SCENARIO OF PRESENT AND FUTURE OF SOLID WASTE GENERATION IN ETHIOPIA: A CASE STUDY OF MEKELLE CITY

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Abstract

Solid Waste generation is the by-product of the Urbanization. It is commonly considered as a Urban Issue. It is highly related with Economic growth, degree of industrialization and consumption pattern and lavish lifestyle of urbanites. Solid Waste generation and management is a burning issue all over the world and the planners and policy formulators are finding it extremely difficult to handle this problem mainly because of haphazard urbanization. Solid Waste contributes 3% of total Green House Gases Emission Globally, which are culprit for Global Warming and Climate Change. Largely whole of Africa continent is very much vulnerable to the Climate Change. Lack of technological advancement with poverty makes the problem of GHGs emission compound which will prove to be suicidal if not timely tackled.

In Ethiopia, similar to other developing countries, the increasing amount of solid waste generation is resulted mostly from rapid urbanization and population explosion. Majority of inhabitants in most towns and cities of the country usually use unsafe solid waste disposal practices, such as open dumping, burning, burying etc. (Melaku and Degnet, 2008).

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Total urban population of Ethiopia is 12,566,942. On the basis of current available data the Municipal Solid Waste generation per capita (kg/capita/day) is 0.30.Total Solid Waste Generation is 3781 tones/day in the country.

Information available on existing Solid Waste rate of generation, composition and source of Mekelle City is deemed to be scant. There is no comprehensive study conducted in Mekelle city to investigate the rates of generation and characteristics of solid waste from different urban activities and sources.

The main aim of this paper is to quantify the present generation of Solid Waste and project the generation in future by projecting population growth in Mekelle City and find out the causative factors for the same.

Key Words

Solid Waste, Urbanization, Population Green Hose Gases (GHGs) and Tabias/Kebelle (Administration Unit of the Mekelle City)

Introduction

Solid waste is generally an 'Urban Issue'. Today, more than 50% of the World's population lives in the cities and the rate of urbanization is increasing quickly. Solid Waste generation is the by-product of the Urbanization. It is highly related with Economic growth, degree of industrialization and consumption pattern. With the increase of urban population of the cities and towns all other activities associated with population also increases resulting in more and more generation of Municipal Solid Waste. And in the absence of technology and efficient and effective methods of disposing refuse worsen the quality of Air of the urban centers which have detrimental impacts on human health.

More or less every human activity creates some kind of waste. As countries develop economically, socially, and technologically waste generation also increases. Both developed and developing countries face the problems associated with solid waste generation and its

management. Rapid urbanization directs to the densification and an increase of large amounts of solid waste within a concentrated area.

Global population rose to 6.9 billion in 2010 and the majority of people live in developing countries. A major challenge is how to manage the ever-increasing waste generated, especially in developing countries already lacking a sufficient public service infrastructure to manage municipal waste, and where poverty and unplanned settlements lead to unmanaged waste.

Globally, we live in "throw-away" societies in which we consume packaged products that often do not last past a single use or even a year, and we discard as waste what we no longer want. This wasteful lifestyle seriously impacts the environment, public health, and produces social and economic problems. Waste disposal can have serious environmental impacts: landfills consume land space, and cause air, water and soil pollution - including the emission of greenhouse gases, while incineration results in emissions of dangerous air pollutants. Our consumptive and often wasteful behavior needs to be examined, and changed, so that we can live more sustainably.

Solid waste generation is the common basis for activity data to estimate emissions from solid waste disposal, biological treatment, and incineration and open burning of waste. Solid waste generation rates and composition vary from country to country depending on the economic situation, industrial structure, waste management regulations and life style.

The availability and quality of data on solid waste generation as well as subsequent treatment also vary significantly from country to country. Statistics on waste generation and treatment have been improved substantially in many countries during the last decade, but at present only a small number of countries have comprehensive waste data covering all waste types and treatment techniques.

Solid waste is generated from households, offices, shops, markets, restaurants, public institutions, industrial installations, water works and sewage facilities, construction and demolition sites, and agricultural activities.

Solid waste management practices include: collection, recycling, solid waste disposal on land, biological and other treatments as well as incineration and open burning of waste.

