Impact of methane emissions from wastewater sector in India through a case study of an effluent treatment plant

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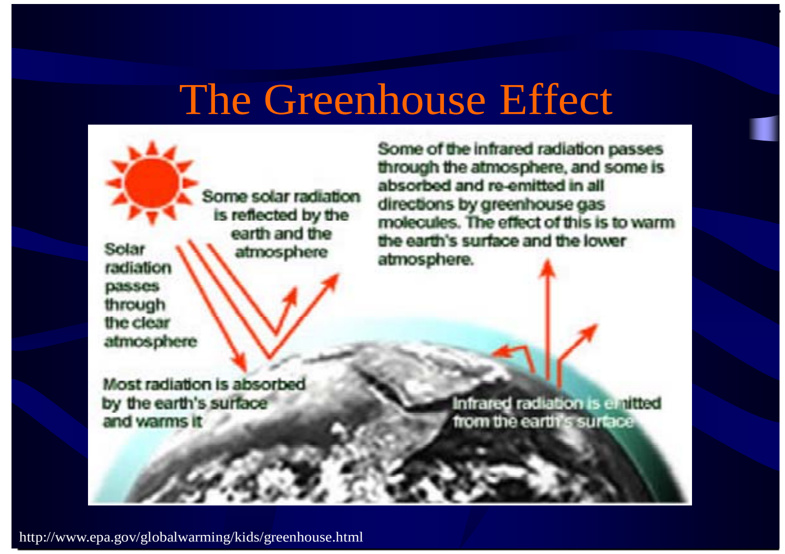
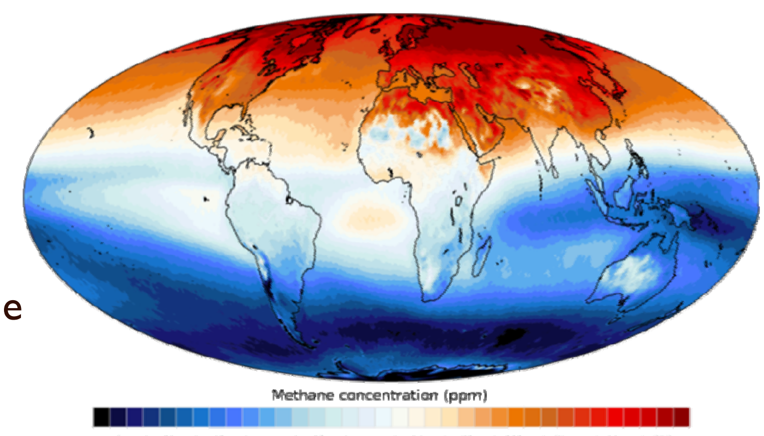
Introduction

- Green house gases are gaseous components of the atmosphere that contribute to the greenhouse effect.
- Major greenhouse gases are water vapor, carbon dioxide, methane and nitrogen oxides, Manmade gases like sulphurhexafluoride and chlorofluorocarbons……..
- Change in lifestyle and food consumption, improvement in quality of living through extensive use of technologies dependent on energy, are contributing to higher emissions in every sphere of life.
- Increase in greenhouse gases causes global warming. Global warming increases the average earth atmosphere's temperature. The average near surface atmospheric temperature of earth has increased from 0.2°C to 0.6°C in the 20^{th} century.



Effects of global warming

- Sea level rise.
- Impacts on agriculture.
- Reductions in the ozone layer.
- Increased intensity and frequency of extreme weather events.
- Spread of disease.



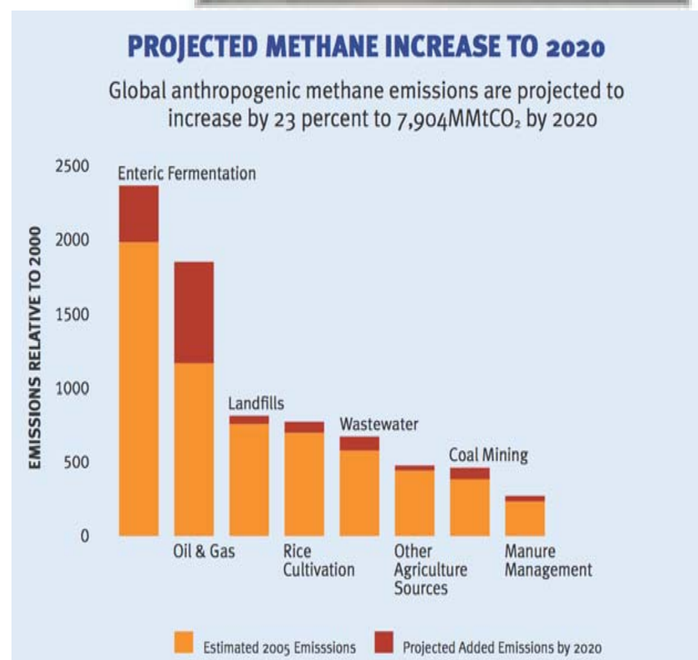
GHG's Status and Governmental Actions

- **Global methane concentration in the atmosphere has doubled In the last two centuries during industrialisation, however recently the growth rate of methane in the atmosphere has slowed between 1990-2006 and increased again since 2008 onwards.**
- **China, India, United States, Russia, Indonesia, and Brazil are the world's largest wastewater methane emitters contributing to about 70 % of the total global wastewater emissions.**
- **India is a party to the United Nations Framework Convention on Climate Change (UNFCC).**
- **The Convention aimed at stabilizing greenhouse gas (CH_4, CO_2, NOX, NMVOC) concentrations in the atmosphere at levels that would prevent dangerous anthropogenic interference with the climate system .**
- **We have submitted First National Communication in the year 2004 and the second NATCOM is being submitted after review process**




