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Solid Waste Management Challenges and Possible Solution in Kabul City

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***Abstract*—**Most developing nations face energy production and supply problems. This is also the case of Afghanistan whose generating capacity does not meet its energy demand. This is due in part to high security and risk caused by war which deters foreign investments and insufficient internal revenue. To address the issue above, this paper would like to suggest an alternative and affordable way to deal with the energy problem. That is by converting Solid Waste to energy. As a result, this approach tackles the municipal solid waste issue (potential cause of several diseases), contributes to the improvement of the quality of life, local economy, and so on. While addressing the solid waste problem in general, this paper samples specifically one municipality which is District-12, one of the 22 districts of Kabul city. Using geographic information system (GIS) technology, District-12 is divided into nine different zones whose municipal solid waste is respectively collected, processed, and converted into electricity and distributed to the closest area. It is important to mention that GIS has been used to estimate the amount of electricity to be distributed and to optimally position the production plant.

***Keywords*—**Energy problem, estimation of electricity, GIS zones, solid waste management system.

I. Introduction

THE city situations are such that the peoples face a lot of problems due to unsuitable management of solid wastes. This is not because the municipality is not doing their work correctly or due to work negligence, but it is due to the old typical working methods which need to be replaced with the advanced ICT based systems using GIS for a better management.

Currently Kabul city generates 2000 tons of MSW per day with the capita of 0.4 kg per person per day. If we go a few steps back in 2008, the amount of generation of MSW was 1603 tons per day with the capita of 0.4 kg per person per day. In 2020, this amount will grow to 2563 tons per day with the capita of 0.5 kg per person per day [1]. In 2025, this amount will increase to 3300 tons per day [1] with the capita of 0.6 kg per person per day (Fig. 1). It shows that the amount of the solid waste increases dramatically in the few coming years, and Kabul Municipality does not have a good MSW Management system to deal with Municipal Waste, thus this will bring a lot of serious health and economic issue to the capital city of Afghanistan.

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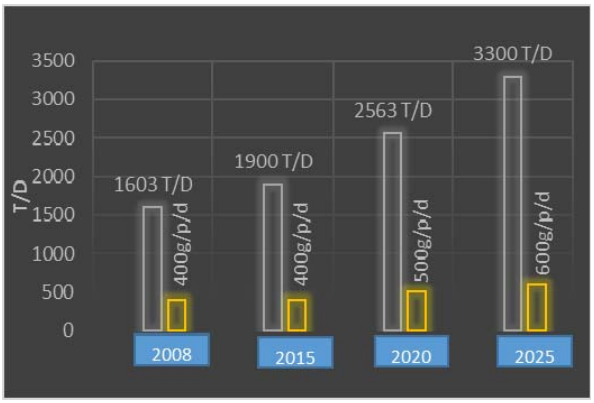

Fig. 1 Solid waste amount generated in Kabul city (T/D)

II. Study Area

Kabul is the capital city of Afghanistan, located in the eastern section of the country with 22 districts. It is positioned at latitude: 34.6°, longitude: 69.2°, and altitude: 1791 m (5876 ft.) [3]. The area of Kabul city is 1008.70 km^2 [1] (Fig. 2).

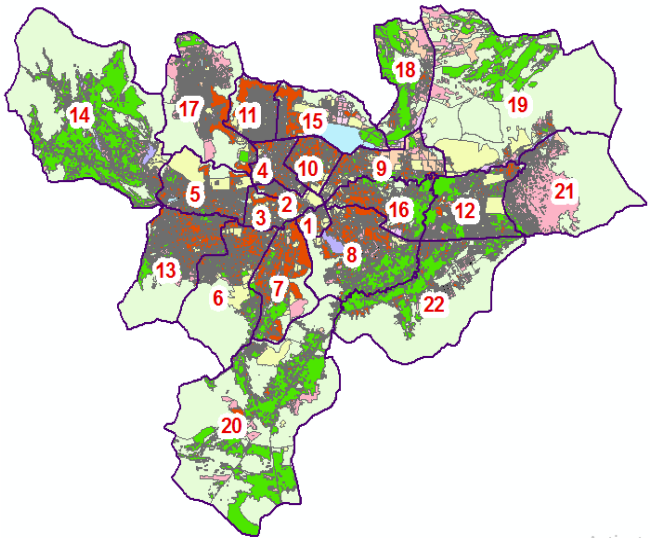

Fig. 2 The whole Kabul City with 22 Districts

The study area will be specifically District-12 because of its existing situation, it is the nearest area to the dump site, and people are suffering from many types of diseases (e.g. Malaria, Tuberculosis, Cholera, Typhoid and Dysentery) in the mentioned area. The objective of this study is to find out effective ways of waste management which will lead to decreasing the number of diseases in mention area (see Fig. 3).

