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Assessment of approximate chemical formula and energy content by Modified Dulong formula of municipal solid waste of Allahabad city

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ABSTRACT

Due to the liberalization of the Indian economics since 1991, a huge growth has been taken place in the all the sectors of the economics especially in industrial sector and tertiary sector. Due to this the purchasing power of the common people has increased many folds which resulted in the higher purchasing of the consumer products and improvement of the life style of the people. But this improvement or development has resulted in the generation of huge amount of the municipal solid waste because consumer products are packaged as well as the products are of use and throw type. So there is a great burden on the municipal corporations of different cities to handle and manage this huge amount of municipal solid waste. Different steps for waste management include collection, transportation, storage, processing, energy recovery and disposal. Energy recovery is a very useful method as this reduces the waste as well as provides useful energy as our cities are facing the problem of energy scarcity. Assessment of the energy recovery from the waste is a primary step for the initiation of the energy recovery program because it is very necessary to assess that whether the energy recovery is cost effective or not. The methods of energy recovery are incineration, gasification and biomethanation etc. Modified Dulong formula is a very effective method for the assessment of the energy content of any material, so we can use it for the exploration of the energy content of the municipal solid waste.

KEYWORDS: Municipal solid waste, Energy Content, Modified Dulong formula, Approximate chemical formula

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1. INTRODUCTION:

As mentioned in Municipal solid waste (management and handling rule) 2013 in India municipal solid waste includes the commercial and residential waste generated in municipal or notified areas in either solid or semi-solid form excluding industrial hazardous waste; e-waste and including treated bio-medical waste. Solid waste is waste comes from anthropogenic and livestock activities which are discarded as useless or unwanted material[1]. The German Waste Act (1972) defined waste as ‘‘portable objects that have been abandoned by their owner(s)’’ or ‘‘requiring orderly disposal to protect the public welfare’’[2]. The USA defined waste in the Resource Conservation and Recovery Act (1976), as ‘‘any garbage, refuse, sludge from a waste treatment plant, water supply treatment plant, or air pollution control facility and other discarded material, including solid, liquid, semisolid or contained gaseous material resulting from industrial, commercial, mining, and agricultural operations, and from community activities’’. There are several categories of MSW such as food, rubbish, commercial, institutional, street sweeping, industrial, construction and demolition and sanitation waste etc. MSW contains recyclables (paper, plastic, glass, metals, etc.), toxic substances (paints, pesticides, used batteries, medicines), compostable organic matter (fruit and vegetable peels, food waste) and soiled waste (blood stained cotton, sanitary napkins, disposable syringes[3-4]. Increasing waste generation rates due to population growth, changing lifestyles of people, development and consumption of products with materials that are less biodegradable have led to the diverse challenges for municipal solid waste management in various cities of the world. Distinct differences have been identified in literature between municipal solid waste management in developed and developing countries. The current focus is on optimization of waste management practices with a broader goal of resource conservation. To incorporate a long-term, viable, solid waste management system into a societal context requires that all of the elements in the waste management hierarchy be addressed in an integrated approach. The system needs to be one that is market oriented, has the benefit of the economy of scale and is socially acceptable[5-6]. The Indian urban population is increasing rapidly in magnitude and density due to reasons such as the heavy concentration of industries in urban areas. Consequently the civic bodies face considerable difficulties in providing adequate services such as supply of electricity and water, roads, education and public sanitation, including collection and removal of solid waste[7].

From the study of CPCB[8] on status of solid waste generation, collection, treatment and disposal in metro cities; it is observed that the differences in the MSW characteristics indicate the effect of urbanization and development. In urban areas, the major fraction of MSW is compostable materials (40–60%) and inert (30–50%). Rural households generate more organic waste than urban households. For example, in south India the extensive use of banana leaves and stems in various functions results in a large organic content in the MSW. It has been seen that the percentage of recyclables is very low, because of rag pickers. Rag pickers collect and segregate the materials at waste generation sources, points of collection and site of disposal MSWM is one of the major environmental problems of Indian megacities. It involves activities associated with generation, storage, collection, transfer and transport, processing and disposal of solid wastes. But, in most cities, the MSWM system comprises only four activities, i.e., waste generation, collection, transportation, and disposal[9].

