Methane Emissions from Landfills

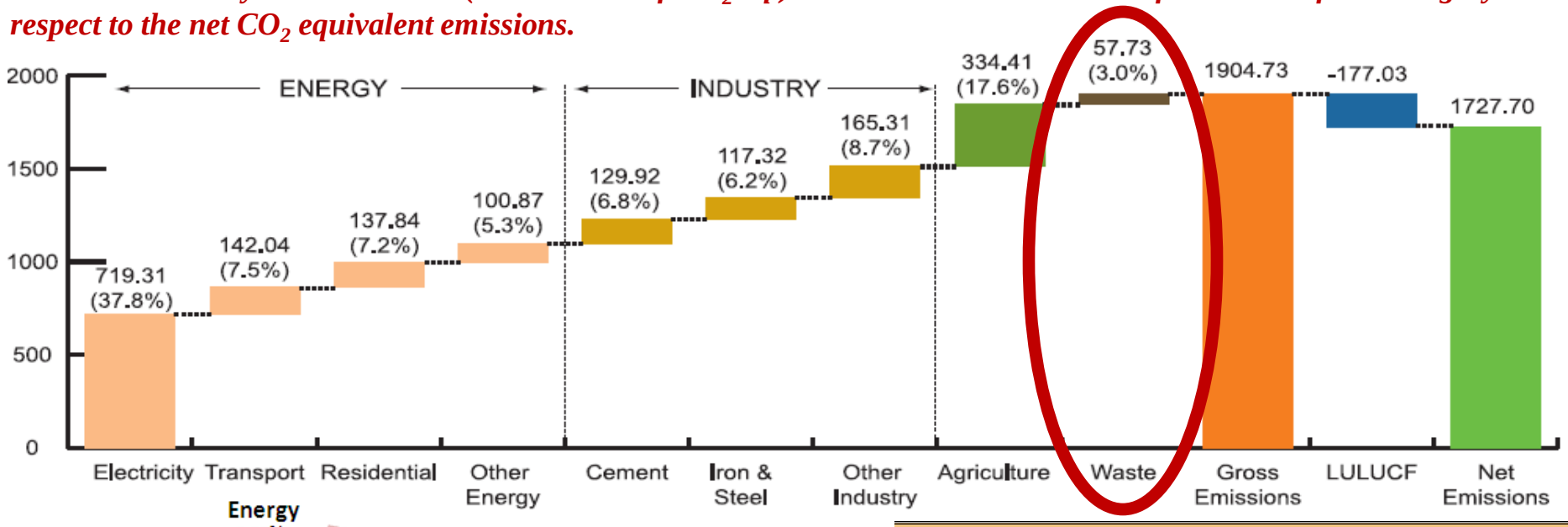
Chhemendra Sharma

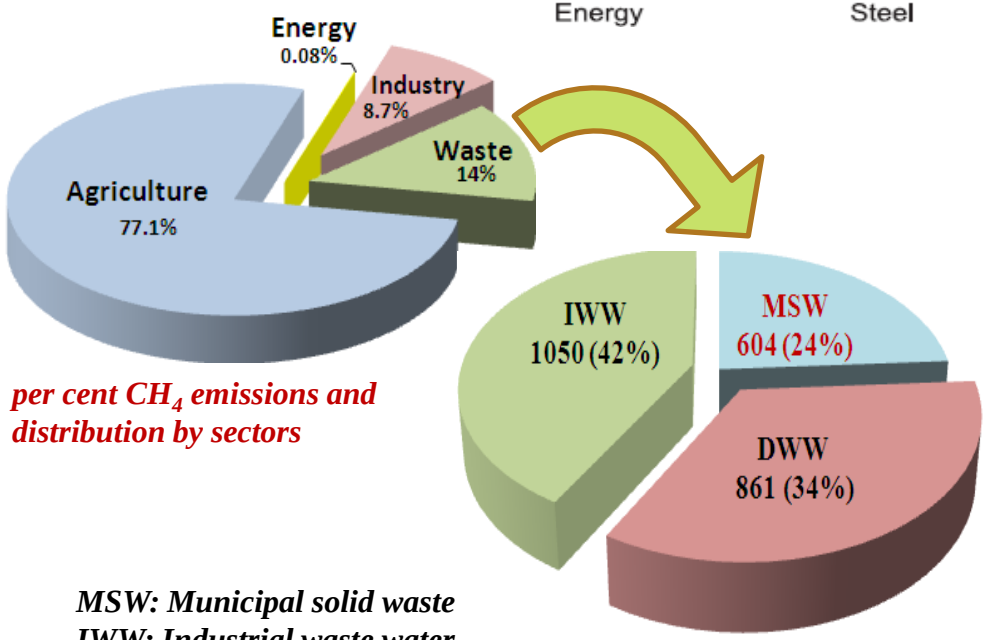
Principal Scientist
Radio & Atmospheric Sciences Division
CSIR-National Physical laboratory
New Delhi – 110012
Email: csharma@nplindia.org

Background:

- ✓ **Landfill** is the site for the disposal of waste materials by burial and it is oldest method for waste management.
- ✓ **Landfills gas (LFG)** is produced in landfills due to the anaerobic digestion by microbes on any organic matter. Major constituents of LFG are: **Methane** (45 – 60%), **Carbon Dioxide** (40 – 50 %), **Nitrous oxide** (2 – 5%), **Oxygen** (0.1 - 1.0%), **Ammonia** (0.1 - 1.0%), **Hydrogen** (0 - 0.2%) and Volatile organic compounds (VOCs)
- ✓ It is estimated that world-wide CH_4 generation from landfills is about 10% (~36Tg) of all anthropogenic sources (USEPA-2006).

