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A Study on Holistic Approach of Solid Waste Management and Climate Change –A Mini Review

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Abstract- This review deals the interaction between solid waste and climate change. Unaccountable dump structures or even some landfills do not include methane collecting systems, in developing countries. In this condition, the greenhouse gas escapes to the atmosphere. The review discussed the emission of greenhouse gases from solid waste and their contribution to climate change with special reference to methane. The Importance has been placed on Municipal solid waste generation quantity in Indian cities and its effects on environment and climate change. Finally, concludes that the problem of solid waste needs some holistic approaches such as reuse of solid waste to produce energy and bio-manures.

Keywords*: Landfill, Methane generation and climate change*

1. INTRODUCTION

In many metropolitan cities, open, uncontrolled and poorly managed dumping is commonly practiced, giving rise to serious environmental degradation. More than 90% of MSW in cities and towns are directly disposed of on land in an unsatisfactory manner [1].In the majority of urban centers, MSW is disposed of by depositing it in low-lying areas outside the city without following the principles of sanitary landfilling. Compaction and leveling of waste and final covering by earth are rarely observed practices at most disposal sites, and these low-lying disposal sites are devoid of leachate collection system or landfill gas monitoring and collection equipment [2], [3]. Land filling would continue to be the most widely adopted practice in India in the coming few years, during which certain improvements will have to be made to ensure the sanitary land filling [4],[5]. The review deals with solid waste management with emphasis on urban waste, Landfill gas emission, its composition. The paper also highlights the contribution of waste sector in climate change mainly focusing methane gas emission and its estimation in not only India but also in others country too. The review also provides details of the status for various LFGE plants set up in India. It will help the stake holders to find the more appropriate options for waste management in India which may fulfil the gap in existing technologies.

1.1. Solid Waste Management

Municipal solid waste management (MSWM) is associated with the control of waste generation—its storage, collection, transfer and transport, processing, and disposal in a manner that is in accordance with the best principles of public health, economics, engineering, conservation, aesthetics, public attitude, and other environmental considerations. Presently, most of the metropolitan cities and MSWM systems include all the elements of waste management. However, in the majority of smaller cities and towns, the MSWM system comprises only four activities: storage, collection, transportation, and disposal [6].The important processing techniques include compaction, thermal volume reduction, and manual separation of waste components, incineration, anaerobic digestion, and composting. The organic fraction of the waste is processed either through composting (aerobic treatment) or biomethanation (anaerobic treatment). Composting through aerobic treatment produces stable product-compost, which is used as manure or as soil conditioner.

1.2.Composition of Landfill gas:

Landfill gas (LFG) is about 50.60% methane with the remainder CO_2 and traces of non-methane volatile organics, halogenated organics and other compounds [7],[8].N_2O is produced as an intermediate gaseous product of microbial nitrogen cycling.N_2O emissions depend zon the type of waste treatment as well as conditions during the transport, storage and treatment. These emissions are small compared to total global emissions [7],[9].Assessment of trends including future emissions for the waste sector often emphasizes CH_4 emissions from landfills[8],[10].These studies indicate that there is a significant potential to reduce CH_4 emission in this sector, and mitigation measures are cost-effective [11],[12] [13],[14],[15]. For example, the [8] estimated that mitigation potential of waste CH_4 in 2020 is more than700 Mt CO_2 eq/yr. About 75% of this is CH_4 recovery from landfills at net negative direct cost, and 25%

at a cost of about US$20/t Co_2eq. A majority of emission reductions were assumed to occur in OECD countries [8].Similar results were obtained by [12]. Where mitigation potentials ranging from approximately 40.75% were estimated to be achievable with negative or low costs (< 20 US$/$CO_2$ eq) by 2030 for a selected set of countries (China, Mexico, South Africa, Ukraine, and the United States).

1.3. Urban waste.

The urban waste produces Methane by their anaerobic decomposition which contributes to the climate change [16].Methane is the second largest GHG emission from India, and about 400 to 600 Gg (about 25-35percent of total Methane emission) are produced from municipal solid waste [17].Other study reveals 30-40 percent of urban waste remains uncollected[18]. And normally, Urban Local Bodies spend Rs 500 to 1500 per ton on Solid waste management. About 60-70 percent spends on collection, 20-30 percent on transportation and less than 5 percent on treatment and disposal [19].

