A Brief Review on Climate Change Vis a Vis Solid Waste Management

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Abstract
This review deals with 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 methane emissions from landfills in India are ranked second next only to coal mining. The estimation of methane emission from landfills is important in order to evaluate measures for reducing these greenhouse gases. We have also discussed about the emission of greenhouse gases from solid waste and their contribution to climate change. 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

Introduction

In many metropolitan cities, open, uncontrolled and poorly managed dumping is commonly practiced, giving rise to serious environmental issues. More than 90% of Municipal Solid Waste (MSW) in cities and towns are directly disposed of on land in an unsatisfactory manner (Mor *et al.*, 2006).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 a leachate collection system orlandfill gas monitoring and collection equipment (Bhide and Shekdar, 1998; Gupta *et al*., 1998). Landfilling 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 landfilling (Kansal, 2002; Das *et al*., 1998).

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 (Sharholy *et al*., 2008).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.

Solid waste management options

Landfill gas (LFG) is about 50 to 60% methane with the remainder CO_2 and traces of non-methane volatile organics, halogenated organics and other compounds (IPCC, 2006; IPCC, 2001). N_2O is produced as an intermediate gaseous product of microbial nitrogen cycling. N_2O emissions depend on the type of waste treatment as well as conditions during the transport, storage and treatment. These emissions are small compared to total global emissions (IPCC, 2006; UNFCCC, 2005). Assessment of trends including future emissions for the waste sector often emphasizes CH_4 emissions from landfills (IPCC, 2001; Bogner & Matthews, 2003). These studies indicate that there is a significant potential to reduce CH_4 emission in this sector, and mitigation measures are cost-effective (Delhotal, 2005; USEPA, 2003; Pipatti & Wihersaari, 1998; Tuhkanen, 2001; IEA 1999 and others). For example, the IPCC (2001) estimated that mitigation potential of waste CH_4 in 2020 would be 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$20/t Co_2eq. A majority of emission reductions were assumed to occur in OECD countries (IPCC, 2001). Similar results were obtained by USEPA (2003) where mitigation potentials ranging from approximately 40.75% were estimated to be achievable with negative or low costs (< 20 US$/$CO_2$ eq) by 2030 for a selected set of countries (China, Mexico, South Africa, Ukraine, and the United States).

Urban waste management

The urban waste produces Methane by their anaerobic decomposition which contributes to the climate change (Doorn and Barlaz, 1995). 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 (Kumar, Gaikwad *et al.*, 2004; Thakur, 2009). Other study reveals 30- 40% percent of urban waste remains uncollected (Joardar, 2000). 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 (India, 2008).

Climate change

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 (Intergovernmental Panel on Climate Change (IPCC, 2007). 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 (NOX), 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 (Smith *et al.*, 2001). 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 (Bogner *et al.*, 2007). 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 (Betsill, 2001). 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 (Obama, 2009), proper scrutiny may reveal that climate change has a hand in it. According to Holdern (1992), climate change is the most important and dangerous, and certainly the most complex global environmental issue to date.

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 (USEPA, 2009). 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, would reach up to 300 MT and land requirement for disposal of this waste would be 169.6km^2 (Gupta *et al.*, 1998). Anaerobic decomposition of MSW in landfills generates about 60% methane (CH_4) and 40% carbon dioxide (CO_2) together with other trace gases (Hegde *et al*., 2003).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 Rathi, (2006); Sharholy *et al.*, 2005; Jha *et al.,* 200; Kansal, 2002 and Kansal *et al.,* 1998. Using an energy proxy to estimate MSW generation, Bogner and Matthews (2003) estimated that landfilled 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 Degradable Organic Carbon (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 Tg CH_4 in 1996 implying a CH_4 yield of 0.03 kg CH_4 /kg dry solid waste. USEPA (2006) 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. Bingemer and Crutzen (1987) observed that landfills contribute between 5-10% of global methane emissions and about 10% of the anthropogenic fraction.

Michiel et al., (1995) observed that 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.

(Bogner *et al*., 1995) 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 (Bogner and Spokas, 1993).

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

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 (Tchobanoglous *et al.*, 1993). 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 (IPCC, 1996). 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 (IPCC, 1995). 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 4^{th} largest emitter behind China, Russia and India) (USEPA, 1994).

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 (IEA 2008). A study using the Integrated Assessment Model for Developing Countries (Garg *et al*, 2003) 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 Sharma *et al. (*2006) was 1228 million tonnes, which accounted for only 3 per cent of the total global emissions, and of which 63% 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 tonnes 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.

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 460000 tonnes of MSW in 2007)(Beede and Bloom, 1995). The LFG could initially produce around 2.5 MW of capacity, but this would likely fall to 1 MW by 2016. The report (US EPA 2007a) 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 (US EPA 2007b) indicates that the site, which currently receives 3000- 4000 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** (US EPA 2007c). This site will close soon having received around 4.6 million tonnes of MSWsince 1980. Gas flow models and pump tests suggest a flow rate of around 1100-1700 m^3/ h, 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 (Cointreau *et al* 1984).

• 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 (US EPA 2007d) 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

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

Mg: Megagram (106 g = 1 t); Gg: Gigagram (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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