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RESEARCH ARTICLE

EXISTING AND FUTURE MSW GENERATION NEXUS POPULATION AND GDP GROWTH, THE CASE OF MEKELE CITY, ETHIOPIA

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Abstract

Municipal Solid Waste(MSW) generation is unavoidable phenomena in any Economic levels and population size. The fast expansion of urbanization, agricultural practices and industrial activities encouraged by quick population growth has produced an enormous amount of solid wastes are pollutes the environment and destroy resources.The data was generated from secondary data sources of various institutions. The range and the composition of MSW generation are highly variable and heterogynous with the contemporary way of life experience of both in low, middle and high income inhabitants. The result showed that the current scenario of MSW generation rate is small but it is tremendously in an increasing fashion parallel with population and GDP growth of Mekele City. Thus, it is important and advisable to underway well comprehensive kinds of research works in the City to identify and predict the prospect MSW generation trends together with its integrated management options.

Introduction:-

Solid wastes are the materials which arise from various human and animal activities and discarded as useless or unwanted (Rana, 2007). Solid waste generation is an inevitable consequence of production and consumption activities in any economy (Eugenia et al., 2002). (UNEP, 2005) also reported that fast expansion of urban, agricultural and industrial activities spurred by rapid population growth has produced a huge amount of solid waste that pollutes the environment and destroy resources. Globally the per capita amounts of municipal solid waste generated on a daily basis vary significantly (WRI, 1996). Globalization can promote economic growth, a desirable outcome. However, this economic growth in addition to population increase and urbanization will seriously strain municipal resources to deal with booming amounts of wastes (Medina, 2002). Solid waste generation depends on the economy of the people and level of income of the family or individual. Previous studies have shown that for every Indian, an increase in income by Rs. 1000 results in an increase of solid waste generation by one kilogram per month. It is a common observation that with an increase of economic growth the waste generation grows in an equal manner. Economic growth and waste generation have not been decoupled in both developing and industrialized world (Visvanathan & Trankler, 2006). Medina (2002) also reported that a positive correlation tends to exist between a community's income and the amount of solid waste generated. Wealthier individuals consume more than lower-income ones, which result in a higher waste generation rate for the former. Income and household size are the most significant factors affecting the quantity of solid wastes from household consumption (Richardson & Havlicek,

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1974). Visvanathan & Trankler (2003) reported that in a family with rich socioeconomic condition, daily waste generation rates were generally higher than the lower socioeconomic families.

Increasing population levels, booming economy, rapid urbanization and the rise in community living standards have greatly accelerated the municipal solid waste generation rate in developing countries (Minghua et al., 2009). Municipalities, usually responsible for waste management in the cities, have the challenge to provide an effective and efficient system to the inhabitants. However, they often face problems beyond the ability of the municipal authority to tackle (Sujauddin et al., 2008) mainly due to lack of organization, financial resources, complexity and system multi dimensionality (Burntley, 2007).

Global MSW generation Scenario:-

Generally, in European countries and Organization for Economic Cooperation and Development (OECD) countries, MSW covers waste from households (82% of total MSW) including bulky waste, waste from commerce and trade, office buildings, institutions and small businesses, yard and garden waste, street sweepings, the contents of litter containers, and market cleansing waste (Eurostat, 2003). The definition of MSW excludes waste from municipal sewage networks and treatment, as well as municipal construction and demolition waste. However, national definitions of MSW may differ (OECD, 2007a).

The annual waste generation in East Asia and the Pacific (EAP) Region is approximately 270 million tons per year. This quantity is mainly influenced by waste generation in China, which makes up 70% of the regional total (UNEP, 2010; Wasswa & Schluep, 2008).

Table1:- Waste Generation Per Capita by Region

Region	Waste Generation per Capita(kg/capita/day)		
	Lower Boundary	Upper Boundary	Average
AFR	0.09	3.0	0.165
EAP	0.44	4.3	0.95
ECA	0.29	2.1	1.1
LAC	0.11	5.5	1.1
MENA	0.16	5.7	1.1
OECD	1.10	3.7	2.2
SAR	0.12	5.1	0.45

Source: Hoornweg et al., 2005)

In Eastern and Central Asia (ECA), 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/ person/day, with an average of 1.1 kg/capita/day. Latin America and the Caribbean (LAC) 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. Similar to the high per capita waste generation rates on islands in Africa, the largest per capita solid waste generation rates are found in the islands of the Caribbean. In the Middle East and North Africa (MENA), solid waste generation is 63 million tons per year. Per capita waste generation is 0.16 to 5.7 kg/person/day, and has an average of 1.1 kg/capita/day. The (OECD) countries generate 572 million tons 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 Region (SAR), 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. Table 3 shows current waste generation per capita by region, indicating the lower boundary and upper boundary for each region, as well as average kg per capita per day of waste generated within each region.