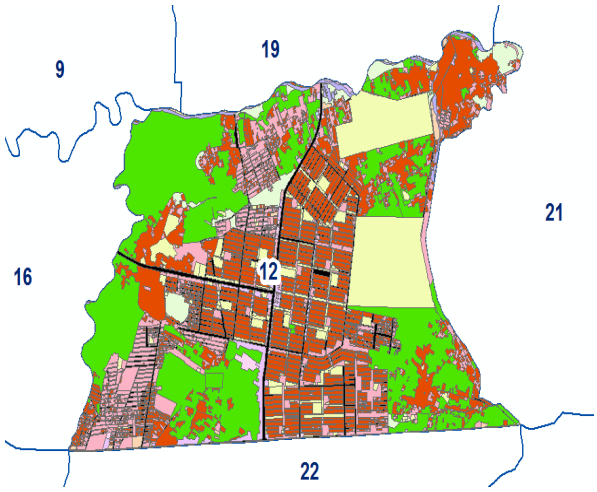

Fig. 3 District-12 (study area)

III. Methodology

Satellite imagery of District-12 and some spatial GIS techniques will be used to divide the mentioned district in a different corresponding zone to fill the current municipal management system gap and to know the residential area, and find the amount of MSW in each zone. At the end, we will be able to find out the amount of electricity from generated MSW accordingly.

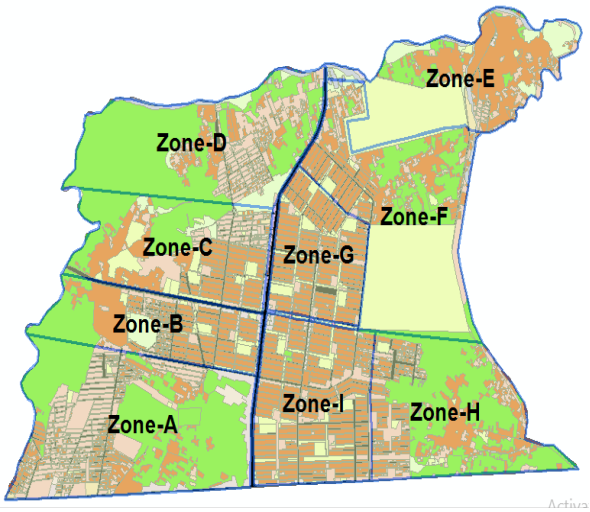

Fig. 4 Different 9 (A-I) zones of District-12 in GIS

The layers have different categories like residential, green area, road and streets institutional, transport, agriculture, commercial, buildings, water, industrial, barren land, vacant plot, and so on (Fig. 2). To analyze the land use map, we need to know the residential, road, and streets data which are in different categories because we want to know how many people are living in each zone of District-12, so GIS will be the better precise tools to know the clear information about each zone's residential area which will be helpful for analyzing the amount of energy from MSW in the mentioned district (Fig. 4).

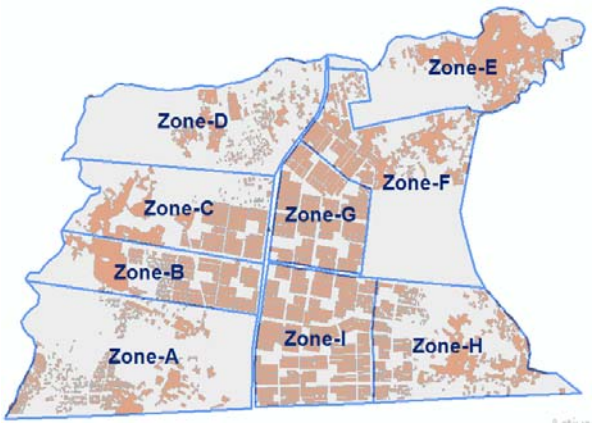

Fig. 5 Residential area and corresponding zones in District-12

To precisely collect and carry out the MSW from household to the corresponding plant, it will be better to divide District-12 into different zones (zones names are in English alphabetical order respectively), so GIS will be the best tool for isolating the mentioned district in different corresponding zones (Fig. 5)

IV. Municipality Waste Estimation in District-12

A. Population Density and Area

According to Table I, total population in District-12 is 156000 [1], and total land area which covers district-12 is 3437 hectares which is equal to (34.37 square kilometer). In addition, residential area which is the living area for people equals 1018 hectares (10.18 square kilometer), which shows that 29.62% is the residential area in the whole district. Finally, the population density in residential area of mention district is 153 persons/hectare.

