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Landfill practice in India: A review

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ABSTRACT

This paper highlight the landfill practices in India over the period 1987 - 2010 and provides details of the main sources of guidance on the safe control and use of landfill gas. Control measures include provision of proper cover over each site along with surface water drainage system and also vertical barriers (cut-offs), wherever necessary. Historically, there have been only a few projects in India but recently some new projects were sanctioned by the Indian government for getting rid of problems associated with MSW. Unfortunately, many of these disposal sites have not been properly engineered and monitored and the results have sometimes been tragic. However, remediation at older sites that have leaked toxic leachate into the soil and groundwater and gas leakage problems has proven to be tremendously costly. Mostly some choices are also in conjunction with landfills are recycling, incineration and especially composting is appreciated.

Key words: Municipal solid waste management (MSWM), Landfill gas (LFG), Leachate, Waste-to-energy, Reuse, Recycle.

INTRODUCTION

Generally, MSW is disposed of in low lying areas without taking any precautions or operational controls. Therefore, municipal solid waste is one of the major environmental problems of Indian megacities. It involves activities associated with generation, storage, collection, transfer and transport, processing and disposal of solid wastes. But, in most cities, the MSWM system comprises only four activities, i.e., waste generation, collection, transportation, and disposal. The management of MSW requires proper infrastructure, maintenance and upgrade for all activities. This becomes increasingly expensive and complex due to the continuous and unplanned growth of urban centers. The difficulties in providing the desired level of public service in the urban centers are often attributed to the poor financial status of the managing municipal corporations [1,2,3,4,5].

Of all available management options for solid waste management, landfill disposal is the most commonly employed waste management worldwide. Such landfill have served as ultimate waste receptors for municipal refuse, industrial or agricultural residues, wastewater sludge, incinerator ash, recycle discards, and/or treated hazardous wastes, and have thereby promoted greater interest in landfill system innovation and advancement. Landfill has been widely used for municipal solid waste (MSW) disposal all over the world. Conventionally, landfill is designed to contain or store the wastes so that the exposure to human and environment could be minimized. Most of the global MSW is dumped in non-regulated landfills and the generated methane is emitted to the atmosphere. When methane is allowed to escape to the atmosphere, it has a global warming potential that IPPC [6] estimates to be 23 times greater than that of the same volume of carbon dioxide. Sanitary landfills [7] can provide better solutions than open dumping for reducing many of the problems, still there is a potential for improvement. Some of the modern regulated landfills attempt to capture and utilize landfill biogas, a renewable energy source, to generate electricity or heat. In India, most of the landfills are not designed to recover the gases for energy recovery but some ongoing projects works on methane capture.

We have considered 22 cities to highlight the current situation of Municipal Solid Waste Management in India. Most of the cities concerned are metropolitan or urban centres of population more than 2 million. This paper brought to light the immense potential that the surveyed cities have for implementing landfill gas to energy projects. Greater Mumbai is the only city to have conducted a methane feasibility study as well as undertaken the first landfill gas to energy project in India.

Only 5 out of 22 cities have conducted a feasibility study on methane emissions – Delhi, Ahmedabad, Surat, Greater Mumbai and Jamshedpur. Although 16 out of the 22 cities have evinced interest in undertaking landfill gas to energy projects, all of them indicate the need for assistance in conducting studies for estimating waste quantification and methane emissions. 15 cities have indicated that they need assistance from external organizations for technological support, capacity building of officials and imparting knowledge on methane capture and utilization projects. This distinctly reveals the technical skill gap in Municipal Corporations to overcome these barriers. Delhi, Kanpur, Greater Mumbai, Jaipur, Lucknow, Pune, Surat, Ludhiana and Ahmedabad have been supplying more than 80% of their waste to the dumpsites, therefore revealing the maximum potential for landfill gas to energy projects among the surveyed cities. Greater Mumbai is the only city to have initiated a landfill gas to energy project.

Landfill Leachate can be toxic, acidic, and rich in organic acid groups. They can contain sulphate ions as well as high concentration of common metal ions. It contains mixtures of many chemicals having a potential risk to human health through penetrating into the ground water. Many researchers undertaken the studies on ground and surface water contamination [25, 26,27,28,29].