Table2:- Waste Generations Per Capita by Income Level

Income Level	Waste generation per capita (kg/capita/day)		
	Lower Boundary	Upper Boundary	Average
High	0.70	14	2.1
Upper Middle	0.11	5.5	1.2
Lower Middle	0.16	5.3	0.79
Lower	0.09	4.3	0.60

Source: Hoornweg et al., 2005

Of the world's waste, while Africa and South Asia figure as the regions that produce the least waste. Table 4 below shows estimates of waste generation for the year 2025 as expected. According to Hoornweg et al., 2005, current trends in population growth in each region. In the coming 10 years the East Asia and Pacific regions are the most dominant solid waste producers.

Table3:- Waste Generation Projections for 2025 by Region

Region	Current Available Data			Projection for 2025			
	Total urban population (Millions)	Urban waste Generation		Projected Population		Projected Urban waste	
		Per capita (kg/capita/day)	Total (tons/day)	Total population (millions)	Urban population (millions)	Per capita (kg/capita/day)	Total (tons/day)
AFR	260	0.65	169,119	1,152	518	0.85	441,840
EAP	777	0.95	738,958	2,124	1,229	1.5	1,865,379
ECA	227	1.1	254,389	339	239	1.5	354,810
LCR	399	1.1	437,545	681	466	1.6	728,392
MENA	162	1.1	173,545	379	257	1.43	369,320
OECD	729	2.2	1,566,286	1,031	842	2.1	1,742,417
SAR	426	0.45	192,410	1,938	734	0.77	567,545
Total	2,980	1.2	3,532,252	7,644	4,285	1.4	6,069,703

Source: Hoornweg et al., 2005)

Waste generation varies as a function of affluence, however, regional and country variations can be significant, as can generation rates within the same city. Throughout the report, when Africa is mentioned as a region, we refer to Sub-Saharan Africa (AFR). Data are particularly lacking for Sub-Saharan Africa. 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 countries with the highest per capita rates are islands, likely due to waste generated by the tourism industry, and a more complete accounting of all wastes generated, (Wasswa & Schluep, 2008). For example the composition of wastes in East African Cities are illustrates on table 4:

Table4:- Composition of solid wastes generated in East African urban centers

Waste composition (%)	Dare Salaam	Moshi*	Kampala	Jinja	Lira	Nairobi*
Bio-waste	71	65	77.2	78.6	68.7	65
Paper	9	9	8.3	8	5.5	6
Plastic	9	9	9.5	7.9	6.8	12
Glass	4	3	1.3	0.7	1.9	2
Metal	3	2	0.3	0.5	2.2	1
Others	4	12	3.4	4.3	14.9	14
Kg/cap/day	0.4	0.9	0.59	0.55	0.5	0.6
% collection	40	61	60	55	43	65
Population	3,070,060	183,520	1,700,850	91,153	107,809	4,000,000
Population paying for collection	ND	35	ND	ND	ND	45

ND= Not determined; Source: #NEMA, 2007;*Scheinberg et al., 2010

Current Waste Generation and in Emerging Cities of Ethiopia:-

Waste management in Addis Ababa is fundamentally different from other emerging cities of Ethiopia. There has been no form of waste management in emerging cities until very recently. A few of these new municipalities, as seen in Figure 5, were designed to decrease human exposure to unsanitary conditions and environmentally degrading practices. Yet, as Table 3 illustrates, the collection and management of waste in most of the municipalities is still quite inefficient.

Two exceptions, Mekele and Dire Dawa, have recently experienced promising results for improved waste management and waste-to-energy conversion through biogas capture from landfills using both technical and

institutional strategies (Fikreyesus, 2011). International financing, such as the Clean Development Mechanisms, could support the transition to sustainable waste management in these emerging cities, similar to the Addis Ababa municipality.