GHG emissions by sector in 2007 (million tons of CO_2 eq.) and brackets indicate % of emission of the category with respect to the net CO_2 equivalent emissions.





per cent CH_4 emissions and distribution by sectors

MSW: Municipal solid waste
IWW: Industrial waste water
DWW: Domestic waste water

CH_4 emission (Gg) from all waste sectors

Source: INCCA, 2010

A comparison of GHG emissions by sector s between 1994 and 2007 in million tons of CO_2 eq.

Sectors	1994	2007	CAGR (%)
Electricity	355.0 (28.4%)	719.3 (37.8%)	5.6
Transport	80.3 (6.4%)	142.0 (7.5%)	4.5
Residential	78.9 (6.3%)	137.8 (7.2%)	4.4
Other Energy)	78.9 (6.3%)	100.9 (5.3%)	1.9
Cement	60.8 (4.9%)	129.9 (6.8%)	6.0
Iron & Steel	90.5 (7.2%)	117.3 (6.2%)	2.0
Other Industry	125.4 (10.0%)	65.3 (8.7%)	12.2
Agriculture	344.5 (27.6%)	334.4 (17.6%)	-0.2
Waste	**23.2 (1.9%)**	**57.7 (3.0%)**	**7.3**
Total without LULUCF	1252.0	1905.0	3.3
LULUCF	14.29	- 177.0	

Process of CH_4 Generation :

Acetogenesis

$C_6H_{12}O_6 \longrightarrow 2C_2H_5OH + 2CO_2$ (1)

Organic waste

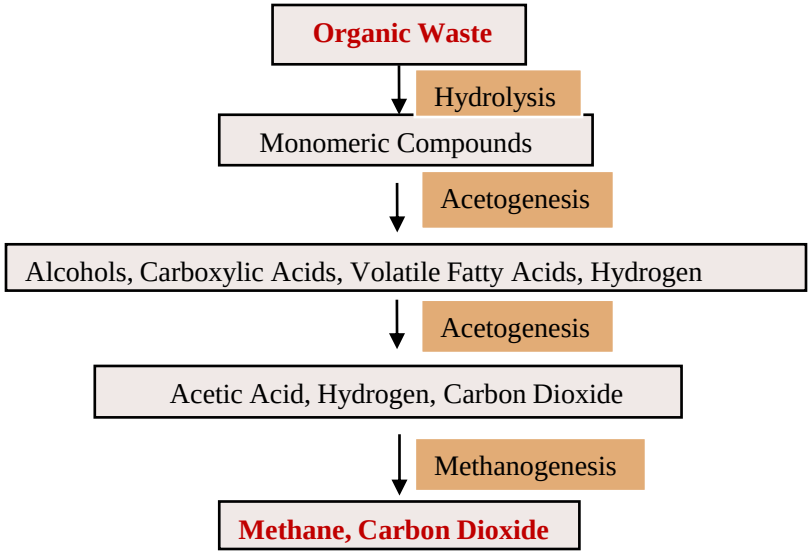
Methanogenesis

$CH_3COOH \longrightarrow CH_4 + CO$ (2)

$CO_2 + 4H_2 \longrightarrow CH_4 + 2H_2O$ (3)

