Modeling Greenhouse Gases Emissions from MSW of Lahore

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Abstract-In this study, an attempt is made to evaluate the characteristics of MSW generated from the Ravi Town, Lahore and assess the level of greenhouse gases (GHG) emissions along with the associated global warming potential (GWP), from the collection and landfilling operations of the waste. The MSW of the Ravi Town mainly consists of kitchen waste, covering 29.19% during Season 1 (late summer) and 59.66% during Season 2 (winter). Among the GHG, a total 40,947,871.866 kg of CO_2, 9,855,720.054 kg of CH_4, and 269.320 kg of N_20 is released into environment with a combine GWP of 248,001,482.237 kg for MSWM of Ravi Town. As MSW contains 56% biomass in Season 1 and 60% in Season 2 so the significant global warming potential can be reduced through integration of bio-gasification. This would not only reduce substantial greenhouse gases emissions but also produces energy and compost, a suitable soil conditioner with economic returns.

Keywords-Municipal Solid Waste, IWM-2 Model, Greenhouse Gases, Bio-Gasification

I. INTRODUCTION

In the recent years, a significant increase in the solid waste generation has been occurred in the less developed countries due to population explosion, rapid urbanization, change in lifestyle and standards of living [i]. At the same time, the proper management of municipal solid waste (MSW) is highly neglected in this part of the world [ii]. The poor management of MSW causes a significant emission of greenhouse gases (GHG), globally it accounts 5% of the total GHG emissions [iii]. The GHG in the atmosphere traps the heat, leading to global warming and climate change [iv]. Therefore, the waste management shall not only consider the safe treatment and disposal of MSW but also the proper management of GHG generation [v].

In Pakistan, the sixth most populated country of the world with 35% urban population, 55,000 tons of MSW is generated each day in the urban areas [vi]. As mentioned by [vii], the city of Lahore with population 8 million generates 5000 tons MSW per day. The management of MSW in Lahore only comprises of collection of the waste and its open dumping at designated sites. Moreover, the amount of waste being produced in the cities is beyond the capability of the municipal authorities due to lack of the organizational framework, budget and multi-dimensional and the complicated system [vi]. To overcome these issues, an integrated waste management model is needed. Life Cycle Assessment (LCA) is an efficient environmental management tool that is used to consider the whole waste management systems to predict their probable environmental burdens [viii].

The present study focuses on the chemical and physical characterization of the MSW being generated in Ravi Town, Lahore and the quantification of associated air emissions and level of GHG contribution along with the subsequent global warming potential (GWP) using IWM-2 Model.

II. MATERIALS AND METHODS

A. Sampling & Data Collection

Samples were collected from waste collection vehicles of each union council of the Ravi Town, Lahore. Sample collection was carried out in accordance to ASTM - D5231-92 standard during October, 2012 Late Summer (Season 1) and December, 2012 Winter (Season 2).

B. Physical Characterization of Municipal Solid Waste

The physical characterization of the MSW into kitchen waste, paper, plastic, metals, glass, wood and textile was conducted in the solid waste laboratory of the College of Earth and Environmental Sciences, University of the Punjab, Lahore.

C. Characterization of Municipal Solid Waste

1) Proximate Analysis

The proximate analysis, involving the determination of moisture content, volatile matter, and ash content was carried out in accordance to ASTM D 3173-11, ASTM D3175-11 and ASTM D3174-11 respectively.

2) UltimateAnalysis

The ultimate analysis to determine the percentage of carbon, hydrogen, nitrogen, oxygen and sulphur

contents in waste components was performed using formula [ix]. The results of the ultimate analysis were used to characterize the chemical composition of the municipal solid waste.

3) Energy Content

The gross calorific value of each component of the waste was calculated in accordance to ASTM D5468-02 using LECO AC 500 Auto Bomb Calorimeter.

D. Estimation of Air Emissions and Global Warming Potential

The estimation of gaseous emissions and global warming potential associated with the greenhouse gases emitted from the waste management system were calculated using IWM-2: A Life Cycle Inventory Model for Integrated Waste Management.