- Estimated global methane generation – 688 Tg/year (2010).
- Wastewater contribution is about 8-10% of global estimates.
- Year 1994 was agreed as the base year for estimations.
- Total estimated methane emissions from wastewater is expected to increase upto 20 % by next decade since very little efforts are made in this sector for mitigation (please remember methane has GWP of 21).

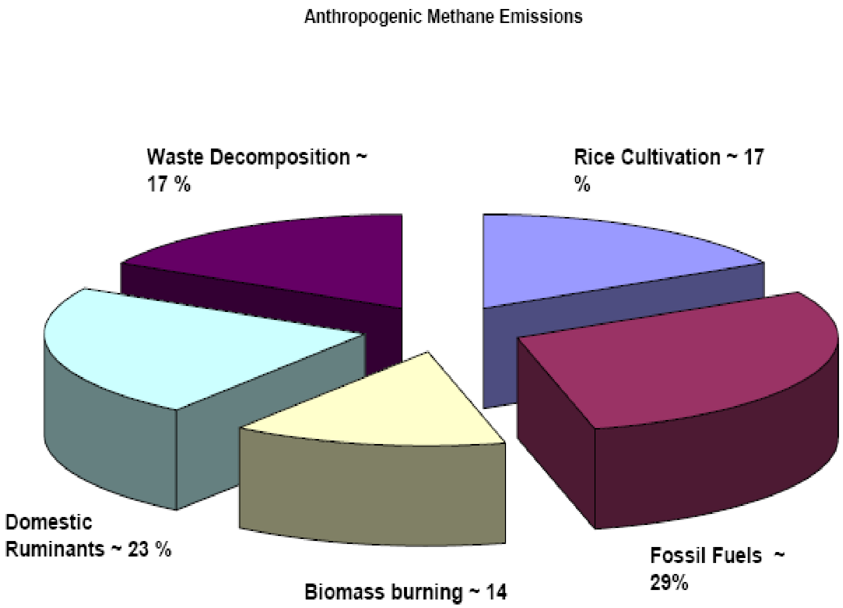
Land mark meetings on Environment issues	
The Earth Summit, **Brazil**	*June 3-14, 1992*
Kyoto Protocol, **Japan**	*December 1-11, 1997*
Conference on Environment, Security and Sustainable Development, **Hague**	*May 9-12, 2004*
The UN Climate Change Conference, **Bali, Indonesia**	*December 3-15, 2007*
Copenhagen Summit, **Denmark**	*December 6 - 18. 2009*
Cancun Climate Summit, **Mexico**	*November 29 – December 10, 2010*

