A STUDY ON SOLID WASTE COMPOSITION AND CHARACTERISTICS OF MOSUL CITY/IRAQ

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ABSTRACT

Mosul city, like many other cities in IRAQ, is currently experiencing serious problems at all stages of solid-waste management, that is the collection, sorting, transportation, and disposal of garbage. Presently, Mosul city (1.52 millions inhabitants and 3.0 % growth rate) produces over 377264 tons of waste a year or 1033.6 tons per day .

The above estimates was obtained through solid waste survey comprising selected families. These families were thought to represent the city in terms of cultural, religious, economical and social aspects. 1680 sample of solid waste were collected from February to end of June 2009.

The results revealed that the city generated 0.68 kg/capita/day and that the usual composition was dominated by organic and food constituents. It appeared that social & economical aspects as well as the current instability and insecurity conditions of the country had a considerable impacts on both generation and composition of solid waste.

The average studied physical and chemical properties were estimated and tabulated. Their values were (65-480Kg/m^3), (90812KJ/Kg), (50.2%) and (48.86Kg/100Kg) for density, total energy, moisture content and dry weight respectively.

Keywords: solid waste, composition. Waste Generation, solid waste characteristics

INTRODUCTION and LITERATURE REVIEW

Solid waste, especially Municipal Solid Waste [MSW], is a growing problem in urban areas of the whole IRAQ and Mosul city in particular. This problem is aggravated due to the absence of proper solid waste management systems in the country. The absence of economic resources and fiscal incentives to promote environmentally sound development may add to this inconveniences.

Solid waste can be defined as any unwanted material that is not discharged to the atmosphere or via pipe, and cannot flow directly into streams or rise immediately into the air (Qusus, 1988). Solid wastes are all arising from human and animal activities that are normally solid and that are discarded as useless or unwanted.

Solid wastes are simply 'material of wrong place', which can be segregated, transformed, recycled and reused with great financial and environmental benefits (Iqbal and Ahsan, 2003). Solid wastes include all solid materials that the processor no longer considers of any sufficient value to retain (WHO, 1977 and Tchobanoglous et. al., 1993). There are eight major classifications of solid waste generators i.e. residential, industrial, commercial, institutional, construction and demolition, municipal services, process, and agricultural. The words “garbage”, “trash”, “refuse”, “rubbish” etc. are used to refer to some forms of them.

The generation of solid waste has become an increasing environmental and public health problem everywhere in the world, particularly in developing countries. This is due to rapid population growth that has generated vast amounts of solid and liquid wastes that pollute the environment and destroy resources.

The issue of solid waste has long suffered from neglect and ignorance. The Local Government of Mosul has currently prioritized solid waste management as a pressing issue and recognizes the value and importance of integrating environment and development objectives in the decision making process(Al-rawi, 2010).

Nineveh governorate has a population exceeding 3 million people with 3.0 % annual growth rate. Mosul city , the capital of Nineveh has a population of more than 1.4 million people . Substantial amounts of solid waste are likely to be generated (360,000 tons per year or 1000 tons per day) (Al-rawi, 2007).

This paper aims at revealing the extent of the problem, knowing composition and generation of solid waste, as well as determination of some important characteristics of the produced wastes. The focus in this study will be on domestic/ residential solid wastes as it represents the people daily problem as well as it has an intimate relation to human health and well being.

MATERIALS and METHODS

Six areas(sectors) in each side of Mosul city were selected for the purposes of this study. These areas were thought to possess major aspects and features of whole Mosul areas. Different people of different social, cultural levels, religions….etc. could be met in the selected areas.. Arbitrary selection of houses was made . Again these houses were single, multifamily, with and without kids and infants, old aged, young.. etc.

A questionnaire form (Table 1) was distributed among families to aid in gathering information - as much as possible - concerning serviced quarters. However, the obtained information could help in conducting necessary calculations related to purposes of this study.

Table (1) : Questionnaire for Solid waste data analysis

Sample No.		
Area name	House No.	
Number of persons	Weight of Solid Waste Total	
Date	Generation Rate	
Street		
Solid Waste Category	Weight(kg)	Percent(%)
Food waste		
Paper		
Glass		
Plastic		
Metals		
Aluminum cans/Tin		
Textiles		
Wood		
Rubber		
Yard trimmings		
Miscellaneous		

Large size plastic bags were provided to the randomly selected houses and apartments. It was ten houses in each sector (six sectors). Residents were asked to deposit generated solid waste into them over a period of 24 hours. The bags were collected back, transferred ,and then sorted. A total of (1680) solid waste samples from selected quarters were collected in each side of the city. A greater coverage though was desirable but it could not be achieved due to insecurity conditions, time and financial constraints. Photographs (1-4) show the process of collection, sorting and handling with solid wastes.

