Journal of Environment and Earth Science
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
Vol.5, No.8, 2015

Scenario of Present and Future of Solid Waste Generation in India: A Case Study of Delhi Mega City

Dr Mary Tahir[1] Dr Tahir Hussain[2] Ayele Behaylu[3]
1 Associate Professor, Department of Geography, Jamia Millia Islamia University, New Delhi, India
2 Professor, Department of Geography and Environmental Studies, Adigrat University, Adigrat, Ethiopia, NE Africa
3.Lecturer, Department of Geography and Environmental studies, Adigrat University, Ethiopia, NE Africa

Abstract
Solid waste generation is the by-product of the Urbanization, rapid industrialization, population growth and migration from the country side. It is commonly considered as an Urban Issue. It is highly related with Economic growth, degree of industrialization and consumption pattern and lavish lifestyle of urbanites. On one hand more generation of Solid Waste indicate the economic development but on the other it increases environmental stresses. 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 and unchecked urbanization. Solid Waste contributes 3% of total Green House Gases Emission Globally, which are culprit for Global Warming and Climate Change. Huge amount of Solid Waste generation and their improper management worsen the air quality in the cities which ultimately affect the human health severely.The problem of Municipal Solid waste management is much more acute environmental problems in mega cities like Delhi where land available for landfill sites is scarce. Agricultural land of Delhi has been grabbed by the unauthorized private colonizers and builders by changing the land use overnight. Delhi is the adobe of 14 million people out of which approximately half of the population (52%) population lives in slums and 1400 unauthorized colonies. In 2012, 900 colonies have been authorized or regularized providing bare minimum civic amenities. In the present study, an attempt has been made to provide a comprehensive review of the present infrastructure available, the future requirements to manage Municipal Solid waste and the Organizations and agencies involved in it. 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 Delhi Mega City. This study will be proved to be an eye opener for the city planners, managers, stakeholders and different Organizations and agencies which are actively engaged in the Management of this "Urban Menace".
Keywords: Solid Waste, Urbanization, Population, Green House Gases (GHGs)

Introduction

Solid waste is mostly an urban phenomenon, and 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. The most common problems associated with improper management of solid waste include disease transmission, odor, nuisance, atmospheric, land & water pollution, fire hazards, aesthetical nuisance and economic losses. (Yeny and Yulinah, 2012)

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. (World Bank, 2012)

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. (World Bank, 2012)

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 (Hoornweg and Thomas, 1999).

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, 2012).

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 (UNEP, 2001).

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) (World Bank, 2012).

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. (ibid)

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 2013).

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 (World Bank, 2012).

Latin America and the Caribbean has the most comprehensive and consistent data. 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. (ibid)

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 (ibid).

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 (ibid).

India, one of the fastest growing economies in the world, faces a challenge of MSW Management. To address the issue, the Indian Government enacted MSW Rules in the year 2000 with a view to improve the

present scenario. All Urban Local Bodies (ULBs) were supposed to have MSW management systems by end of year 2003. Being engrossed in their day-to-day activities and due to typical nature of Indian MSW, no single ULBs could achieve the targets. The Courts of Law in India are now issuing summons to ULBs for non compliance with the law of the land.

Urban India generates about 1.0 lakh MT/day of Municipal Solid Waste and it requires more than 1500 Acres of land/year for land fill. This is a very imposing land demand, in a land- scarce India. Land filling is the ultimate disposal technology which is relevant even when other advanced options are being used for recycling and/or volume reduction. It is the method of choice in developing nations because it is the lowest cost disposal option. Indeed, most industrial nations, including many European Union countries and the USA, still rely on land filling as an integral part of solid waste management infrastructure (Agamuthu, 2013).

On the other hand, the lower middle income countries (that is, China, India, Thailand, and Sri Lanka) and the lower income countries (that is, Ghana, Lao, Tanzania) had less generation rate between 0.60 to 0.78 kg/capita/day (Sharifah and Latifah, 2013).

Despite the fact that the urban local bodies utilize major part of its staff and resources for collection and disposal of MSW, nearly half of MSW generated remains unattended in many cities. Out of the funds spent on MSW management, ULBs typically spend about 65% funds on collection, 30% on transportation and a mere 5% on waste disposal. There is thus an urgent need to address the problem with a more scientific approach than the commonly adopted; crude dumping of MSW. Proper management of MSW can play significant role in national progress. Not many Municipalities have been able to take desired steps in this direction.