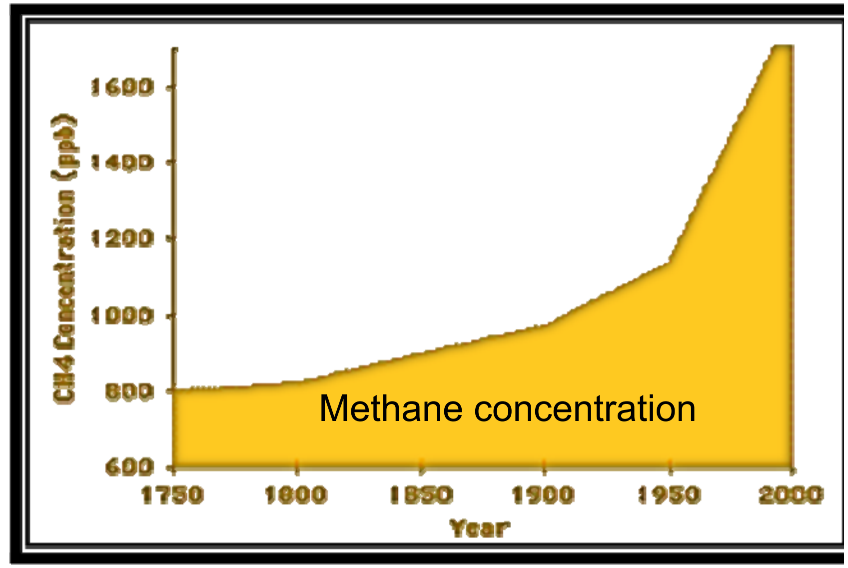


Source: US EPA

Methane – WHY

Anthropogenic methane emission sources

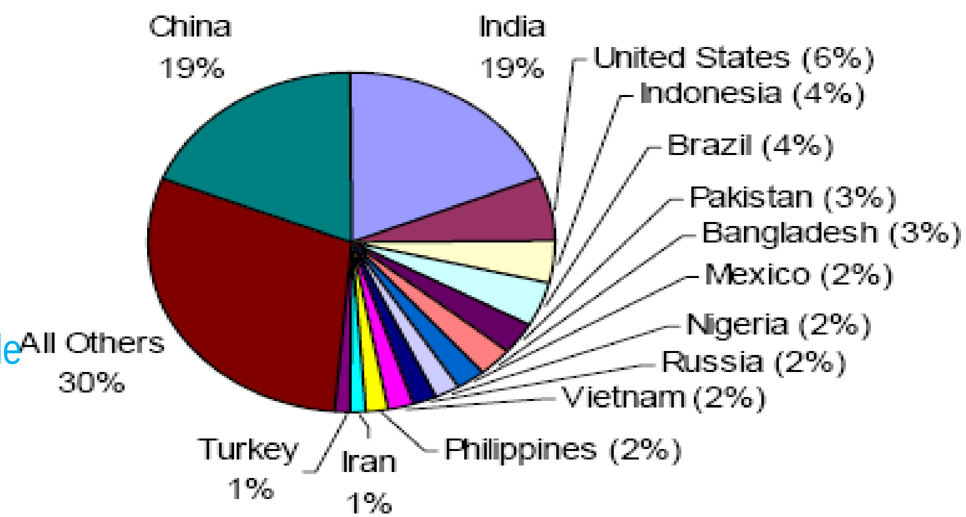




Benefits from methane mitigation

- Reduced GHG emissions from wastewater visavis CO_2.
- Energy cost reductions from utilization of biogas .
- Progress towards goals for use of renewable energy.
- Improved local air and water quality.

Worldwide methane emissions from wastewater (2006)



Methane Emissions from Wastewater Handling

- Methane is produced when wastewater is under anaerobic conditions. Various factors govern CH_4 emissions from wastewater viz.,
- .

Bio-chemical Reactions Involving Methane Formation

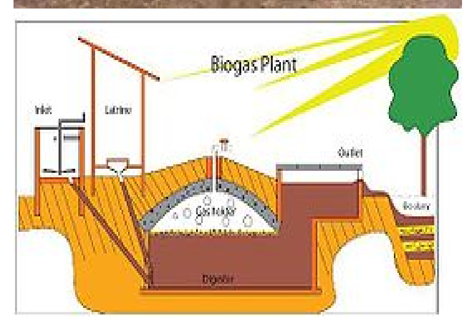
- $4CH_3NH_2 + 2H_2O \longrightarrow 3\,CH_4 + CO_2 + 4NH_3$
- $2(CH_3)2NH + 2H_2O \longrightarrow 3\,CH_4 + CO_2 + 2NH_3$
- $CH_3COOH \rightarrow CH_4 + CO_2$
- $4HCOOH \rightarrow CH_4 + 3CO_2 + 2H_2O$
- $4CH_3OH \rightarrow 9CH_4 + 3CO_2 + 2H_2O$
- Methane is also produced through CO_2 reductions with hydroxide
- $4H_2 + CO_2 \rightarrow CH_4 + H_2O$
- $4CO + 2H_2O \rightarrow CH_4 + 3CO_2$

Sources of methane emissions in wastewater handling

- Conveyance.
- Sewage Treatment Plants.
- Common Effluent Treatment Plants.

Handling/treatment unit & process

- Primary treatment (Solids removal).
  - Clarification/sedimentation/settling.
- Biological Treatment.
  - Anaerobic reactors.
  - Aerobic reactors .
- Sludge handling systems.

Existing Approach for Global National Inventories for UNFCCC

- Tier I*, II** & III*** Approach (IPCC 1996, 2006 guidelines)

  Total emissions of national activity data and national emission factors/IPCC default values if not available

  Emissions = (Total Organic Waste X Emission Factor) – Methane Recovery

  * Used by nations with no secondary data.

  **Existing method and undertaken by majority of nations. but country specific representative emission factors and activity data.

  ***Used by developed and some developing nations. Based on Tier I & II approach but with categorization of activity data and emission factors, extensive physical data and modeling.

- Activity data
  - Domestic wastewater (Population, urbanization, organic content)
  - Industrial wastewater viz., Iron & steel, fertilizer, sugar, & distillery, beverage & food processing units (fish, meat, dairy), pulp & paper, petroleum, textile, rubber etc.

Methodology I – Estimated CH_4 Generation in the city

Estimation of methane emission through IPCC (2006) Guidelines for the Nagpur city

Methane emissions from domestic wastewater have been estimated following IPCC guidelines (2006). The estimate was calculated based on the Equation 1.

Default values as provided in IPCC guidelines were used when values were not available.

$$Td = \left[\sum_{i,j} (Ui \bullet Tij \bullet EFi) \right] x (TOW - S) - R$$

Td - Total domestic emission, kg CH_4/yr.

Ui - Fraction of population in income group i in inventory year (Table 1).

Tij - Degree of utilization of treatment discharge pathway or system, j, for each income group fraction i in the inventory year.

i - Income group: rural, urban high income and urban low income.

j - Treatment/discharge pathway or system.

EFi - Emission factor, kg CH_4 / kg BOD.