Table5:- Ethiopian municipalities and waste generation, in 2010

City	Region	Population	MSWG	MSWC
Addis Ababa	Addis Ababa	2,979,100	1,132t/d	70% collected
Mekele	Tigray	261,200	78t/d	82% collected
Dire Dawa	Dire Dawa	256,800	77t/d	48% collected
Jima	Oromya	120,960	87t/d	30% collected
Adama	Oromya	260,600	59t/d	48% collected
Bahr Dar	Amhara	170,300	27t/d	58% collected
Hawassa	SNNPR	200,400	46t/d	44% collected
Harer	Harer	108,200	32t/d	45% collected

- t/d= tons/ day; Source: Central Statistical Agency of Ethiopia, 2010; Fikreyesus, 2011

Mekele is another Ethiopian city that has recently increased solid waste generation but lacks management to accommodate the growing rates of waste. The municipality currently offers poor disposal services throughout the city, with a total of 58 collection containers (Tadesse et al., 2008). Final collectors dispose of waste in two open dumping sites about 10km outside of the city (Tadesse et al., 2008).

Materials and Method:-

Area description:-

Mekele 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 the city administration has expanded its land holding to 100KM ^{2}in 2004 by engulfing the vast agricultural lands of neighboring villages and towns. The altitude of Mekele varies from 2150 m.a.s.l. - 2270 m.a.s.l. Mekele Experiences mild climatic condition with annual average maximum temperature of 24.1^{0}C and annual average minimum temperature 11.11^{0}C. June is the hottest month with a monthly mean maximum temperature of 27.1^{0}C and monthly mean minimum temperature of 13.03^{0}C. December is the coldest month with a mean monthly maximum temperature of 21.9^{0}C and monthly mean minimum temperature of 8.51^{0}C. 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 229 mm (37% of the annual) and July is the second largest rainy month with a monthly rainfall of 207.7mm (33.5% of the annual).

Data Collection Methods:-

The data was generated from the secondary data sources of Mekele City administration Municipality; Waste management and control stream. The projected population growth was estimated by the average growth rate of Mekele City; that is 4.4%,from Finance and Economic Development Office (October 2004), Mekele.The total current solid waste generated and projected waste generation was calculated based on the daily per capita generation of the City; the daily per capita waste generation of Mekele City is 0.268kg/c/d**,** (ECSA, 2010 and Feasibility study of ISWM for Mekele City, 2012). The GDP growth of Mekele City was also extrapolated from the Ethiopian GDP growth of the last 10 years by Statista, 2016 and www.Trading Economics.com/ World Bank (2015). Its extrapolated by divided the yearly GDP growth to GDP per Capita and Multiplying by the total population of Mekele City for each year.

The Existing Municipal solid waste generation Rate of Mekele:-

According to the Feasibility study in 2012 of Mekele City, the daily generation rate of every Kebele and City level is tracked with volume and weight per capita per day basis in table 6- below.

Table 6:- Solid waste generation rate of inhabitants in Mekele Sub-City bases

SN	Tabias	Per capita per day volume (cu m/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	Addishum Dhun	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
Mekele City		**0.924**	**0.268**	**371.13**

Source: Feasibility study ISWM for Mekele City 2012

Table7:-Rates and quantities of solid waste generation Of Mekele City Bases

Summary of Rate of Generation for MSW sources	Rates & Quantities of solid waste	
Years	2010	2015
Master plan population	285489.00	335583.00
Average annual quantity (cu.m/yr)	129540.33	156238.10
Average annual quantity (kg/yr)	1406307.50	1715342.27
Average monthly quantity (cu.m/m)	10795.03	13019.84
Average monthly quantity (kg/m)	117192.29	142945.19
Average weekly quantity (cu.m/wk)	2491.16	3004.58
Average weekly quantity (kg/wk)	27044.37	32987.35
Average daily quantity (cu.m/d)	355.88	429.23
Average daily quantity (kg/d)	3863.48	4712.48

Source: Feasibility study ISWM for Mekele City 2012

Population Size, GDP growth and Solid waste generation forecast:-

The total solid waste generated from Mekele City was calculated based on the projected population number and the per capita waste generation. The population growth also calculated by using the average annual growth rate of the City and the following formula was used to calculate the annual increment of population number.

