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Research Article

APPLICATION OF IPCC MODEL IN METHANE EMISSION POTENTIAL EVALUATION IN SELECTED LANDFILLS OF TAMIL NADU

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Abstract: In India it is observed that more than 90% of Municipal Solid Waste (MSW) is disposed on land without taking any specific precautions. Methane emission from landfills amount to 6 to 20% of total methane emission from the anthropogenic sources. It is highly imperative to assess the landfill methane (CH_4) emission from such sources. Application of models for inventorying and replicating the methane emission to the wide area is crucial and critical for determination of the management practices required to be followed to mitigate global warming. Different models *viz*., IPCC, Theoretical First Order Decay model (FOD) and USEPA regression models were available for assessment. Out of the available quantification techniques, the model two and three need extensive data on number, size and quantity of waste deposited in landfills of respective areas. The Chennai population according to 2011 census was recorded as 4.68 million, from this source, the total amount of MSW generated is 2738 tonnes per day, out of this only 1826 tonnes per day reaches landfill sites. Based on IPCC model, the Methane generated in Chennai region is estimated as 0.010 Tg/yr and is having a perfect agreement with seasonal integration flux. The required information not enough in available in India for fitting parameters in FOD and USEPA regression models. The scope for the IPCC model used here for Chennai region may be extrapolated extensively to the other areas.

Keywords: *Landfill, MSW, Methane emission, IPCC*

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Introduction

Methane influences the background photochemical system and also affects the earth's thermal budget by absorbing infrared radiation around 8µm. At the current rate of increase by the middle of the next century the greenhouse emission of methane is expected to be nearly 25% as that arising from increasing CO_2 concentrations [1]. To control these emissions, it is necessary to identify the various processes contributing to increase in atmospheric methane concentration. Methane released to the atmosphere by biogenic and abiogenic processes. Biogenic production generally results from anaerobic bacterial decomposition of organic material. A significant fraction of carbon is recycled through the environment by the human activities consists of domestic and industrial wastes. An appreciable fraction of carbon is dumped in landfills which often turn anaerobic and serve as a potential source of methane. IPCC (1992) estimated global anthropogenic sources to emit total methane emissions of 352 - 360 Tg/yr, out of which landfills expected to contribute 20 - 70 Tg/yr representing 6 to 20 % of the total [2]. More than 80 % of the municipal solid waste collected from urban areas of the world is estimated to be deposited in the landfills or in the open dumps [3]. In India, it is observed that more than 90% of municipal solid waste is disposed of on land without taking any specific precautions [4]. The deposited waste is rarely covered and compacted and the depth of filling is normally less than five metres. The organic and moisture content of the municipal solid waste in India is higher than that in the waste from the developed countries. Further the higher atmospheric temperatures result from the developed countries. Methods of managing household and industrial waste differ substantially among different countries. Land filling is still the predominant method, especially in developing countries, but even in Australia, the United Kingdom and the Mediterranean countries more than 85% of municipal solid waste is land filled [5]. Due to the complexity of the factors affecting the main process regulating the LFG emissions, modeling is necessary for understanding of 1. The emissions, 2. Gas recovery through extraction and 3.Methane oxidation. Today the lack of reliable data is an important constraint for such efforts, thus ways to circumvent this problem are being investigated. As an example, Bogner and Mathews (1999) presented a model, in which global contribution per capita, which was proportional to the amounts of generated waste [6]. Their calculations were obstructed by a lack of data on gas recovery, for which actual statistics are missing at present.

Materials and Methods

Early estimates of methane emission from landfills to the atmosphere are built solely on results from a few laboratory experiments of degradation of different waste fractions. Thus, in the calculation by Bingemer and Crutzen (1987), it was assumed that the ratio of organic matter in land filled waste corresponded to a certain amount of methane. The models of today are also developed from this approach [7]. The IPCC model for estimation of national methane budgets for landfills has become the common standard [8]. The landfill methane emission at specified time domain is estimated by the use of static chambers. They have been placed on the landfill surface with an open part attached to the surface and the accumulated methane concentration in the closed volume has been measured. This method is simple, but laborious if the total emission rate of a landfill is required. This is mainly due to spatial heterogeneity of the landfill cover. The methane emissions from existing landfills in different countries /regions can be estimated by using one of the two approaches.