NEERI studied the common physical composition of MSW in Indian cities on population basis in 1995 and found that 30.84% to 56.57% of MSW is the compostable waste[10]. MSW per capita generation and collection efficiency standby were conducted in some Indian states by Nema[11] and reported the maximum generation is 516 gm/cap/day in Rajasthan and minimum were found in west Bengal (158 gm/cap/day). The maximum collection efficiency was observed in Haryana (82%) and Kerala (82%) and minimum were observed in Bihar. Integrated waste management has been accepted as a sustainable approach to solid waste management in any region. It can be applied in both developed and developing countries. The difference is the approach taken to develop the integrated waste management system[12]. The objectives of MSWM have evolved from the primary concerns of environmental health protection to considering human safety, resource conservation and the reduction of, as much as possible, the environmental burdens of waste management (energy consumption, pollution of air, land and water and loss of amenity)[13]. MSWM in most developing countries is often characterized by inadequate service coverage, operational inefficiencies of services, limited utilization of recycling activities, inadequate management of non-industrial hazardous waste and inadequate landfill disposal[14]. Many researchers have reported that the MSW generation rates in small towns are lower than those of metro cities, and the per capita generation rate of MSW in India ranges from 0.2 to 0.5 kg/ day. It is also estimated that the total MSW generated by 217 million people living in urban areas was 23.86 million tonnes/yr in 1991 and more than 39 million tonnes in 2000[15-23].

2. MATERIALS AND METHODS:

2.1. Study area:

The geographical extension of Allahabad city falls from 25°27′ N to 25.45° N and 81°51′ E to 81.85° E. The geographical area of the city is about 62 square km. Census data of 2011 states Allahabad city as the 32nd most populous city in India. The population of the city is 975000. The city has poor sex ratio at 807 females per 1000 males. The male and female population of the city is 539,772 and 435,621. About 10% population falls between 0-6 years. The literacy rate of the city was 81% which is better than many other cities of U.P. the population growth rate of the city is 23%.

About 30% population of the city lives in the slums which can be categorised as urban poor category[24].

2.2. Collection of data:

Data was collected from primary and secondary sources. In the first phase of the study, sampling sites have been chosen in a way so that the data obtained may represent the composition of the municipal solid waste of the whole city. Four sites have been chosen for this research purpose namely Kareli (KA), Daragnaj (DA), Bakshi Bandh (BB) and Jhunsi (JH). Samples of MSW from different sites were collected every month from January 2011 to December 2013 to determine its composition. The sampling and analysis of MSW were carried out as per standard procedures described by Peavy et al[25] 100 k.g. of Samples were collected from all the four sites including Kareli, Daragnaj, Bakshi Bandh and Jhunsi per month and analysed for its moisture content and the percentage weight of different chosen components (CO) which were paper (PA), plastic (PL), glass (GL), metal (ME), cloth (CL), biodegradable (BD), inert (IN) and others (OT) waste. Inert waste included crockery, dirt and ash types of material. Other types of waste were those which are difficult to categorize into a particular category of waste like leather, rubber, thermo coal, foam etc. Moisture (MO) content of solid wastes is usually expressed as the weight of moisture per unit weight of wet material. Estimation of the moisture was very necessary as the moisture determines the characteristics of the municipal solid waste, moisture plays an important role in the weight of the solid waste as well as moisture determines the energy content of the municipal solid waste. Estimation of the moisture content was done through the help of procedure given in the Tchobanoglous et al[26]. The typical moisture content of the different components of waste is given in table: 1. These typical values have been taken as the standard values of the moisture content of the different components during study. During sampling 100 k.g. of waste was collected from the sites. Waste is weighted by the general spring balance. Waste material was collected from corners and the middle of the sampling sites. Collected waste was mixed thoroughly so that all the points of sample become homogeneous and all the parts of sample give similar characteristics. Now different components of municipal solid waste have been sorted out by hand like paper, plastic, metal, glass, biodegradable, inert and other wastes. Different components were filled in different polythene bags and tagged. Now every polythene bag was weighted and data was recorded. The average total waste generated per day in a year was obtained from the Allahabad Municipal Corporation[27] which was 524 ton in 2011, 541 ton in 2012 and 562 ton in 2013. For the energy recovery point of view the percent weight of the inert and other waste has not assessed because their percentage was very low. Only combustible wastes have been taken for the investigation of the energy recovery by modified Dulong formula[28] which includes paper, plastic, cloth and biodegradable waste. There are many steps for the assessment of the energy recovery which are following:

