

ESTIMATION OF MUNICIPAL SOLID WASTE GENERATION RATE (CASE STUDY OF HILLA CITY)

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ABSTRACT

This paper, estimated Hilla Municipal Solid Waste (MSW) generation rate for five years period (from year 2012 to year 2016). This Period is estimated as a minimum duration of landfill site operation time. Geographic Information System (GIS) technique are used to prepare digital map of Hilla city to determine all of Hilla district areas and its geographic distribution. Population forecasting is interpolated to find urban population size of each district and its population density. Depending on economic studies of population wealth variation of Gross Domestic Product (GDP), the individual waste generation in Hilla districts is 183923 ton /year. A value of 0.93 kg / capita /day is concluded for the year 2012 and may increase with a 4% per year to reach 1.06 kg / capita /day in year 2016. Comparison between the obtained estimation with other studies for other countries, puts Iraq in class of middle income countries.

Keywords: Municipal Solid Waste; Landfill; Generation Rate; Population.

الخلاصة

في هذه الدراسة , تم تخمين معدل نفايات البلدية الصلبة المتولدة لمدينة بابل لفترة خمسة سنوات (من عام 2012 الى عام 2016) والذي يعتبر اقل مدة لاشتغال موقع الطمر الصحي. استخدمت تقنيات نظم المعلومات الجغرافية لاعداد خارطة لمدينة بابل لايجاد مساحة كل من مناطقها الخمسة وتوزيعها الجغرافي . تم ايجاد عدد المتمدنين من السكان وكثافتهم في مدينة بابل لكل منطقة من دراسات توقعات السكان. واعتمادا على الدراسات الاقتصادية للثروة السكانية وتغير الناتج المنزلي الاجمالي في بابل. تم اخذ قيمة معدل النفايات المتولدة في بابل وبمقدار 183923 طن / السنة. واستنتجت قيمة 0.93 كغم / شخص/ يوم للعام 2012 والتي تزداد كمعدل صافي لناتج منزلي اجمالي مرتقب بحوالي 4% لكل عام ليصل الى 1.06 كغم / شخص/ يوم في العام 2016. مقارنة هذا التخمين مع دراسات دول اخرى. وضعت العراق في خانة الدول متوسطة الدخل.

INTRODUCTION

Municipal Solid Waste (MSW) is usually expressed in terms of kilograms per capita per day. The unit of measure is easily applicable for household waste where the per capita value can be directly multiplied by the population to obtain the total amount. For urban areas, household wastes constitute the largest percentage of waste generated. In the case of the other waste types such as industrial, hospital, commercial municipal services or institution waste, the relation is not direct. When the objective is to develop an assessment for estimating the total amount of MSW reaching landfill sites, the waste quantities generated from non-household sources are back calculated in order to be expressed as a function of the population serviced. Another method is to increase the amount of household waste by the pro-rata of the waste from other sources in order to obtain an easily comparable unit of measure [1].

The city of Hilla is divided into five districts: Alfayha, Alfrdous, Alforat, Alsalam, Alzehara. These five districts are further subdivided into many neighborhoods. As a part of this study, a digital map of Hilla city is prepared by the implementation of Geographic Information System (GIS) as shown in Fig.1 in scale of 1: 250,000.