Photo.(1): Sampling Containers, Balances and plastic bags

Photo. (2): Sample Collection

Photo. (3): Samples sorting

Photo. (4): Samples sorting

The waste samples were sorted into 11 primary categories, which were explanted later in table (5). The composition of each sample was then determined. The study was performed for the period February until end of July 2009. This period was thought to represent seasons of the year.

The method chosen for waste characterization in this study was that used by Bernache- Perez et. al., (2001). This method involved the direct sampling of solid waste from specific sources, a labour-intensive manual process of sorting, classifying and weighing all items in each sampling unit and a detailed recording of the data.

Each of the waste samples from the source of generation was emptied on a polythene sheet (1 meter square) laid on the bare floor for sorting, weighed and sorted into categories. The total wet weight of each waste category was determined and expressed in gram .

The solid waste characteristics specified in this study were:

1. Densities; usually expressed in kg/m^3 . it is estimated through dividing the weight of solid waste that fill a container by the volume of that container.
2. Moisture content (i.e., the percentage of the weight of the water in the waste); This can be determined by drying a known weight of waste and measuring the weight change. This weight loss is then expressed as a percentage.
3. Calorific value; This is the amount of heat energy that can be produced if all of the combustible components of the waste are burnt. A waste sample is usually burnt at a high enough temperature to combust both the biodegradable and non-biodegradable organic materials such as vegetable matter, plastic, wood, paper, and rubber. This information is essential when considering waste combustion technologies to determine whether or not the waste will "self-support" combustion, or require fuel such as oil or gas to make it burn.
4. Physical composition; Information on physical composition was also necessary in evaluating processing and recovery options.
5 .Waste generation per person; measuring the amount of waste each person produces each day usually expressed as kilograms of waste per person per day.

RESULTS and DISCUSSION

The quantity and composition of municipal solid wastes vary greatly for different places and time of the year. Numerous factors are influencing the listed characteristics of municipal solid wastes. Some of these factors are degree of urbanization and industrialization, social customs, per capita income and other factors like geology, geography, climate etc. What complicates the problem is the presence of only very few statistics available on the waste generation and characteristics of Mosul city.

Waste Generation Rates

Typical Waste generation of the studied areas is illustrated in (Table 2). Generally, the greater the economic prosperity and the higher percentage of urban population, the greater the amount of solid waste produced. The results

yield a minimum and maximum values as 0.100 and 0.608 kg/ person/ day. The average value is estimated to amounts to (0.34 kg/person/ day).

In order to approximately estimate the WHOLE generation rate , a knowledge of other solid waste types i.e. industrial and commercial … are needed. During the period of this study, most of industrial factories and firms were not operating. Generated solid waste of those facilities that were partially working will not give a reliable data.

It is thought from Iraqi and regional as well international experience that domestic solid waste constitutes 50% or more of the total generated waste, (Hickman,1999). This is valid for developing countries where heavy industries or special wastes were rarely found. This is supported by (Table 3).

As previously stated, the inadequate information on quantification and characterization of waste; health, social, economic and environmental impact of municipal solid waste management are a common occurrences in Mosul. For example Yousuf (1988) estimated the domestic/residential generation rate to be (0.48kg/person/day).

Table (2): Generation rate of solid waste in Mosul city (gm/person/ day) (arbitrarily selected samples of the studied areas)

Sample No.	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
1	417	382	342	460	410	608
2	460	375	425	255	285	211
3	188	250	230	358	482	530
4	269	312	340	240	320	290
5	210	295	215	230	205	216
6	212	254	322	225	250	216
7	100	216	184	460	315	385
8	417	475	365	410	345	294
9	345	428	210	310	213	370
10	425	375	285	256	145	195
11	400	368	455	510	240	240
12				290	165	235
13				200	0	280
14				320	341	380

Table (3) : Mean percentages of solid wastes types

Solid waste type	**Percentage % out of total**
Municipal/domestic	50
Commercial	25
Industrial	12.5
Institutional	12.5

It had been estimated that in 1997 Iraq produced (285 kg/capita) as a total municipal waste per year (UNEP, 2003) which is equivalent to (0.78 kg/capita/day). Al-Wattar (2006) on the other hand had estimated the Domestic waste generation as (0.30 kg/person /day). Al-wattar study bear some reliability as it covered a wide area (20 quarters) and had been conducted carefully to achieve the intended goal of that study. Moreover, this result highly agrees with the findings of the current study. Similarly UNOPS estimated the total generation rate of Mosul city to approach (0.70 kg/person/ day) (UNOPS,2007).