1. Assessment of the weight of the elements (C, H, O, N, S and Ash) in the dry mass of the waste components (Table 3,4,5,6,7) with the help of typical percent values of these elements (Table 2) and typical percent value of moisture and ash in different components in municipal solid waste (Table 1)
2. Preparation of summary table of the weight of the moisture (weight – dry mass) and elements (C, H, O, N, S and Ash) (Table 8).
3. Dividing the moisture into Hydrogen and Oxygen (Table 9).
4. Revised summary table of the weight of the moisture and elements (C, H, O, N, S and Ash) dividing the moisture into Hydrogen and Oxygen and calculation of the percentage of elements (Table 10).
5. Calculation of moles of the elements according to their weight (Table 11 and Table 12).
6. Preparation of approximate chemical formula of the sampled municipal waste (Table 13).
7. Calculation of the approximate energy content of the waste by the use of Modified Dulong formula (Table 14).
8. [Energy (Kj/Kg) = 337C + 1428 {H - (O/8)} + 95S] where C, H, O and S are the percent of mass of Carbon, Hydrogen, Oxygen and Sulfur.
9. Total energy (Kj/day) = (Energy content by modified Dulong formula) X (Total weight in a day) (Table 14)
10. Total energy (Gj/day) = Total energy (Kj/day) / 10^6 (Table 14)
11. Total energy (Mwh) = Total energy (Gj/day) X 0.278 (Table 14)

3. RESULT AND DISCUSSION:

All the data collected and results have been arranged in the form of tables. Several mathematical operations have been performed on the basis of the formulas given above to calculate the energy content and approximate chemical formula of the municipal solid waste of Allahabad city. In these tables abbreviations for different months has been used which are JA, F, M, A, MY, J, JU, AU, S, O, N and D for months of January, February, March, April, may, June, July, August, September, October, November and December respectfully. Abbreviation AVG has been used for the average of percent values of components.

Table 1: Typical data of moisture content of municipal solid waste components[25]

S. No.	Components	Moisture (%)	Ash (%)
1.	Food waste	70	5
2.	Paper	6	6
3.	Cardboard	5	5
4.	Plastic	2	10
5.	Textile	10	2.5
6.	Rubber	2	10
7.	Leather	10	10
8.	Garden trimmings	60	4.5
9.	Wood	20	1.5
10	Miscellaneous organics	25	5
11.	Glass	2	0
12.	Tin cans	3	0
13.	Nonferrous metal	2	0
14.	Ferrous metal	3	0

Table 2: Typical percent values of elements in different municipal waste components[25]

S. No.	Component	C	H	O	N	S	Ash
1.	Food waste	48	6.4	37.6	2.6	0.4	5
2.	Paper	43.5	6	44	0.3	0.2	6
3.	Cardboard	44	5.9	44.6	0.3	0.2	5
4.	Plastic	60	7.2	22.8	-	-	10
5.	Textile	55	6.6	31.2	4.6	0.15	2.5
6.	Rubber	78	10	-	2	-	10
7.	Leather	60	8	11.6	10	0.4	10
8.	Garden Trimmings	47.8	6	38	3.4	0.3	4.5
9.	Wood	49.5	6	42.7	0.2	0.1	1.5
10.	Misc. organics	48.5	6.5	37.5	2.2	0.3	5
11.	Dirt, ashes bricks etc.	26.3	3	2	0.5	0.2	68