II. CONTRIBUTION TO CLIMATE CHANGE

2.1 Climate Change: An overview-The Earth has gone through many natural cycles of warming and cooling during droughts, flooding and extreme weather patterns. Scientists have confirmed that the Earth's atmosphere and oceans are warming gradually as a result of human activity [20].This warming will exacerbate climate variability and ultimately, adversely impact food and water security around the planet. Central to global warming and climate change is the "greenhouse effect". Carbon dioxide (CO_2), Nitrogen Oxides (NO_X), Sulphur dioxide (SO_2), dioxins, fine particles and other greenhouse gases entering the Earth's atmosphere by activities of everyday energy use and the way of management of the environment still contribute to the build-up of Green House Gases (GHG), which are directly released into the atmosphere. Climate change impacts are only one of a number of environmental impacts that derive from solid waste management options. Other impacts include health effects attributable to emissions of ozone-depleting substances like Chloro-Flouro-Carbons (CFC), contamination of water bodies, depletion of non-renewable resources, noise, accidents and so on. These environmental impacts are in addition to the socio-economic aspects of alternative ways of managing waste [21].Waste minimization, recycling and re-use represent an important and increasing potential for indirect reduction of GHG emissions through the conservation of raw materials, improved energy, resource efficiency and fossil fuel avoidance. Half the world's population lives in urban areas and a significant portion of human activities that lead to global climate change are concentrated in cities [22].Climate change is thought to be the culprit responsible for some of the recent environmental problems the world over, most prominent of which are severe flooding in parts of Asia and America, droughts in parts of Africa and the global food crises which gave rise to civil unrests in many parts of the world. Even though the current global economic recession has been blamed on unscrupulous economic practices, proper scrutiny may reveal that climate change has a hand in it. According to [23], climate change is the most important and dangerous, and certainly the most complex global environmental issue to date.

2.2 Contribution of LFG by Waste Management: A report by the United States Environmental Protection Agency estimates that 42% of total greenhouse gas emissions in the US are associated with the management of waste materials [24]. In India, about 960 million tonnes of solid waste is generated annually as by-products during agricultural, industrial, mining, municipal and other processes. Of this -350 million tonnes are organic wastes from agricultural sources; -290 million tonnes are inorganic waste of industrial and mining sectors and -4.5 million tonnes are hazardous in nature. Efforts are being made for recycling different wastes and utilize them in value added applications. About19 billion tonnes of solid wastes are expected to be generated annually by the year 2025. Annually, Asia alone generates _4.4 billion tonnes of solid wastes and MSW comprise 790 million tons (MT) of which about 48 (-6%) MT is generated in India. It is expected that by the year 2047,MSW generation in India, will reach up to reach 300 MT and land requirement for disposal of this waste would be 169.6km^2[3]. Anaerobic decomposition of MSW in landfills generates about 60% methane (CH_4) and 40% carbon dioxide (CO_2) together with other trace gases [25].The management of MSW is going through a critical phase, due to the unavailability of suitable facilities to treat and dispose of the larger amount of MSW generated daily in metropolitan cities. Adverse impact on all components of the environment and human health are caused by unscientific disposal [4], [[6], [26], [27], 28].

A further development in landfill technology is the bioreactor landfill. Bioreactor landfills are designed, constructed and operated to optimize moisture content and increase the rate of anaerobic biodegradation. Leachate recirculation distinguishes bioreactor landfills from conventional landfills [29].Land filling is considered to be an important global source of this greenhouse gas. Among anthropogenic CH_4 sources landfills are ranked third and range between 19-40 Tg/yr [10].These emissions are mainly caused by inadequate gas collection systems, uncontrolled emissions from old dumps and from unauthorized open dumping. Furthermore, because of the increase in population in developing countries, CH_4 emissions are estimated to increase by up to 60% within the next two decades [30]. published the first global estimate of methane emission from landfills reporting a high value of 70 Tg CH_4 /yr which is the net effect of estimates for waste generation (low) and fraction of degradable organic carbon (DOC) anaerobically dissimilated to CO_2 or CH_4 (high); oxidation within the landfill and landfill gas capture, which both reduce methane emission, were not considered. Dissimilated DOC was assumed to be 0.77 corresponding to a methane yield of 0.10 kg CH_4 /kg dry solid waste; later studies suggest that lower values may better represent field conditions.