2. Waste composition of typical Indian cities:

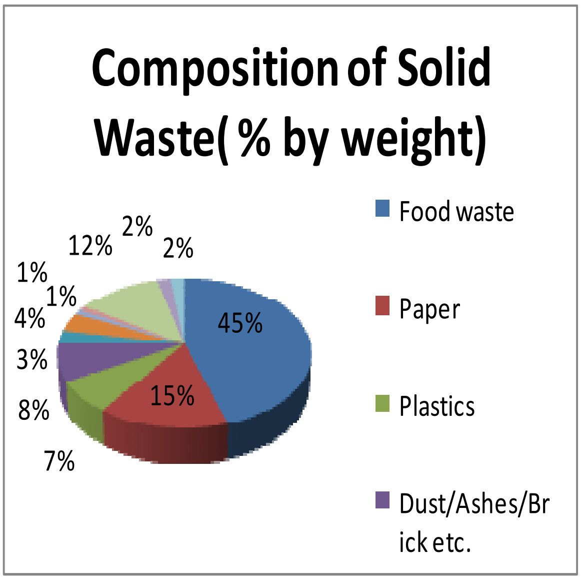
Increasing amounts of waste, both solid and liquid, are being generated as a result of the rapid rate of urbanisation. This in turn presents greater difficulties for disposal. The problem is more acute in developing countries, such as India, where economic growth as well as urbanisation is more rapid. Fig. 1 shows the typical composition MSW in Indian cities. Effective management of urban waste is required, but urban governments are constrained by limited finances and inadequate services.

On a global level, it is estimated that in 1990, approximately 1.3 billion metric tonnes of municipal solid waste was generated, averaging about two-thirds of a kilo per person per day[8].

Yet, the difference between high and low income countries is considerable, especially in terms of composition. As economic prosperity increases, the amount of solid waste produced consists mostly of luxury waste such as paper, cardboard, plastic and heavier organic materials.

In cities in the south, on the other hand, waste densities and moisture contents are much higher [9]. In addition, the hazardous content is quite high since the regulatory and enforcement system to control such waste disposal are usually non-existent or not operating [10]. This is a particular problem with waste from hospitals located within the city area, which is often found mixed with municipal waste in open dumps and landfills [11].

Fig 1: Typical composition of MSW in Indian cities
Source: Status of solid waste generation, collection, treatment and disposal in metropolitan cities, (CPCB, 2008).



These differences mean that waste management systems each require distinct approaches. For example, as the waste content in developing countries is highly organic and susceptible to rapid decay, the emphasis of the SWM process in these countries should be on the collection process. Studies have shown that expensive collection trucks and compactors developed and used in industrialised countries are difficult to operate and maintain, and are unsuitable for narrow lanes, the high traffic density and the nature of waste in developing countries [12].Table. 2 shows the urban population growth in lakhs by Census of India 2001.