A new, far-reaching report on the state of municipal solid waste around the world predicts a sharp rise in the amount of garbage generated by urban residents between now and 2025. The report estimates the amount of municipal solid waste (MSW) will rise from the current 1.3 billion tons/year to 2.2 billion tons/year, with much of the increase coming in rapidly growing cities in developing countries. **(World Bank Report, 2011)**

Globally, waste volumes are increasing quickly even faster than the rate of urbanization. World Bank report shows that the amount of municipal solid waste is growing fastest in China (which surpassed the US as the world's largest waste generator in 2004), other parts of East Asia, and part of Eastern Europe and the Middle East. In the last two decades the amount of waste generated in China is very high due to increased number of population and economic growth. For instance the waste generation in China is parallel to its economic growth, i.e. from 1979-1995 the average annual rate of increase in its solid waste had been 9% slightly below the average annual growth of its economy 10% (Zang, 1998).

There is a direct correlation between the per capita level of income in cities and the amount of waste per capita that is generated. In general, as a country urbanizes and populations become wealthier, the consumption of inorganic materials (e.g. plastics, paper, glass, aluminum) increases, while the relative organic fraction decreases.

As the world hurtles toward its urban future, the amount of municipal solid waste (MSW), one of the most important by-products of an urban lifestyle, is growing even faster than the rate of urbanization. Ten years ago there were 2.9 billion urban residents who generated about 0.64 kg of MSW per person per day (0.68 billion tons per year). This world report estimates that today these amounts have increased to about 3 billion residents generating 1.2kg per person per day (1.3 billion tones per year). By 2025 this will likely increase to 4.3 billion urban residents generating about 1.42 kg/capita/day of municipal solid waste (2.2 billion tons per year).

Waste generation in sub-Saharan Africa is approximately 62 million tons per year. Per capita waste generation is generally low in this region, but spans a wide range, from 0.09 to 3.0 kg per person per day, with an average of 0.65 kg/capita/day.

The annual waste generation in East Asia and the Pacific Region is approximately 270 million tones per year. This quantity is mainly influenced by waste generation in China, which makes up

70% of the regional total. Per capita waste generation ranges from 0.44 to 4.3 kg per person per day for the region, with an average of 0.95 kg/capita/day (Hoornweg et al 2005).

In Eastern and Central Asia, the waste generated per year is at least 93 million tons. Eight countries in this region have no available data on waste generation in the literature. The per capita waste generation ranges from 0.29 to 2.1 kg per person per day, with an average of 1.1 kg/capita/day.

Latin America and the Caribbean has the most comprehensive and consistent data (e.g. PAHO's Regional Evaluation of Solid Waste Management, 2005). The total amount of waste generated per year in this region is 160 million tons, with per capita values ranging from 0.1 to 14 kg/capita/day, and an average of 1.1 kg/capita/day.

In the Middle East and North Africa, solid waste generation is 63 million tons per year. Per capita waste generation is 0.16 to 5.7 kg per person per day, and has an average of 1.1 kg/capita/day.

The OECD (Organizations for Economic Co-operation and Development) countries generate 572 million tones of solid waste per year. The per capita values range from 1.1 to 3.7 kg per person per day with an average of 2.2 kg/capita/day.

In South Asia, approximately 70 million tons of waste is generated per year, with per capita values ranging from 0.12 to 5.1 kg per person per day and an average of 0.45 kg/capita/day.

Uruguay has the distinction of generating the least MSW that is 0.11kg/capita/day while Trinidad and Tobago generates 14.40 kg/capita/day, which is the highest in the world. And surprisingly both the countries lie in Latin America and the Caribbean Region.

In Ethiopia, similar to other developing countries, the increasing amount of solid waste generation is resulted mostly from rapid urbanization and population explosion. Majority of inhabitants in most towns and cities of the country usually use unsafe solid waste disposal practices, such as open dumping, burning, burying etc. (Melaku and Degnet, 2008).

Total urban population of Ethiopia is 12,566,942. On the basis of current available data the Municipal Solid Waste generation per capita (kg/capita/day) is 0.30, which is undoubtedly very low. Total Solid Waste Generation (tones/day) is 3781.

Information available on existing Solid Waste rate of generation, composition and source of Mekelle City is deemed to be scant. There is no comprehensive study conducted in Mekelle city to investigate the rates of generation and characteristics of solid waste from different urban activities and sources.