B0 - Maximum methane producing potential CH_4/kg BOD (Default value 0.6).

MCF - Methane correction factor (IPCC 2006).

TOW - Total organics in the wastewater in inventory year, kg BOD/yr.

S - Organic component removed as sludge in inventory year, kg BOD/yr.

R - Amount of CH4 recovered in the inventory year, kg CH_4/yr.

Urbanization for Selected States in India

State\Union territory	Urbanization (U)[1]		
	Rural	Urban High	**Urban Low**
Andhra Pradesh	0.73	0.03	**0.24**
Arunachal Pradesh	0.79	0.01	**0.20**
Andhaman & Nicobar	0.40	0.14	**0.46**
Assam	0.77	0.05	**0.18**
Bihar	0.63	0.13	**0.24**
Goa	0.51	0.32	**0.17**
Gujarat	0.63	0.19	**0.18**
Haryana	0.71	0.12	**0.17**
Himachal Pradesh	0.54	0.18	**0.28**
Jammu & Kashmir	0.61	0.07	**0.32**
Karnataka	0.89	0.03	**0.08**
Kerala	0.74	0.10	**0.16**
Madhya Pradesh	0.73	0.13	**0.14**
Maharashtra	0.58	0.16	**0.26**
Nagpur	**0.36**	**0.25**	**0.39**
Manipur	0.76	0.07	**0.17**
Meghalaya	0.70	0.05	**0.25**
Mizoram	0.50	0.32	**0.18**
Nagaland	0.78	0.02	**0.20**
Orissa	0.75	0.05	**0.20**
Punjab	0.66	0.10	**0.24**
Rajasthan	0.75	0.01	**0.24**
Sikkim	0.59	0.15	**0.26**
Tamil Nadu	0.56	0.25	**0.19**
Tripura	0.81	0.01	**0.18**
Uttar Pradesh	0.69	0.10	**0.21**
West Bengal	0.49	0.23	**0.28**
Delhi	0.07	0.66	**0.27**
Pondicherry	0.33	0.37	**0.30**
Lakshadeep	0.55	0.25	**0.20**
Chandigarh	0.10	0.62	**0.28**
Chattisgarh	0.71	0.08	**0.21**
Daman & Diu	0.64	0.16	**0.20**
Dadar &Nagar Haveli	0.77	0.03	**0.20**
Uttranchal	0.26	0.26	**0.48**
India	**0.71**	**0.06**	**0.23**

Degree of utilization of treatment or discharge pathway or method for each income group. (T_{ij})

State	Rural					Urban High					Urban Low				
	ST	LAT	SEW	Oth	No	ST	LAT	SEW	Oth	No	ST	LAT	SEW	Oth	No
Andh.Prad.	0.15	0.03	0.08	0.13	0.62	0.12	0.03	0.01	0.66	0.13	0.20	0.11	0.03	0.44	0.22
Arun. Prad.	0.02	0.01	0.03	0.03	0.97	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Andh. & Nico.	0.22	0.02	NA	0.00	0.97	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Assam	0.03	0.01	0.51	0.00	0.45	0.01	0.02	0.04	0.93	0.00	0.00	0.01	NA	0.99	0.00
Bihar	0.05	0.04	0.07	0.01	0.82	0.01	0.02	0.06	0.84	0.07	0.02	0.01	NA	0.97	0.03
Goa	0.03	0.03	NA	0.01	0.99	0.00	0.01	0.01	0.99	0.00	0.01	NA	NA	0.99	0.00
Gujarat	0.01	0.02	NA	0.05	0.87	0.10	0.04	NA	0.82	0.04	0.03	0.02	0.27	0.66	0.02
Haryana	0.02	0.02	NA	0.02	0.94	0.03	0.02	0.08	0.92	0.03	0.01	0.01	NA	0.89	0.08
Him. Prad.	0.02	0.00	0.00	0.01	0.97	0.00	0.01	0.00	0.98	0.01	0.00	NA	0.96	NA	0.04
J & K	0.04	0.02	0.06	0.01	0.91	0.01	0.01	0.04	0.94	0.00	0.00	0.01	0.02	0.97	0.01
Karnataka	0.02	0.06	0.01	0.06	0.85	0.06	0.12	0.02	0.79	0.01	0.03	0.13	0.07	0.73	0.05
Kerala	0.06	0.29	0.00	0.00	0.64	0.03	0.17	0.03	0.77	0.01	0.00	0.06	0.00	0.94	0.00
Madh. Prad.	0.02	0.01	0.02	0.09	0.86	0.05	NA	0.86	NA	0.03	0.09	NA	0.71	0.17	NA
Maharashtra	0.09	0.01	0.02	0.11	0.77	0.00	0.02	0.05	0.76	0.17	0.50	0.12	0.22	0.41	0.21
Manipur	0.02	0.01	0.01	0.00	0.98	0.00	0.01	0.01	0.97	NA	0.00	0.01	0.00	0.99	NA
Meghalaya	0.00	0.01	0.01	0.00	0.98	0.00	0.00	0.00	0.99	0.00	0.01	0.01	0.01	0.97	NA
Mizoram	0.01	0.00	0.00	0.00	0.99	0.02	0.01	NA`	0.99	NA`	0.01	0.01	NA	0.99	NA
Nagaland	0.01	0.02	0.01	0.03	0.93	0.01	0.02	0.01	0.99	NA	NA	NA`	NA	NA	NA
Orissa	0.02	0.02	0.06	0.02	0.89	0.02	0.01	0.10	0.81	0.00	0.00	0.03	NA`	0.96	0.01
Punjab	0.04	0.05	NA	0.02	0.89	0.04	0.05	NA	0.88	0.03	0.01	0.01	NA	0.99	0.00
Rajasthan	0.02	0.03	0.05	0.07	0.88	0.04	0.05	0.02	0.88	0.90	0.00	0.02	0.01	0.96	0.03
Sikkim	0.02	0.02	0.00	0.01	0.94	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Tamil Nadu	0.09	0.01	NA	0.09	0.80	0.13	0.04	0.06	0.57	0.20	0.05	0.03	0.13	0.71	0.07
Tripura	0.01	0.03	0.01	0.00	0.97	0.00	0.01	0.01	0.98	0.00	NA	0.01	NA	0.99	NA
Uttar Pradesh	0.09	0.07	NA	0.23	0.61	0.13	0.21	0.11	0.38	0.18	0.04	0.05	0.17	0.71	0.03
West Bengal	0.08	0.13	0.10	0.09	0.59	0.08	0.16	0.27	0.39	0.08	0.09	0.27	0.16	0.46	0.02
Delhi	0.03	0.01	NA	0.00	0.96	0.04	0.01	0.00	0.95	0.00	0.02	0.06	NA	0.99	0.01
Pondicherry	0.01	NA	NA	0.00	0.99	0.06	0.01	NA	0.99	0.00	0.06	0.01	NA	0.99	0.00
Lakshadeep	0.06	0.01	NA	0.02	0.99	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chandigarh	0.01	0.01	NA	0.00	0.99	0.01	0.00	NA	0.99	0.01	0.00	0.01	NA	0.99	0.01
Chattisgarh	0.03	NA	NA	0.00	0.97	0.01	0.00	NA	0.98	0.00	0.00	NA	NA	0.99	0.01
India	**0.00**	**0.47**	**0.10**	**0.10**	**0.33**	**0.18**	**0.08**	**0.67**	**0.07**	**0.00**	**0.14**	**0.10**	**0.53**	**0.03**	**0.20**