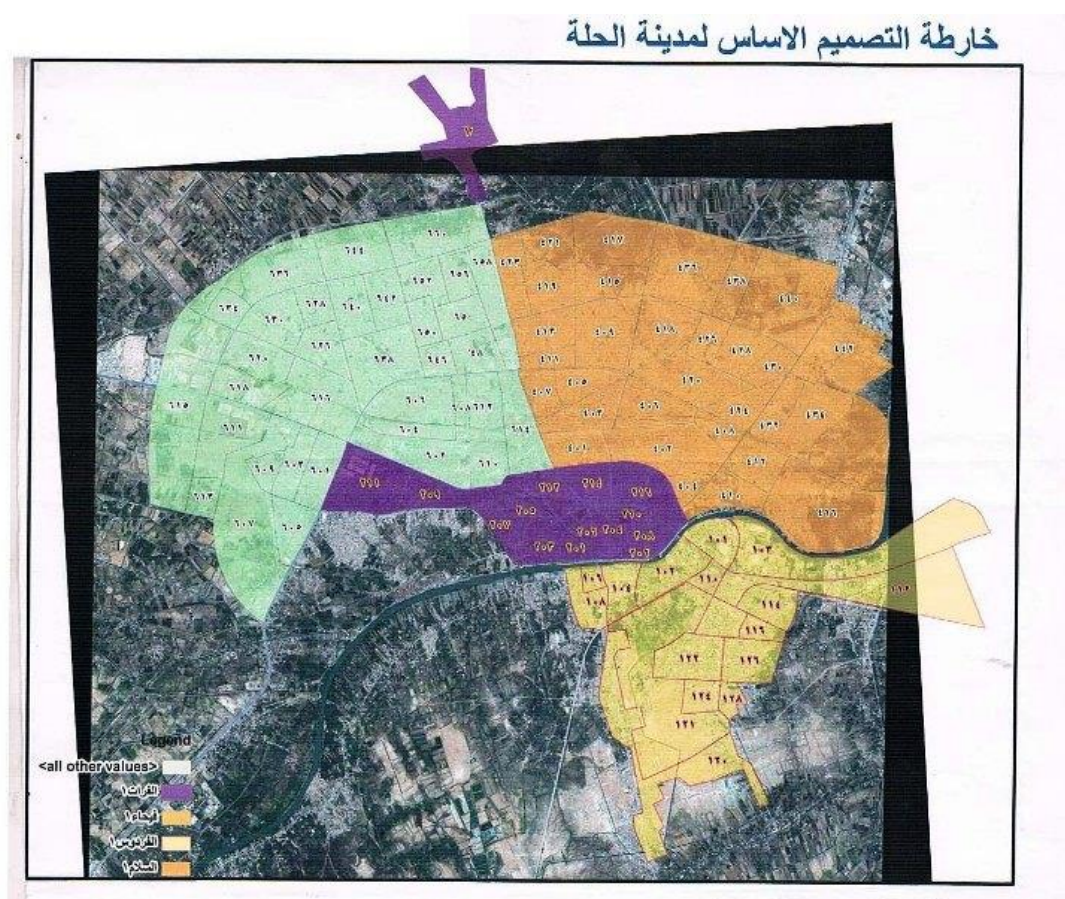


Fig.1: Digital Map of of Hilla City (Hilla municipal office, 2012)

According to this digital map produced of urban Hilla area. Its five districts areas obtained from the prepared digital map, and some of district neighborhood named are presented in Table 1.

Table 1: Hillas five Districts and Its Nighborhoods

District	Mahalleh	Nighborhood
Alfayha (0.94 km ²)	17	Tuhmaiza.
Alfrdous (10.8km ²)	101-128	Thayla, Khratda, kalg and Wardya dahal, Housohra, Malab(1), Jhamyia Almohalmen (Bakarla), Sakak(1), Malab (2), Babil, Bakarla, Safe sahad andAlnumhany, Huther, Alraa (2), Alraa(1), Sakak (2), jhzaher.
Alforat (4.68km ²)	201-216	Nader(1), Nader (2), zehara, Shaoay(1), Shaoay (2), Jomhory, Jamhan, Mahdya (1), Akrahd, Tahes , Mahdya (2), Mahdya (3), Abrahmya, Mustafa rakeb, kadyia.
Alsalam (19.44km ²)	401-442	Buohtary, Ahaa, Mahazem(1), Moharben, Mahazem(2), Shuhda in Makrory, Amam, Thoubat in Makrory, Methak and Mahazem, Sader, Abo hasnoyi and wazir, Antefada, Asateda, Amarat alsakanya(1), Amarat alsakanya(2), 17Neshan(1), Bastan, 17Neshan (2), 17 Neshan (3), 17Neshan (4), Jazra and Marina, Saeha, Tayhra, Muohafda aljedyda, Karahma (1), Tadamen, Karahma (2), Hassen, Jhamyia and Asalah, Muokabrat, Sendbad.
Alzehara (20.1km ²)	601-660	Sanha aljedyda (2), Sanha aljedyda (1), Sanha (2), Noor,Mahzen (2), Fazha and maina, Adil, Sanha(1), Afrah, Mohndsen(1), Askri(1), Fayha(1), Mahzen(1), Fayha(3), Akramen(2), Akramen(1), Fayha(2), Nader(3), Sanha aljedyda (3), Askri (2), Askri(3), Amer, Nasegh, Jhamiaa, Tasnek Askri, Iskan(1), Iskan (2), Muortath, Akramen (5), Akramen (3), Akramen (4), Mohndsen (2), Salam, Mohalmen, Hamza aldaly(1), Hamza aldaly (2).