E. Statistical Analyses

The Statistical Package for Social Sciences (SPSS) 16.0 was used for the data analyses.

III. Results and Discussion

The main component of MSW of the Ravi Town during Season 1 and Season 2 was kitchen waste, i.e. 29.19% and 59.66% respectively (Table I).

TABLE I
PHYSICAL COMPOSITION OF MSW OF THE RAVI TOWN DURING SEASON 1 AND SEASON 2

Waste Component	Composition (%)	
	Season 1	Season 2
Kitchen Waste	29.19	59.66
Metals	1.17	0
Glass	0.44	0
Paper	1.99	8.76944
Textile	4.03	10.85754
Plastic	21.11	10.63164
Wood	15.42	10.08138
Animal Waste	26.61	0
Total	100	100

A similar finding for waste composition was reported by [x] for Lahore waste. This high organic fraction in the waste is due to lifestyle of the local households. The physical composition of the waste is the major factor that governs the greenhouse gases generation during the waste management [xi]. A significant level of methane could be generated by anaerobic decomposition of this organic fraction of waste at dumpsites/ uncontrolled landfill sites. Furthermore, this substantial organic portion of the waste may possesses threat to human health as it will attract rodents and other disease vectors to the collection and dumping sites [xii]. Table I shows the detail physical composition of MSW of the Ravi Town.

TABLE II
WEIGHT CONTRIBUTION OF EACH ELEMENT IN THE SOLID WASTE OF RAVI TOWN DURING SEASON 1 AND SEASON 2

Element	Atomic weight	Season 1	Season 2
		Weight (g)	Weight (g)
C	12	217.52	187.59
S	32	1.778	1.343
H	1	31.72	29.13
N	14	6.611	7.11
O	16	341.76	274.82

Approximate Chemical formula obtained from the calculation in Table II for Season 1 is $C_{18}H_{31}NS0_{21}$ and for Season 2 is $C_{15}H_{29}NS0_{17}$ [ix]. The moisture content, volatile combustible matter, fixed carbon and ash content of the MSW of the Ravi Town is shown in Table III.

The gross calorific value (Kcal/ kg) for MSW of the Ravi Town during Season 1 and Season 2 was determined Table IV. The highest calorific value was noted for plastic and lowest for textile fraction of the waste during both Season 1 and Season 2. During Season 2, the gross calorific value was relative more in the waste fraction of kitchen waste, plastic, textile and paper while the wood has lower calorific value as compared to the Season 1.

TABLE III
MOISTURE CONTENT (MC %), VOLATILE COMBUSTIBLE MATTER (VCM %), FIXED CARBON (FC %) AND ASH CONTENT (%) OF MSW OF THE RAVI TOWN DURING SEASON 1 AND SEASON 2

Component	MC (%)		VCM (%)		FC (%)		Ash Content (%)	
	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2
Kitchen Waste	80.22	70.37	24.8	5.32	10.55	31.24	28.55	13.22
Paper	10.82	45.56	13.42	18.55	20.78	21.35	4.65	19.5
Textile	7.91	4.5	31.22	39.41	3.43	5.11	4.56	15.75
Plastic	7.3	1.7	12	35.31	21.68	9.43	22.87	16.33
Wood	8.3	0.9	16.33	3.44	27.15	34.78	2.51	37.43
Animal Waste	86.45	0	14.66	0	9.21	0	40.4	0

In present study, the MSW is disposed off in low lying outskirt area of the city, i.e. Saggian dump site without any landfill gas collection system, landfill gas monitoring system, leachate collection system, base liner, compaction, and covering of wastes. Therefore, the air pollutants are directly released into environment. Similarly, no proper air emission management strategies have been opted to prevent the release of gases during the collection of MSW of Ravi Town. Consequently, the air pollution has turn out to be a major threat to human health and environment [xiii].