Using an energy proxy to estimate MSW generation, [10] estimated that land filled MSW increased from ~475 Tg in 1980 to 625 Tg in 1996. Applying IPCC default methods for estimating CH_4 emission from landfills but using a lower value for dissimilated DOC (0.5), and incorporating oxidation within the landfill (0.1 of produced CH_4) and landfill-gas capture (3.8 Tg or 18% of produced methane in 1996), they report global net emissions of ~17 CH_4 in 1996 implying a CH_4 yield of 0.03 kg CH_4 /kg dry solid waste. [12] Estimates that global net CH_4 emission from landfills is ~36 Tg for 2000. They also used IPCC methods to estimate waste generation and methane production but included both oxidation and gas capture in their estimate. [30] Observed that landfills contribute between 5-10% of global methane emissions and about 10% of the anthropogenic fraction.

[31] While working on the Jordan landfills observed that Methane emissions generated from domestic solid waste landfills accounted for 91.6% of the total methane emissions. Also in their study to investigate the relation between the development of precipitation in Jordan and the global phenomena of climate change; they found no evidence of a visible trend in the average increase or decrease of precipitation, still there appears to be a clear reduction of temperature range. However, sufficient data generation and analysis cannot be achieved in Jordan simply because of limited meteorological infrastructure and limited data.

Methane (CH_4) produced by the anaerobic decomposition of waste buried in landfills and open dumps is a significant contributor to global CH_4 emissions, with estimates ranging from 10 to 70 teragrams per year (Tg/yr or 1012 g/yr). Estimates of CH_4 emissions from global landfills range from 21 to 46 Tg/yr, with a 33 Tg/yr midpoint. The U.S. is the biggest contributor, accounting for 39% of world emissions.

[32] While working on northern Illinois (USA) landfill, observed there were no net methane emissions during the spring and early summer, 1994. The possibility of a landfill as a sink rather than a source for atmospheric methane has not been previously considered and was in direct contrast to 1992-1993 data for the same site which indicated methane emission rates up to 20 g m-1day-l During 1987-1988, periodic soil gas studies, including field measurement of methane emissions using a static closed chamber technique, were conducted at the Brea-Olinda Landfill, Orange Co., California [32].

[33] While working on in Gazipur landfill Delhi used methane standard of 108 ppvm, EDT, London, UK for the analysis of methane. Methane gas was collected in Perspex chamber using 'Close Chamber' technique and observed the values of methane emission flux ranged as 96-264 mg/m^2/h for summer and for winter season range was as 18-51 mg/m^2/h. [34]. Studied compost as biofilter material for microbial CH_4 degradation and reported high degradation rates of up to 63 g CH_4 m^{-3} h^{-1}[35], studied CH_4 oxidation and formation of exopolymeric substances in compost for the performance of CH_4 biofilters and the effect of oxygen concentration. [36] Studied municipal solid waste compost and sewage sludge compost as cover soil to increase oxidation of CH_4 and found that complete CH_4 oxidation is possible.

[37] Worked on controlled field measurements of methane emissions at sites in Illinois and California (USA) using a closed chamber technique. Overall, observed rates from various controlled monitoring experiments during 1988-1994 ranged from 0.003 to more than 1000 g CH_4 m-2 d-t. Surprisingly, at the Illinois site during spring, 1994, the landfill surface was consuming atmospheric methane rather than emitting landfill methane. This was attributed to high capacities for methane oxidation in well-aerated soils which had reduced landfill methane compared to 1993, the result of an effective pumped gas recovery system. Three independent methods confirmed that the landfill cover soils were functioning as a methane sink: (a) static closed chamber measurements yielding negative flux rates (uptake of atmospheric methane); (b) rates of methane oxidation similar to chamber results from in vitrified incubation studies using ambient methane; and (c) a reversal in the soil gas methane concentration gradient at the 25 cm depth. [38] while conducting a Study on Inventorization of GHGs from Energy and Industrial Sector and their Impacts in the Tungabhadra River basin, South India observed that the ratio of GHG emissions from both energy and industrial sector is intensifying every year in the basin. They found that contribution of GHGs especially carbon dioxide from energy and industry sector was mounting and releasing GHGs to the atmosphere significantly in the basin. The energy sector was contributes about 34-50 percent and the rest of the 50 percent was emitted from the industrial sector.