POPULATION ESTIMATION

Population of Hilla is the key element in the assessment of the quantities of solid waste generated. One method for estimating the total amount of solid waste generated is to rely on published data for countries with similar socioeconomic indicators and obtain the amount of waste per capita per day. This number multiplied by the population being studied can provide the total amount of the generated waste. As can be expected, data on the population of Hilla is not readily available and the data obtained is often either contradictory or at least not converging to the same value. The variation in the number could be caused by the change in the demographic map of Iraq (birth rate, death rate, population migration) over the last two to three decades with the Iran-Iraq war, the Gulf War, the UN Embargo period and the recent events of 2003 and after [2]. Addition to the communalism combat done latter to control Iraq which made political mean deform all population statistics. According to the Humanitarian Information Center for Iraq (HIC) [2], a census conducted on October 16, 1997 indicated that the total population of Iraq was around 22 millions.

POPULATION PERCENTAGES

The total population of Hilla studied at year 2012 by Department of Census Babylon which mentioned earlier in Fig 2, was adopted in this research for MSW generation rate study. In order to help in our evaluation of the waste management services for each of the five districts. Urbanized areas were estimated visually from the IKONOS satellite multispectral image of Hilla city by using GIS for accounting the developed areas in each district. The resulting urban population for Hilla and each of the five districts is shown in Table 2. Population percentages , area percentages and population density of each districts are shown in Fig 3 , Fig 4 and Fig 5.

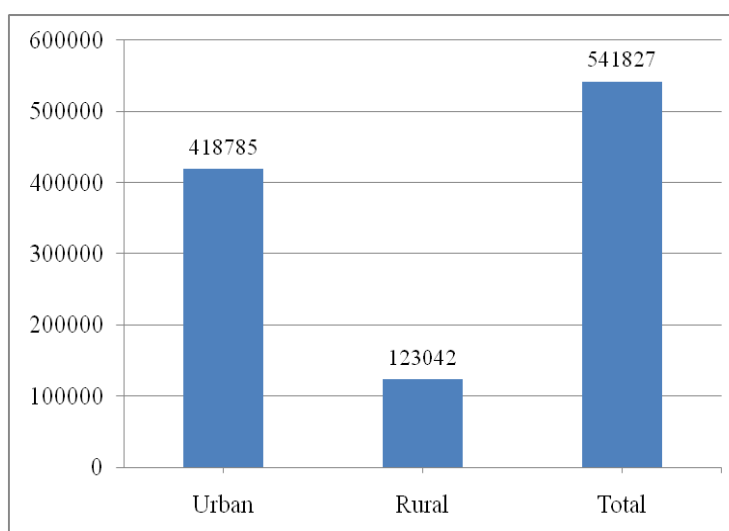


Fig. 2: Hilla population (Department of Census Babylon 2012).

Table 2: Adpted Population of Urban Hilla by District
(Department of Census Babylon 2012)

District	Urbanized Area in km ²	Population (2012)	Percent of Total Population
Alfayha	0.94	10239	2 %
Alfrdous	10.8	59174	14 %
Alforat	4.68	66898	16 %
Alsalam	19.44	140902	34 %
Alzehara	20.1	141572	34 %
Total	55.96	418785	100 %