TABLE IV
GROSS CALORIFIC VALUES (KCAL/ KG) FOR MSW OF THE RAVI TOWN DURING SEASON 1 AND SEASON 2

Component	Season 1	Season 2
Kitchen Waste	3285	3756
Paper	3462	3617
Textile	2865	3256
Plastic	6021	6229
Wood	3687	3546
Animal Waste	3564	0

Air emissions results indicates that the biggest air pollutant being emitted from MSW management of the Ravi Town waste is CO_2 Table V. The extent of remaining air pollutants being emitted from MSW collection and disposal at dump site are represented in Table V.

TABLE V
AIR EMISSIONS ASSOCIATED WITH MSW MANAGEMENT OF THE RAVI TOWN

Emission Parameter	Units	Collection	Landfill	Total
Particulates	Kg	20,300.122	Zero	20,300.122
CO	Kg	3,610.061	311.960	3,922.020
CO_2	kg	18,887,829.740	22,060,042.126	40,947,871.866
CH_4	kg	51,201.427	9,804,518.626	9,855,720.054
NOx	kg	44,972.033	Zero	44,972.033
N_2O	kg	269.320	Zero	269.320
SOx	kg	139,653.253	Zero	139,653.253
HCl	kg	2,900.168	1,622.190	4,522.358
HF	kg	306.365	324.438	630.804
H_2S	kg	Zero	4,991.355	4,991.355
Total HC	kg	Zero	49,913.550	49,913.550
Chlorinated HC	kg	1	873.487	873.488
Ammonia	kg	61.858	Zero	61.858
Cadmium	kg	0.698	0.140	0.838
Lead	kg	7.344	0.127	7.471
Manganese	kg	2.749	Zero	2.749
Mercury	kg	0.393	0.01	0.403
Nickel	kg	53.662	Zero	53.662
Zinc	kg	7.408	1.872	9.28

In terms of magnitude, among the greenhouse gases calculated for the MSW of Ravi Town, the carbon dioxide (CO_2) is the principle greenhouse gas released into environment Table VI. In total 40,947,871.866 kg of CO_2 is being emitted into air through collection and landfilling of MSW of the Ravi Town. The second biggest greenhouse gas released is methane (CH_4) with combine 9,855,720.054 kg emission from collection and landfill activities. The nitrous oxide (N_2O) emission is lowest with 269.320 kg being released during collection process and no N_2O emission is associated with landfill. The EPA, 2002 and IPCC, 2006 reported insignificant N_2O emission at the landfill so its contribution in landfill greenhouse gases studies was also discounted [xi].

TABLE VI
GREENHOUSE GASES EMISSIONS AND ASSOCIATED GLOBAL WARMING POTENTIAL OF MSW OF THE RAVI TOWN

	Units	Collection	Landfill	Total
CO_2	Kg	18,887,829.740	22,060,042.126	40,947,871.866
CH_4	Kg	51,201.427	9,804,518.626	9,855,720.054
N_2O	kg	269.320	Zero	269.320
GWP	kg	20,046,548.955	227,954,933.282	248,001,482.237

The CH_4 has the global warming potential (GWP) of 25 [xiv]. Therefore, despite of relative lower CH_4 emission, the global warming contribution of CH_4 is greater than that of CO_2. Similarly, the GWP of N_2O is 298 [xiv] that manifold amplifies the N_2O contribution in global warming. The total GWP calculated for this study is 248,001,482.237 kg, 20,046,548.955 kg associated with collection of MSW of Ravi Town and 227,954,933.282 kg associated with landfill activities.

This significant contribution in global warming by MSW management strategies in Ravi Town, Lahore may be reduced through biogasification [vii]. Almost 56% biomass in Season 1 and 60% in Season 2 can undergo effective biogasification. This would not only reduce greenhouse gases emissions but also produces energy and compost, a suitable soil conditioner with economic returns [xv].

IV. CONCLUSIONS

Significant GHG emissions are associated with the collection and disposal of MSW of Ravi Town at Saggian dump site. Presently, a total 40,947,871.866 kg of CO_2, 9,855,720.054 kg of CH_4, and 269.320 kg of N_20 is released into environment with a combine GWP of 248,001,482.237 kg for MSWM of Ravi Town. As MSW contains 56% biomass in Season 1 and 60% in Season 2 that favors the effective biogasification of the MSW that would subsequently reduce the global warming potential. Furthermore, along with reduction

of substantial greenhouse gases emissions the production energy and compost would also assist the MSWM with economic returns.