ST – Septic tank, LAT – Latrine, SEW – Sewer, Oth – Other, No – None

Per capita BOD contribution across the states

State	Urban Population (000's)	Wastewater Quantity per day (MLD)	Per capita BOD (gBOD/day)
And. & Nic. Island	116	08	-
Andh. Prad.	20809	1271	-
Aruna.Prad.	228	-	-
Assam	3439	222	-
Bihar & Jharkhand	14676	1363	27
Chandigarh	809	272	61.86
Delhi	12906	2700	46.8
Goa	671	20	-
Gujarat	18930	1709	38.9
Haryana	6115	330	38
Him.Prad.	596	13	19.6*
Karnataka	17962	1036	38
Kerala	8267	428	-
Madh.Prad. & Chhattis.	20153	1159	34
Maharashtra	41101	4692	38
Manipur	576	24	-
Meghalaya	454	30	-
Mizoram	441	4	-
Nagaland	343	20	-
Orissa	5517	374	-
Pondichery	649	36	-
Punjab	8263	616	46.9
Rajasthan	13214	1055	-
Tamil Nadu	27484	1094	-
Tripura	546	22	-
Utt.Prad. & Uttaranchal	36719	2292	39
West Bengal	22427	2113	38.9
overall			
Second Natcom (2001 pop stats)	2,86,120	22,903	40.5
**First Natcom (1991 pop stats)	28,449	2,859	37.4

*Too low and not considered for estimation purpose. **Based on major cities

Methane emissions from domestic and industrial wastewater treatment (Gg)						
Activity	1995	2000	2005	2006	2007	2008
CH_4(Total)	1794	1819	2195	2032	1911	1957
Domestic	624	716	816	838	861	890
Industrial#	1170	1103	1379*	1194*	1050*	1067*

Recovery considered only for sugar, beer and dairy industries (@70%, 75% & 75% resp.).

#Emission estimates are for the following industries iron & steel, fertilizer, beer, meat, sugar, coffee, soft drink, Pulp & paper, petroleum, rubber, dairy and tannery.

* Emission estimates are for the following industries iron & steel, fertilizer, beer, meat, sugar, coffee, soft drink, Pulp & paper, petroleum, rubber and tannery except dairy.

Table 1: Urbanization and degree of utilization of treatment, discharge pathway or method (Tij) for each income group and methane conversion factor for Nagpur city.