Table 3: Month wise variations among different components in study years

CO	YEAR	JA	F	M	A	MY	J	JU	AU	S	O	N	D	AVG
PA	2011	15.17	15.88	16.57	15.3	15.26	15.95	16.12	14.93	14.95	18.09	17.05	15.17	15.87
	2012	16.19	16.69	15.41	15.32	15.33	15.44	14.57	15.89	14.81	16.36	15.74	15.31	15.59
	2013	13.9	14.2	14.48	13.27	13.6	15.04	14.26	13.16	14.12	14.7	14.46	14.02	14.1
	AVG	15.09	15.59	15.49	14.63	14.73	15.48	14.98	14.66	14.63	16.38	15.75	14.83	15.19
PL	2011	16.92	16.9	17.36	18.25	17.49	17.64	18.75	16.7	16.98	16.65	17.64	16.23	17.29
	2012	14.64	14.37	15.67	16.86	15.9	16.34	15.79	14.63	15.4	16.08	15.26	15.65	15.55
	2013	21.33	20.27	21.88	20.88	21.47	19.83	22.57	21.92	22.07	22.94	21.76	21.16	21.51
	AVG	17.63	17.18	18.30	18.66	18.29	17.94	19.04	17.75	18.15	18.56	18.22	17.68	18.12
CL	2011	6.66	7.17	6.88	6.38	8.29	6.75	6.29	5.76	6.29	5.47	7.17	7.83	6.74
	2012	9.16	9.76	9.9	8.98	9.83	9.7	9.49	8.9	9.26	10.09	10.54	9.36	9.58
	2013	6.01	6.76	6.43	5.98	6.34	7.31	6.14	6.71	5.73	6.55	7.59	6.6	6.51
	AVG	7.28	7.90	7.74	7.11	8.15	7.92	7.31	7.12	7.09	7.37	8.43	7.93	7.61
GL	2011	7.96	8.13	8.62	8.04	7.1	7.05	7.42	8.31	8.41	7.84	7.84	8.94	7.97
	2012	5.87	6.86	6.28	6.02	6.49	6.29	6.67	6.72	6.87	7.44	6.31	7.65	6.62
	2013	6.85	6.3	5.83	6.53	6.41	5.5	5.6	6.06	6.16	5.69	5.88	6.19	6.08
	AVG	6.89	7.10	6.91	6.86	6.67	6.28	6.56	7.03	7.15	6.99	6.68	7.59	6.89
ME	2011	6.53	7.09	6.94	7.62	6.49	6.53	7.17	6.61	6.7	7.51	6.89	6.32	6.87