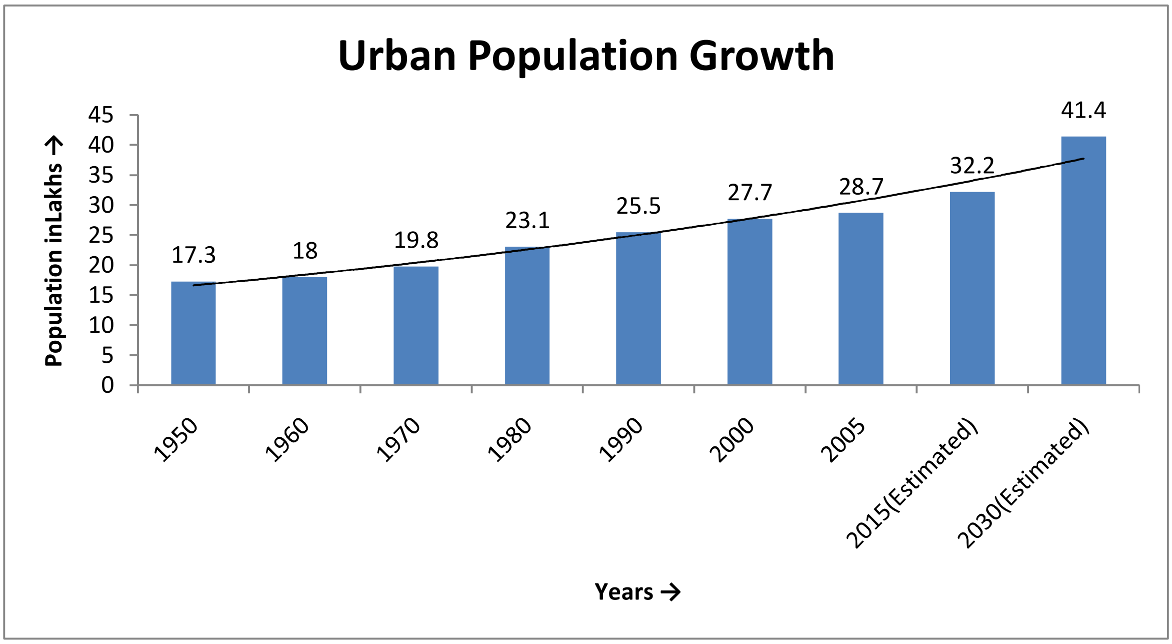


Table 2: Urban population growth in lakhs

Source: Census of India, 2011

The quality and quantity of waste deposited in landfills depend not only on the economy or people's lifestyles but also on the nature of the waste stream, which depends on the generation of waste and the manner of source separation, collection, resource recovering (or recycling), and detoxification and/or volume reduction measures (including incineration). Moreover, the behavior of methane emissions from landfills will be affected by the quality of the waste, the climate and geological conditions of the sites, and the structure of landfills.

The typical urban growth rate has been determined at around 2.5 percent annually , the growth of waste generation is outpacing the urban population growth in Indian cities[13] . Therefore, urban population growth as well as increasing per capita waste generation will continue to amplify the waste problem. To prevent future problems, India must take immediate steps to control waste generation, to enhance recycling recovery and reuse, and to ensure better collection and sustainable disposal.

3. Methane CH_4 capture benefits:

There are two ways in which the problem related to the escape of LFG could be solved. The first one, commonly used in the past, is the extraction and flare of the LFG. In this way the pressure of the LFG within the landfill is decreased which reduces the escape of LFG from the landfill. The flare of the LFG also reduces the problem of odour. The main products of flare of LFG are carbon dioxide and water, which means that the GWP of the released gas has been largely reduced. The other way is to follow a similar strategy as in the first case except that the gas is not flared but used in an economical way. Though the flare of LFG reduces the environmental impact of the landfill site on the environment, methane has a high calorific value and the flare of LFG represents waste of valuable resources. This influences the number of landfills where LFG is used as the supplementary or primary fuel for the production of electric power to increase.

Other possible uses of LFG includes, treatment of LFG for pipeline quality gas and vehicle fuel, supply of heat and carbon dioxide for greenhouses and various industrial processes where the supply of heat is required.

A fundamental problem in expanding methane recovery efforts in developing countries is the lack of reliable data on solid waste. Most estimates of methane emissions from landfills are based on a "top-down" approach, in which the quantities and types of decomposable waste deposited are estimated and multiplied by assumed rates of methane generations [14].

With population growth, economic development, and increased urbanization, methane emissions from landfills in developing countries now account for nearly 40 percent of annual global landfill methane emissions and are expected to increase in the future [15].

Important factors in this increase are the continuing priority of many developing countries to reduce unmanaged dumping and develop larger, solid waste disposal sites, which typically have higher methane emissions [15]. Table-1 below show the ten most MSW producing cities of India.Although most of the waste generated in developing countries is landfilled, much of it is deposited in open dumps. As these dumps are replaced with covered landfills, methane emissions will increase substantially. However, there are also substantial opportunities for capturing methane emissions in these countries.

Table 1: ten largest msw producing cities in India

City	Per capita waste(kg/cap/day)	Population(in millions)[a]	Total waste generated(in kilotonnes/year)[b]	Tonnes per day
Delhi	0.57	10386926.219	2161	5920
Mumbai	0.45	11,978,450	1941	5320
Chennai	0.62	4,343,645	1108	3035
Kolkata	0.58	4,572,876	968	2650
Hyderabad	0.57	3,637,483	798	2185
Bangalore	0.39	4,301,326	609	1670
Ahmedabad	0.37	3,520,085	475	1301
Pune	0.46	2,538,473	428	1172
Kanpur	0.43	2,551,337	401	1098
Surat	0.41	2,433,835	365	1000

Sources: FICCI environment conclave 2006, New Delhi

a. Population according to 2011 census

b. Data acquired from Local government

4. Status of LFGE (Landfill gas to energy) development in India:
In 2000, recognising the environmental problems associated with MSW, India's Ministry of Environment and Forests required that all organic waste be organised and processed separately and not be dumped into landfills. The ban immediately faced difficulties in enforcement, as a number of municipalities failed to implement the new rules. As a result, organic wastes continued to be dumped at waste sites, leading to significant methane emissions. While the ban was in place, however, LFG recovery and use was not seen as economically viable. Recognising this problem, the Ministry has begun the process to withdraw the organics ban. In this way, LFG use can provide a new revenue source to help fund the upgrade and improvement of the dump sites toward cleaner, safer sanitary landfills [16].