Fraction of Population (U)		
Rural	Urban high	Urban low
0.36	0.25	0.39

Degree of utilization of treatment or discharge pathway or method for each income group, T									
Urban high					Urban low				
Septic Tank	Latrine	Sewer	Other	None	Septic Tank	Latrine	Sewer	Other	None
0.02	0.09	0.09	0.64	0.15	0.36	0.12	0.23	0.08	0.21

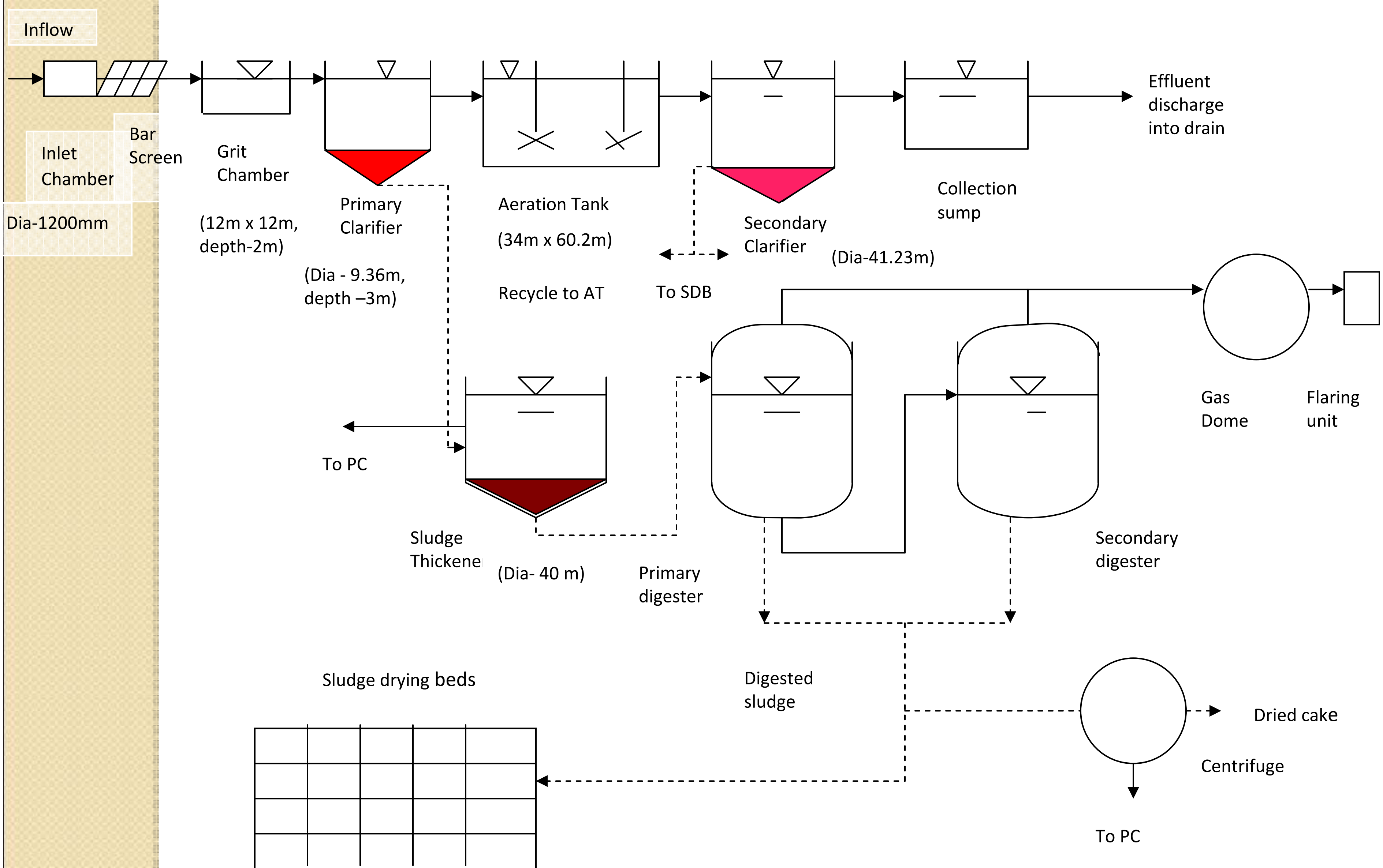
Default MCF values used for types of treatment and discharged pathway or system				
Septic Tank	Latrine	Sewer	Other	None
0.5	0.1	0.5	0.1	0

Total methane emission offsite (kg/d) – 7123

Methodology II – CH_4 generation in sewage treatment plant

Urban population (000's)	2613
Total wastewater generation (MLD)	380
Wastewater Treated (MLD)	70±4
Biological oxygen demand (mg/l)	174 – 240 (205±117)
Methane correction factor (at 31^{0}C)	0.45
Maximum methane production capacity (kg CH_4/kg BOD)	0.6
Emission factor (kg CH_4/kg BOD)	0.27
Methane generation onsite (kg/day)	3140±235

Source: STP



Flow Diagram of Sewage Treatment Plant, Nagpur

Methodology III - Flux measurement

For non-aerated surfaces,

Methane gas flux, E (mass/area/time) is calculated from the following equation

$E = (V / A) \times \rho \times (dC / dt)$

V = Volume of Chamber.

P = Density of gas at the temperature recorded in the chamber.

dC/dt = Linear increase in the gas concentration in the chamber during the sampling period.

For aerated surfaces

$E = \rho \times C \times Q / A$

ρ = Density of gas at the temperature recorded in the chamber.