Simplified molecular formula is that

$C_6H_{10}O_4 + 1.5\ H_2O = 3.25\ CH_4 + 2.75\ CO_2$

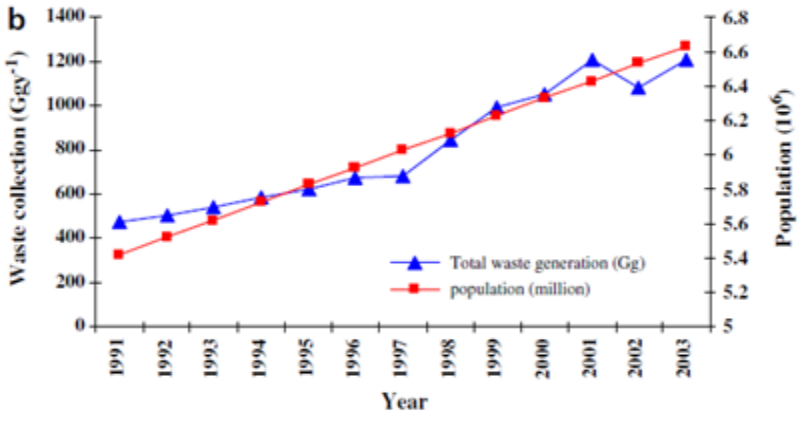


Major degradative steps during the anaerobic decomposition phase

Scenario of municipal solid waste management in four Indian mega cities

Parameter	Year	Mega-cities			
		Chennai	Delhi	Kolkata	Mumbai
Area (km2)		174.0	148.4	187.33	437.71
Population (million)	2001	6.56	12.87	13.2	16.43
Waste generation (kg /capita/d)	1994	0.66	0.48	0.32	0.44
	1999	0.61	1.1	0.55	0.52
Garbage pressure (tons /km²)	1999	17.529	4.042	16.548	13.708
Waste collection (Gg per day)	1999	3.124	5.327	3.692	6
	2009	3.036	5.922	2.653	5.32
Mode of disposal (%)	Landfilling	100	93	80	91
	Composting	-	7	20	9

Fig. (a) Variation in the daily MSW collection in different months from 1996–2003 in Chennai; (b) increase in MSW and population growth in Chennai. (Source: Jha et. al., Chemosphere 2008)



LANDFILL SITES IN DELHI

Ghazipur landfill (GL)

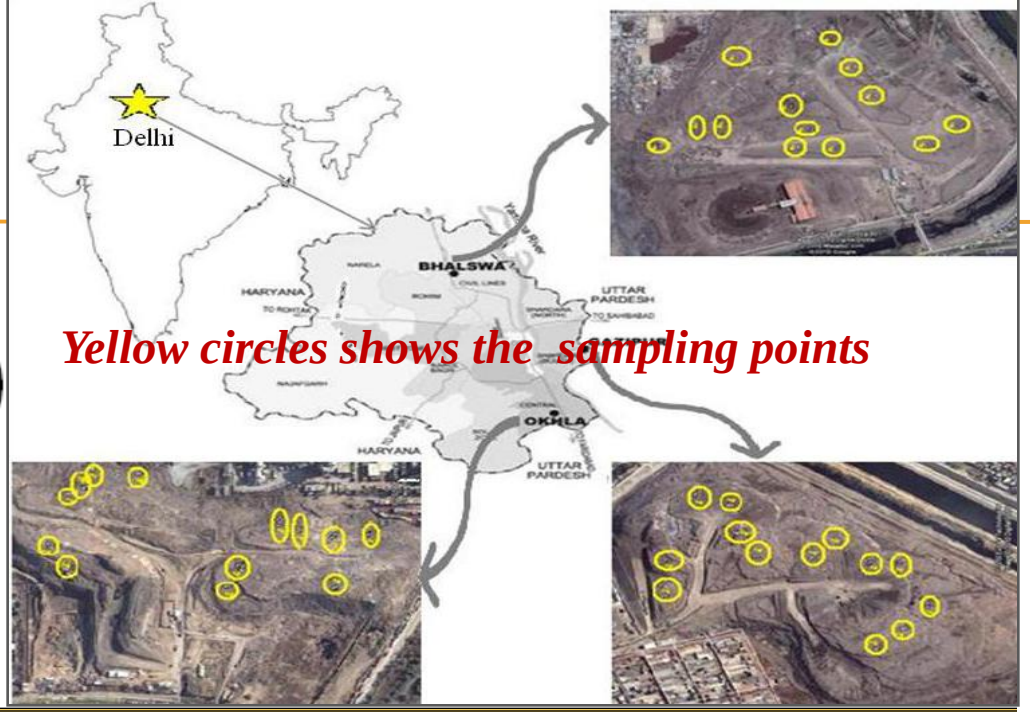
Okhla landfill (OL)

Focus: to reduce uncertainties in CH_4 emission estimations

Bhalswa landfill (BL)

