original article

Feasibility energy recovery potential of municipal solid waste in Northwest of Iran

Amir Mohammadi, Afshin Ebrahimi[1], Mohammad Mehdi Amin[1]

Department of Environmental Health Engineering, School of Health, Urmia University of Medical Sciences, Urmia, Iran, [1]Environment Research Center, Isfahan University of Medical Sciences, Isfahan, Iran

Address for correspondence:
Dr. Mohammad Mehdi Amin,
Hezar Jerib Avenue, Isfahan University of Medical Sciences, Isfahan, Iran.
E-mail: amin@hlth.mui.ac.ir

ABSTRACT

Aims: The goal of this study was the ultimate analysis and chemical composition of SW for energy recovery in Urmia city.
Materials and Methods: A cross-sectional, descriptive study was done on municipal SW in Urmia city, northwest of Iran. The samples were collected during the four seasons of a year. Experiments were analyzed according to the American Society for testing and Materials (ASTM) Method D 5231-92. The chemical composition of the SW was calculated, to determine the quantity of produced biogas and heat value.
Results: The findings showed that food waste percent had been 68.9%, carbon/nitrogen (C/N) 18.33, containing 10.4% ash and 54% moisture. The calculated chemical composition of organic SW was ($C_{27.7}H_{43.1}O_{15.3}N_1S_{0,065}$) with a heat value of the 2.2×10^4 Kj/Kg. The produced methane and heat value of the biodegradable organic SW, chemical formula $C_{23.63}H_{37.52}O_{14.65}N_1S_{0.069}$, were 212 liters (151 g) and 9992 Kj per 1 Kg of SW.
Conclusions: The recovery of SW energy through incineration was a better choice, due to the high heat value. However, it would produce more than 300 tons/day of greenhouse and poison gases, but land filling produced 200 tons/day of different gases. Thus, on the basis of the calculated SW composition in this research, it seemed that energy recovery through methane collection was a better option for this study area.

Key words: Chemical composition, energy recovery, Iran, solid waste

INTRODUCTION

'Solid waste' (SW) management is one of the important problems in Iran. There are many methods for SW management, but energy and materials recovery would be the best choice to protect human health and the environment and to protect the resources. The SW management in Iran, including collection, disposal, and recovery is different from other countries in the world, due to the different type and quality of SW.[1] Therefore, using any technology without knowledge of the materials and compatibility of the local factors is not a convenient approach for this management. Seventy percent compostable compounds and more than 40% moisture make up the domestic SW in Iran. The changing climate or ecological conditions, different lifestyle, and people's culture are the reasons that one must not use any technology without enough research.[2] Inadequate experience in the composting process and non-cost-effective methods of SW collection and disposal in many cities of Iran, that is, approximately 20% of the municipal budget, indicate the importance of this problem in planning. Generally, the cost of SW collection and transport comprise of about 80% of the total cost of SW management. The high percent of these amounts are related to labor fees and human resources. As modification and mechanization will accelerate the operation of SW collection and the transportation system, there is a

Access this article online
Quick Response Code:
Website: www.ijehe.org
DOI: *****

need to decrease human resources. Thus determining SW production per capita person would also be important.[3] For planning of the SW collection, recovery, and disposal system, it is necessary to analyze the SW components, moisture, and ash content, as also the density and dimensions. The moisture value is usually expressed as available moisture in a dry or wet mass unit. Understanding the chemical composition of SW is more important for its management, collection, recovery, and disposal.[4] The chemical composition of the SW elements must be measured to prepare fertilizer, including hydrogen, carbon, oxygen, nitrogen, and sulfur. Also, the carbon/nitrogen (C/N) ratio, ash percentage, heavy metals, pH, electrical conductivity, phosphorous, calcium, potassium, and micronutrients are included.

The conventional handling of SW poses serious environmental and public health concerns. There is a great deal of agricultural land in Urmia that is not well-engineered. As in other cities, management of SW in Urmia is the responsibility of the municipality. The population of northwest Iran is more than three million persons. Thus, management of municipal solid waste (MSW) needs to improve in the coming years. Also, with regard to Urmia and the northwest of Iran, the country's climate is semiarid with moderately cold winters, mild springs, hot, dry summers (although mild for Iran), and crisp autumns. Precipitation is heavily concentrated in late autumn, winter, and especially in spring, thus it could have a good potential for biogas produced in the natural condition. Also vegetative and animal waste is available to complement the carbon and nitrogen sources, to produce biogas from the municipal SW.