SWM involves activities associated with generation, storage and collection, transfer and transport, treatment and disposal of solid wastes. But, in most Indian cities, the MSWM system comprises only four activities, i.e., waste generation, collection, transportation, and disposal. Poor collection and inadequate transportation causes the accumulation of MSW at every nook and corner.

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

Delhi, the capital city of India is located between the 28º 24' 17" and 28º 53' 00" N latitudes and 76° 45' 30" and 77 º 21' 30" E longitudes (fig. 1). The National Capital Territory of Delhi covers an area of 1,484 km^2 (573 sq mi), of which 783 km^2 (302 sq mi) is designated rural and 700 km^2 (270 sq mi) urban. Delhi has a length of 51.9 km (32 mi) and a width of 48.48 km (30 mi). The Yamuna is the only major river flowing through Delhi. Delhi has the third highest number of trees among Indian cities. Delhi was one of the ten most polluted cities in the world during the 1990s, with 70% of the polluting emissions produced by vehicles and still having distinction being 3rd most polluted city of India Delhi ranks third with 198 micrograms per cubic meter of PM10 (particulate matter-10) even after taking so many precautionary measures by the Government. The total population of Delhi was nearly 0.4 million in 1901, which kept on increasing slowly and it was 1.74 million in 1951 and 9.42 million in 1991. But sharp rise in population was recorded in the last decades and it reached to 13.78 and 16.75 million in 2001 and 2011respectively (Census of India 2001). Delhi has been divided into 9 districts (fig. 1).