$Pi = Po * (1 + r)^t$

Where: Pi = Total population number for the target year

Po = Total population number in 2010

r = Annual growth rate

t = number of years from 2006 to the target year

Table8:-Population growth rate Trends of Mekele City

Year	Growth Rate
1965-1970	4.6%
1970-1978	5.1%
1978-1984	6.3%
1994-2004	4.4%
2004+	4.4

Source: Finance and Economic Development Office (October 2004)

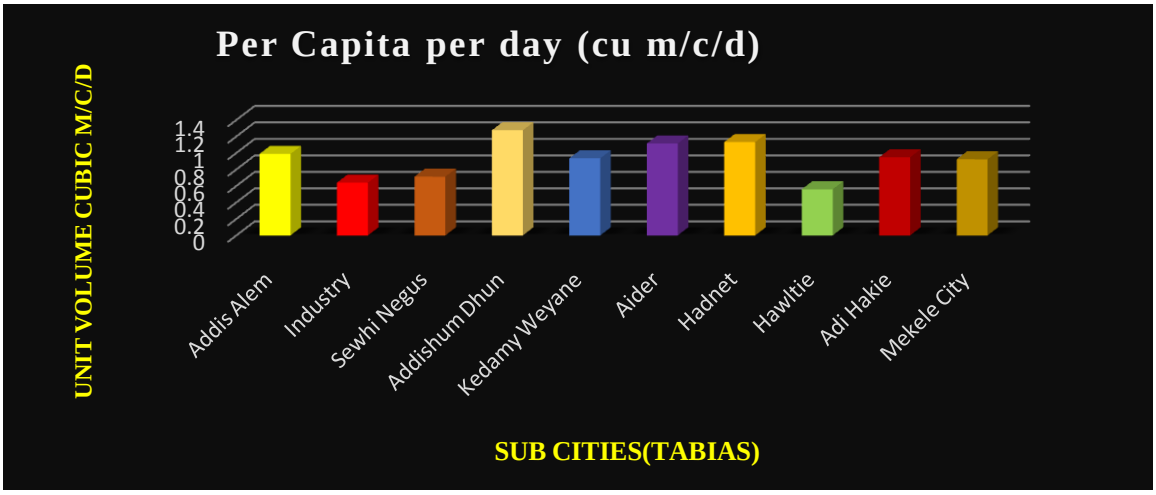
Table9:-Projected Population and Waste generation of Mekele City

Year	Population size in Thousands	GDP in Million (USD)	Waste Generation (Tons/c/day)
2010	261.200	89.2935708	25,550.73
2011	272.693	100.9940341	26,674.93
2012	284.691	111.6572337	27,848.41
2013	297.218	125.6792257	29,073.71
2014	310.295	141.113788	30,353.04
2015	323.948	157.525870	31,323.57
2016	338.202	174.9349845	33,082.87
2017	353.083	192.9598595	34,538.49
2018	368.619	212.0554521	36,058.35
2019	384.838	233.1156185	37,645.01
2020	401.771	255.707153	39,301.38
2021	419.449	278.3715233	41,030.38
2022	437.904	303.686424	42,835.67
2023	457.172	331.2439726	44,720.53
2024	477.288	359.7653758	46,688.25
2025	498.289	390.1852015	48,742.47