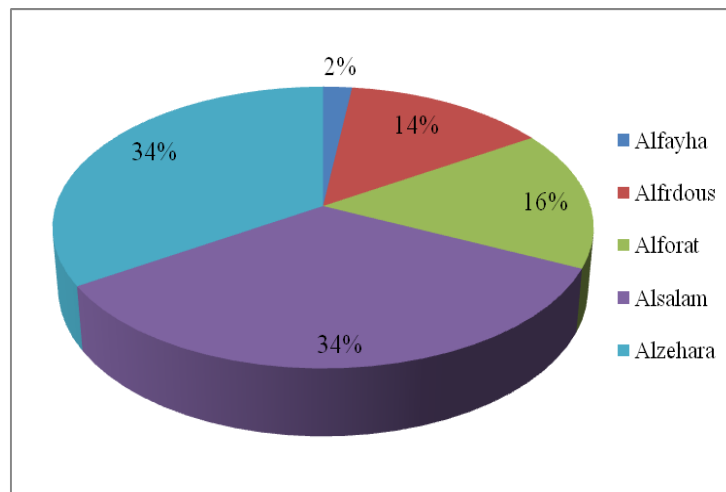


Fig. 3: Population percentages of urban Hilla districts

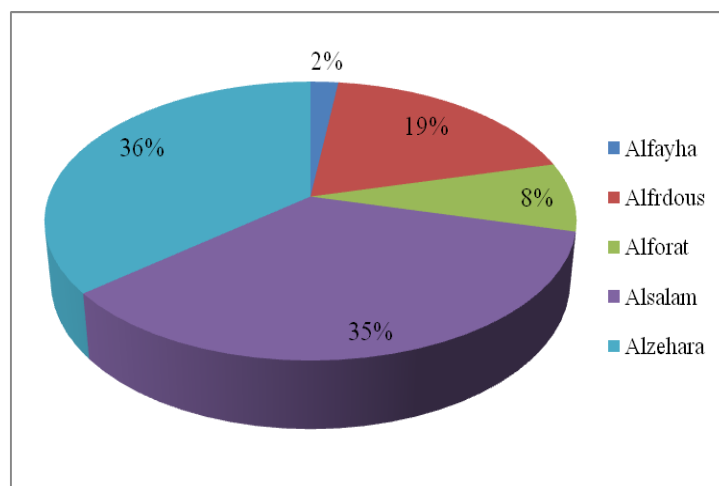


Fig. 4: Urbanized area percentages of Hilla districts

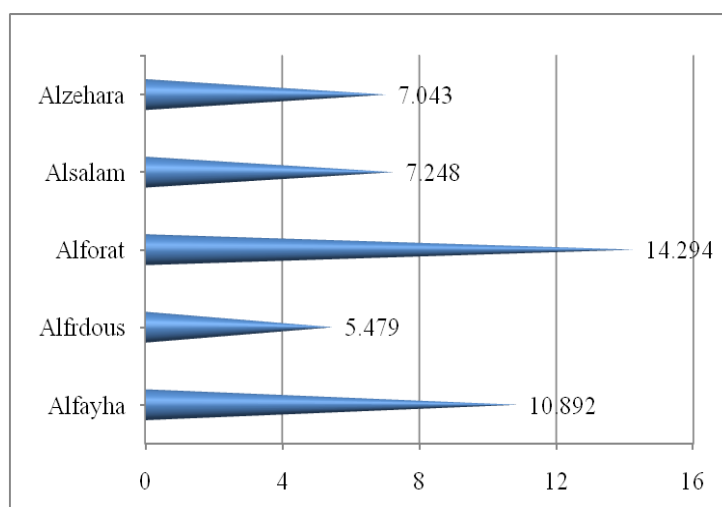


Fig. 5: Population density of Hilla districts In 1000 persons per km² of urbanized Area

POPULATION GROWTH

The population growth rate in the case of Hilla is based on the compounding effect of two growths. One is the net growth between birth rates and death rates. The other is based on population migration between rural and urban centers[3]. This second rate is directly related to economic indicators and employment opportunities in the city when compared in the rural centers[4]. According to [5], the population growth rate, which was 3.2 percent per year in the 1980s, declined in the early 1990s as the country's birth rate fell. By the end of the decade, however, it had regained its former level. In 2002 the rate of population growth was 2.82 percent with a birth rate of 34.2 per 1000 persons, and a death rate of 6 per 1000 persons. Over the coming years birth rate and security situation improves. The current instability may lead to a temporary decrease in the birth rate until the situation improves once again. Mortality rate is also expected to decrease after the security situation improves. Therefore, population growth rates in excess of 3% are not unlikely to be seen in the coming years. Migration is a direct result of employment opportunities decreasing in rural areas and increasing in major cities. Based on the above, a migration into the cities is anticipated in the coming years based on the expected business and employment opportunities in a city the size of Hilla. In the past, this influx has been extremely drastic whereby for example, the urban population in Iraq increased from 35.1% in 1950 to 74.5% in 1995[6]. Over the 45 years between 1950 and 1995 and based on net birth rate of 3%, the population migration would be equivalent to just under 2% per year. It is quite likely that the population migration into Hilla over the next 20 years will be larger than the past average of 2%. One should not underestimate the possibility of a net migration outside of Iraq as traveling becomes less controlled and especially if the security situation takes longer to improve. Based on the above on the above, the propose to adopt values of 3% for the population growth with declining 0.25% in each 5 years (as stated in 541827) and a value of 2% for the population migration into Hilla. The population increase over the next 5 years can therefore be estimated as shown in Table 3.

