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INCINERATION ALTERNATIVE FOR MUNICIPAL SOLID WASTE DISPOSAL OF NAJAF CITY, IRAQ

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Abstract

Solid waste is composed of a broad array of materials discarded by households, businesses, industries, and agriculture. Municipal solid waste MSW is typically known by the public as trash or garbage, and basically consists of food scraps, bottles, product packaging, newspapers, grass clippings, clothing, furniture, appliances, and batteries. The objectives of this paper are to predict the per capita generation of MSW in Najaf city and its physical composition, as well as the energy content and incineration feasibility. Najaf city is located in the south-central part of Iraq, 160 km south of Baghdad. Gathering of data was done through field measurements and investigation. The city has two transferee stations where the waste is collected daily. Random samples were collected at the two stations, weighed, sorted, and classified, to measure the weight and estimate generation rate and energy content. The results showed that the estimated average density is 318 kg/m^3, and the average MSW production rate is 17913 ton/month corresponds to 0.57 kg/capita.day. The physical composition shows combustible ingredients with content that correspond to 6750 kJ/kg energy content which is critical to support energy recovery through incineration.

Keywords: Composition, Incineration, MSW, Najaf, Physical.

1. Introduction

Solid waste is composed of a broad array of materials discarded by households, businesses, industries, and agriculture [1]. Municipal solid waste MSW is typically known by the public as trash or garbage, and basically consists of food scraps, bottles, product packaging, newspapers, grass clippings, clothing, furniture, appliances, and batteries [2, 3]. MSW if not disposed of according to sound methods, it may cause serious pollution problem, especially, to urban areas where concentrated population produce effective rates of. To manage MSW correctly, an integrated management system should be followed [4, 5]. Although such a system is traditionally deal with storage at source (generation), collection, transportation, and landfilling [6-10], it has been sustainably oriented towards recycling and reuse [11]. Recycling is typically directed towards metals, glass, and rubber, while reuse is mainly directed towards energy recovery through incineration and producing fertilizers through compositing [12-17].

Recent technologies for using MSW to produce energy other than incineration are; gasification, generation of biogas and utilization in a combined heat and power plant as well as generation of biogas and conversion to transport fuel [18]. Adopting incineration requires investigating waste composition and waste generation rate. Theses main two parameters are essential to study the feasibility of adopting incineration to produce energy [19-21]. Other parameters like energy need and environmental impact of incineration are also important and may be controlling [22-24]. However, the incineration is categorized into two categories: with energy recovery and without energy recovery. The kind without energy recovery is not a preferable option because of financial costs and resulted pollution [22].

To check MSW energy content, three bases are usually considered for energy content estimation as physical composition, ultimate analysis, and proximate analysis [25]. The physical one depends on waste components like food, plastic, paper, textile, etc. The ultimate analysis depends on the chemical content of waste as Carbon, Nitrogen, Hydrogen, Oxygen, and Sulfate. The proximate analysis depends on fixed carbon, volatile matter, and water content. Nevertheless, any of the basis above when followed the governing parameter is the low heating value LHV, which is the heat amount released from combustion when water is still at vapor state and its latent heat of vaporization is not recovered [26, 27]. Energy content (E) with units of MJ/kg can be used instead of LHV for the physical composition of waste [28].

In Iraq, infrastructure services deteriorated through the eighties and nineties of the previous century due to wars and international sanctions. Accordingly, MSW management was greatly affected. Right now, no energy recovery practices have been extensively done. Traditional management of collection to landfilling is followed. The main objective of local studies was focusing on estimating generation criteria of MSW per capita to support the planning, design, and operation of the traditional management. Such studies found that the generation rate varies slightly in the provinces of Iraq. It was ranged between 0.35 - 0.65 kg/capita. day in 2012 with an average of 0.42 kg/capita. day [29]. It was 0.42 kg/capita. day in Najaf province [30], 0.62 kg/capita. day in Basra [31], 0.44 kg/capita. day in Kirkuk city [32] and 0.496 kg/capita. day in Mosul city [33], 0.673 kg/capita. day in Baghdad [34]. These rates do not remain constant. They increased with time due to some factors like change in people standard of living and the

country economic level. Some previous studies estimated the rate to reach 0.875 kg/capita. day in the first decade of the present century [30, 34-36].

The objectives of this paper are to predict the per capita generation of MSW in Najaf city and its physical composition, as well as the energy content and incineration feasibility.