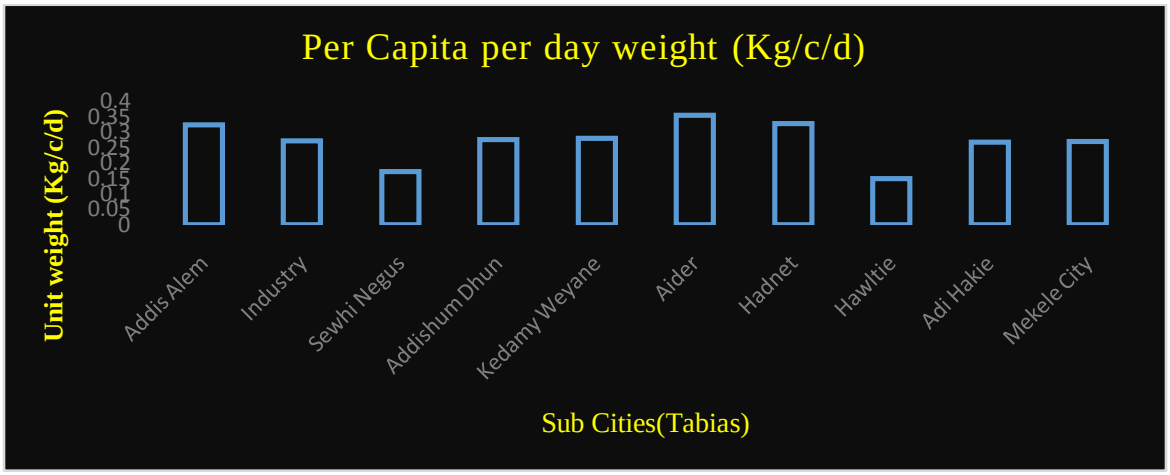
From 2016 onwards are forecasted numbers. Source: CSA, Reports of the 2007 and 2010 Census and 2012 Annual Statistical Abstract; Statista, 2016 and www.Trading Economics.com/ World Bank (2015)

Result and Discussion:-

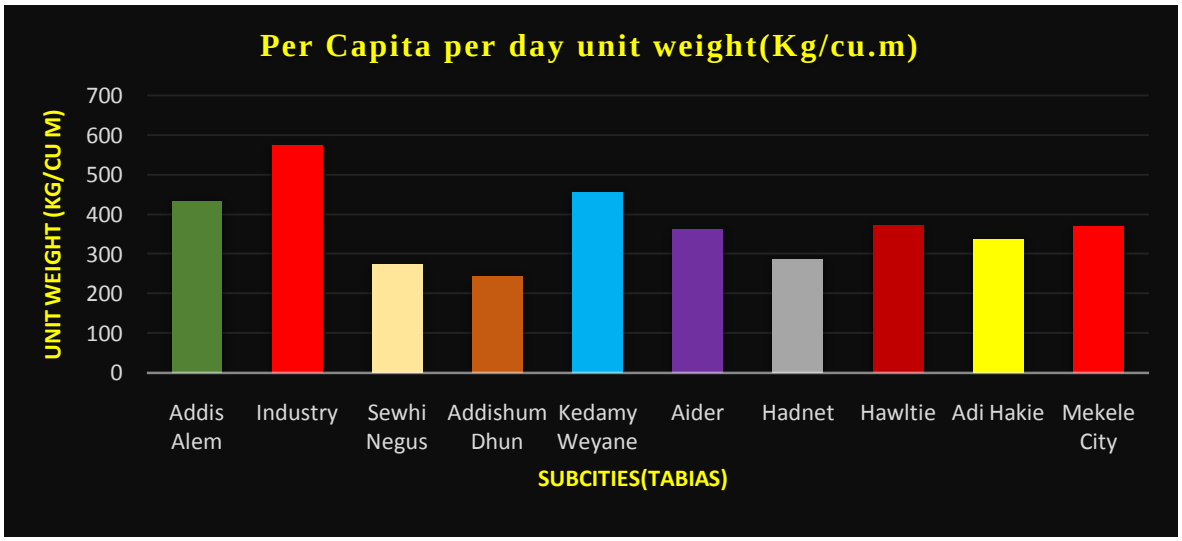
In the Solid waste generation rate of residential establishments of Sub-City bases; table 6, shows that the highest per capita per day volume, per capita per day weight and per capita per day unit weight of MSW is recorded in Hadnet, Addis Alem and Industry Sub-City respectively. There are also huge differences among the largest and the smallest waste generation Scenarios ofthe Sub-City; this is due to the economic level and the number of populations within the Sub-Cities. And generally in a City level the per capita per day volume, per capita per day weight and per capita per day unit weight are 0.924, 0.268, 371.13 respectively.Thus, Solid waste generation rate of inhabitants in Mekele Sub-City bases is elaborated below graphically (per capita per day (cu m/c/d) :



