from both household and commercial sources in Mahabad. The daily MSW produced was equal to 131.7 tons day^{-1}. The production rate of the MSW in the whole northwest of Iran is more than 2,000 tons per day, utilized as the dumping method. The chemical composition of a biodegradable organic fraction in the MSW in Mahabad city was calculated as $C_{23.7}H_{37.7}O_{14.6}N_1S_{0.069}$ produced methane equal to 148 g, a volume of 207 liters. Consequently, the total daily methane production is approximately 19 tons for 131.7 tons of MSW per day in Mahabad city (Table 1).

Discussion

The heat value of methane per Kg of the MSW was 10077 Kj (Table 4). Therefore, the heat value of produced methane for MSW is 1315855 Mj day^{-1}. The result of a study on MSW showed that decomposed wet MSW in Tehran (capital of Iran) produced 102 g of CH_4 and 253 g of CO_2 per Kg, and it will be 345 g for CH_4 per Kg for dried MSW (9). Any carbon dioxide added to the atmosphere will hang around for a long time, between 300 and 1,000 years, contributing to trapping heat and warming the atmosphere.

According to the United Nation protocol for climate change calculation, 23 and 13 ton/day CO_2 is produced due to methane and landfill gas in the study area (10). In an investigation conducted in the north of Iran (Mazandaran), the production of biogas from biodegradable MSW was in the range of 0.21 to 0.61 m^3 Kg^{-1}, which can be led to power generation (11). The result of that study was in accordance with our findings. Different amounts of methane produced can be assigned to the high percentage of biodegradable compositions. In this study, the heat value for the organic component of waste ($C_{28.7}H_{43.6}O_{15.3}N_1S_{0,065}$) was about 21 Mj Kg^{-1}, while the heat value for produced methane from the biodegradation fraction of the waste ($C_{23.7}H_{37.7}O_{14.6}N_1S_{0.069}$) was ~0.5-fold that from the organic component as 10 Mj Kg^{-1}. This ratio can be associated with the high percentage of food waste, plastic, and paper (approximately 90%) in MSW in Mahabad. However, a review study showed that biogas recovery from biodegradable MSW is preferred over heat recovery from MSW incineration. It is due to the production of lower greenhouse gases in the first method (12). Incineration will generate more than 300 tons day^{-1} of greenhouse and toxic gases, but landfilling produces less than 200 tons day^{-1} of different gases (11).

Conclusion

The findings of this study show that energy recovery of MSW in the study area is an acceptable choice, though it had environmental challenges. Moreover, the production of biogas from MSW is better than the incineration approach. Since incineration burns a mixture of organic solid waste containing plastic materials, it could produce toxin gases such as furan and dioxin. Dioxins are classified as lethal persistent organic pollutants that cause cancer and neurological damage and disrupt reproductive thyroid and respiratory systems. Biogas burning had no dioxin and furan problem but produced carbon dioxide, which had a high potential for global warming. Thus, MSW had to be performed using integrated methods in order to control total by-products compounds, which could harm the environment and human health.

Acknowledgments

None declared.

Conflict of interest

The authors have no conflict of interest in this study.

Funding/support

None declared.

Data availability

The raw data supporting the conclusions of this article are available from the authors upon reasonable request.

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