LANDFILL SITES IN DELHI

Focus: to reduce uncertainties in CH_4 emission estimations



Yellow circles shows the sampling points

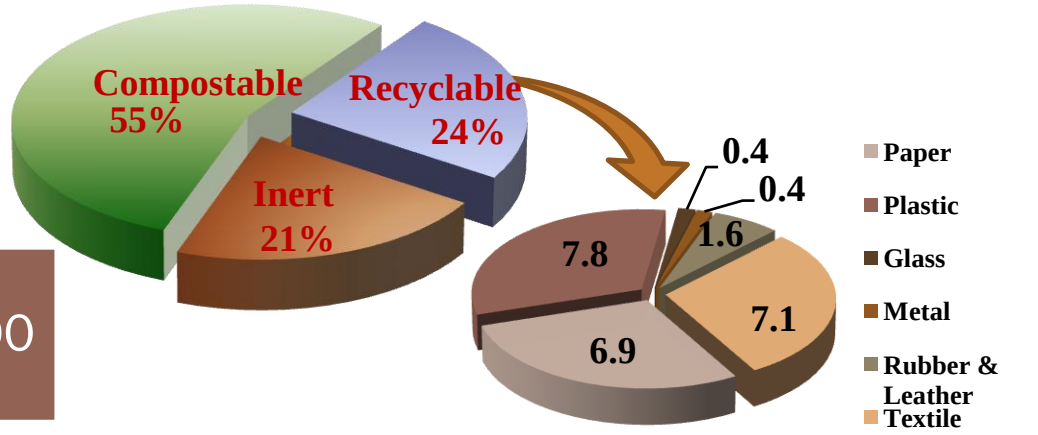
Salient features of Delhi's landfills

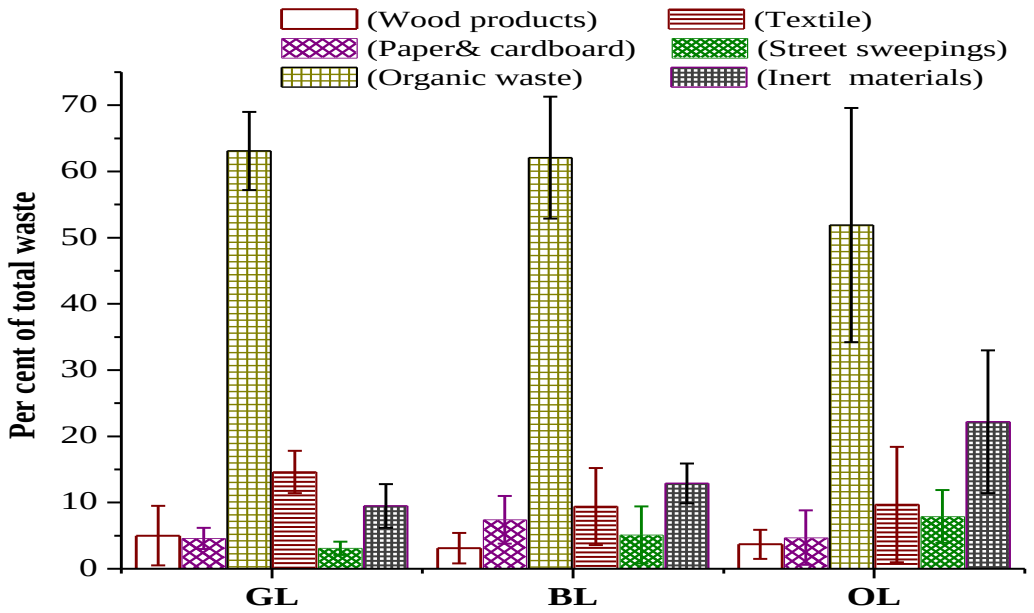
Characteristics	Ghazipur (GL)	Bhalswa (BL)	Okhla(OL)
Location	28° 37' 22.4" N, 77° 19' 25.7" E	28^0 44'27.16" N, 77^0 9'27.92" E	28^0 30'42" N, 77^0 16' 59" E
Starting year	**1984**	**1992**	**1996**
Area (Ha)	29.62	26.22	16.89
Average height (m)	25.5 -30.5	18	27-40
Dumping quantity (TPD)	**2200**	**1500**	**1200**
Waste management facility	Daily spreading and compaction	Basic systems, irregular leveling and compaction	Regular covering with C & D waste and compaction
LFG collection system	No gas collection system and no composting plant	No gas collection system but composting plant	Currently not operational, only composting plant
Type of waste	Household, animal waste from poultry, fish market & slaughter house	Household, vegetable market, C& D waste	Mainly household with C&D waste

WASTE QUANTIFICATION & COMPOSITION :

Generation of waste 7700 TPD

- Existing landfills 4900 TPD
- Existing composting facilities 825 TPD
- Rest of waste i.e. 1975 TPD managed through recycling by rag pickers at the collecting points and some of unattended





** Composition of GL & BL taken from MCD

* Composition of OL is personnel communication

SAMPLING & ANALYSIS

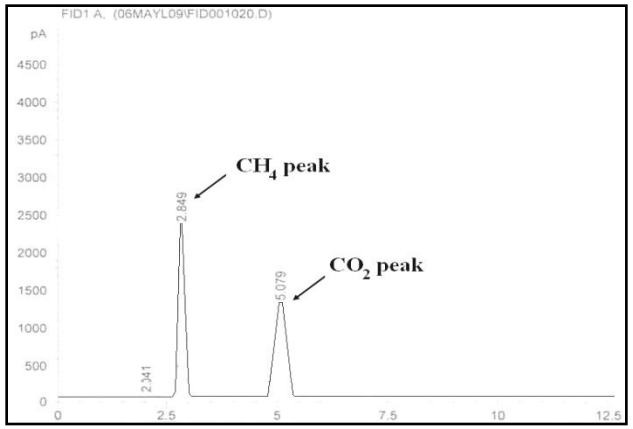
Thermometer for monitoring box temperature