Table 3: Population Projection for the Estimated Period

Year	Population (Urban)	Population (Rural)	Total Population	Population Growth Rate	Population Migration Rate
2012	418785	123042	541827	3.00%	2%
2013	439724	129194	568918	3.00%	2%
2014	461710	135654	597364	3.00%	2%
2015	484795	142437	627232	3.00%	2%
2016	509035	149559	658594	3.00%	2%

POPULATION WEALTH

The population wealth has a direct impact on the solid waste generation rates and the type of waste being generated. As the spending power of the population increases, the waste quantities typically increase. Excess food starts getting thrown away rather than kept for another day. Individually packaged food starts replacing bulky food purchased, more packaging waste is generated. some studies [7];[8];and[9] have even concluded that the increase in solid waste is equal to the increase in Gross Domestic Product(GDP) per capita. According to estimates by the Economist Intelligence Unit in The Economist, Iraqs GDP prior to the first Gulf war was around \$60 billion, or over \$3000 per capita[10]. The total GDP was reported to have fallen in 1999 to just \$5.7 billion, or \$ 247 per capita. In 2004 the Economist Intelligence Unit estimated Iraqi GDP at \$30.4 billion, or \$1300 per capita. A number of sources give values that are in the range of \$1300 to \$1600. However, a number of other sources, including the Central Intelligence Agency (CIA) indicate values closer to \$1600[2]. GDP growth rate has of course been negative for a number of years as the GDP per capita dropped from \$3000 to \$247. With the increase in salaries and purchasing power and the number of infrastructure and development projects planned for Iraq, GDP

growth could well exceed the 3% growth rate observed during the period between 1997 and 2001[11]. The main concern is the escalated inflation that is accompanying the increase in purchasing power. In the short term, the GDP growth rates are likely to be quite erratic based on the significant variation noted in the past four years. According the Economist Intelligence Unit, the GDP growth rate for Iraq to be in the order of about 55% in 2004 and a further growth of 25% in 2005(this follows a 22% drop in 2003), until it stabilizes to more realistic figures. Despite the potential growth in GDP, poverty is still a major concern in Iraq in general and in Hilla in particular[10]. Table 4 presents the baseline population data adopted for the 5 years duration. This table lists the population estimate by district for the major dates.

Table 4: Population Estimation Over The Duration of the Estimated Landfill Operation Time For Hilla Districts

District	Population (2012)	Population (2013)	Population (2014)	Population (2015)	Population (2016)
Alfayha	10239	10751	11288	11852	12445
Alfrdous	59174	62133	65240	68502	71927
Alforat	66898	70243	73755	77443	81315
Alsalam	140902	147947	155344	163111	171267
Alzehara	141572	148650	156083	163887	172081
Rural	123042	129194	135654	142437	149559
Total	541827	568918	597364	627232	658594

PER CAPITA WASTE GENERATION

In order to determine per capita generation from total generation of waste data collected for duration of twelve months for Hilla city, one would require the population. Conversely, if reasonable estimations of per capita generation are available. The amount of MSW generated in Hilla in 2012 is shown in Table 5. Approximately 503.899 ton/day or 183923 ton /year.

Table 5: Waste Generation Calculation for Hilla (Hilla municipal office, 2012)

Year	Population (thousands)	MSWamount (ton /year)	MSW amount (ton/day)	Percapitageneration (kg/ capita /day)
2012	541827	183923	503.899	0.93

According to United Nation Population Division, 2002 [12], the growth rate of middle income countries was about nearly 4% per year. Therefore, instead of having the waste generation rate increase at a rate of say 5%, this rate is reduced with time to say 4% based on the implementation of proper waste management policies. Therefore adopt the value of 0.93 kg/capita/day for the year 2012 and increase it at the net rate of the expected GDP increase of 4% per year . so , the waste generation rate over the proposing duration of this research is presented in Table 6.