According to the last estimate of generation rate provided by the authors of the present study , that of Al-Wattar , and above table facts, a total value generation rate of (0.66 kg/person/day) seems reasonable for the city of Mosul.

Municipality authorities suggest a value of (1.5 kg/person/ day) (municipality,2007) as an average. It is thought however that the latter figure of the municipality is overestimated.

Collectively, the estimated of domestic solid waste generation rate were as listed in (Table 4). It clearly demonstrated generation rates of the conditions of Iraq through recent three decades of sanction, wars, and conflicts.

Table(4): generation rate estimations by various agencies &authors

Domestic Solid waste (according to)	Total solid waste generation (kg/person. day)	Domestic solid waste generation (kg/person. day)
Yousif (1988)	0.96	0.48
UNEP(1997)	0.78	0.39
Al-Wattar(2006)	0.60	0.30
UNOPS(2007)	0.70	0.35
Al-Rawi(2007)	0.60	*0.32*

Figures (1&2) demonstrates urban MSW generation rates in the two sides of Mosul, as a weighted average of the waste data available from various studied quarters. On the other hand, (Fig .3) illustrates the average generation rates of some Arabic cities for comparison.

In brief , the quantities of solid waste discarded each day vary through the week according to whether it was the week end, shopping days or holidays. They also varied through the season depending on the availability of fresh fruit and vegetables.