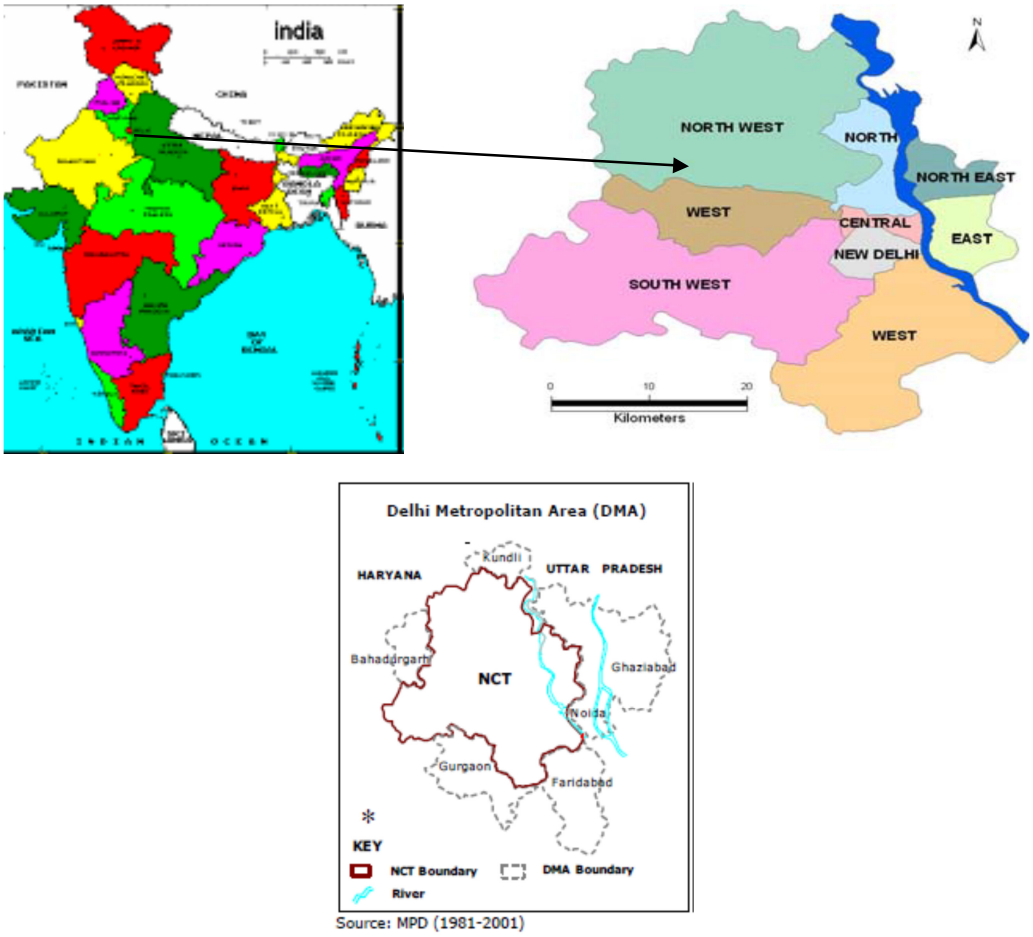

Figure 1: Map of Delhi

Data Base and Methodology

Secondary data was used for this study. Secondary data was gathered from published reports of the city administration. 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

A positive correlation tends to exist between a population's income and the amount of solid wastes generated. Rich individuals or affluent class consume more than lower-income or poor ones, resulting in a higher waste generation rate for the former. The processes of rapid population growth and urbanization translate into a greater volume of wastes generated. 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 a extraordinarily huge amount of solid wastes generation.

Higher incomes and economic growth also tend to have an impact on the composition of wastes.

Wealthier individuals consume more packaged products, which results in a higher percentage of inorganic materials –metals, plastics, glass, textiles, and so on– in the waste stream. Higher generation of wastes and a changing composition with changing of income level have a profound impact on waste management practices. It also points out and stress upon the policy changes that developing countries need to make.

More wastes being generated and with a higher content of inorganic materials could have a significant impact on human health and the environment. If those additional wastes resulting from population and economic growth are not collected, treated and disposed of properly, health and environment in cities will further deteriorate undoubtedly.

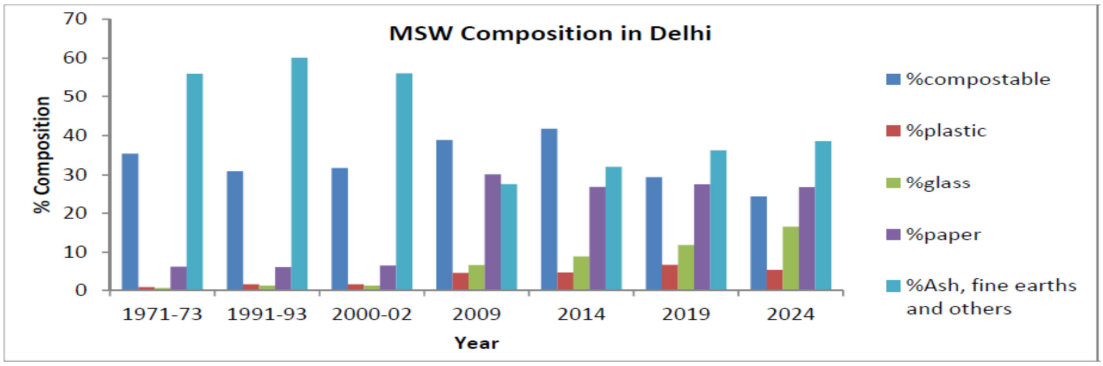

Figure 2: SW composition in Delhi
Source- Delhi Urban Environment and Infrastructure Improvement Project

Solid Waste management in Delhi

The present municipal waste production in the NCTD (National Capital Territory of Delhi) is approximately 7,000 tons per day. Thus, it is estimated that the quantity of waste produced in 2021 would be between 17,000 and 25,000 tons per day. Even if it was possible to provide the maximum reduction of waste through composting and incineration there would still be a minimum 20% residue of 4,000-5,000 tons per day that would have to be land filled in 2021. (DUEIIP)

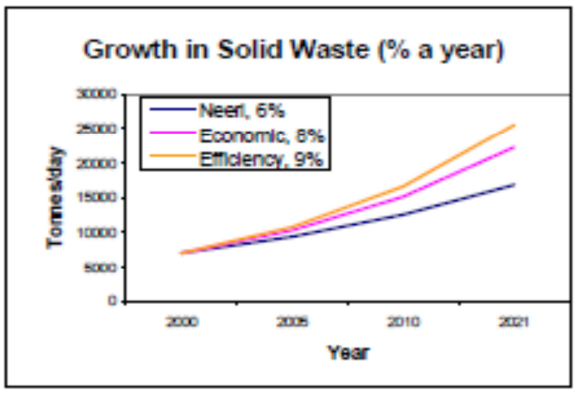

Figure 3: Growth in Solid Waste
Source- Delhi Urban Environment and Infrastructure Improvement Project

Agencies/organizations involved in waste management

The Municipal Corporation of Delhi ("MCD") and New Delhi Municipal Council ("NDMC") together provide municipal services to over 14 million citizens in Delhi. To find an appropriate solution to MSW disposal problem, NDMC and MCD desired to implement on Build, Own, Operate & Transfer (BOOT) basis, an Integrated Municipal Waste Processing Facility.