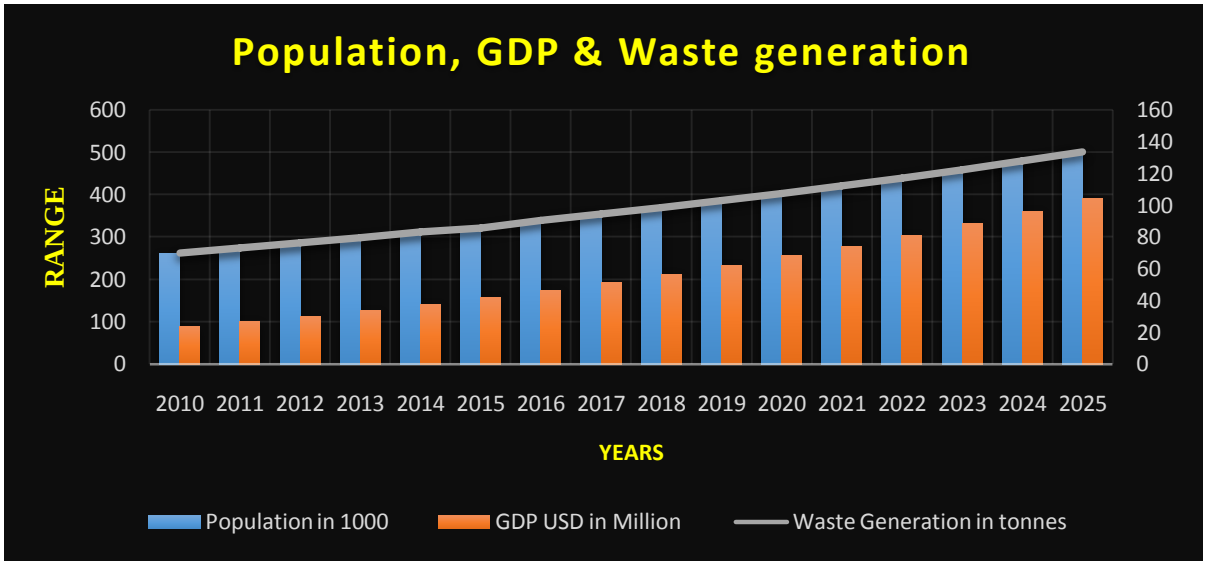
The rate of waste generation is known to be changed for every fiscal year. Among other factors economic status of residents is the main reason. However due to the difficulty of predicting the dynamics of economic changes and lack of previous recorded data to be used for trend analysis; so, the rate of generation is forecasted using probabilistic model.Thus, Solid waste generation rate of inhabitants in Mekele Sub-City bases is elaborated below graphically (Per capita per day weight (kg/c/d) :



From table six again theSolid waste generation rate of inhabitants in Mekele Sub-City bases is elaborated below graphically (Per capita per day unit weight (kg/cu m) :



According to table 9-results, the connection of population, GDP and waste generation is linear relationships. As the population and the economic growth increases the waste generation per capita also increase and the waste generation of the City per year is sharply increases. For the coming ten years of waste generation in Mekele City will also increasing tremendously by the influence of the population growth and the economic developments of the City as well. It was projected the future population growth by using the following population projection formula:$Pi = Po * (1 + r)^t$



Mekele City solid waste generationin relative to the high income countries/ developed nations the recent rate of waste generation per capita is very small. The average waste generation of OECD countries (kg/capita/day) is 2.2, (Hoornweg et al., 2005). But the average waste generation of Mekele City (kg/capita/day) is 0.268; that is only 12% of the OECD countries is generated in Mekele City.

Conclusion and The Way for wards:-

- Generally the Mekele City MSW generation is highly linked with the population size and the income level of the inhabitants. The MSW generation scenario of Mekele City in the Past six and the coming 10 years both the per capita and total annual generation rate for the City showed that ever increasing with linear relationships of the influencing Factors (Population and Income level of the Inhabitants).
- Even though the amount of waste generation is on the sharply increment Manner, it is very insignificant relatively to the high income level countries' generation rate.
- The population growth together with the economic development of the City has positive impacts in solid waste generation of the City; thus, the municipality should give serious concern on the controlling of the ever increasing MSW generation.
- The generated waste must be treated accordingly the nature, compositions and the characteristics of the MSWs.
- The Heterogeneity of MSW generation of the City should be managed by the participatory approaches of all stakeholders by involving in the waste Recycling, Reducing and Reuse (3R-Rules approach) responsibility roles.
- There should be a strong Policy and Laws to control and treat the generation and management processes of MSWs both in Sub-Cities and City levels.

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