Table 6: Total Waste Generation Calculation for Hilla

Year	Waste Generation Rate (kg/capita/day)	Adopted Growth Rate
2012	0.93	4 %
2013	0.96	4 %
2014	0.99	4 %
2015	1.02	4 %
2016	1.06	4 %

Waste generation rates in cities and urban areas are usually significantly higher than those of rural areas. For this reason , the waste generation rate of Hilla is expected to be above the national

average. Urban residents generate about two to three times more waste solid than their fellow rural citizens[13]. Table 7 presents the baseline waste generation data of each Hilla districts for the major dates of the estimated landfill operation time.

Table 7: Waste Generation per District (Tone Per Year)

District	(2012)	(2013)	(2014)	(2015)	(2016)
Alfayha	3475	3767	4078	4413	4815
Alfrdous	20086	21771	23571	25503	27829
Alforat	22709	24613	26648	28832	31461
Alsalam	47829	51841	56126	60726	66263
Alzehara	48057	52087	56393	61015	66578
Rural	41767	45270	49012	53029	57864
Total	183923	199349	215828	233518	254810

COMPARISON WITH IRAQI GOVERNORATES AND INTERNATIONAL WASTE GENERATION RATER

Different generation rates were obtained through studies carried out in some Iraqi governorates as shown in Table 8. Generation rates varied from 0.32 kg/ capita /day for Fallujah city [17] to 0.93 kg/ capita /day for Hilla in this study.

Table 8: Generation rates in some Iraqi governorates.

City or governorates	Date	Generationrates (kg/capita /day)	References
Al-Mussel	1988	0.54	(14)
Baghdad	1995	0.70	(15)
Kirkuk	1998	0.44	(16)
Al-Fallujah	1998	0.32	(17)
Al-Najaf	2005	0.42	(18)
Al-Ammarah	2010	0.60	(19)
Al-Hilla	2012	0.93	Current study

Other examples of generation rates in many neighbors states and countries with similar socioeconomic indicators are illustrate in Table 9.

Table 9: Generation rates of different countries

State	Date	Generationrates (kg/capita /day)	References
India	1998	0.5	(20)
Jordan	1999	0.60	(21)
United Arab Emirate	2000	2.30	(22)
Yemen	2000	0.80	
Turkey	2001	1.31	(23)
Egypt	2003	0.50	(24)
Tunisia	2003	0.50	
Morocco	2003	0.60	

VARIATION WITH INCOME LEVEL

Typically low-income countries have the lowest percentage of urban populations and the lowest waste generation rates, ranging between 0.1 to 0.5 kg per capita per day [25]. Countries that have a Gross National Product (GNP) per capita less than US \$400 produce under 0.5 kg per capita per day [26].

As GNP increases toward the middle –income range, the per capita urban waste generation rates also increase, ranging from 0.5 to 1.1 kg per day. As predicted, the high-income countries show the greatest urban waste generation rates, typically above 1.1 kg per capita per day.

A study presented by [27] evaluated the solid waste composition and rates in accordance with the income level of selected countries. Three categories were presented. Three categories were presented, namely low income, medium income, and industrialized countries. Countries were categorized according to their mean annual income per capita:

Low income countries were selected as those countries with less than US\$400 mean annual income per capita.

Middle income countries were selected as those countries whose mean annual income per capita was between US\$400 and US\$3500.

Industrialized countries were selected as those countries whose mean annual income per capita exceeded US\$3500.

CONCLUSIONS

1. With 541827 population size in year 2012, daily solid waste generated is about 503.899 tons/day or 183923 ton per year. With population growth reaching about 658594 at 2016, the expected waste generation of 698.109 ton per day or 254810 ton is generated in this year for landfill capacity requirements.
2. Based on the estimated population the rate of solid waste generation 0.93 kg/capita/day is adopted for the year 2012 and it increases at a rate of 4% per year. This rate is calculated to be 0.96, 0.99, 1.02 and 1.06 kg/capita/day for years 2013, 2014, 2015, and 2016 respectively.
3. Comparison of Hilla MSW composition and generation rate with other studies of other cities in Iraq, puts all Iraq governorates in class of middle income countries.
4. Comparison of Hilla MSW composition and generation rate with other studies of other countries, puts Iraq in class of middle income countries.

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