Delhi Government's wing, Delhi Jal Board (DJB) takes care of Sewage Management. Other Agencies/organizations are Central Govt. (Ministry of Urban Development), NGOs, RWAs & Societies and Private Operators which are actively engaged in Solid Waste Management in the city.

Municipal Solid Waste overview

Table 1: Agencies and their roles

Agency	Area (Km^2)	Population (Million)	Waste Generation (MT/Day)	Landfill(MT/Day)	Composting(MT/Day)
MCD	1399	13.8	7000	5500-6000	350-400
NDMC	42.8	4.5	250	170	80
Delhi Cantonment Board	43	0.13	60	60	0

Sanitary Land Fill Sites

Existing Sanitary Land Fill Sites: (3)

- Ghazipur (70Acres),
- Okhla (56Acres),
- Bhlasawa (40Acres)

Proposed sites Land Fill Sites: (2)

- Jaitpur (26 Acres)
- Bawana (150 Acres)

Figure 4: Municipal Solid Waste Disposal Sites
Source- Delhi Urban Environment and Infrastructure Improvement Project

Disposal in Sanitary Landfill

Incineration is expensive (Rs 3000/ton compared to about Rs 300/ton for sanitary landfill). Nowhere in the world has large scale composting proved economic and is dependable on a ready market for the product. So, the scope for waste reduction is limited. Landfill is the only economic option for the foreseeable future. Thus, even assuming moderate waste minimization can be achieved, planning must allow for the disposal of at least15, 000 tones of municipal waste per day by 2021.Including Existing and proposed sites for disposal city has only 348 acres of land against the requirement of 1500 acres. During the next 20 years this would require over 800 Ha (2,000 acres) of land. There is no shortage of land in public ownership but there are competing uses for that land. A solution might require the cooperation or joint development of municipal refuse disposal sites outside the NCTD with DMA towns.

Composting Plant

MCD Plant at Bhalaswa Sanitary Land Fill site

- ⇒ Capacity 500 MT/day
- ⇒ Composting is being done for 350-400 MT/day

Status of Waste to Energy Plants in Delhi

Authorization given by DPCC for following 3 new plants for conversion of Solid waste into RDF for generation of power

- ✓ Timarpur: 650 Tons per day MSW giving 225 Tons per day RDF.
- ✓ Okhla Plant : 1300 Ton per day MSW giving 450 Tons RDF.
- ✓ Ghazipur: 1300 Ton per day MSW giving 450 Tons RDF.

The first large-scale MSW incineration plant was constructed at Timarpur, New Delhi in 1987 with a capacity of 300 tons/day and a cost of Rs. 250 million INR (US$5.7 million) by Miljotecknik volunteer, Denmark. The plant was out of operation after 6 month and the Municipal Corporation of Delhi was forced to shut down the plant due to its poor performance.

Power Generation in Waste to Energy Plants in Delhi

Okhla Plant: 16 MW power generation from 450 Tons per day RDF from Okhla Plant + 225 Tons per day RDF

from Timarpur Plant + Biogas from Bio-methanation Plant (100 Tons per day) at Okhla using segregated green waste.

Ghazipur Plant: 10 MW power generations from 450 Tons RDF productions from same plant.

Projection of population and Solid Waste Generation

Population Growth

Table 2: Population Growth Trend of Delhi

SN	Year	Population	Growth rate
1	1901	405,819	-
2	1911	413,851	2.0%
3	1921	488,452	18.0%
4	1931	636,246	30.3%
5	1941	917,939	44.3%
6	1951	1,744,072	90.0%[@]
7	1961	2,658,612	52.4%
8	1971	4,065,698	52.9%
9	1981	6,220,406	53.0%
10	1991	9,420,644	51.4%
11	2001	13,782,976	46.3%
12	2011	16,753,235	21.6%
13	2021	20,483,000	22.3%
14	2031	23,442,000	14.4%
15	2041	25,821,000	10.2%
16	2051	27,723,000	7.4%

[@] Huge population rise in 1951 due to large scale migration after Partition of India in 1947.