Emperor Yohannes IV founded Mekelle in 1872 and the Municipality was established in 1934 E.C. In those days solid waste generation in the city was not very high. About 18% of the generated SW materials were disposed off in open garbage pits and more than 60% of SW generated was disposed at open fields. The garbage pits and open fields were considered as good options of disposal inside the city. The currently operating system of solid waste collection, transportation and disposal was started by the year 2000.

Objectives

- To find out the present generation and composition of Solid Waste from different sources like- Domestic, Commercial and Institutional areas.
- To project the future generation of Solid Waste with increasing population and urbanization

Study Area

Mekelle City, seat of Tigray National Regional State, is located at about 783 km from the nation's capital, Addis Ababa. It is situated at $13^0$32 North Latitude and $39^0$28 East Longitude. The land demand increase as the population size of the city rose from time to time. Mekelle had a built up area coverage of 16 KM^2 in 1984 after ten years, in 1994 the size of built up area reached 23.04 KM^2 adopting a continuous increase with the rise of population size and job opportunity the city administration has expanded its land holding to 100KM^2in 2004 by engulfing the vast agricultural lands of neighboring villages and towns. The altitude of Mekelle varies from 2150 MSL to 2270 MSL. Mekelle Experiences mild climatic condition with annual average maximum temperature of 24.1^0C and annual average minimum temperature 11.11^0C. June is the hottest month with a monthly mean maximum temperature of 27.1^0C and monthly mean minimum temperature of 13.03^0C. December is the coldest month with a mean monthly maximum temperature of 21.9^0C and monthly mean minimum temperature of 8.51^0C.

There is one short rainy season, which starts on June and lasts on August. The rainy season is characterized by erratic, unreliable and uneven distribution. The city has annual average rainfall of 618.3mm/Year of which the substantial amount falls on July and August. The highest monthly rainfall occurs on August with a monthly rainfall of 229mm (37% of the annual) and July is the second largest rainy month with a monthly rainfall of 207.7mm (33.5% of the annual).