TABLE I
Population Density and Land Use Area in District-12

Population	156000
Residential Area(Hectare) in District-12	1018
Population Density/He in Residential Area	153
Total Land Area in Districtc-12	3437

B. Zones and Residential Area

As mentioned, the whole district is divided into nine different zones for easy municipality waste collection, to know each zone residential area (Table II), which will be helpful for calculating the total amount of MSW in each zone.

C. Total Amount of MSW in District-12

To summarize, Table III shows that the total land area of nine zones (which is occupied by the District-12) is equal to 3437 hectares (34.37 square kilometer) and the residential area which is specifically for inhabitant is 1018 hectares (10.18 square kilometer). Furthermore, the total population, which is living in nine different zones of Districtc-12 is 156000 people, which generate 12.2 tons of dry waste, 40.6 tons of wet waste, and 9.7 tons of demolition waste, so on this regards, total nine zones generate 62.4 tons of MSW. Furthermore, each zone in District-12 whose total residential area is 1018 hectares is

equal to 10.18 square kilometer. Moreover, the recyclable waste in ton column represents that we have different amount of dry waste in different zones. In the same way, regarding wet waste also, we will see the different amount in different zones. Totally, we have 40.6 ton per day in the all zones (Table III).

TABLE II
DESCRIBE THE 9 ZONES AND THE TOTAL AREA IN HECTARE

Total Residential Area in District-12 in Hectare									
Zone-A	Zone-B	Zone-C	Zone-D	Zone-E	Zone-F	Zone-G	Zone-H	Zone-I	Total
88	108	108	55	126	109	122	112	190	1018

TABLE III
TOTAL AMOUNT THE MUNICIPAL WASTE IN DIFFERENT ZONES OF DISTRICT-12

Residential Zones in D-12	Each Zone Land Area	Residential Area(Hectare)	Population in Each Zones	Dry Waste in Ton	Wet Waste in Ton	Demolition Waste in Ton	Total MSW in Ton
Zone A	591	88	13485	1.1	3.5	0.8	5.4
Zone B	253	108	16550	1.3	4.3	1.0	6.6
Zone C	346	108	16550	1.3	4.3	1.0	6.6
Zone D	446	55	8428	0.7	2.2	0.5	3.4
Zone E	357	126	19308	1.5	5.0	1.2	7.7
Zone F	491	109	16703	1.3	4.3	1.0	6.7
Zone G	214	122	18695	1.5	4.9	1.2	7.5
Zone H	394	112	17163	1.3	4.5	1.1	6.9
Zone I	345	190	29116	2.3	7.6	1.8	11.6
Total 9 Zones	3437	1018	156000	12.2	40.6	9.7	62.4

Note: Dry Waste = Plastic + Glass + Paper + Metal + Wood + Textile Wet Waste = Food + Kitchen + Garden + Fruit

TABLE IV
COMPOSITION OF MUNICIPALITY WASTE GENERATED TON/ DAY

Component	Percentage	Amount
Dry Waste	19.5%	12.2 tons
Wet Waste	65%	40.6 tons
Demolition Waste	15.5%	9.7 tons

V. CHARACTERIZATION OF MSW

MSW mainly combines in District-12 with a different category which is generated by household in residential area (Fig. 6).

The range of percentage for each category is 65% organic or food (vegetable and fruit) waste, 5% plastic, 2.5% glasses, 6% paper and cardboard, 2% textile, 2% wood, 15.5% demolition, and finally 2% of metal waste [2].

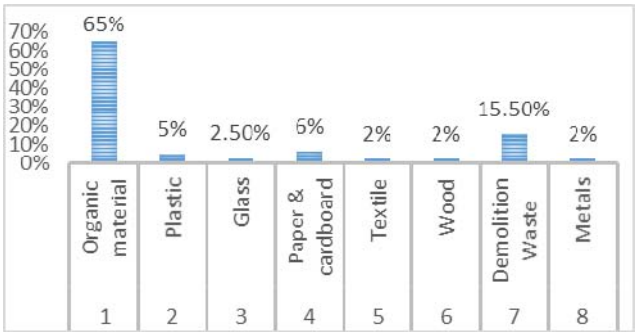

Fig. 6 Waste characterization in District-12 by percentage

Dry waste = Recyclable waste= 9.7 ton. (plastic, glass, paper and metal) +1.25 ton (wood waste) +1.25 ton (textile waste) = 12.2 ton. Wet waste (65%) is 40.56 tons, and demolition waste (15.5%) is 9.67 tons. The amount of total waste generated in District-12 is 62.4 ton/day.