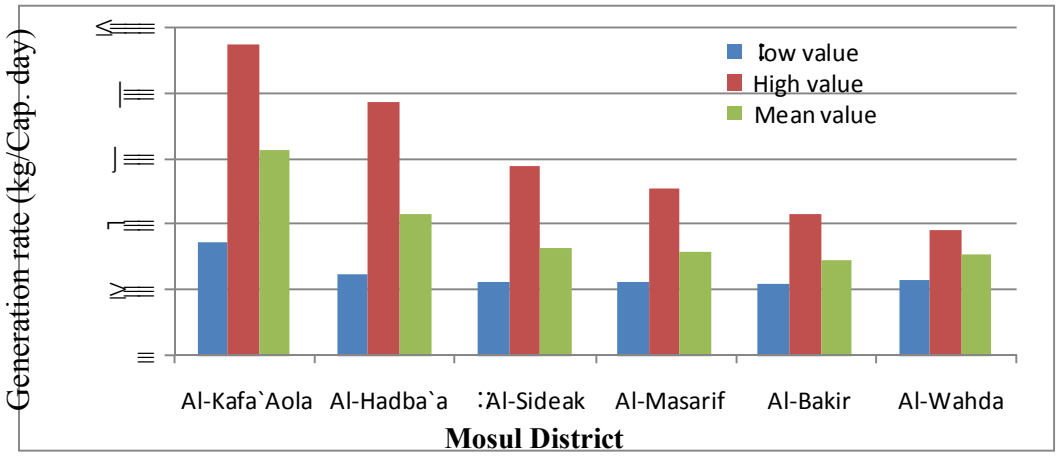

Figure (1): Urban MSW generation rates in the left side of Mosul

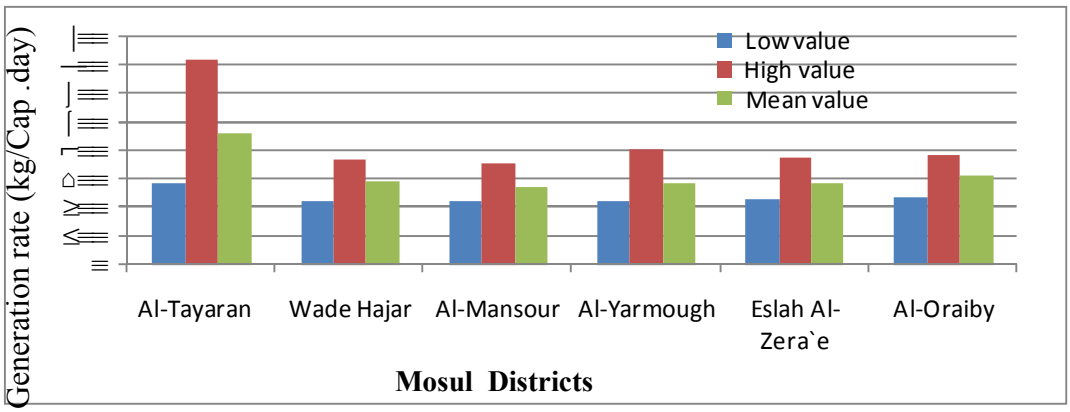

Figure (2): Urban MSW generation rates in the right side of Mosul

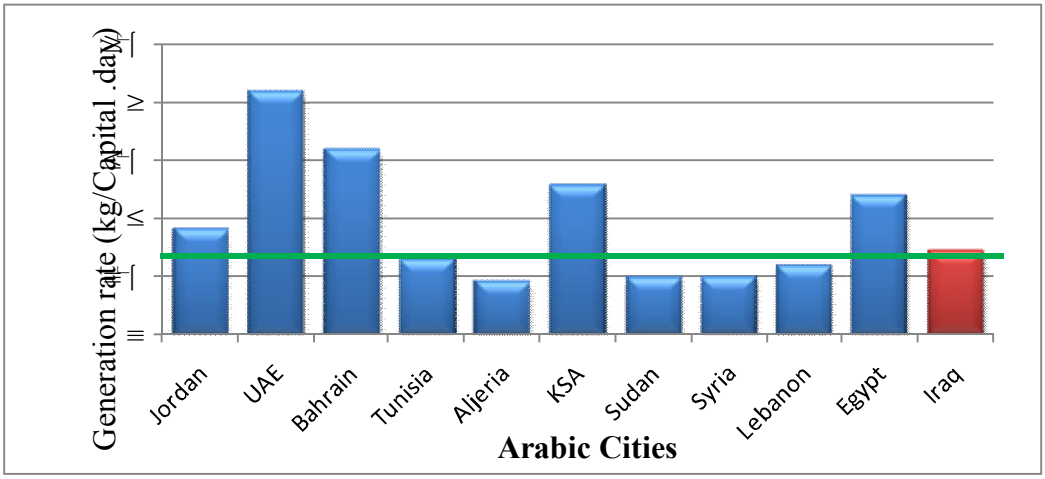

Figure (3): Average generation rates of some Arabic cities
(green line represents Mosul Generation Rate Kg/capita .day)

Residents of large towns also seem to throw away more than the people in small towns. In short, the general rule is that as one goes from a small poor traditional, illiterate community to a large, rich, modern, and literate one, the refuse weight becomes more, the food preparation waste becomes less, the paper and packaging fraction increases (Qusus 1988; Srivastrava et. al., 2005, Idris et. al., 2004).

Solid Waste Composition

The composition of the waste, in general, differs from country to another based on the economic level of countries as well as other factors such as geographical location, energy resources, climate, living standards and cultural habits. Table (5) lists a typical results and their descriptive statistics.

As noted in the table ,there was a clear variations in the solid waste composition. The precise composition of MSW depends upon locality, season of the year, standard of living, and land use (Iqbal and Ahsan, 2003; Srivastrava et. al., 2005). Good measures of the waste stream composition are hard to obtain, in part because the opening of bags to determine the wastes percent is an onerous task. Also, people are reluctant to have their garbage sorted. Additionally, seasonal trends relating to yard wastes, spring cleanup, ashes, and the like, as well as the need to collect data over a large number of households to ensure a representative sample, complicate the problem of determining refuse composition (Mcbean et. al., 1995).

Table (6) lists the percentage of solid waste composition which generated in some Arabic countries(Asafari and Al-mishan, 2001), except Mosul city by (Al-RAwi, and Al-Tayyar,2011).

Similar to generation rates, the income and economic growth have impacts on the composition of wastes. areas with high-income earners consume more packaged products, which result in a higher percentage of inorganic materials such as metals, plastics, glass, and textile. Waste characteristics vary according to season, income level, population, social behavior, climate, and industrial production, the size of markets for waste materials and the extent of urbanization, effectiveness of recycling, and work reduction.

The majority of substances composing municipal solid waste include paper, vegetable matter, plastics metals, textile, rubber and glass. It can be seen that great majority of the total solid waste generated in Mosul is organic. The high level of reuse of recyclable waste reflects the extent of poverty in the developing countries. Fig.(4) explains the range of solid waste components (min. and max percentage) and the average.

Fig (5) shows the distribution of composition of generated solid waste among studied areas. Fig.(6) illustrates the composition comparison between the two banks of Mosul city.