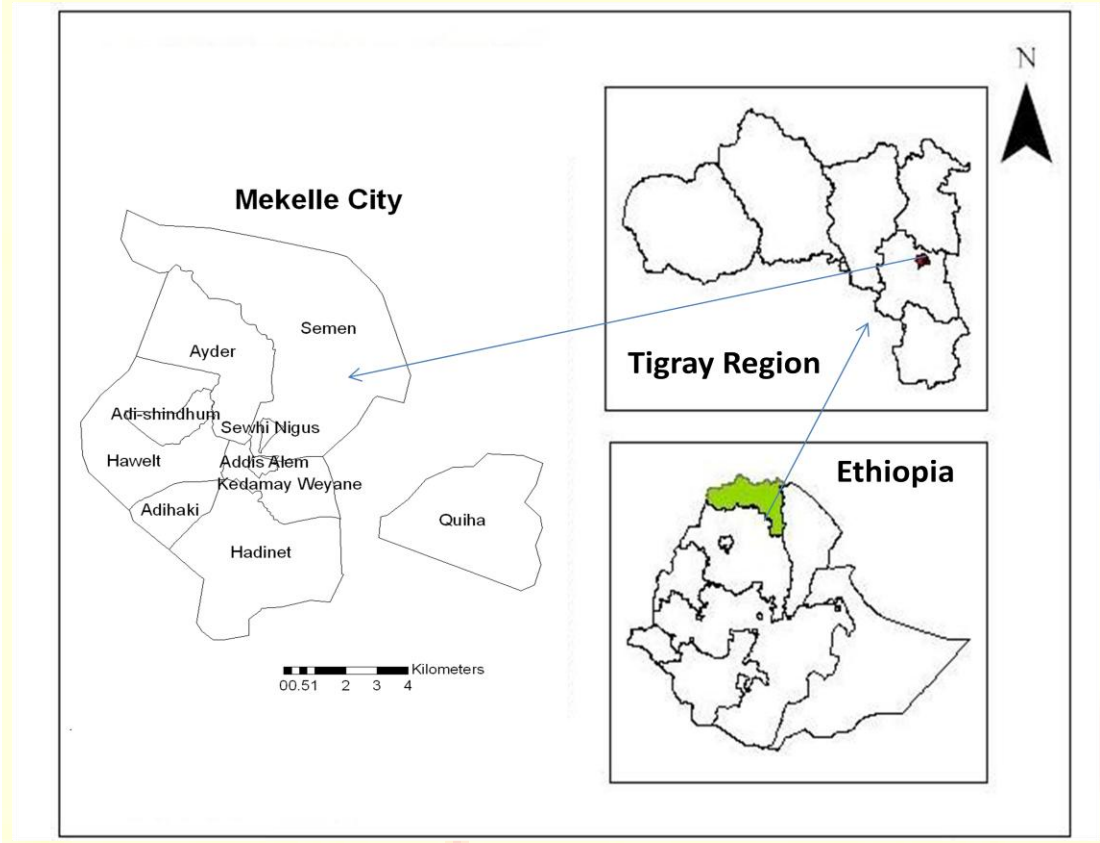


Figure 1 Location Map of Mekelle City

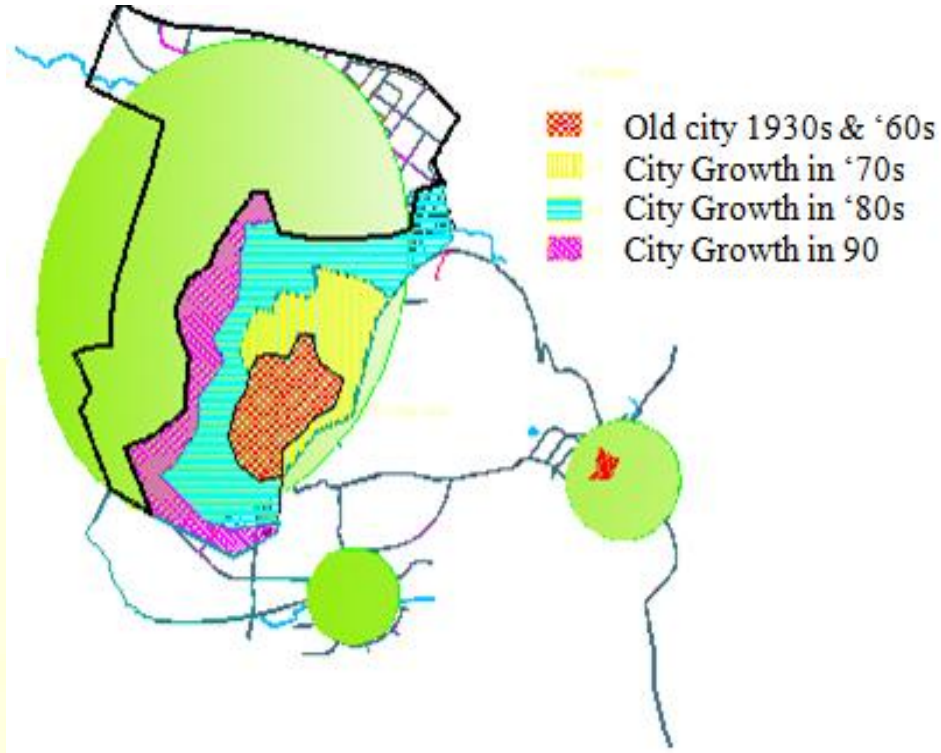


Figure 2: Mekelle growth trend from 1930s-1990s

Source: Mekelle municipality plan, 2006

Data Base and Methodology

Both, primary as well as secondary data was used for this paper. Primary informations were collected through structured questionnaire and personal observations. Secondary data was gathered from published reports of the city administration specifically Municipality of Mekelle City. To analyze the data and project the population growth and Solid Waste Generation simple statistical techniques like percentage, mean, probabilistic model and geometric methods were used.

Results and Discussions

Generation and characteristics

There is no comprehensive study conducted in Mekelle city to investigate the rates of generation and characteristics of solid waste from different urban activities and sources. Even the sources

and solid waste category are not clearly identified in the existing municipal solid waste (MSW) management service. Following pictures are the ample proof of the poor management of Solid Waste generated in the city.