	2012	9.11	8.08	7.39	8.52	8.13	8.56	8.03	9.34	9.0	9.29	9.59	8.15	8.6
	2013	5.73	5.08	5.5	7.22	5.57	5.95	6.18	5.77	5.97	7.19	6.67	5.63	6.04
	AVG	7.12	6.75	6.61	7.79	6.73	7.01	7.13	7.24	7.22	8.00	7.72	6.70	7.17
BD	2011	43.53	41.96	40.77	41.68	42.92	42.92	41.48	45.02	43.79	41.43	40.84	42.89	42.44
	2012	41.68	41.19	42.37	41.32	41.21	40.77	42.36	41.61	41.43	38.13	39.64	41.21	41.08
	2013	42.28	43.17	42.11	41.99	42.3	42.38	41.94	42.52	42.02	39.35	40.28	42.29	41.89
	AVG	42.50	42.11	41.75	41.66	42.14	42.02	41.93	43.05	42.41	39.64	40.25	42.13	41.80
IN	2011	1.91	1.58	1.6	1.62	1.52	1.86	1.54	1.59	1.77	1.96	1.43	1.59	1.67
	2012	1.89	1.56	1.54	1.48	1.65	1.46	1.53	1.36	1.59	1.31	1.31	1.29	1.5
	2013	1.95	2.03	1.62	1.92	2.22	2.06	1.84	1.68	2.07	1.97	1.86	2.13	1.95
	AVG	1.92	1.72	1.59	1.67	1.80	1.79	1.64	1.54	1.81	1.75	1.53	1.67	1.71
OT	2011	1.33	1.3	1.26	1.11	0.94	1.32	1.24	1.1	1.11	1.06	1.16	1.05	1.17
	2012	1.48	1.49	1.46	1.49	1.47	1.46	1.56	1.55	1.64	1.3	1.62	1.39	1.49
	2013	1.95	2.19	1.65	2.22	2.11	1.95	1.73	2.18	1.87	1.62	1.52	1.98	1.92
	AVG	1.59	1.66	1.46	1.61	1.51	1.58	1.51	1.61	1.54	1.33	1.43	1.47	1.53
MO	2011	33.22	32.16	31.37	31.87	32.77	32.79	31.79	34.04	33.26	31.73	31.44	32.75	32.45
	2012	32.26	31.98	32.72	31.95	31.94	31.62	32.68	32.17	32.07	29.86	30.97	31.86	31.84
	2013	32.41	33.14	32.25	32.26	32.49	32.63	32.16	32.64	32.21	30.43	31.11	32.49	32.17
	AVG	32.63	32.43	32.11	32.03	32.40	32.35	32.21	32.95	32.51	30.67	31.17	32.37	32.15

Table 4: Summarized Table for the grand average of percent weights of all components for all the months for all the years

CO	JA	F	M	A	MY	J	JU	AU	S	O	N	D	AVG
PA	15.09	15.59	15.49	14.63	14.73	15.48	14.98	14.66	14.63	16.38	15.75	14.83	15.19
PL	17.63	17.18	18.3	18.66	18.29	17.94	19.04	17.75	18.15	18.56	18.22	17.68	18.12
CL	7.28	7.9	7.74	7.11	8.15	7.92	7.31	7.12	7.09	7.37	8.43	7.93	7.61
GL	6.89	7.1	6.91	6.86	6.67	6.28	6.56	7.03	7.15	6.99	6.68	7.59	6.89
ME	7.12	6.75	6.61	7.79	6.73	7.01	7.13	7.24	7.22	8.0	7.72	6.7	7.17
BD	42.5	42.11	41.75	41.66	42.14	42.02	41.93	43.05	42.41	39.64	40.25	42.13	41.80
IN	1.92	1.72	1.59	1.67	1.8	1.79	1.64	1.54	1.81	1.75	1.53	1.67	1.70
OT	1.59	1.66	1.46	1.61	1.51	1.58	1.51	1.61	1.54	1.33	1.43	1.47	1.53
MO	32.63	32.43	32.11	32.03	32.4	32.35	32.21	32.95	32.51	30.67	31.17	32.37	32.15

Table 5: Average of percent weight of components in different years at different sites

CO	KA				DA				BB				JH			
	2011	2012	2013	AVG	2011	2012	2013	AVG	2011	2012	2013	AVG	2011	2012	2013	AVG
PA	16.44	16.7	14.6	15.91	17.7	15.52	14.42	15.88	15.2	13.95	13.78	14.31	14.14	16.21	13.59	14.65
PL	18.18	15.38	20.92	18.16	15.54	19.2	21.34	18.69	17.49	12.73	21.59	17.27	17.95	14.88	22.17	18.33
CL	7.63	12.26	7.28	9.06	6.82	7.8	6.53	7.05	7.03	11.43	6.00	8.15	5.49	6.83	6.23	6.18
GL	8.89	5.82	6.36	7.02	7.27	6.46	5.35	6.36	8.46	8.52	6.12	7.70	7.27	5.69	6.5	6.49
ME	6.22	6.3	6.22	6.25	8.31	6.29	5.89	6.83	7.24	9.98	5.76	7.66	5.69	11.82	6.27	7.93
BD	40.13	40.71	41.44	40.76	41.61	41.56	41.99	41.72	41.68	40.37	42.14	41.40	46.32	41.66	41.98	43.32
IN	1.5	1.35	1.61	1.49	1.56	1.64	2.04	1.75	1.5	1.5	2.49	1.83	2.1	1.5	1.64	1.75
OT	1.02	1.5	1.57	1.36	1.19	1.53	2.37	1.70	1.41	1.52	2.09	1.67	1.05	1.42	1.63	1.37
MO	30.94	31.82	31.86	31.54	32	32.02	32.3	32.11	32	31.46	32.38	31.95	34.93	32.06	32.12	33.04