Table (5): Typical Composition Component Percentages of Mosul City Generated Solid Waste (arbitrarily selected sample)

Sample No.	Food waste	Paper	Glass	Plastics	Metals	Al. cans	Textiles	Diapers	Wood	Rubber	Trimmings	Misc.
1	41	7	0.5	6	0	0.8	0	34	2.6	4	4	0.4
2	82	4.87	0	8.4	0	4.7	0.06	0	0	0	0	0
3	66	3	0	19.3	1.7	3.3	2.6	0	0	0	0	3.3
4	77.2	5.3	4.6	4.6	0	1.1	5.1	0	0	1.8	0	0
5	78.2	77	0	7.15	1.35	0	0	0	3.13	0	2.4	0
6	87.7	4.4	1.7	6.1	0	0	0	0	0	0	0	0
7	69.3	3.1	6.25	3.1	3.75	6.2	2.7	0	0	2.5	0	3.1
8	76	6.8	7.8	1	0	1.8	2.5	0	0	2	2	0.2
9	67	5.9	2	1	0	1	1.6	8.1	2.5	4	2.15	3
10	72	16.4	0.7	1.76	0	1.6	0.3	0	1	2.47	1.54	0
11	87.5	0.3	0	0.3	3.7	1.25	2.5	0	0	0	0	3.1
12	58.5	4.4	2	3.8	0	0	0	28	0	0	0	0
13	75	0	1.6	6.7	0	2.5	14	0	0	0	0	0
14	80	0	2	5.5	0	5	2.5	0	0	5	0	0
15	68	12	2	0.8	0	0	16.5	0	0	0.8	0	0
16	89.5	2.2	6	0	0	0.85	0.85	0	0.65	0	0	0
17	74.6	11	3.5	1.6	0	4.8	2.2	0	0	0	0	0
18	76	6.7	2.85	8.5	1	4.8	0	0	0	0	0	0
19	86	4.2	3.5	1.8	0	2.1	1	0	1	0	0	0.35
20	42	5.1	1.8	4.2	0	2.3	0.4	9.6	0	8.4	18.4	8.3
21	66	4.4	7.2	4.2	0	2	4	0	5	5	2.2	0
22	86	0.35	0	6.6	3.3	0	0.35	0	0	0	3.3	0
23	20	4.7	2.2	1	44.4	3.65	3.6	20	0	0	0	0
24	79.4	0.6	1.4	2.9	0	1.4	0	12.6	0	0	1.4	0

Table (6): Solid waste composition percentage for selected Arab cities (%)

Components/ city	**Amman**	**Bahrain**	**Tunisia**	**Riyadh**	**Kuwait**	**Cairo**	**Mosul (now)**
Organic/food	54.4	59.07	68	34	50	67	68.17
Paper	14	12.8	10	31	20.6	18	9.6
Plastic	13.2	7.44	11	2	12.6	3.4	5.29
Metals	2.4	2.05	4	16	2.6	2.2	3.15
Glass	2.8	3.29	-	2	3.3	2.5	2.61
Wood	-	-	-	10	4.8	-	0.85
Textiles	4.7	6.92	2	2	4.8	0.5	5.48
Miscellaneous	6.0	1.41	2	2	1.2	6.4	*7.45*