2. Methodology

Gathering of data was done through field measurements and investigation. As a solid waste of Najaf city collected and stored in two locations of transfer stations before being sent to the landfill site, random samples were collected at the two stations and weighed. The samples were taken with a volume of one cubic meter by means of the plastic container having a capacity of one cubic meter with calibrated weight. Spring balance was used to hang the container with the waste sample included an empty container. Sampling and weight measurement were carried out once a week for February, March, September, and October of 2019. Each sampling time included measuring the weight of ten samples drawn randomly from the collecting trucks arriving at the station. For each sample, after measuring the weight, sorting, and classification were carried out to quantify the constituents for plastic, rubber, glass, metals, paper, cardboard, and food garbage. Those ingredients after classification, were weighed to get proportioning percentages for each ingredient by weight. Density was calculated for each sample by calculating the mass of samples and then dividing by one-meter volume. Total volume of MSW arrived at the two stations was estimated through the summation volume of the waste unloaded by collecting trucks arrived at the days of measurements. Average density of MSW was estimated based on densities of the 160 samples collected through the four months. Accordingly, the average mass of MSW is estimated. Then, dividing the average mass over the population served results in the approximate per capita MSW generation rate.

Energy content was estimated according to the model developed by Ali Khan and Abu-Ghurrah [37], which is

$$E = 0.051\,[F + 3.6\,(CP)] + 0.352\,(PLR) \quad (1)$$

3. Study Area

The study area is Najaf city located at (440377E, 3538119N to 436439E, 3550611N, longitudinally, and 434200E, 3544047N to 439441E, 3545283N, transversally) in the south-central part of Iraq. It is about 160 km south of Baghdad. The total area of the city is about 62.5 km^2. The present population of the city is estimated at 923000 [35]. The city is residential with horizontal type housing at most. The city has two industrial zones of minor workshops and factories. The two zones together have 2 km^2, and they do not considerably participate in MSW. The city has no agricultural activates. Commercial centres and axes are distributed over the city with much concentrated in the old city centre. The old city centre is located nearly at the southwest edge of the city embracing the holy shrine of Imam Ali Bin Abi Talib (peace be upon him). The shrine is daily visited by thousands (1000-5000) of Muslims around the year. Those visitors who come to the city, usually do not reside in Najaf but leave on the same day of visiting. However, there are some religion occasions at which millions of Muslims come to visit the shrine and may stay for 1-2 days. Those occasions happen two times

a year and do not be considered for the purpose of estimating MSW average energy content around the year.

MSW generated in the city is collected by trucks and temporarily stored in two locations doing as transfer stations TS. Those locations are presented in Fig. 1. One of them is located in the southern part of the city at (440584E, 3538783N; 440612E, 3538714N; 440449E, 3538648N; 440422E, 3538716N). The northern TS is located at (431109E, 3545327N; 430890E, 3545206N; 430769E, 3545425N; 430988E, 3545546N). The municipality is planning in near future to construct additional one at (431821E, 3534621N; 431957E, 3534475N; 431667E, 3534477N; 431804E, 3534331N). MSW is transported from the transfer station to the landfill site at 23 km southwest the boundaries of the city.

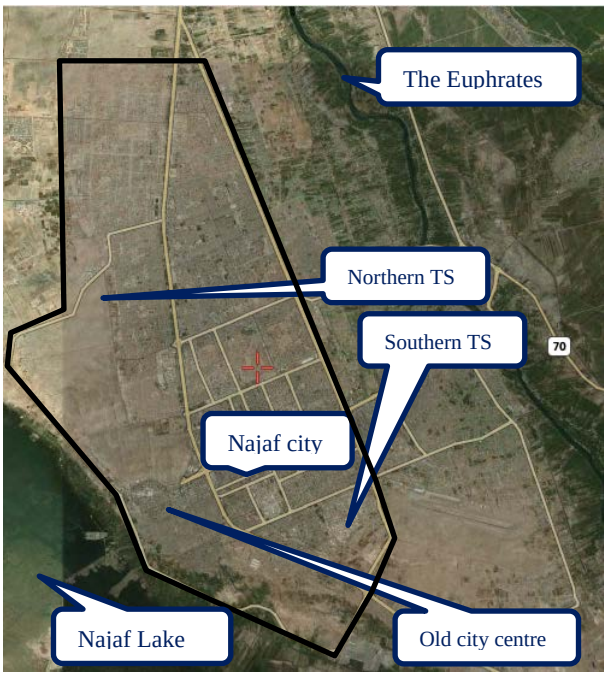

Fig. 1. Area of study (Najaf city, Iraq).