Table 6: Grand average weights (MT/Day) of the components in different years

Year	2011	2012	2013
Weight (MT/Day)	524	541	562
PA	83.15	84.39	79.24
PL	90.59	84.12	120.88
CL	35.31	51.82	36.58
GL	41.76	35.81	34.16
ME	35.99	46.52	33.94
BD	222.38	222.24	235.42
IN	8.75	8.11	10.95
OT	6.13	8.06	10.79
MO	170.14	172.25	180.79

Table 7: Average weight of the elements and ash in components of municipal waste per day

Year		2011					2012					2013				
Waste components		PA	PL	CL	BD	T	PA	PL	CL	BD	T	PA	PL	CL	BD	T
Weight		15.87	17.29	6.74	42.44	82.34	15.6	15.55	9.58	41.08	81.81	14.1	21.51	6.51	41.8	84.01
Dry weight		14.91	16.94	6.06	12.73	50.66	14.66	15.23	8.62	12.32	50.84	13.25	21.07	5.85	12.5	52.75
Weight of Elements	C	6.48	10.16	3.33	6.11	3.31	6.37	9.14	4.74	5.91	26.16	5.76	12.64	3.22	6.03	27.65
	H	0.89	1.21	0.4	0.81	17.09	0.87	1.09	0.56	0.78	3.3	0.79	1.51	0.38	0.80	3.50
	O	6.56	3.86	1.89	4.78	0.64	6.45	3.47	2.69	4.63	17.24	5.83	4.8	1.82	4.72	17.17
	N	0.04	-	0.27	0.33	0.07	0.04	-	0.39	0.32	0.75	0.03	-	0.26	0.32	0.62
	S	0.02	-	0.00	0.05	3.37	0.02	-	0.01	0.04	0.07	0.02	-	0.00	0.05	0.08
Ash		0.89	1.69	0.15	0.63	3.31	0.936	1.55	0.23	2.054	4.78	0.84	2.15	0.16	2.09	5.25

Table 8: Summary table

S. No.	Elements	Weight of the Elements and moisture in study years		
		2011	2012	2013
1	Moisture	31.68	30.96	31.26
2	C	26.08	26.16	27.65
3	H	3.31	3.3	3.50
4	O	17.09	17.24	17.17
5	N	0.64	0.75	0.62
6	S	0.07	0.07	0.08
7	Ash	3.37	4.78	5.25

Table 9: Conversion of moisture into Hydrogen and Oxygen

S. No.	Elements	2011	2012	2013
1.	H	3.52	3.44	3.47
2.	O	28.16	27.52	27.78

Table 10: Revised summary table

S. No.	Year	2011		2012		2013	
	Elements	Mass	Percentage by mass	Mass	Percentage by mass	Mass	Percentage by mass
1	C	26.08	31.70	26.16	31.51	27.66	32.54
2	H	6.83	8.30	6.74	8.12	6.98	8.21
3	O	45.25	55.04	44.76	53.92	44.96	52.90
4	N	0.64	0.77	0.75	0.90	0.63	0.74
5	S	0.079	0.096	0.07	0.084	0.08	0.10
6	Ash	3.37	4.09	4.78	5.75	5.25	6.18
7	Total	82.249	100.00	83.26	100.00	85.56	100.00