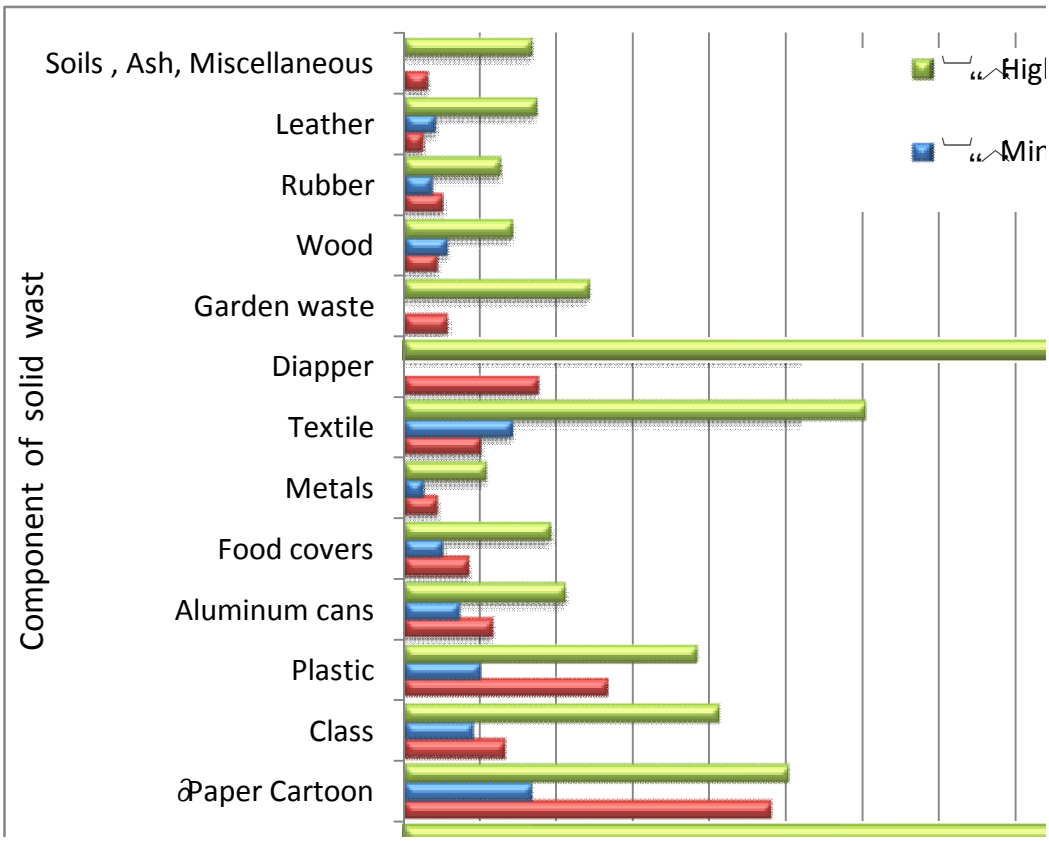

Figure (4): Range of solid waste components (min. and max percentage weight) and the average weight percentage

As solid waste is generated from many different sources, it naturally contains an almost infinite variety of materials. These in turn range in size from specks of dust to discarded automobiles. The major constituents of domestic and commercial wastes are fermentable organic matters; glass, wood, metals and plastic with relative proportion depending upon many local factors. Solid waste composition and quantities also vary over the year with changes in diet, packaging, etc.