The goal of this study is the ultimate analysis and chemical composition of SW for energy recovery, in Urmia city.

MATERIALS AND METHODS

Sampling and analysis

A cross-sectional, descriptive study has been done on municipal SW of Urmia city, northwest of Iran [Figure 1]. Solid waste sampling was performed during all the four seasons of a year.

The SW composition was analyzed according to the American Society for testing and Materials (ASTM) Method D 5231-92.[5] Thus, the physical composition of the MSW was manually separated into the following categories: Food waste, plastic, paper and cardboard, yard waste, textile, glass, metals, and others.

Moisture content and ash content

For determination of the moisture content and ash content, the SW samples were separated in eight components, including food waste, plastic, paper and cardboard, yard wastes, textile, glass, metals, and others. Each component was weighted and placed within the oven for 24 hours, at 105°C, to determine the moisture content following the ASTM D2974-87 procedure. The ash contents of the samples were measured in an oven, at 770°C, for one hour. All the experiments were conducted in triplicate. The weighting of the samples was performed using a digital scale, with decimal precision.[5]

Calculation, chemical composition, and heat value

The SW's heat value and also its chemical composition, to determine the quantity of produced biogas, were calculated according to the recommendations in the text book.[6] Biogas production and heat value on burning were obtained separately, and then were compared with each other.

RESULTS

The findings showed that food waste percent had been 68.9%, C/N 18.33, containing 10.4% ash and 54% moisture. The calculated chemical composition of organic SW for Urmia city was $C_{27.7}H_{43.1}O_{15.3}N_1S_{0,065}$ with a heat value of the 2.2×10^4 Kj/Kg, as per the Dolang formula.[6] The produced methane and heat value of the biodegradable organic SW, chemical formula $C_{23.63}H_{37.52}O_{14.65}N_1S_{0.069}$, were 2121(151 g) and 9992 Kj 212 L (151 g) and 9992 Kj per Kg of SW]' replaced with '[were 212 liters (151 g) and 9992 Kj per Kg of SW. Its density was 328 Kg/m^3. The weight percent of the components and their wet weights are given in Table 1. The ash and wet percent is shown in Table 2. Tables 3 and 4 reveal the molar mass of each component and element, respectively. The calculation of the chemical composition of organic and biodegradable SW in Urmia city is indicated in the Tables 5 and 6. Using the Dolang formula, the heat value on burning is given in Table 7.

DISCUSSION

In this scenario all the waste was collected from the households and commercial sources in Urmia. There was no discrimination between commercial and household waste. The daily production of SW obtained was 400 tons/day in

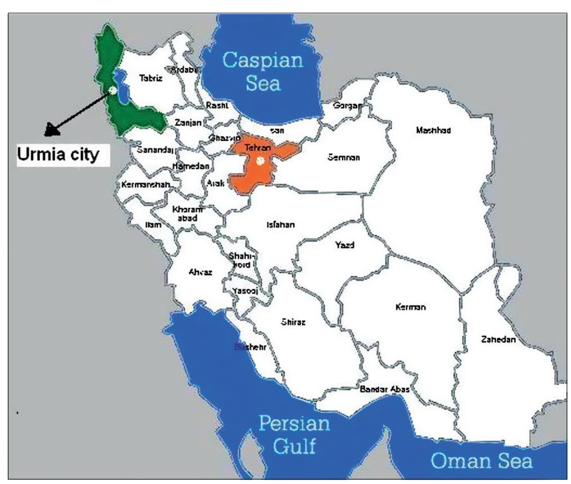

Figure 1: Map of the study area

Table 1: Composition of daily municipal solid waste in Urmia city

Component	Wet weight (ton/day)	Weight percent
Food waste	275.68	68.92
Plastic	28.4	7.1
Paper and cardboard	22.72	5.68
Yard waste	20.44	5.11
Textile	6.2	1.55
Glass	5.04	1.26
Metals	5.12	1.28
Others	36.4	9.1
Total	400	100

Table 2: Organic fractions of the solid waste

Component	Wet percent	Ash percent
Food waste	54.3	10.4
Plastic	4.05	8
Paper and Cardboard	10	7.7
Yard waste	6.18	16
Textile	3.5	5

Table 3: Molar mass organic fractions of the solid waste (g)