VI. TOTAL GENERATED WASTE IN DISTRICT-12

To accumulate the total amount of MSW from Fig. 6, we will ignore the demolition waste because it is not combustible waste to produce energy. From Table III, we have:

Table IV represents the amount of dry waste 19.5% = 12.2 ton (which includes plastic, glass, paper, metal, wood and textile), and on the other hand, we have wet waste with contribution of 65% = 40.6 ton (food, kitchen, garden, yard waste), finally we have demolition waste with 15.5% = 9.7 ton. The demolition waste is not included either in dry waste or in wet waste, so in this regard, it does not generate electricity. It will be ignored (demolition waste) in the calculation of energy.

The total net amount of waste for generating electricity will be 12.2 ton + 40.6 ton = 52.8 ton

VII. POWER GENERATION FROM MSW

A. Dry Waste Power Generation

During combustion, the calorific value is 800 kcal/kg to 1000 kcal/kg, but to keep the average amount, it will be 900 kcal/kg. So, the amount of power energy from dry waste is calculated as follows [6]:

$$\text{Net Calorific Value (NVC)} = 900 \text{ kcal/kg} \quad (1a)$$

$$\text{Energy in (kWh)} = \text{NVC} \times W \times 1.16 \times 10^{-3} \quad (1b)$$

$$\text{Power in (kW)} = (1.16 \times \text{NVC} \times W \times 10^{-3})/24 \quad (1c)$$

$$= 0.048 \times \text{NVC} \times W \times 10^{-3} \quad (1d)$$

$$\text{Net Power generation} = 0.012 \times \text{NVC} \times W \times 10^{-3} \quad (1e)$$

B. Generation Energy from Wet Waste

The standard net calorific value is 5000 kcal/m^3, which means that 5000 kcal NVC of biogas is generated from 1 cubic meter (m^3) of wet waste (Formula 2c) [6].

$$\text{Biogas efficiency (B)} = 0.8 \text{ x fraction destroyed} \quad (2a)$$

$$=0.8 m^3/kg \quad (2b)$$

$$\text{NVC of biogas} = 5000 \text{ kcal}/m^3 \quad (2c)$$

$$\text{Energy in (kWh)} = \text{NVC x B x } 1.16 \text{ x } 10^{-3} \quad (2d)$$

$$\text{Power in (kW)} = (1.16 \text{ x NVC x B x} 10^{-3})/24 \quad (2e)$$

The total amount of generated energy from dry waste in District-12 is about 111.6 kW. (for more details, Fig. 7).

Total waste		53000	Kg
Dry Waste	10335 Kg	,10^{-3}	0.001
Wet waste	34450 Kg	NVC	900
Net Power generation	0.012	x NVC x W x 10^{-3}	
1	Dry Waste Total Energy	111.6 KW	

Fig. 7 The amount of energy generated from Dry waste in District-12

Organic biodegradable fraction 33%	0.33	11369	Kg		
Typical digestion efficiency 60%	0.6	6821	Kg		
Typical biogas efficiency (B)	0.8 x fraction destroyed	$0.8 m^3/kg$	0.8	5457	m^3
Net calorific Value (NVC) of biogas	5000 Kcal/m^3	5000			
Net Power generation	0.0145	x NVC x B x 10^{-3}	,10^{-3}	0.001	
2	Wet Waste Total Energy	395.62 KW			

Fig. 8 The amount of energy produced by wet waste in District-12

Considering the conversion efficiency to be 30%, estimation of wet waste total energy amount, the above formula is a quick and accurate process. The total amount of generated energy from wet waste in District-12 is about 395.62 kW (Fig. 8).

C. Total Energy Generated from both Dry and Wet Waste

Main road image identifies in Google Earth. After saving the images, they are imported to CAD software, and total length of the main roads is 29361 m (29.36 km) (Fig. 10).

VIII. Energy Required for Main Roads Network Lightening in District-12

The average distance between two lights is 23 m [5]. So, the number of road side lights which is required for the whole network will be: total network length = 29361/23(light spacing) = 1277 number of lights, for both side will be 1277 x 2 = 2554 units of lights which is necessary for entire road network. Moreover, the consumption energy for one-unit light will be 250W which is use for 12 hours for all night. So, the energy consumes by one-unit light will be 250W X 12 = 3000Wh or 3kWh. Therefore, the energy should need for whole road network is 2554 (lights) X 3 (kWh) = 7662 kWh Furthermore, total energy generated is 12174 kWh – 7662 kWh (required energy for road network in District-12) = 4512 kWh (remaining energy from road network).