DC fan for homogeneous mixture

Perspex box

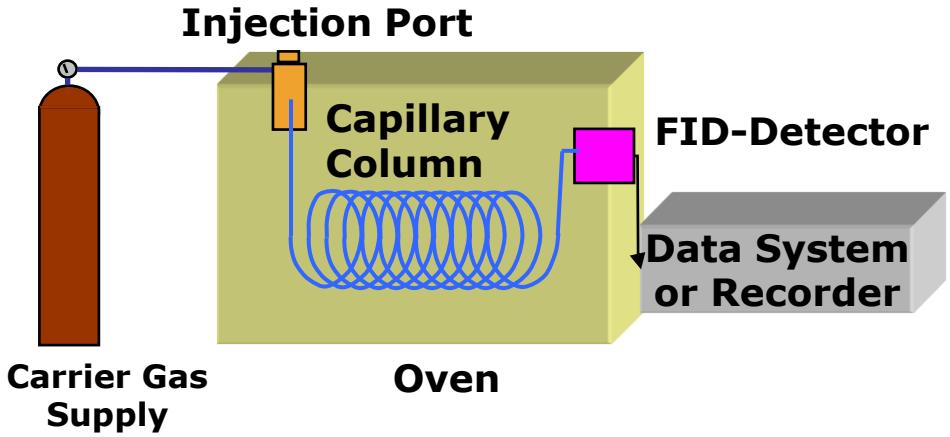
Water column for isolation

Sampling with syringe



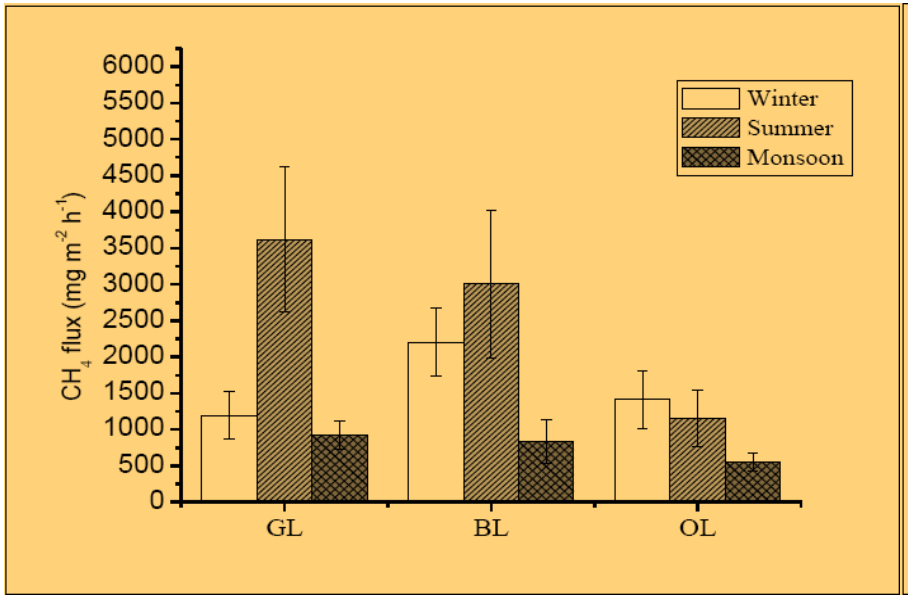
Chromatogram for CH_4 by GC

Gas chromatograph

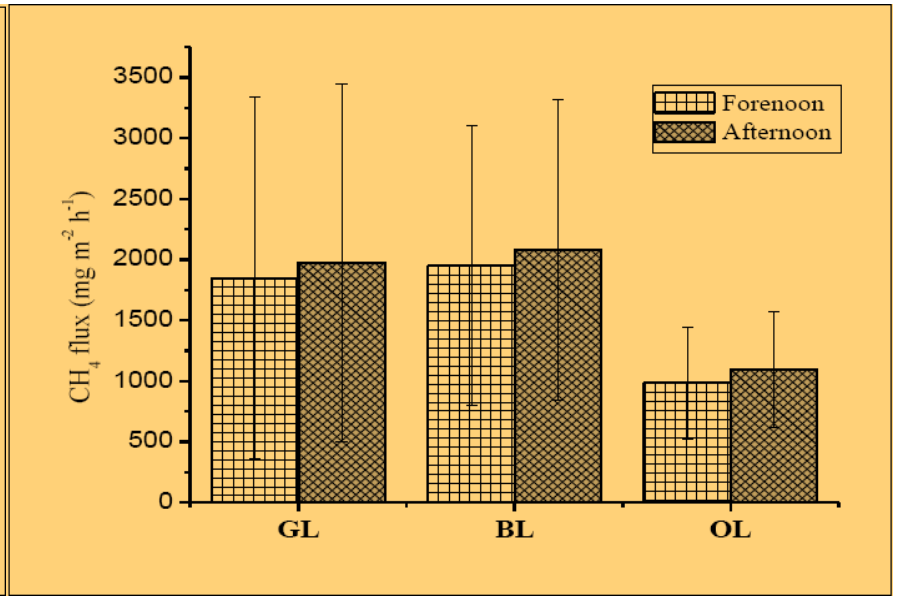


Schematic of a Gas Chromatography

METHANE FLUX ESTIMATION



Seasonal variations in CH_4 emission flux

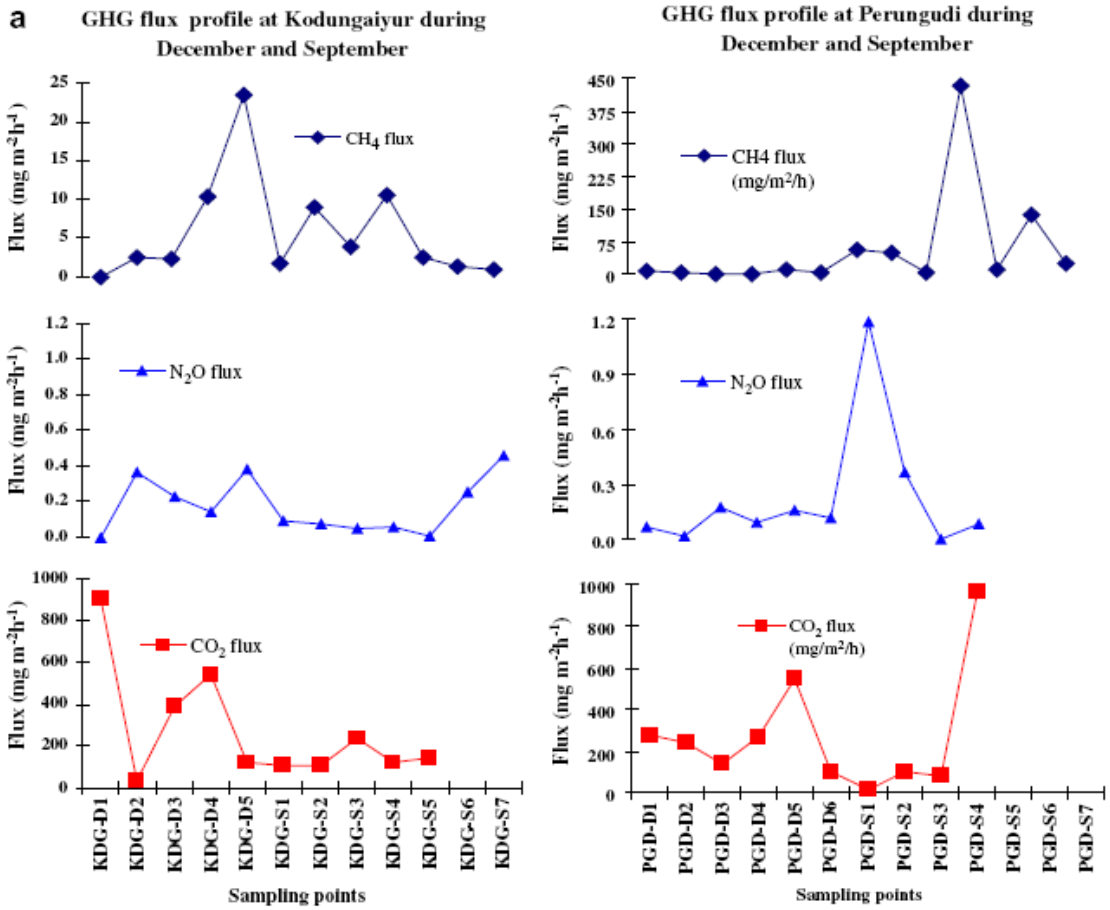


Variation in forenoon & afternoon CH_4 emission flux

Seasonal & average CH_4 emission flux values for Delhi's landfills