C = Sample gas concentration

Q = Gas flow rate inside the gas data analyzer

A = Enclosed surface area.

Monitoring Instruments and Analytical Facilities used for work

Flux Measurement for domestic sewage

Gas data analyzer

Methane emissions from unit treatment process at STP				
Treatment unit	Flux * ($g.m^{-2}.d^{-1}$)		Area (m^2)	Quantity, kg/d
Collection chamber	9.4	4.3 – 6.8+	1.13	0.010
Grit chamber	16.7	6.2-18.9	144	2.405
Primary clarifier	7.2		68.84	0.496
Aeration tank	5.15	1.1-2.8	2047	10.542
Secondary clarifier	4.8	0.1-0.11	1336	6.413
Sludge thickener	56.65	1.1-1.9	1257	71.209
Methane generation onsite	-			91.075

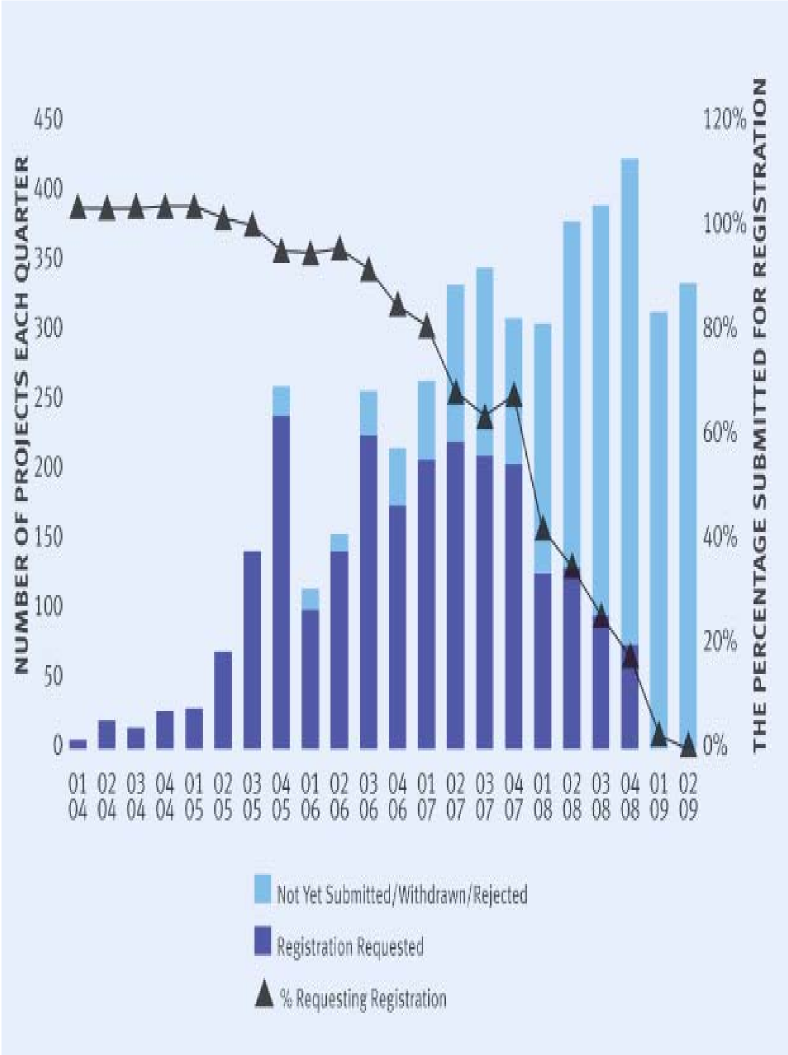
- Average flux generated over the day based on 6 hr sampling.
- \+ Wang J, et al, 2010

Comparison of estimates for the city between methodologies

Parameter	IPCC 2006 Guidelines *	Secondary data*	Flux generation
Methane generation, kg per day	7123(Urban high & low)	3140 (26%)	91.1
Estimated	4006(Rural)	8792(74%)	3140
Total, kg per day	11,129	11,932	3231
Possible sources of error and uncertainty	– Urbanisation – Degree of treatment – Seasonal variations – Difference in organic content – Recovery/flaring	– Fugitive emissions – Emissions during conveyance – Microbial dynamics	– Emissions during conveyance – Microbial dynamics – Fugitive emissions – Organic content – Temperature – Degree of aeration – Leakages

Conclusions

- Greenhouse gas emissions from wastewater particularly methane is increasing annually with rise in population, urbanisation and consumption .
- Emissions occur at different sources in the effluent management system and has to be inventoried for mitigation.
- Aids in understanding emission pattern in effluent treatment units.
- Helps in developing strategies and techniques to mitigate methane emissions from effluent treatment facilities and enables better wastewater management practices for methane emissions reduction.
- The methane data from effluent treatment facilities can be used if other data was not available inventory preparation.
- A proper wastewater management system with complete collection, conveyance, treatment and disposal systems enhances mitigation.
- Market based incentives like Clean Development Mechanisms have invoked for energy recovery.