Finally, we know that the energy which is generated from municipality of solid waste in D-12 is more than the requirement energy (which is 4512 kWh remaining energy) of the main roads network.

A. Remaining Energy Utilization

The utilization of electricity may relate up on season, usage hours and so on, but to calculate in an average amount of power units which is Watt, we use item such as fluorescent lamp, fan, TV, refrigerator, washing machine, computer mixer and iron [4] for one family which include seven people/ household beneficiaries (Fig. 11). Furthermore, the total number of houses which are powered by 0.2 MW electricity will be 70; on the other hand, the total number of persons who are benefiting from 0.2 MW electricity in District-12 will be 490 persons.

Total Energy Generated from both dry and wet Wastes	507 KW	Total Energy Generated	12.17	MWh
Total Energy Generated = (Total Power Generated x 24)	12174 KWh	Total Energy Generated	0.5	MW

Fig. 9 The total amount of energy generated from both dry and wet waste in District-12

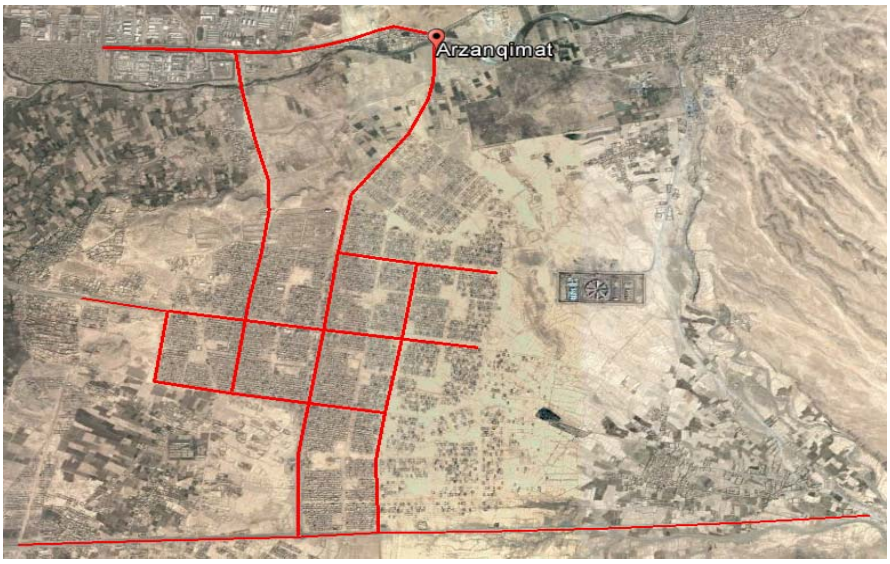

Fig. 10 The main roads network (which is shown by red color) in District-12 [7]

Remaining Energy Utilizing (Which is Genertated from MSW) in District-12				
S.No	Items	Avg(W)	N.o.Items	for 1 family (7 people)(W)
1	Fluorescent lamp	60	5	300
2	Fans	50	3	150
3	TV	150	2	300
4	Refrigerator	350	1	350
5	Washin Machine	500	1	500
6	Computer	75	2	150
7	Mixer	110	1	110
8	Iron	1000	1	1000
Total	8 Items	2295	16	2860
	Total Home Power by 0.2 MW Electricity in District-12			70
	Usage of Person(Per family 7 persons)			490

Fig. 11 Utilization of the remaining energy in household

IX. Conclusion

This study attempted to show how to deal with MSW as a way to contribute to the production of energy and improve the quality of life. On one hand, through the collection of solid waste which is generally the source of spreading diseases, we contribute to improvement of the quality of life. On the other hand, the collected solid waste is converted to energy thus partially adding the capacity of energy production, which is so far insufficient.

In the era of technologies, it will be better to tackle problems with in advance management system, and to convert it to source, GIS is one of the smartest software which helps us, for instance, to analyze residential area, population, and amount of dry and wet waste in each different zone in very simple and easy way.

The energy utilization shows that total energy generated from solid waste in D-12 is 0.5 MW electricity. From that amount, 0.3 MW electricity will be utilized for the entire main road network, and the remaining 0.2 MW electricity will be used for the residential area in zone D which can power almost 6% of houses, including seven persons per family.

Finally, it is observed that the generation of electricity from garbage can help to reduce the huge amount of MSW as well as to produce some necessary amount of energy for community. At the end, it will provide a better and clean environment for the citizens.

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