Landfills	Seasonal CH_4 emission fluxes (mg m^{-2} h^{-1})			
	Winter	Summer	Monsoon	Average flux
GL	1197±325	3617±994	919±199	1911±506
BL	2201±472	3006±1021	834±294	2014±596
OL	1411±404	1154±394	557±123	1041±307

VARIATIONS IN EMISSION FLUXES IN CHENNAI LANDFILLS



PGD = Perungudi, KDG = Kodungaiyur, D = December, S = September

[Source: A.K. Jha et al. / Chemosphere 71 (2008) 750–758]

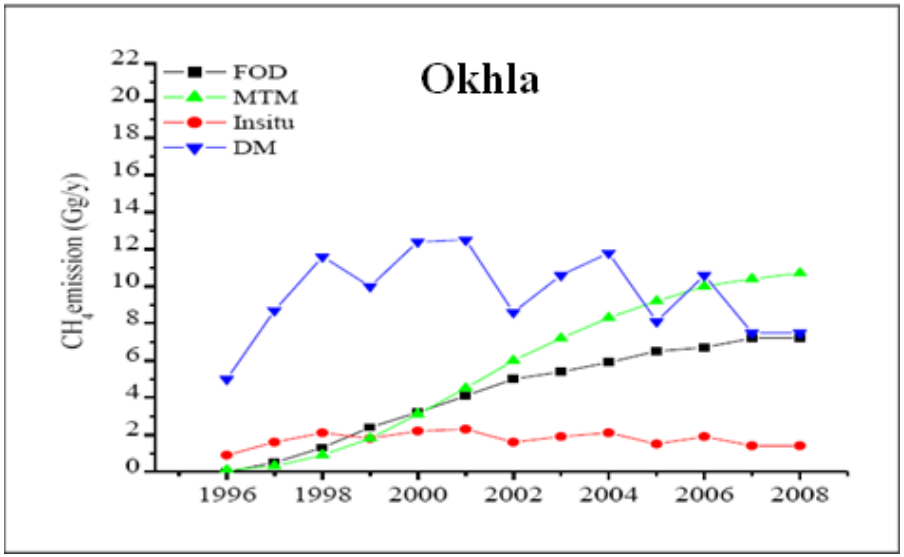
CH_4 EFs & estimations for Delhi's Landfills and its comparison with earlier reported estimations