Table 11: Molar composition of the elements without ash

S. No.	Element	Year	2011		2012		2013	
		Kg/Mole	Mass	Moles	Mass	Moles	Mass	Moles
1	C	12.01	26.08	2172	26.16	2178	27.66	2303
2	H	1.01	6.83	6762	6.74	6673	6.98	6906
3	O	16.00	45.25	2828	44.76	2798	44.96	2810
4	N	14.01	0.64	46	0.75	54	0.63	45
5	S	32.06	0.079	2	0.07	2	0.08	3

Table 12: Mol ratios

S. No.	Element	Mol ratios					
		2011		2012		2013	
		S=1	N=1	S=1	N=1	S=1	N=1
1	C	1086	47.21	1089	40.33	767.66	51.17
2	H	3381	147	3336.5	123.57	2302	153.46
3	O	1414	61.47	1399	51.81	936.66	62.44
4	N	23	1	27	1	15	1
5	S	1	-	1	-	1	-

Table 13: Probable approximate chemical formula of municipal solid waste

S. No.	Year	Chemical formula with Sulfur	Chemical formula Without Sulfur
1.	2011	$C_{1086}H_{3381}O_{1414}N_{23}S$	$C_{47.21}H_{147}O_{61.47}N$
2.	2012	$C_{1089}H_{3336.5}O_{1399}N_{27}S$	$C_{40.33}H_{123.57}O_{51.81}N$
3.	2013	$C_{767.66}H_{2302}O_{936.66}N_{15}S$	$C_{51.17}H_{153.46O62.44}N$

Table 14: Energy content in different sample years by Modified Dulong formula

S. No.	Energy parameters	Years		
		2011	2012	2013
1.	Energy (Kj/Kg)	12715.78	12600.21	13256.71
2.	Total Energy (Kj/day)	6663068720	6816713610	7450271020
3.	Total Energy (Gj/day)	6663.06	6816.71	7450.27
4.	Total Energy (Mwh/day)	1852.33	1895.04	2071.17

Above calculations shows the approximate value of the energy content of the municipal solid waste in the year 2011, 2012 and 2013 which are 1852.33, 1895.04 and 2071.17 Mwh/day respectively. These amounts of energy content are very high and if we can convert these into thermal or electrical form we can provide a large amount of energy to the city from its municipal solid waste. The chemical formula developed for the municipal solid waste with sulphur were $C_{881.3}H_{2744.47}O_{1147}N_{18.53}S$, $C_{997.6}H_{3056.35}O_{1281.25}N_{24.51}S$ and $C_{878.91}H_{2635.76}O_{1072.57}N_{17.02}S$ and without sulphur were $C_{47.53}H_{148.03}O_{61.90}N$, $C_{40.68}H_{124.65}O_{52.25}N$ and $C_{51.62}H_{154.80}O_{62.99}N$ in 2011, 2012 and 2013 respectively.

4. CONCLUSION:

As the population of a city increases and the life style of the people become more and more consumptive the amount of the municipal solid waste also increases rapidly. The large amounts of the municipal solid waste are a burden on the city as well as the municipalities. A big share of the budget of the municipalities get used in the municipal solid waste management practices like collection, storage, transportation, recycling and disposal etc. municipalities can reduce this burden by the energy recovery from the waste. Municipalities can use this recovered energy for their own daily operations or can sell to the energy gird. For the energy recovery it is necessary to find out whether the amount and properties of the collected waste is good enough to carry a cost effective energy recovery. The modified Dulong formula is a method to evaluate the approximate value of the energy content of the municipal solid waste. The chemical formula developed is for general assessment of the probable chemical properties of the municipal solid waste which can further help to develop better methods of the waste management including composting, anaerobic digestion, incineration, pyrolysis, gasification, sanitary landfilling, and energy recovery etc.

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