Source: (Population for the year 1901-2011), Census of India: Provisional Population Totals for Census 2011: NCT of Delhi

Source: (Projected Population for the year 2021-2051), Population Foundation of India, august 2007.

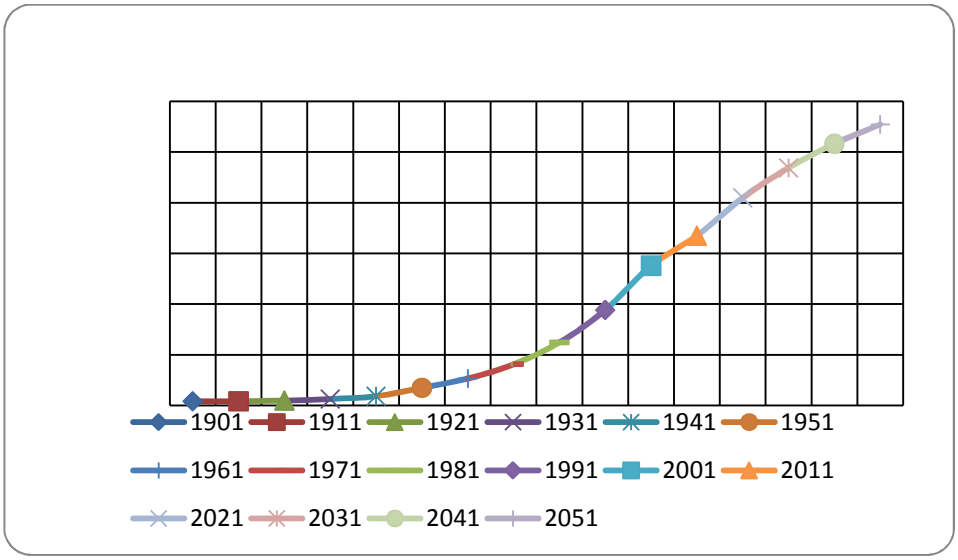

Figure 6: Growth Trend of Delhi Population

Source- Delhi Urban Environment and Infrastructure Improvement Project

Population growth Rate

Population growth can be calculated as below-

$$GR = \frac{P2-P1}{P1} \times 100$$

Where

P2 = present population

P1 = Base year population

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)

Solid Waste Generation forecasting

In 2005 the solid waste generation of Delhi was 0.57 kg/capita/day (Global Review of Solid Waste 2005). Assuming this generation rate will remain constant, which of course is not statistically 100% justifiable, forecasting of solid waste generation is made. Why because this forecasting method considers only population, which is very important factor, out of several factors responsible for Solid Waste generation. Economic Development and Generation of solid waste are positively correlated. So with the increase in income level of the households the generation will also increase. Similarly expansion of industries also results in more and more generation of solid wastes. But it can also be assumed optimistically that public awareness created by different sources and active participation of the community will help in reducing the generation of Municipal Solid Wastes.

So the projection of solid waste generation quantity given in the following table is just bare minimum. The quantity will definitely be on higher side if all the factors generating solid waste will be taken into consideration.

Table 3: Generation of Solid Waste in Delhi

SN	Year	Population	Total MSW Generation(kg/day)
12	2011	16,753,235	9549344
13	2021	20,483,000	11675310
14	2031	23,442,000	13362265
15	2041	25,821,000	14717970
16	2051	27,723,000	15202110

Source- Computed by the authors

Concluding Remarks

Except few posh areas or colonies and Lutyens Delhi the rest part of Delhi is a "Garbage City", plainly speaking not worth living. Time is running out. Politicians, planners, policy makers, executives, academicians and researchers specifically politicians have to think about the so called plague of Solid Waste Management genuinely otherwise it will be proved suicidal.

Active participation and awareness of the Public is utmost important in effective and fruitful Municipal Solid Waste Management without which it is not only impossible but next to impossible also. Public at large do not segregate the waste at source which is the demand of the hour to get rid of this "Urban Menace" partially.

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