REFERENCES

[i] W. Zhao, E. V. D. Voet, Y. Zhang and G. Huppes, "Life cycle assessment of the municipal solid waste management with regard to greenhouse gases emissions: Case study of Tianjin, China," *Sci. Total Environ.,* vol. 407, pp. 1517-1526, 2009.

[ii] G. Murtaza and A. Rahman, "Solid waste management in Khulana city and a case study of a CBO: Amader Paribartan," in *Community based solid waste management: The Asian experience*. Dhaka, Bangladesh: Waste Concern, 2000.

[iii] R. Mahmoudkhani, B. Valizadeh and H. Khastoo. "Greenhouse gases life cycle assessment (GHGLCA) as a decision support tool for municipal solid waste management in Iran," *J. Environ. Health Sci. Eng.,* vol. 12, p.71, 2014.

[iv] H. Jicong, X. Yanhua, W. Fengde and D. Renjie, "Greenhouse gas emissions from livestock waste; China evaluation," *Int. Congr. Ser.,* vol. 1293, pp. 29-32, 2006.

[v] S. Seo, T. Aramaki, Y. Hwang and K. Hanaki, "Environmental impact of solid waste treatment methods in Korea," *J. Environ. Eng.,* vol. 130, pp. 81-89, 2004.

[vi] JICA (Japan International Cooperation Agency) and Pak-EPA (Pakistan Environmental Protection Agency), *"Guidelines for solid waste management,"* Pakistan: Pak-EPA, 2005.

[vii] S. A. Batool and M. N. Chuadhry, "The impact of municipal solid waste treatment methods on greenhouse gas emissions in Lahore, Pakistan," *Waste Manage.*, vol. 29, pp. 63-69, 2009.

[viii] F. McDougall, P. White, M. Franke and P. Hindle, *"Integrated solid waste management: A life cycle inventory,"* London: Blackwell Science Ltd., 2003.

[ix] G. Techobanoglous, H. Theisen and R. Eliassen, *"Solid waste: engineering principles and management issues,"* New York: Mc Graw-Hill, 1977.

[x] S. A. Batool and M. N. Ch, "Municipal solid waste management in Lahore City District, Pakistan," *Waste Manage.,* vol. 29, pp. 1971-1981, 2009.

[xi] T. C. Chen and C. F. Lin, "Greenhouse gases emissions from waste management practices using Life Cycle Inventory model," *J. Hazard. Mater.*, vol. 155, pp. 23-31, 2008.

[xii] S. K. Gupta, R. Mohan, S. Prasad, S. Gupta and A. Kansal, "Solid waste management in India: options and opportunities," *Resour. Conserv. Recy.,* vol. 24, pp. 137-154, 1998.

[xiii] B. A. Lingan, G. Poyyamoli and U. J. C. Boss, "Assessment of air pollution and its impacts near municipal solid waste dumping site Kammiyampet, Cuddalore, India," *Int. J. Innov. Res. Sci. Eng. Technol.*, vol. 3, pp. 12588-12593, 2014.

[xiv] P. Forster, V. Ramaswamy, P. Artaxo, T. Berntsen, R. Betts, D. W. Fahey, J. Haywood, J. Lean, D.C. Lowe, G. Myhre, J. Nganga, R. Prinn, G. Raga, M. Schulz and V. D. Robert, "Changes in atmospheric constituents and in radiative forcing," in *Climate change 2007: The physical science basis. Contribution of working group i to the fourth assessment report of the intergovernmental panel on climate change* (Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor, H. L. Miller). Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press, 2007.

[xv] S. E. Mbuligwe and G. R. Kassenga, "Feasibility and strategies for anaerobic digestion of solid waste for energy production in Dar es Salaam city, Tanzania," *Resour. Conserv. Recy.,* vol. 42, pp. 183-203, 2004.