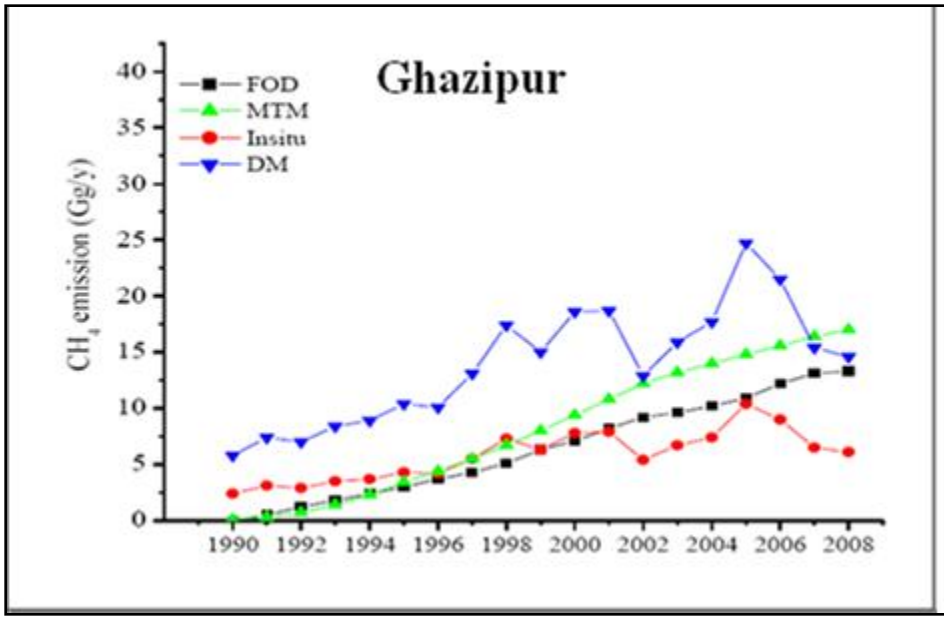
Landfills	Reported CH_4 emission		in-situ method	
	Methodology/ Reference	Estimate (Gg y^{-1})	CH_4 EF (g/ kg of waste)	CH_4 emission Gg)
Ghazipur			9.7±2.6	4.6±1.2
Bhalswa	In-situ/ Sahu et al., (2000)	2.4	5.5±1.6	4.2±1.3
Okhla	In-situ/ Kumar et al., (2004)	1.78	5.5±1.7	1.4±0.4
Total CH_4 estimations				10.2±2.9

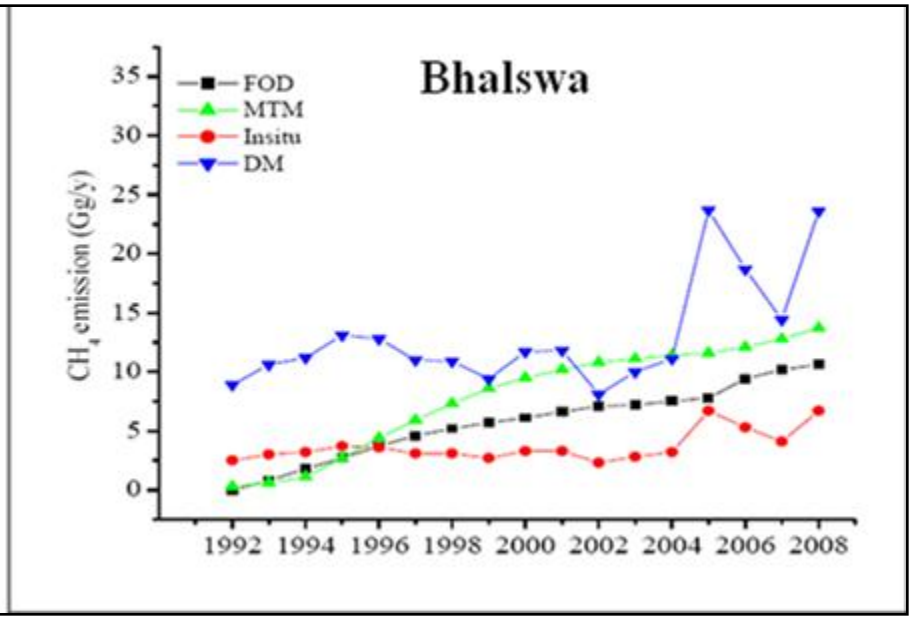
TIME SERIES COMPARISON BY USING DIFFERENT METHODOLOGIES

Methodologies Used

1. **IPCC 1996 default method (DM)**
2. **IPCC First order decay (FOD-IPCC, 2006)**
3. **Modified triangular method (MTM)**
4. **In-situ CH_4 Measurement (In-situ)**







MAIN FINDINGS OF DELHI'S LANDFILL STUDY

❖ The average CH_4 flux values have been estimated from Delhi's landfills as **1911±506, 2014±596** and **1041±307 mg m^{-2} h^{-1}** for Ghazipur (GL), Bhalswa (BL) and Okhla (OL) landfills.