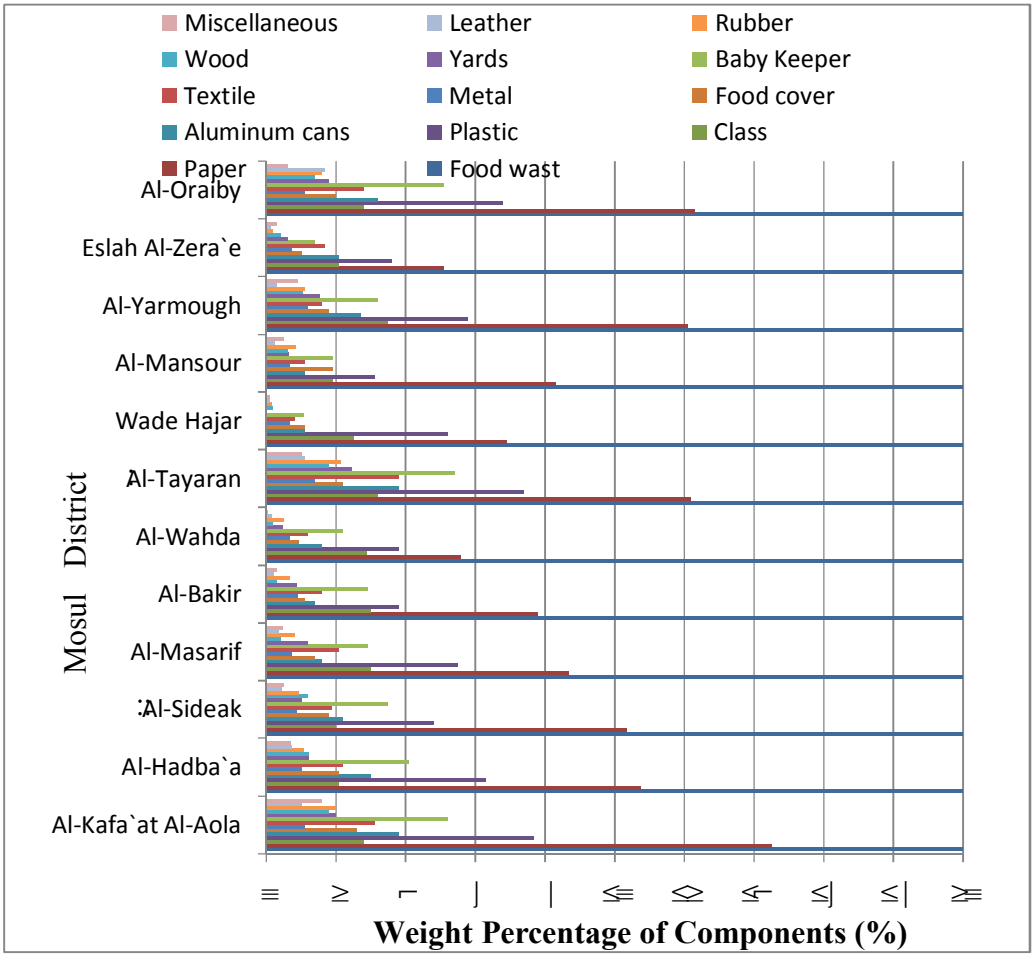

Figure (5): Distribution of composition of generated solid waste among studied districts in Mosul

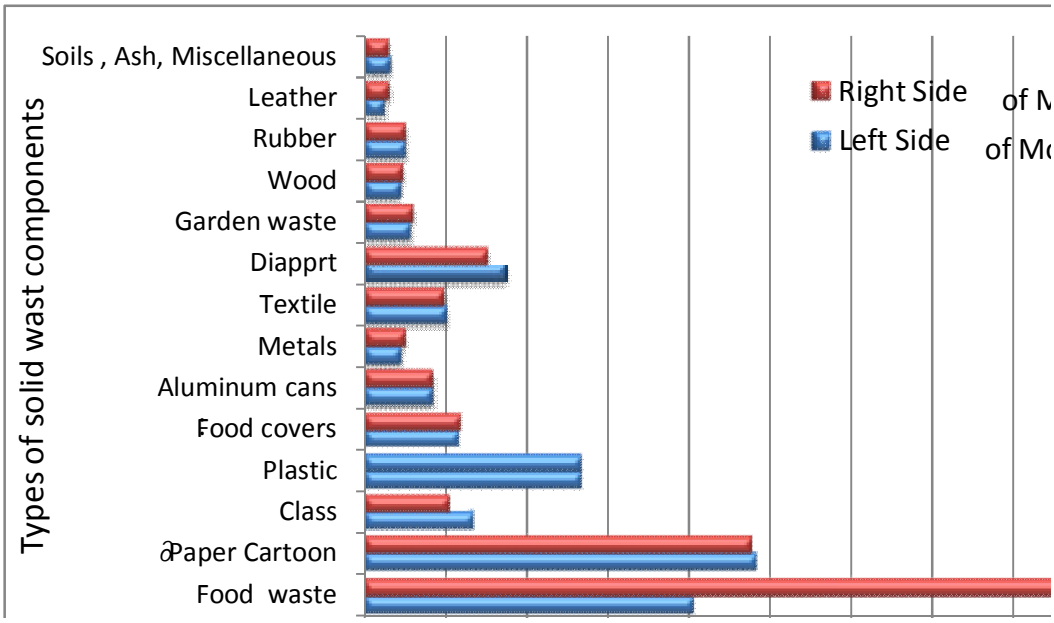

Figure (6): Average composition comparison between the two banks of Mosul city

Waste Physical and Chemical Properties

(i):Waste physical and chemical properties of the studied samples are shown in Table(7). The density of solid waste ranged from 250 kg/m^3 to 370 kg/m^3 which are higher than solid waste densities found in cities of developed countries. This may be of interest to planners, designers and decision makers. Whether the intent is to collect gas from landfill or energy recovery by combustion is the objective.

The density of waste changes at different stages between generation and final disposal. The waste density figures of most interest to a waste manager are the density wastes in a storage container, the density in collection vehicles (since this determines how many vehicles are required to collect waste in a local area), and finally, the density of waste in a landfill as indication of the amount of space that is used up and from which the lifetime of a landfill can be estimated).