Estimate the emission potential of a representative waste through theoretical consideration (e.g., carbon content) or the laboratory simulation. IPCC mainly relies on this approach as given methods I and II.

Method I: In this method proposed by IPCC/OECD, the theoretical calculations for CH_4 release potential are based on a mass balance approach developed by Bingemer and Crutzen (1987). It is assumed that the release of CH_4 to atmosphere is instantaneous and in the same year the refuse is land filled. It is also assuming that all the waste decomposes anaerobically and the produced methane escapes to atmosphere and no oxidation occurs.

CH_4 emission = Total MSW generated (Tg/yr) X MSW land filled (%) X DOC in MSW (%) X Fraction dissimilated DOC (%) X 0.5 g CH_4/g C X Conversion factor (16 g CH_4/12 g C)-recovered – CH_4 (Tg/yr)

Where DOC is the Degradable organic carbon; Fraction Dissimilated DOC is the portion of carbon in substrate that is converted to landfill gas and the recovered CH_4 that is recovered through gas recovery systems and never emitted to the atmosphere. The uncertainties of this approach are attributed to assumptions regarding "fraction dissimilated DOC" or the extent of anaerobic decomposition. A number of factors affect the process anaerobic decomposition in landfills and this approach is considered to overstate potential emissions. Further this methodology does not consider the methane oxidation occurring in the surface layer of landfill.

Method II: This method is based on the theoretical first order decay model is also sometimes used for CH_4 emissions from landfills. It can be applied to a country or region. The model as applied in Netherland states.

$$A=0.8\ k\ PO\ e^{-kt}$$

Where A is the production of biogas in meter cube /tonne refuse per year; P0 the conc. of degradable organic carbon in kg/tone refuse; 0.8 is the part of P0 that is actually degrading: k is the degradation rate coefficient = 0.1 (half of the P0 is degraded in 7 years and t the time after land filling). However, for the use of this model, details about the existing landfills such as their area, quantity of waste deposited, age of landfill, any gas recovery mechanism and its capacity would be required. Out of the available methods, the number I and II need extensive data on number, size and quantity of waste deposited in landfills. As this information not available in India, the method proposed by Bingemer and Crutzen is used. Extensive studies conducted out by NEERI in more than 50 towns and cities in India are applied to Chennai region of Tamil Nadu [9]. The assumption made by NEERI is given as 1) The average per capita waste generation rate can be taken as 0.33 kg/c/d, 2) In towns having a population less than 50,000; waste collection is rarely carried out. The remaining uncollected waste remains scattered around the town and degrades aerobically. A regular waste collection hence occurs only for 164.93 million urban population.3) Out of refuse generated, 20-40 % (average 30%) of waste is not collected and tends to spread around or gets deposited in sewers, drains and water where is degrading aerobically. 4) A small proportion of the waste is composted. 5) A small portion of waste is composted at site. 6) The waste reaching the landfill can hence be taken as 2/3 of the generated quantity. Based on the above assumptions, the waste deposited in landfills is generated from the population is estimated as 164.93 million. Out of the 0.33 Kg/c/d waste generated only 2/3, *i.e*., 0.22 kg/c/d, reach the landfill. For this waste quantity, the methane calculated by IPCC method, worked out as 0.334 Tg/yr. Out of the total waste generated per day, *i.e*., 2738 tonnes; only 1826 tonnes only reach the Landfill site. Based on 2011 Census the population of Chennai city was 4.68 millions, by the application of NEERI assumptions 164.93 million population generates 0.334 Tg /yr; that has been proportionally applied for Chennai region and it is estimated as 0.0097 Tg/yr. Rates of methane emission from landfills of Chennai, Kodungayur and Perungudi hot spots were measured. The emission followed a seasonal pattern. Accordingly, the emission fluxes are integrated and arrived a value of 0.008 Tg/yr, which is in agreement with a theoretical value.