Component	C	H	O	N	S
Food waste	18.8	2.5	14.7	1.02	0.15
Plastic	4.08	0.4	1.5	0	0
Paper and cardboard	2.2	0.3	2.2	0.01	0.01
Yard waste	2.2	0.2	1.8	0.16	0.01
Textile	0.8	0.09	0.4	0.06	0.002

Table 4: Molar mass of the SW organic fractions

Organic fractions	C	H	O	N	S
Molar Mass, g/mol	1.97	3	1.09	0.07	0.004

Table 5: Chemical formula for organic fractions of the solid waste

C	H	O	N	S
27.7	43.1	15.3	1	0.06

Table 6: Chemical Formula for biodegradable organic fractions of the solid waste for methane gas production

C	H	O	N	S
23.63	37.52	14.65	1	0.069

Methane production ($C_{23.63}H_{37.52}O_{14.65}N_1S_{0.069}$), 151 g

Table 7: Heat value for methane production and organic composition for 1 Kg SW

Heat value (Kj/Kg) for organic composition SW as per the Dolang formula: Btu/lb = 145C + 610(H-1/8O) + 10N + 40S	Heat value (Kj/Kg) for methane production of biodegradable SW
$C_{27.7}H_{43.1}O_{15.3}N_1S_{0,065}$	$C_{23.63}H_{37.52}O_{14.65}N_1S_{0.069}$
21885.614 Kj/Kg	9992.15 Kj/Kg

Urmia city and more than 2000 tons of SW/day in the total northwest of Iran, where the disposal method was dumping.[7]

Chemical composition

The chemical composition of biodegradable organic municipal SW in the northwest of Iran (Urmia city) is $C_{23.63}H_{37.52}O_{14.65}N_1S_{0.069}$. This formula indicates that methane production per each kilogram of wet SW will be 151 g, with a volume of 212 liters. Therefore, the total daily methane production is approximately 61 tons per 400 tons of SW/day in Urmia city [Table 1].

Heat value

Considering the heat value of methane, which is 5×10^4 Kj/Kg, the heat value of methane produced due to SW in this study will be 3×10^9 Kj. The result of a study on SW in Tehran (Iran's capital) shows that 1 Kg of decomposed wet SW in Tehran produces 102 g CH_4 and 253 g CO_2, and it will be 345 g CH_4/Kg dried SW.[8] Different amounts of methane production may be due to the high percentage of spoilage compounds. In the study, the biogas production rate of SW in the north of Iran (Mazandaran) is in the range of 0.21 to 0.61 m^3/Kg of biodegradable SW, and may be used to generate electricity.[9] The result of this study confirms our findings. In our study, the heat value of methane produced from biodegradation fraction waste ($C_{23.63}H_{37.52}O_{14.65}N_1S_{0.069}$) is about 9992 Kj/Kg and the heat value for the organic component of waste ($C_{27.7}H_{43.1}O_{15.3}N_1S_{0,065}$) is about 22 Mj/Kg. This reason for this high energetic value in Urmia is because of more than 80% food waste, plastic, and paper. The heat values are 10.47 MJ/kg in the US and 12.48 MJ/kg in Europe. It is reported to be between 5.82 and 9.12 MJ/kg in Brazil.[10] However, a review study shows that recovery of the produced biogas from SW biodegradation is preferred rather than heat recovery from SW incineration, due to the generation of low levels of greenhouse gases.[11] Incineration will generate more than 300 tons/day of greenhouse and poison gases, but landfilling produces less than 200 tons/day of different gases.

Effect of kinetic on biogas production of solid waste

A survey on the kinetic production of methane and aerobic degradation or composting of biodegradable SW in Italy (Genoa University) showed that the degree of reaction kinetics was of the first order and the operation could be easily possible.[12] Another research indicated that the produced compost from food residue and yard waste in Greece was rapidly biodegradable and contained 70 to 80% organic carbon, with a high potential to produce energy. The results revealed that the kinetics of these reactions followed the Monod equation.[13] In another study that was carried out in Greece, it was recommended that rapidly biodegradable SW be used with wastewater bio solids for biogas production.[14]