4. Results and Discussion

Based on the data of field measurement and investigation over the four months, the following sections cover estimation of density, physical composition, energy content, and generation rate of the MSW in Najaf city.

4.1. Solid waste density

Table 1 lists the estimated wet (field) density of the waste. Each value of the average density corresponding to each of the four months has been calculated as the average of 40 values covering four weeks and 10 values per week. The standard deviation shows a relatively greater fluctuation in February in contrast to September. This may belong to the moisture content caused by rain that wetted the waste in February, while dry weather through September kept the waste away from

wetting surroundings. The overall average density of 318 kg/m^3 agrees with previous studies [29, 30, 35].

Table 1. MSW average density of Najaf City.

Month	*Average density kg/m^3	Standard dev.
February	292	84.31
March	283	59.26
September	388	37.42
October	312	63.47
Overall average	**318.75**	61.12

*Each value of the four months is the mean of 40 values

4.2. Estimation of solid waste generation rate

Table 2 shows the total MSW produced per month for the four months considered. Accumulative volume of waste daily collected in the two transfer stations has been observed and multiplying by the average waste density (318 kg/m^3) leads to obtaining the production as tabulated in Table 2. No considerable variation in the values of the total production per month. The production was in the range of 17,403 to 17,976 ton/month excepting 18,570 ton recorded in September. In September, there were religious visits to the city from Muslims that may cause the production to raise slightly.

Table 2. MSW monthly production of Najaf city.

Month	*total production (ton)
February	17976.87
March	17403
September	18570.87
October	17704.01
Average	**17913.69**

*Summation of MSW along a month

The population of Najaf city in 2019 was estimated at 923000. With the addition of an average of 123750 visitors [35], the per capita MSW generation rate is estimated at 17.114 kg/capita. the month that corresponds to 0.57 kg/capita. day. This value is higher than that estimated previously in 2005 as 0.42 kg/capita. day for Najaf city [30]. This may belong to the rise up in people standard of living and general economic status in the city and Iraq at all. However, the estimated 0.57 kg/capita. the day is close to the estimated rates by other studies for neighboring cities [31, 34].

4.3. Solid waste physical constituents

Table 3 lists the waste constituent percentages according to the physical composition. A considerable percentage of food garbage characterize the waste. This is attributed to the habits and lifestyle of people. People preferring canned food that is why considerable metal content was observed. The considerable content of plastics belongs to the extensive use of bottled drinking water with plastic bottles. The content of combustible ingredients (food garbage, cardboard, paper, rubber and plastic) is moderate.

Table 3. MSW physical composition.

Month	February	March	September	October	Average
Avg. Temp., ºC	14	19	72	13	**29.5**
Food garbage %	64	65	3.15	63	**66**
Cardboard %	1.92	2.43	1.21	2.71	**2.5525**
Paper %	1.18	1.17	1.87	1.11	**1.1675**
Rubber %	1.62	0.84	6.96	1.82	**1.5375**
Plastics %	6.53	5.82	7.93	6.1	**6.3525**
Metals %	8.71	9.96	4.52	7.72	**8.58**
Glass %	4.5	3.25	1.58	4.91	**4.295**
Wood %	1.85	4.21	72	2.94	**2.645**
Inert materials %	9.69	7.32	0.7	9.69	**6.87**
Summation	100	100	100	100	100

4.4. Energy content considerations

Back to Eq. (1), the energy content may be estimated as: -

$$E = 0.051\,[66 + 3.6\,(1.1675 + 2.5525)] + 0.352\,(6.3525 + 1.5375) = 6.75\ \text{MJ/kg} = 6750\ \text{kJ/kg} \quad (2)$$

This value is critical to apply incineration. The average value that should produce from MSW must be higher than 6000 kJ/kg for all seasons of a year, and the annual average not less than 7000 kJ/kg, but some studies determined that the lower value must not be less than 6500 kJ/kg. [11]

5. Conclusions

Based on the results obtained in this study, the following may be drawn:-

- The estimated average density of MSW in Najaf city at present is 318 kg/m^3, which agrees with previous studies for the city.
- The average MSW production rate is 17913 ton/month corresponds to 0.57 kg/capita.day.
- The physical composition of MSW of Najaf city shows combustible ingredients with content that correspond to 6750 kJ/kg energy content which is critical to support energy recovery through incineration.

Abbreviations

CP	Cardboard and Paper
E	Energy Content
F	Garbage Food
LHV	Low Heating Value
MSW	Municipal Solid Waste
PLR	Plastic and Rubber
WHO	World Health Organization

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