(a) River side (b) Fence and skip sides

(a) Fence side (b) Uncovered solid waste slope

Figure- 3. Illegal solid waste dumping sites

Sources, type and composition of the Solid Waste

Residential Sources: All the ten Tabias currently existing in the cities of Mekelle are considered as observation sites for Residential SW sources taking a total sample size of 3% of the total house holds (i.e. 1162HHs on the basis of the year 2004 population) in each Tabia. The survey investigates the total and per capita rates of solid waste generations, proportion of various solid waste materials in household SW samples, and properties of the Residential SW in four household socio-economic groups. The SW from Residential sources are characterized based on a total sample households of 1162 collected from all socio-economic groups in the Tabias.

Table- 1. Distribution of sample household sizes in Residential establishments

SN	Locality	Inhabita-nts (2004)	Estimated Households	Sample HHs	Number of sample households for each income group (Monthly average income in Birr)			
					0-500	500-1000	1000-2000	>2000
					A	B	C	D
1	Aider	24300	4959	149	68	36	27	18
2	Hawelti	25125	5128	153	72	36	27	18
3	Adi Haki	25650	5235	157	71	38	29	19
4	Kedamay Weyane	27157	5542	166	76	40	30	20
5	Hadenet	26106	5328	160	74	38	29	19
6	Sewhi Niguse	19000	3878	116	53	28	21	14
7	Adise Alem	18000	3673	110	51	26	20	13
8	Industry	11766	2401	72	31	18	14	9
11	Adi-shumduhun	6376	1301	39	16	10	8	5
12	Ellala	6515	1330	40	17	10	8	5
	Total	189995	38775	1162	529	280	213	140

Source: Field Survey

Then standard plastic bags of $1m^2$ minimum area is issued to each sample house holds and are advised to store their household garbage honestly and carefully for a minimum generation time of one week.

As the measurement of observations house-to-house is a cumbersome task, convenient and centralized observation sites are located within the proximity and boundary of the sample households. The Enumerators collect household samples on each observation sites and take all the necessary measurements using the standard forms for recording observations of generation rate, proportion of constituent and properties of SW.

Other Solid Waste sources

The socio-economic and service data clearly indicate that the manufacturing, construction, transportation and service sectors have leading share in the urbanization of Mekelle City. The construction sector mainly represents the housing and industrial development activities in the City. These activities are expected to generate significant SW quantities in different parts of the City, which is not known at the moment. Therefore, field observations need to be conducted in selected sample urban activities and services.

Projection of population and Solid Waste Generation

Population Growth trend and average family size

The total average family size for city of Mekelle is 4.9 persons. (Finance and Economic Development Office, October 2003)

Table2: Population Trend

SN	Year	Growth rate
1	1965-1970	4.6%
2	1970-1978	5.1%
3	1978-1984	6.3%
4	1994-2004	4.4%
5	2004+	4.4%

Source: Finance and Economic Development Office (October 2003)

Assuming that the existing population growth rate would remain the same for the planning period seems unjustifiable as it is difficult to control and dictate the population policy, the economic growth rate, cultural attitude, security etc. Therefore to minimize the risk of over and under estimation of population size, it has been professionally expedient to assume the medium growth variant which is 5.4 in our case for future population projections.

Population forecasting

Geometric method:

The kinetics:

$$\frac{dP}{dt} = K_g P$$

Population:

$$\text{Ln } P_t = \text{Ln } P_1 + K_g (T_t - T_1)$$

Growth rate:

$$K_g = \frac{Ln\, P_t - Ln\, P_1}{T_t - T_1}$$

Where K_g is population growth rate

P_t is projected population size at time T_t

P_1 is base year population (i.e. at time T_1)

Projected Population size of Mekelle from Medium Variant (5.4%)