Decline in Methane CDM Applications

Source: Clean Air Task Force, 2009

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Agencies working in this area

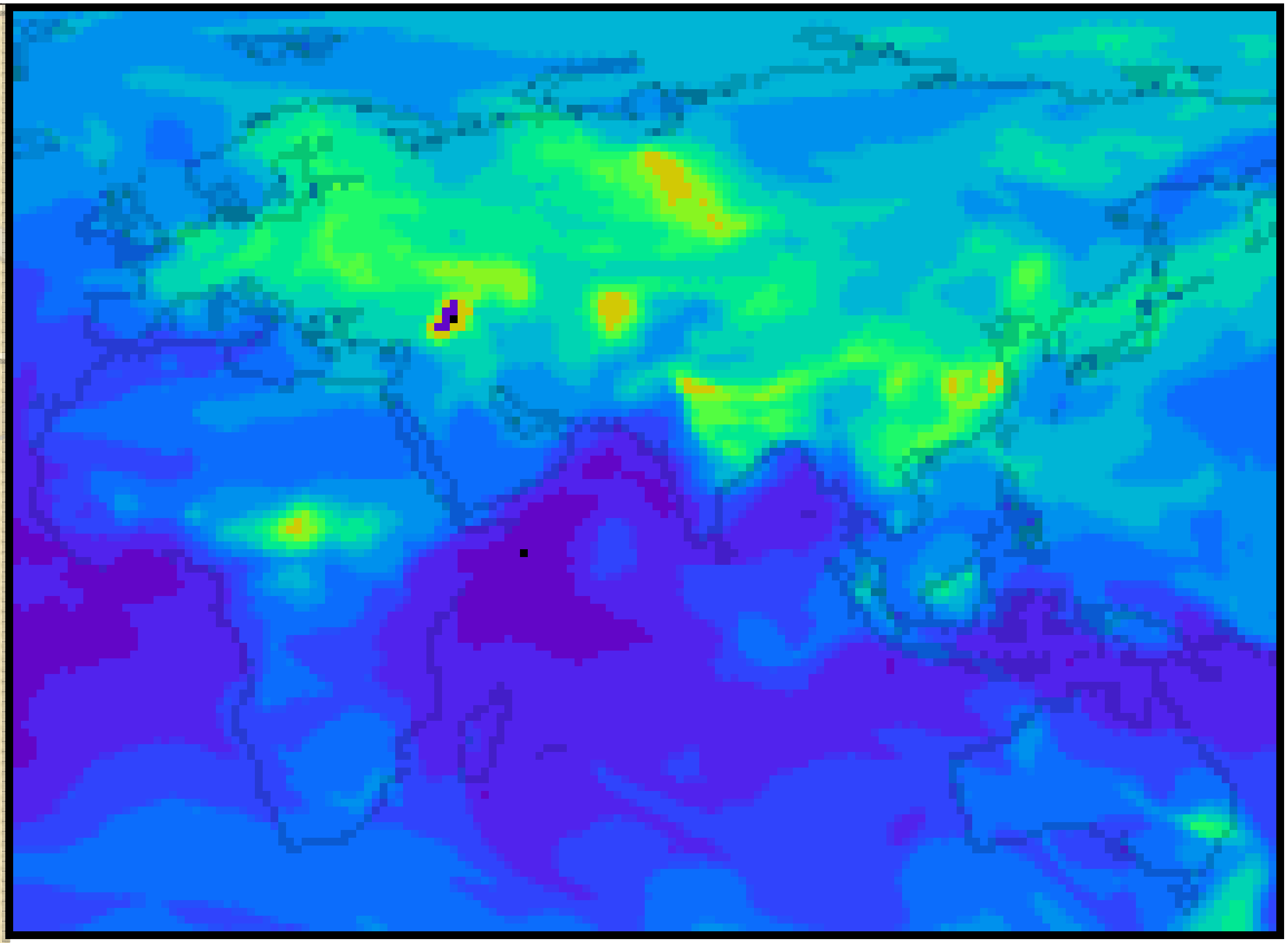
- National Bio Energy Board (National Master Plan)
- Ministry of Environment & Forests
- Ministry of Non-Conventional Energy Sources
- Ministry of Urban Development.

Power Generation Potential from Urban Liquid Waste

Year	Sewage Generated (MLD)	Power Generation (MW)
2002	15402	287
2007	17775	332
2012	20680	386
2017	24752	462

Power Generation Potential in Identified Industrial Sectors

Sectors	Period		
	2007	2012	2017
Dairy (Liquid waste)	61	77	96
Distillery (Liquid waste)	503	628	785
Maize Starch	105	132	164
Liquid Waste	*24*	*30*	*37*
Solid Waste	*81*	*102*	*127*
Tapioca Starch	24	30	37
Liquid Waste	*18*	*22*	*27*
Solid Waste	*6*	*8*	*10*
Poultry (Solid waste)	65	81	102
Paper (Liquid waste)	58	72	90
Slaughterhouse (Solid Waste)	94	117	146
Sugar	363	453	567
Liquid Waste	*59*	*73*	*92*
Solid Waste	*304*	*380*	*475*
Tanneries (Liquid waste)	6	8	10
Total	**1279**	**1598**	**1997**



From NASA's *Earth Observatory*Newsroom...
Atmospheric Methane (February 2005)

Thank you….