Results and Discussion

Organic matter in waste deposited in landfills creates an anaerobic environment, generating landfill gas (LFG). Among the potential hazards with LFG are: 1) Fires and explosions; 2) Odours and toxicity; 3) Damage to vegetation, 4) Climate effects (greenhouse and smog); water pollution. LFG normally consists of > 50% methane, which is a serious greenhouse gas, but also an energy source.

Table-1 Population estimates and total waste arising in MMA in 1995 (Madras Municipal Authority)

Municipalities	Population 1991	Popln. Estm. 1995	Percapita waste gen/ Kg/d	Waste arising (tonnes/day)
Alandur	125224	156280	0.585	91
Ambattur	223332	278718	0.585	163
Avadi	183215	228652	0.585	134
Kathivakkam	27000	33696	0.585	20
Madhavaram	49005	61158	0.585	36
Pallavaram	111317	138924	0.585	81
Tambaram	130000	162240	0.585	95
Thiruvottiyur	188000	234624	0.585	137
Sub total	1037093	1294292	-	757
Madras corporation	3827905	4157105	0.585	2430
Town panchayats	159749	195668	0.439	86

**Population estimate are based on the data in the MMDA Master plan 2011 [10,11].*

Table-2 Waste growth in Madras Metropolitan Area 1996-2011(est. comp gr. rate 3.0% annum)

Year	Qty. of Waste arising (tonnes per day)	Year	Qty. of Waste arising (tonnes per day)
1995	3735	2004	4731
1997	3847	2005	4873
1998	3962	2006	5020
1999	4081	2007	5170
2000	4204	2008	5325
2001	4330	2009	5485
2002	4460	2010	5650
2003	4594	2011	5819

**MMDA., Master plan, 1996-2011 [10,11]*

Due to the energy burden in the atmosphere, there is a need to know the methane emission from the landfills. Based on IPCC model the theoretical value arrived is 0.0097 Tg/yr, as such compounded growth rate of population and per capita waste generation is applied. The value is having closest relationship with that established by seasonal integration and it is obtained as 0.00817 Tg/yr. There are many questions are need to be answered on methane production and also more data needed on degradation rates for different types of wastes under realistic conditions. Landfills with different climatological and geological conditions should be investigated. Above all, data from warmer regions are lacking completely. The field data produced to update the methane emissions from landfills are also difficult to interpret due to lack of uniform variables. In addition, more information is needed about the establishment of methane-oxidising organisms in different types of cover materials. Of course, there is a nearby agreement is established for IPCC model and seasonal integration flux, but there is a question of applying it in quite large area with spatial heterogeneity as to be probed further [12].

Conclusion

Precise inventorying the methane emission from different sources is of immense use and interest for Environmentalists, Climatologists and most importantly for Agricultural scientists. Among the different sources of methane emission landfill alone contributes 6-20% of the other anthropogenic sources. Previous years due to lack of data and systematic handling of Municipal Solid Wastes, there exist a problem of precise measurement. Correlations of methane emission with a number of environmental variables are statistically significant but too weak to serve as a basis either for prediction or mechanistic analysis. In Chennai region; the exact land filling data is available after 1995 only. So, to estimate the methane emission at global level application of different types of models could be given with top most priority provided as long as the land fillings are handled scientifically and systematically. The alternate concern to evade the emission is to develop strategies for complete collection of LFG and could be utilized for most essential developmental purposes.

Application of research: This research is reveals a sensitized protocol for monitoring and estimation of Greenhouse gas emission in rural and as well as urban areas, since waste management is a serious concern in global environmental situation.

Research Category: Waste management

Abbreviations:
LFG-Land Fill Gas
Tg-Tega Gram
IPCC-Intergovernmental Panel on Climate Change
USEPA-United States Environmental Protection Agency
MSW-Municipal Solid Waste

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