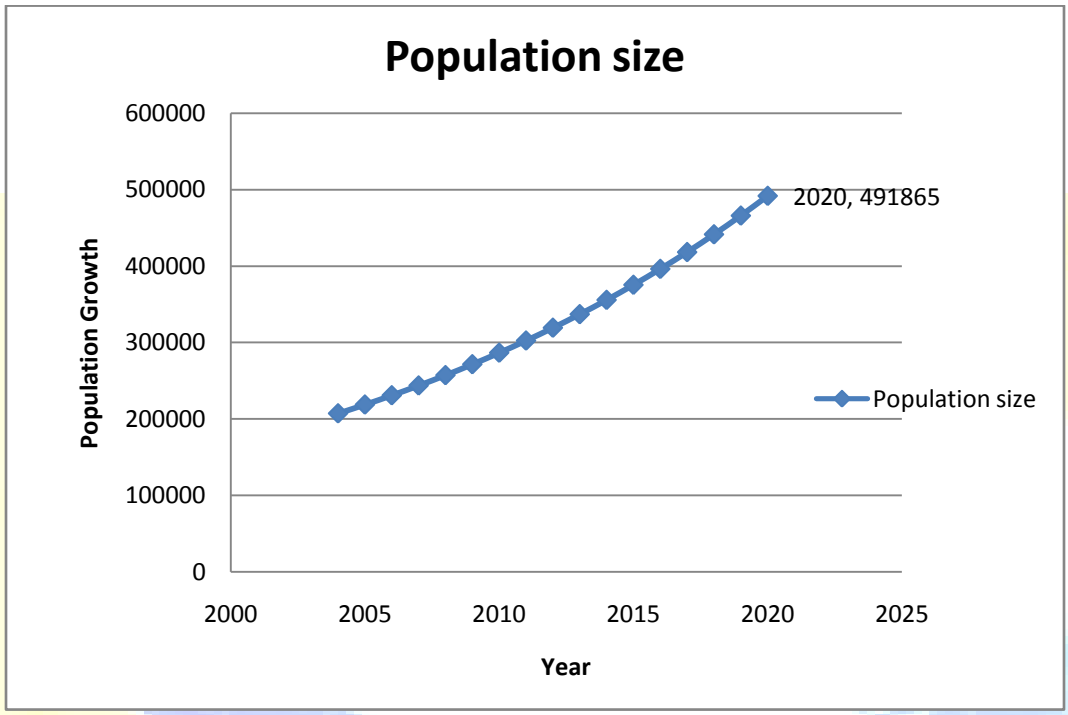


Figure- 4.

Solid Waste Generated-Results of the survey

Table 3: Generation rate of residential establishments Tabia wise

SN	Tabias	Per capita per day volume (l/c/d)	Per capita per day weight (Kg/c/d)	Per capita per day unit weight (Kg/cu.m)
1	Addis Alem	0.989	0.322	434.27
2	Industry	0.641	0.271	573.63
3	Sewhi Negus	0.713	0.171	272.98
4	AddishumDhun	1.276	0.275	242.91
5	Kedamy Weyane	0.936	0.279	456.76
6	Aider	1.115	0.352	362.20
7	Hadnet	1.133	0.325	286.12
8	Hawltie	0.560	0.148	373.62
9	Adi Hakie	0.948	0.267	337.70