The practice of running a LFGE project mean that only those sites that are closed or about to close are being considered for LFG capture. In the future, with the development of sanitary landfills, LFG management should be considered at the design stage as a way to minimize odours, maximize safety risks and generate revenue through LFGE. Currently, several LFGE projects are in the feasibility stage.

• In **Delhi**, the World Bank is working with the Municipal Corporation of Delhi to carry out pumping tests at the three main dump sites in the areas surrounding the city (Okhla, Gazipur and Bhalswa). Reports from these tests should be finished in September 2008. An initial assessment of the **Okhla Landfill** [17] indicates that the site will be closing in 2008 (the site received around 460 000 tonnes of MSW in 2007). The LFG could initially produce around 2.5 MW of capacity, but this would likely fall to 1 MW by 2016.

• **Deonar landfill** is located in the northern part of Mumbai, are nearly 30-40km from South Mumbai which explains the huge costs on transportation. The US EPA is working with the local government testing the LFG flow at the **Deonar Landfill site in Mumbai**. The detailed report from the pump test [18] indicates that the site, which currently receives 3 000-4 000 tonnes of MSW per day, and will stop receiving organic material in 2010, will generate enough LFG to power two 820 kW generators until 2016, and one 820 kW generator until 2022. Assuming a price of emission reduction credits of 8 to 10 USD/tonne CO_2 eq, and sales of electricity to the grid at the renewable energy tariff of 0.058 USD/kWh, and capital costs of 3 million USD for the extraction equipment and 2.5 million USD for the generators, the project is economically feasible. The returns range from 20 to 100% depending on price assumptions and investment scenarios. Much of the return comes from the sale of the emission credits.

• A pre-feasibility and pump test has also been commissioned by the US EPA at the **Pirana Landfill in Ahmedabad** .This site will close soon having received around 4.6 million tonnes of MSW since 1980. Gas flow models and pump tests [19] suggest a flow rate of around 1 100-1 700 m^3/hour, enough to support a 1.3 MW power plant initially and 700 kW from 2016. Economic modeling supports the alternative of direct use of LFG by local industry, as this avoids the cost of installing generators. This assumes that a local plant is available to take advantage of the LFG.

• In **Mumbai**, India is working on a pre-feasibility study on the **Gorai landfill** site which is, anticipated to generate 4 MW of electricity capacity. Data collection is being done through the IL&FS (Infrastructure Leasing and Financial Services, a private entity).

• In **Hyderabad**, an assessment of a landfill site that closed in 2005 came to the conclusion that the site was unlikely to be viable for capture as the flow rates were too small and declining. This landfill site is relatively shallow and there was evidence of fires. The report highlighted the fact that a large percentage of the biodegradable material in typical Indian landfills is food scraps which decay quickly, especially when the site is not capped effectively. It is therefore desirable to install LFG capture projects in currently active landfill sites, and to caps cells as they are filled to maximize the methane capture.

5. Methane (CH_4) Production:
Methane production begins six months to two years after waste disposal and may last for decades, depending on disposal site conditions, waste characteristics, and the amount of waste in the landfill. Methane migrates out of landfills and through zones of low pressure in soil, eventually reaching the atmosphere. During this process, the soil oxidizes approximately ten percent of the methane generated by a landfill, and the remaining 90 percent is emitted as methane unless captured by a gas recovery system and then used or flared [20].

The amount and rate of methane production over time at a landfill depends on five key characteristics of the landfilled material and surrounding environment [21]. These characteristics are briefly summarized below.

Quantity of Organic Material: The most significant factor driving landfill methane generation is the quantity of organic material, such as paper and food and yard wastes, available to sustain methane producing microorganisms. The methane production capacity of a landfill is directly proportional to its quantity of organic waste. Methane generation increases as the waste disposal site continues to receive waste and gradually declines after the site stops receiving waste. However, landfills may continue to generate methane for decades after closing.

Nutrients: Methane generating bacteria need nitrogen, phosphorus, sulfur, potassium, sodium, and calcium for cell growth. These nutrients are derived primarily from the waste placed in the landfill.

Moisture Content: The bacteria also need water for cell growth and metabolic reactions. Landfills receive water from incoming waste, surface water infiltration, groundwater infiltration, water produced by decomposition, and materials such as sludge. Another source of water is precipitation. In general, methane generation occurs at slower rates in arid climates than in non-arid climates.