Table (7): Solid waste properties

Component	Weight Kg	Volume (m^3)	Density (kg/m^3)	Typical energy content (kJ/kg) *	Total energy (kJ)	Typical moisture content %*	Dry weight kg/100kg B
Food waste	68.173	0.227	300	5800	395403.4	70	20.451
Paper	9.602	0.12	80	16300	156512.6	6	9.025
Glass	2.610	0.013	195	140	365.4	2	2.557
Plastic	6.290	0.097	65	32800	206312.0	2	6.164
Metal	0.880	0.007	130	700	616.0	3	0.853
Tin cans	2.270	0.025	90	-	-	3	
Textiles	6.590	0.101	65	17500	115325.0	10	5.93
Wood	0.470	0.002	240	18600	8742.0	20	0.375
Rubber	1.00	0.006	160	17500	17500.0	2	0.98
Trimmings	1.130	0.011	100	6500	7345.0	60	0.452
Misc.	0.59	0.001	480				
Total	99.62 =A	0.612			908121.4		49.53= B

The knowledge of density is important for the design of all elements of the solid waste management systems like storage, transport and disposal .For example for a known volume of the solid waste its density gives the idea about the requirement of the truck in tonnage. Every truck or similar vehicle has a permitted load capacity say 12 tons or so which it can carry according to law. In developed countries as their waste is light so compaction reduces the cartage charges substantially. The density varies significantly from source to the disposal site because of handling, change in moisture content, densification due to vibration of movement, disturbance by animals and birds (scavengers) etc

(ii): Moisture content: Moisture content of the solid waste is expressed as the weight of moisture per unit weight of wet material. Moisture content varies generally from 20% to 45% as with the climatic conditions and level of studied quarters The increase of moisture content increases the weight and thus the cost of transportation and thus the storage section should take care of it. Moisture content also determines feasibility of using solid waste for heat recovery.

The proportion of biodegradable material in the total waste is a good measure of the amount of bio-degradation possible and hence, the potential leachate or gas production that the waste is likely to produce once put into a landfill. The simplest way to estimate this is to dry the waste at a temperature high enough to bum off the organic component of the waste after having removed non-biodegradable organic materials such as plastic and rubber.

(iii): Calorific value: Calorific value is the amount of heat generated from combustion of a unit weight of a substance, expressed as kilo calorie per kilogram.

Conclusions And Recommendations

The current study comes out with the following findings:

1. It appears that solid waste management issues in Mosul city have minor concerns. This is reflected on the huge amount of daily solid waste generated and type of composition components.
2. Conditions of wars, conflicts as well as sanction and economic incomes have greatly influence this situation.
3. Daily generation rate of solid waste amounted to 0.68 kg/person.
4. Domination of organic and food composition in the generated solid waste.
5. A considerable portion of generated solid waste could be recycled, reused and recovered for beneficial uses.
6. The average studied physical and chemical properties were estimated and tabulated. Their values were (65-480Kg/m^3), (90812KJ/Kg), (50.2%) and (48.865Kg/100Kg) for density, total energy, moisture content and dry weight respectively .
7. The study highly stressed on adopting integrated solid waste management coupled with efficient guides and laws.

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دراسة عن تركيبة وخصائص النفايات الصلبة في مدينة الموصل/ العراق

الخلاصة

مدينة الموصل حالها حال العديد من المدن العراقية التي تعاني من مشاكل خطيرة تخص مختلف مراحل إدارة النفايات الصلبة، مثل الجمع والفرز والنقل والتخلص الآمن والصحي من النفايات الصلبة. تنتج مدينه الموصل حاليا والبالغ عدد سكانها (1.52 مليون نسمة ومعدل النمو السكاني السنوي 0.3%) ما يقرب من 377264 طن سنويا، أي ما يكافئ 1033.6 طن يوميا.

جرى احتساب المقادير أعلاه من خلال عملية مسح لمناطق المدينة المختلفة. شملت العديد من العوائل الذين يمثلون مختلف شرائح المجتمع الموصلي ، من حيث المستوى الثقافي والاجتماعي والناحية الاقتصادية وحتى الديانة. وجرى نمذجة النفايات الصلبة وإجراء التحاليل المختلفة عليها للمدة من شباط ولغاية تموز 2009 . وبلغ عدد النماذج المأخوذة 1680 نموذجا.

أوضحت النتائج أن مقدار إنتاجية الفرد الموصلي من النفايات بلغ (0.68) كغم يوميا. وان تركيبة النفايات الصلبة يغلب عليها المكونات العضوية وفضلات الأغذية والطعام. كما أوضحت النتائج أن الجوانب الاقتصادية والاجتماعية فضلا عن الناحية الأمنية وعدم الاستقرار توثر بشكل مباشر على تركيبة وإنتاجية النفايات.

جرى احتساب وجدولة الخصائص الفيزياوية والكيمياوية للنفايات، حيث بلغت مقادير الكثافة والطاقة الحرارية والمحتوى الرطوبي والوزن الجاف (65-480) و (90812) و (50.2%) و(48.86) على التوالي.