10	Mekelle City	0.924	0.268	371.13

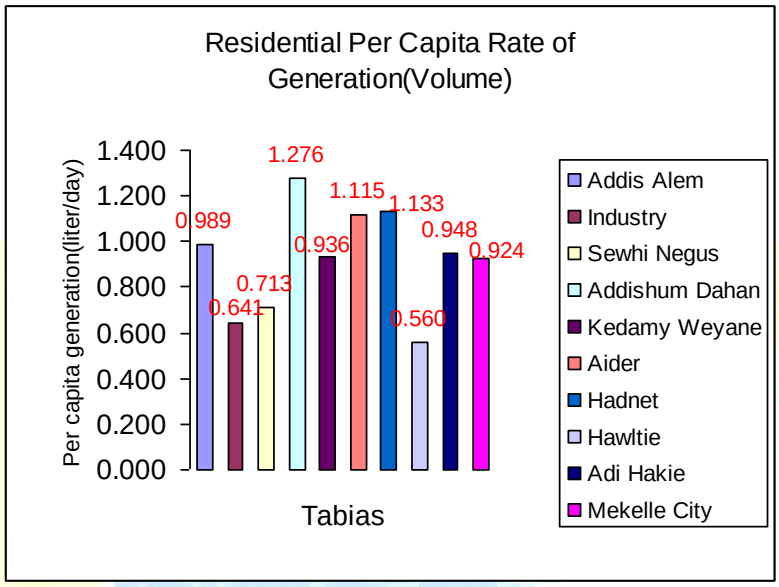
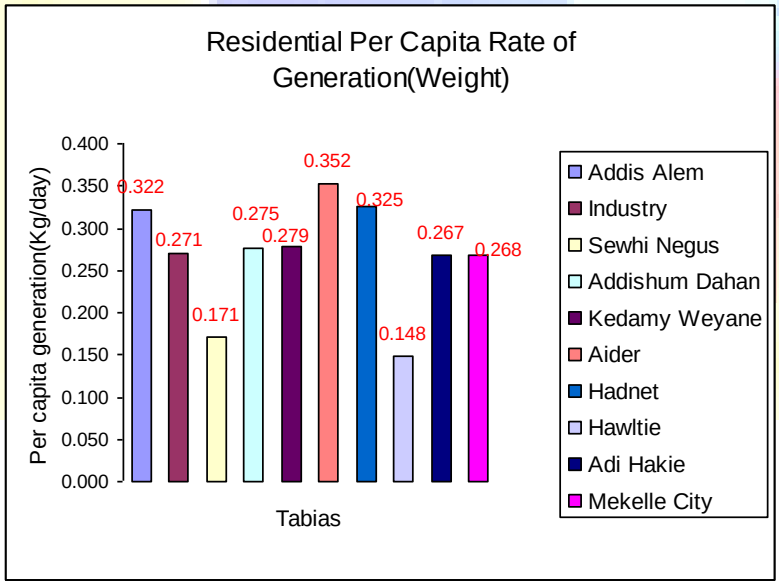


Figure- 5.



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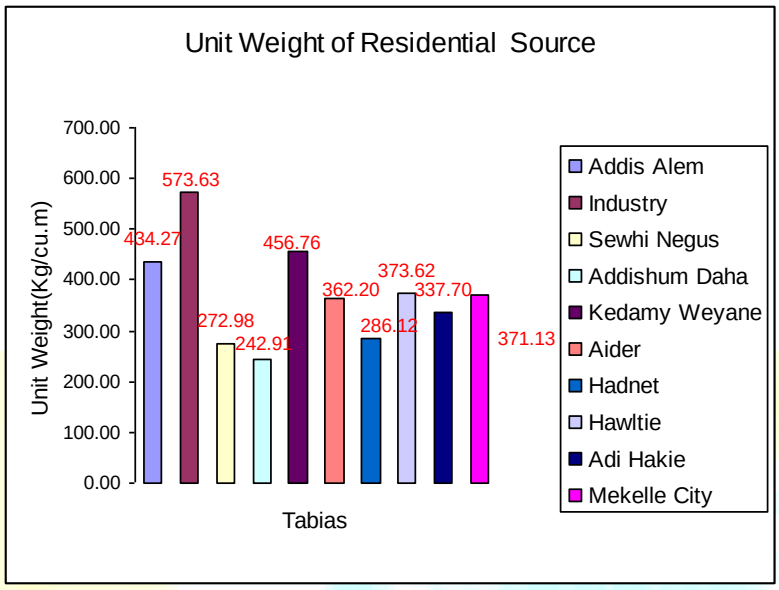

Figure- 7.

The rate of generation is known to be changed with the consumption pattern of the people and that is fully dependent on the level of income of the family/household. so economic status of residents is the main reason for higher rate of generation of Solid Waste. However due to the difficulty of predicting the dynamics of economic change and lack of previous records to be used for trend analysis the rate of generation is forecasted using probabilistic model.

Model Equations for forecasting the rate of generation

per capita rate of generation (l/c/d)	Y=0.3215Ln(X)+1.2371	where X is frequency factor
per capita rate of generation (kg/c/d)	Y=0.0913Ln(X)+0.3568	
unit weight(kg/cu.m)	Y=127.61Ln(X)+495.62	$X = \frac{PlanningYear}{PlanningYear+1}$

Table 4: Forecasted rate of generation

Year	2004	2005	2006	2007	2008	2009	2010	…….……
Planning year	0	1	2	3	4	5	6	……..
Frequency		0.500	0.667	0.750	0.800	0.833	0.857	……

factor(X)								
Rate of generation (Y)	0.924	0.924	1.014	1.107	1.145	1.165	1.178	.....