Temperature: Warm temperatures in a landfill speed the growth of methane producing bacteria. The temperature of waste in the landfill depends on landfill depth, the number of layers covering the landfill, and climate.

pH : Methane is produced in a neutral environment (close to pH 7). The pH of most landfills is between 6.8 and 7.2. Above pH 8.0, methane production is negligible.

Two approaches exist for reducing methane emissions from landfills: (1) recovering and either flaring or using landfill methane for energy; and (2) modifying waste management practices to reduce waste disposal in landfills, through recycling and other alternatives. The first approach is an increasingly common practice as demonstrated by the over 250 landfills that currently collect and use their gas for energy [22]. This report focuses on evaluating the cost-effectiveness of methane recovery for energy. The second approach is not assessed, although expected changes in MSW disposal rates due to recycling are reflected in the emission projections.

6. Technologies for Reducing Methane Emissions:

Gas collection, by vertical wells and horizontal trenches, typically begins after a portion of a landfill, called a cell, is closed. Vertical wells are most commonly used for gas collection, while trenches are sometimes used in deeper landfills, and may be used in areas of active filling. The collected gas is routed through lateral piping to a main collection header. Ideally, the collection system should be designed so that an operator can monitor and adjust the gas flow if necessary. Once the landfill methane is collected, it can be used in a number of ways, including electricity generation, direct gas use (injection into natural gas pipelines), powering fuel cells, or compression to liquid fuel. EPA's analysis focuses on the first two options, summarized below.

•**Electricity Generation:** Almost 80 percent of landfill electric power generation projects use reciprocating internal combustion (IC) engines [22]. IC engines are relatively inexpensive, efficient, and appropriate for smaller landfills where gas flows are between 625 thousand cubic feet per day (Mcf/day) to 2,000 Mcf/day at 450 British thermal units per cubic feet (Btu/ft3). This gas flow and energy content is sufficient to produce one to three megawatts (MW) of electricity per project [23].

•**Direct Gas Use:** Landfill gas is used as a medium- Btu (British thermal unit) fuel for boilers or industrial processes, such as drying operations, kiln operations, and cement and asphalt production. In these projects, the gas is piped directly to a nearby customer where it is used as a replacement or supplementary fuel. If medium- Btu fuel is sold to a customer that is in close proximity to the landfill, ideally within five miles, usually only minimal gas processing is required. Ideal gas customers have a steady, annual gas demand compatible with a landfill's gas flow.

The analysis does not assess the following technologies for reducing emissions because they are typically more costly than electricity generation or direct gas use projects and the extent of their use in the landfill gas-to energy industry is difficult to predict.

•**Reduced Landfilling:** Landfilling is reduced through recycling, waste minimization, and waste diversion to alternative treatment and disposal methods, such as composting and incineration.

The US EPA is making significant efforts at both the local and state level to reduce landfilling. Although the analysis does not evaluate the cost-effectiveness of reduced landfilling, the baseline methane emission estimates include the anticipated impacts of changes in waste management practices.

•**Turbine Generators:** Similar to IC engines, turbine generators generate electricity. While turbines are often better for large projects in excess of three MW, IC engines are more cost-effective for the sizes of projects examined in this analysis.

•**Natural Gas Pipeline Injection:** Landfill gas can be sold to the natural gas pipeline system once it has met certain process and treatment standards. This option is appropriate in limited cases, such as when very large quantities of gas are available.

•**Liquid Vehicle Fuel:** Landfill gas is processed into liquid vehicle fuel for use in trucks hauling refuse to a landfill.

•**Flare-Only Option:** India have implemented flare systems without energy recovery systems (situated in Agra). These landfills are either required to flare their landfill gas or they flare to control odor and gas migration. But it did not address flaring as a stand-alone option.

CONCLUSION

This paper presents an overview of landfill practices in India and some summary statistics on some major urban areas. The U.S. Environmental Protection Agency (U.S. EPA) is working in conjunction with the Government of India as part of the M2M Partnership. Some data were collected of an ongoing project by the U.S. EPA to compile a database on municipal solid waste management practices in selected states. The searchable database contains statistics on solid waste generation, composition, and management practices in key urban areas. It also provide detailed information on individual landfills, including ownership, location, capacity, lifespan, waste acceptance rates, and pollution controls. The database helps public policy decision-making with regard to such issues as climate change, water pollution, sanitation, and public health.

About 50-90% of the 42 million tonnes of urban waste produced in India each year is collected and dumped into uncontrolled open landfill sites without sorting, with the remainder left to decompose in streets and drains or dumped illegally in unmanaged sites .And also with the rapid increase in the population living in urban areas, the volume of MSW is likely to increase considerably.

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