Effect of solid waste disposal in landfill

The greatest problem related to Iran's SW disposal is pollution in the environment. When the SW is transferred to the landfill and buried, due to chemical and biological reactions, gas production will start and should be collected and consumed for energy production. These gases include carbon dioxide, ammonium, carbon monoxide, hydrogen, hydrogen sulfide, methane, nitrogen, and oxygen. Methane and carbon dioxide constitute the main gases that result from the anaerobic decomposition of organic biodegradable compounds, which form more than 90% volume of the production gases.[2] If the concentration of methane in the air reaches between 5 and 15 volume percent, an explosion may occur. However, methane will not explode in the SW layers, due to the absence of oxygen. Thus methane must be vacated into the atmosphere under controlled conditions, if not; it may be accumulated under buildings or other barred spaces that are located near or on the landfill. Carbon dioxide is about 1.5 times as dense as air and 2.8 times as dense as methane, thus, it tends to move toward the bottom of the landfill.[15] The carbon dioxide gas penetrates through the underside layers into the ground water and dissolves in it, producing hard water.

CONCLUSION

It is concluded that the chemical composition of municipal SW achieved in this study area, $C_{27.7}H_{43.1}O_{15.3}N_1S_{0,065}$, confirms a high potential of the SW to methane production. Although, the recovery of energy from SW through incineration is a better choice, due to the high heat value, it will produce more than 300 tons/day of greenhouse and poison gases, but landfilling produces 200 tons/day of different gases. Therefore, because the methane production process is a first order reaction, it needs less time than other processes, such as composting, to produce energy. In addition, biogas production has lesser harmful effects on the environment and has more economical benefits. Thus, on the basis of calculated SW composition and a health perspective in this research, it seems that energy recovery through methane collection is a better option for this study area. Furthermore, the authors have suggested an economic evaluation in the next research.

ACKNOWLEDGMENT

The authors wish to acknowledge the financial support provided by the School of Health in Urmia University of Medical Sciences.

REFERENCES

1. Alavi Moghadam MR, Mokhtarani N, Mokhtarani B. Municipal solid waste management in Rasht City, Iran. Waste Manag 2009;29:485-9.
2. Omrani GA. Solid waste-management collection, transportation, sanitary landfill and composting. Iran: Scientific center of Islamic Azad University; 1994.
3. Abduli M, Samieifard R, Zade M. Rural solid waste management. Int J Environ Res 2008;2:425-30.
4. Damghani AM, Savarypour G, Zand E, Deihimfard R. Municipal solid waste management in Tehran: Current practices, opportunities and challenges. Waste Manag 2008;28:929-34.
5. ASTM. Standard test Method for Determination of the Composition of Unprocessed Municipal Solid Waste. test Method D5231 and D2974-87, 1992.
6. Tchobanoglous G, Theisen H, Vigil SA. Integrated solid waste management: Engineering principles and management issues. New York: McGraw-Hill; 1993.
7. Ghanbari R. Evaluation of solid waste recycling in Urmia city. Report of municipality in Urmia city, 2003.
8. Islamineghad P, Shayegan J. The potential recovery of energy from biodegradable solid waste in Tehran. Fifth National Conference on Iran's energy of committee; Tehran - Iran's National Committee for Energy, Electricity and Energy Ministry of Energy Affairs, 2006.
9. Karbassi A, Baghvnd A. Usage of biogas energy in municipal solid waste as alternative fuel. The third National Conference on Waste Management; Tehran - the country's municipalities organization, environmenal protection agency, 2007.
10. Leão AL, Tan IH. Potential of municipal solid waste (MSW) as a source of energy in São Paulo: Its impact on CO_2 balance. Biomass Bioenergy. 1998;14:83-9.
11. Karimi F, Haratyan M. Technologies used for biogas production in municipal solid waste basin. Fifth National Conference on Iran's energy of committee; Tehran - Iran's National Committee for Energy, Electricity and Energy Ministry of Energy Affairs, 2006.
12. Converti A, Rezzani LG, Del Borghi M. Kinetic study on methane fermentation of pre-hydrolyzed lignocellulosics. J Air Waste Manag Assoc 1998;48:366-70.
13. Komilis DP. A kinetic analysis of solid waste composting at optimal conditions. Waste Manag 2006;26:82-91.
14. Ledakowicz S, Stolarek P. Kinetics of biomass thermal decomposition. The 29th International Conference of the Slovak Society of Chemical Engineering; Slovak Academy of Sciences, 2003.
15. Salvato JA, Nemerow NL, Agardy FJ. Environmental engineering. United States: John Wiley and Sons Inc; 2003.

How to cite this article: ???

Source of Support: School of Health in Urmia University of Medical Sciences, **Conflict of Interest:** None declared.