Summary of rate of generation

Table 5. Summary of Rate of Generation from Commercial sources

	Rates & Quantities of solid waste		
	2005	2010	2015
Average rate of generation(l/unit/d)	5.52	5.52	5.52
Average rate of generation(kg/unit/d)	1.15	1.15	1.15
Total number of commercial units	2677.00	3265.94	3984.4468
Average annual quantity of (cu.m/yr)	5393.62	6580.22	8027.86
Average annual quantity (kg/yr)	1123670.75	1370878.32	1672471.54
Average monthly quantity cu.m/m)	449.47	548.35	668.99
Average monthly quantity kg/m)	93639.23	114239.86	139372.63
Average weekly quantity (cu.m/wk)	103.72	126.54	154.38
Average weekly quantity (kg/wk)	21609.05	26363.04	32162.91
Average daily quantity (cu.m/d)	14.82	18.08	22.05
Average daily quantity (kg/d)	3087.01	3766.15	4594.70

Table 6. Constituents of MSW from commercial sources

	Proportion (% by volume)	Yearly volume		
		2005 (cu.m)	2010 (cu.m)	2015 (cu.m)
Grass>50mm	0.00	0.00	0.00	0.00
Grass<50mm	5.17	277.82	340.47	415.37
Food wastes	0.64	34.12	41.82	51.02
Broken glass	0.00	0.00	0.00	0.00
Non-broken	0.00	0.00	0.00	0.00
Rubber	1.00	53.69	65.80	80.28
Ceramics	0.00	0.00	0.00	0.00
Leather	1.66	89.16	109.27	133.31
Garment & Textiles	6.50	349.24	427.99	522.15
Paper	7.80	418.65	513.06	625.93

Tin cans	0.07	3.55	4.35	5.30
Catha Edulis	2.54	136.56	167.35	204.17
Ash	0.88	47.49	58.20	71.01
Ferrous	6.83	366.82	449.54	548.44
Fruits & vegetables	13.52	726.15	889.89	1085.67
Bones	0.00	0.00	0.00	0.00
Special Wastes	0.00	0.00	0.00	0.00
Yard Waste	7.47	401.19	491.66	599.83
Bulky items	1.17	62.88	77.06	94.02
Consumer electronics	0.00	0.00	0.00	0.00
Plastics	12.64	678.53	831.54	1014.47
Hazardous wastes	2.33	125.20	153.43	187.18
Other wastes & fines	29.69	1594.02	1953.47	2383.23
Total	99.92	5365.09	6574.89	8021.36
% Error	0.08			

Table7. Summary of Rate of Generation for Institutional Sources

	Rates & Quantities of solid waste		
	2005	2010	2015
Average rate of generation(l/unit/d)	10.76	10.76	10.76
Total number of Institutional units	233.00	298.00	375.00
Average Total annual quantity	20903.45	30419.92	36142.06
Average monthly quantity of MSW(cu.m/m)	1741.95	2534.99	3011.84
Average weekly quantity of MSW(cu.m/wk)	401.99	585.00	695.04
Average daily quantity of MSW(cu.m/d)	57.43	83.57	99.29

Table 8. Constituents of MSW from institutional Sources

	Proportion (% by volume)	Yearly volume		
		2005 (cu.m)	2010 (cu.m)	2015 (cu.m)
Mixed MSW(more of organic matters)	20.43	4270.04	4270.04	4270.04
MSW paper	36.36	7600.31	7600.31	7600.31
BMW	43.21	9033.10	9033.10	9033.10
Total	100.00	20903.45	20903.45	20903.45

Concluding Remarks

Mekelle is one of the fastest growing cities of Ethiopia. Mekelle had a built up area coverage of 16 KM ^{2} in 1984 after ten years, in 1994 the size of built up area reached 23.04 KM ^{2} adopting a continuous increase with the rise of population size and job opportunity the city administration has expanded its land holding to 100KM ^{2}in 2004 by engulfing the vast agricultural lands of neighboring villages and towns (see figure 2). So it shows clearly how fast the city is growing? population and the generation of Solid Waste are inextricably linked. Huge amount and unmanaged Solid Waste in a city like Mekelle is leading to environmental degradation which in turn having detrimental ramifications on human health. It was also observed from the study that there is positive correlation between level of income of the household and rate of generation.

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