2.3 Methane and other gas emissions from solid waste and their effect on climate change.

2.3.1 Landfill Gas: When organic wastes are degraded, carbon dioxide (CO_2) and methane (CH_4) are produced. Although these originate deep in the landfill, they can readily migrate to the surface and enter the atmosphere. The biochemical reactions that produce them typically continue long after a landfill is capped, so that even after closure, emissions can continue . Since both of these gases contribute to global climate change, gas collection systems are recommended and sometimes required at landfills. While some of the gas escapes capture, gas collection systems can significantly reduce landfill gas emissions.

Methane, on the other hand, exists in the atmosphere at only 1.7 ppmv. Yet even at this trace level, human additions to existing concentrations are expected to be responsible for 17% of enhanced climate change, second only to CO_2 in its global warming impacts [39]. The potency of CH_4 additions relates to their greenhouse warming potential (GWP). GWP is an index used to compare the relative tendency of different gases to cause climate change, and over a 100 yr span, the GWP of one gram of CH_4 is 21-fold greater than an equal mass of CO_2 [40].

2.3.2 Global Scenario: Based on 1997 measures, landfills are estimated to be the largest source (37%) of anthropogenic CH_4 emissions in the U.S. (which is the 4th largest emitter Behind China, Russia, and India [41].

The estimated global annual emissions from solid waste disposal sites (SWDS) are in the range of 20 - 40 million tones of CH_4, of which the most comes from industrialized countries (so-called Annex I countries of the UNFCCC). This contribution is estimated to be approximately 5-20 percent of the global anthropogenic CH_4, which is equal to about 1 to 4 percent of the total anthropogenic greenhouse gas (GHG) emissions. The emissions from developing countries and countries with economies-in-transition will increase in the near future due to increased urban population, increased specific (pro capita) municipal solid waste (MSW) generation due to improved economy and improved SW management practices. From the Annex I countries, the emissions are estimated to remain stable or decline over the next 10 - 20 years. A recent compilation of reported emissions to the UNFCCC [42], indicate emissions of 24 million tonnes CH_4 from Annex I countries in 1990. In the year 1998 these emissions had been reduced to about 20 million tonnes. The reduction is due to increased recycling and alternative treatments and increasing implementation of landfill gas extraction and recovery systems..

2.3.3 Indian scenario: Methane makes up around 29% of the total Indian GHG emissions, while the global average is 15%. This is primarily due to the large amount of agricultural methane emissions (from rice and ruminant livestock). However, emissions from waste (6%) are also proportionally higher than the global average (3%).By virtue of its large population, India is one of the world's largest emitters of methane from solid waste disposal, currently producing around 16 Mt CO_2 eq per year, and predicted to increase to almost 20 Mt CO_2 eq per year by 2020 [43]. A study using the Integrated Assessment Model for Developing Countries , projects a much larger increase to 48 Mt CO_2 eq by 2020 and 76 Mt CO_2 eq by 2030. The same study shows that landfills are the second-fastest growing source for methane emissions in India after coal mining. The growth in methane from landfills is largely due to the rapid urbanization of India, with many people moving from rural areas into the cities resulting in an increase in the amount of MSW produced per person. Presently, virtually none of the methane emitted from solid waste disposal sites in India is captured and utilized. If 25% of the methane produced in landfills could be captured and utilized for electricity generations, around 90 MW1 of capacity could be created (assuming 30% efficiency in the conversion process).