❖ The CH_4 EFs for Delhi's landfills are **9.7±2.6, 5.5±1.6** and **5.5±1.7 Gg** for GL, BL and OL respectively.

❖ The CH_4 emissions are estimated as **4.6 ±1.2 , 4.2±1.3, 1.4±0.4 Gg** for GL, BL and OL respectively.

❖Total CH_4 emission from Delhi's landfills is **10.2±2.9 Gg**.

❖ Comparison with different methodologies for CH_4 emission estimations reveals that in-situ measurement gives the lowest estimation whereas FOD method yields comparable estimations.

KNOWLEDGE GAPS IN DEVELOPING NATIONAL LEVEL EMISSION INVENTORY FOR EMISSIONS FROM LANDFILLS

Activity Data

- ✓ Class wise cities' MSW generation rates
- ✓ Collection efficiencies in different cities
- ✓ Compositions of MSW in different cities

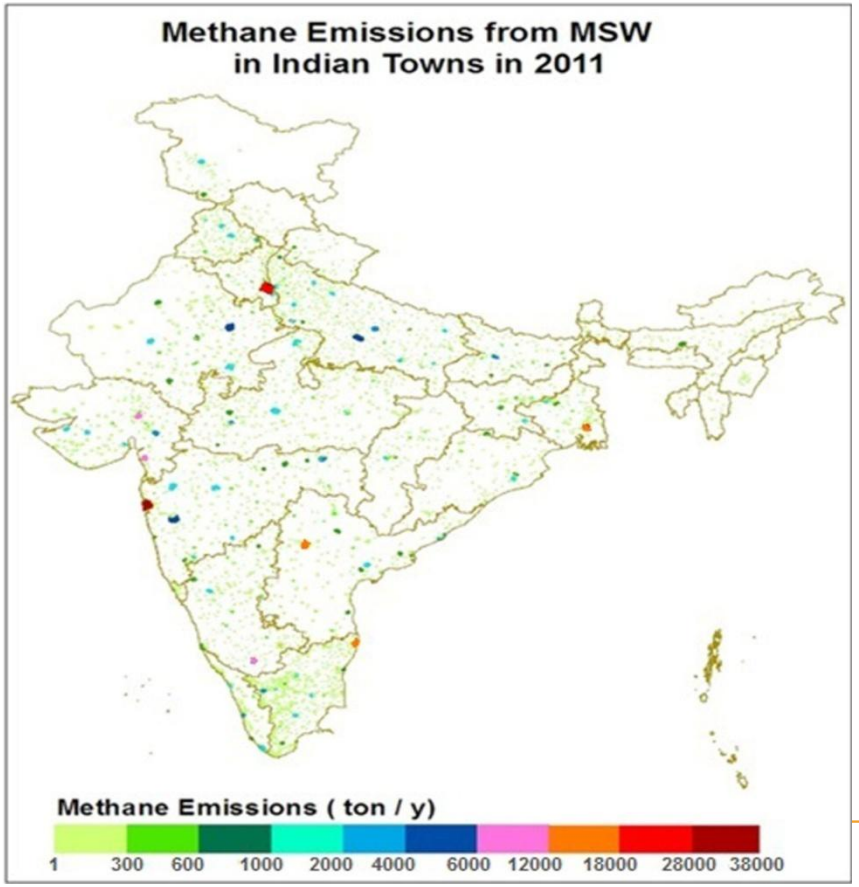
Management practices of Municipalities

- ✓ Compaction activity, soil covering , leachates collection etc.
- ✓ Activities of rag pickers

Other issues

- ✓ Landfill characteristics, topography etc.
- ✓ Climatic conditions
- ✓ Physico-chemical and biological properties of MSW

Development of City-wise methane emission estimates in India using FOD method



City wise CH_4 emission estimation from landfills in India for 2011

Type of Cities	No. of Cities	CH_4 Emissions (Gg/y)
Mega cities	7	136
Class I cities	475	275
Class II cities	493	43
Class III cities	1383	51
Class VI, V, VI towns	2825	39
New towns	2774	26
Total	7957	570

This value is lower than the reported CH_4 emission value from Indian landfills (604 Gg/y) for 2007 (India's SNC) due to incorporation of corrections related to city wise MSW collection efficiencies, waste composition and representative decay constant value.

Contributions:

Monojit Chakraborty

Prabhat K. Gupta

Thanks for the attention