The total amount of GHGs emitted in India, according to was 1228 million tonnes, which accounted for only 3 per cent of the total global emissions, and of which 63 per cent was emitted as CO_2, 33 per cent as CH_4, and the rest 4 per cent as N_2O. The GHG emissions in the years 1990, 1994 and 2000 increased from 988 to 1228 to 1484 million tones respectively and the compounded annual growth rate of these emissions between 1990 and 2000 has been 4.2 per cent. A comparison of the Indian emissions with some of the largest global emitters indicates that the absolute value of Indian emissions is 24% of the US emissions, 31% of China and 80% of the USSR in 2000. The Indian per capita emissions are only 7% of the US, 13% of Germany, 14% of UK, 15% of Japan, 45% of China and 38% of global average in 2000. When the Indian emissions are compared with some of the rapidly developing countries such as China and Brazil, it is seen that their compounded annual emission growth rates are 5 and 6 per cent respectively as compared to the 4.2 per cent per annum for India. The Indian GHG emissions are projected to increase by almost three times with respect to the 1990 emissions in 2020.

2.4. Status of LFGE development in India.

The practicalities 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, Gaziapur and Bhalswa). Reports from these tests should be finished in September 2008. An initial assessment of the **Okhla Landfill** indicates that the site will be closing in 2008 (the site received around 460 000 tonnes of MSW in 2007) [44]. The LFG could initially produce around 2.5 MW of capacity, but this would likely fall to 1 MW by 2016. The report [24], shows that a financially viable LFGE project could be developed, especially if a local user for the LFG can be identified.

• 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 [45]. indicates that the site, which currently receives 3000-4000 tons 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 /ton 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** [46]. This site will close soon having received around 4.6 million tones of MSW since 1980. Gas flow models and pump tests suggest a flow rate of around 1 100-1 700 m3/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 [47].

• In **Mumbai**, USAID 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 [48], 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

III. CONCLUSION

Climate change is an undesirable phenomenon whose negative impacts outweigh the positive impacts. The interaction between climate change and solid waste management is complex one that is difficult to predict with precision. The emission of greenhouse gases through solid waste management practices such as waste collection (transportation), incineration, landfill, anaerobic digestion and composting contribute to global warming and attendant climatic variations. The major greenhouse gases released in the course of solid waste management include CO_2, CH_4 and NO_2. Landfills will likely perform better in early raining season and worse at the peak of the dry season. This is because there will be high moisture content, less flooding and high temperature in early raining season. However, at the peak of the dry season, there will be very high temperatures and very low moisture content: a situation that may lead to drying up of some organic matter and inactivation of micro organisms. Drainage systems will be hit very hard with the consequence that erosion cases will raise drastically.

The role of solid waste management in climate change is significant. Hence greenhouse gas emission can be reduced through a thoroughly formulated and holistic waste management strategy. Though individual waste management options are preferred depending on individual needs of municipalities, emission of greenhouse gases can be drastically reduced by a combination of sorting, anaerobic digestion (biogasification), composting, incineration and landfilling. Anaerobic digestion offers the added advantage of biogas production, composting offers the advantage of carbon sequestration, soil improvement and emission of biogenic CO_2, incineration offers the benefit of energy recovery while landfilling yields biogas and captures carbon. All these benefits are accrued by combining these options. Since solid waste management options generate greenhouse gases which have been implicated in climate change, it is necessary to adopt best management practices in order to sustain the gains of development. Solid waste management is not the sole responsibility of municipal authorities as many people assume, it is a collective responsibility. The role of the individual does not end at waste generation. People are so eager to get the waste out of their homes, but they do not care where these waste materials end up so long as it is not in their backyard. However, no one is relieved of the burden of waste they generate until the waste is responsibly and safely disposed. In the best waste management practice, sorting has been assigned a central role in order to promote resource and energy recovery, and to engender ease of waste handling, treatment and disposal. Other key components of the proposed strategy are recycling, reuse, animal feeding, composting, anaerobic digestion (biogasification), incineration and landfill. This strategy will fare better if individuals are advised to deliver their waste in sorted forms.

List of Abbreviations

MgMegagram (106 g = 1 t)
GgGigagram (109 g = 1000 t)
Tg Teragram (1012 g = 1 Mt)
CH_4 methane
GHG greenhouse gas ,
LF Landfill ,
OD Open Dump
SWDS Solid waste disposal site

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