Inventorisation of Methane Emissions from Domestic & Key Industries Wastewater - Indian Network for Climate Change Assessment

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Objectives

- Estimation of Degradable Organic Content (DOC) based on primary & secondary data of **domestic sewage & key industries (pulp & paper, sugar & distillery, tannery and dairy).**
- Identification of sewage plant and key industries for estimation of plant specific methane emission due to wastewater handling based on secondary data.
- Estimate methane emission factor for wastewater handled through methane conversion factors and methane producing capacity.
- Estimate methane emissions at national scale from domestic and industrial wastewaters using the emission factors determined above.
- Estimate nitrous oxide emission at national scale from domestic wastewater using IPCC 2006 guidelines.

Methane Emission Estimation from Domestic Wastewater

IPCC 2006 GUIDELINE

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

T_d	=	Total domestic emissions
U_i	=	Fraction of population in income group *i* in inventory year.
T_{ij}	=	Degree of utilization of treatment/discharge pathway or system, *j*, for each income group fraction *i* in inventory year.
i	=	Income group: urban high income & urban low income, rural.
j	=	Each treatment/discharge pathway or system.
EF_i	=	Emission factor kg CH_4/kg BOD. $EFj = Bo \bullet MCFj$
B_0	=	Maximum CH_4 producing capacity, kg CH_4/kg BOD. (0.6).
MCF	=	Methane correction factor.
TOW	=	Total organic wastewater in inventory year kg BOD/yr. $TOW = \mathrm{P} \bullet \mathrm{BO}D \bullet 0.001 \bullet \mathrm{I} \bullet 365$
P	=	Country population in inventory year, (person).
BOD	=	Country-specific per capita BOD in inventory year, g/person/day.
I	=	Correction factor for additional industrial BOD discharged into sewers (default value 1).
S	=	Organic component removed as sludge inventory year, kg BOD/yr.
R	=	Amount of CH_4 recovered in inventory year, kg CH_4 /yr.

IPCC 1996 GUIDELINE

$$WM = P \times D \times SBF \times EF \times FTA \times 365 \times 10^{-12}$$

WM	=	Annual methane emission from domestic wastewater (Tg)
P	=	Population of urban cities (class I & II), persons
D	=	Organic load in BOD/person (Kg BOD / person/ day), country average value, 0.37 kg BOD /person /day
SBF	=	Fraction of BOD that readily settles, default value 0.5
EF	=	Emission factor (g CH_4/g BOD), 0.6
FTA	=	Fraction of BOD in sludge that degrades anaerobically, default value 0.8

Urbanization and Per Capita BOD Contribution for Selected States in India

State	Urban Population (000's)	Wastewater Quantity per day (MLD)	Urbanization (U)			Per capita BOD (gBOD/day)
			Rural	Urban high	Urban low	
Andaman & Nicobar Island	116	08	0.40	0.14	0.46	-
Andhra Pradesh	20809	1271	0.73	0.03	0.24	-
Arunachal Pradesh	228	-	0.79	0.01	0.20	-
Assam	3439	222	0.77	0.05	0.18	-
Bihar & Jharkhand	14676	1363	0.63	0.13	0.24	27
Chandigarh	809	272	0.10	0.62	0.28	61.86
Delhi	12906	2700	0.07	0.66	0.27	46.8
Goa	671	20	0.51	0.32	0.17	-
Gujarat	18930	1709	0.63	0.19	0.18	38.9
Haryana	6115	330	0.71	0.12	0.17	38
Himachal Pradesh	596	13	0.54	0.18	0.28	19.6*
Jammu & Kashmir	-	-	0.61	0.07	0.32	-
Karnataka	17962	1036	0.89	0.03	0.08	38
Kerala	8267	428	0.74	0.10	0.16	-
Madhya Pradesh & Chhattisgarh	20153	1159	0.73	0.13	0.14	34
Maharashtra	41101	4692	0.58	0.16	0.26	38
Manipur	576	24	0.76	0.07	0.17	-
Meghalaya	454	30	0.70	0.05	0.25	-
Mizoram	441	4	0.50	0.32	0.18	-
Nagaland	343	20	0.78	0.02	0.20	-
Orissa	5517	374	0.75	0.05	0.20	-
Pondichery	649	36	0.33	0.37	0.30	-
Punjab	8263	616	0.66	0.10	0.24	46.9
Rajasthan	13214	1055	0.75	0.01	0.24	-
Tamil Nadu	27484	1094	0.56	0.25	0.19	-
Tripura	546	22	0.81	0.01	0.18	-
Uttar Pradesh & Uttaranchal	36719	2292	0.69	0.10	0.18	39
West Bengal	22427	2113	0.49	0.23	0.28	38.9
Average	-	22,903	0.61	0.16	0.23	-
India overall						
Second Natcom (2001 pop stats)	2,86,120	22,903	0.71	0.06	0.23	40.5
Initial Natcom (1991 pop stats)	28,449	2,859	-	-	-	37.4

Source: Housing Condition in India NSS Report July-December 2002; Status of sewage treatment plant in India, CPCB 2005.

Degree of utilization of treatment, discharge pathway or method (Tij) for each income group

State	Degree of utilization of treatment or discharge pathway or method for each income group. (T_{ij})														
	Rural					Urban High					Urban Low				
	ST	LAT	SEW	Oth	No	ST	LAT	SEW	Oth	No	ST	LAT	SEW	Oth	No
Andhra Pradesh	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
Arunachal Pradesh	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
Himachal Pradesh	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
Jammu & Kashmir	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
Madhya Pradesh	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
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	**0.04**	**0.03**	**0.06**	**0.04**	**0.83**	**0.03**	**0.04**	**0.03**	**0.83**	**0.07**	**0.03**	**0.04**	**0.03**	**0.06**	**0.83**

Case Study for Domestic Sewage - Nagpur

Fraction of Population (U)			
	Rural	Urban high	Urban low
Nagpur	0.36	0.25	0.39
India	0.71	0.06	0.23

Degree of utilization of treatment or discharge pathway or method for each income group										
	Urban low					Urban high				
	Septic Tank	Latrine	Sewer	Other	None	Septic Tank	Latrine	Sewer	Other	None
Nagpur	0.02	0.09	0.09	0.64	0.15	0.36	0.12	0.23	0.08	0.21
India	0.18	0.08	0.67	0.07	0.00	0.14	0.10	0.53	0.03	0.20

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

Parameters	Nagpur	India
Urban population (000's)	2613	352929
Total wastewater generation (MLD)	380	22900
Wastewater Treated (MLD)	70	8000
Biological oxygen demand (mg/l)	174 – 240 (205)	90 – 955 (187)
Methane correction factor (@ 31^0C)	0.45	-
Maximum methane production capacity (kg CH_4/kg BOD)	0.6	0.6
Emission factor (kg CH_4/kg BOD)	0.27	-
Methane emission onsite (kg/day)	3140	-
Total methane emission offsite (Gg/yr)	3.4	890
Methane recovered in inventory year (Gg/yr)	0.8	-
Net Methane emitted in the inventory year (Gg/yr)	2.6	-

Estimated emission by using following formula:

$$T_d = [\sum_{ij}(U_i.T_{ij}.EF_i)](TOW–S)–R$$

Methane emission estimation from industrial wastewater

$$Ti = \sum_i (TOWi - Si)EFi - Ri$$

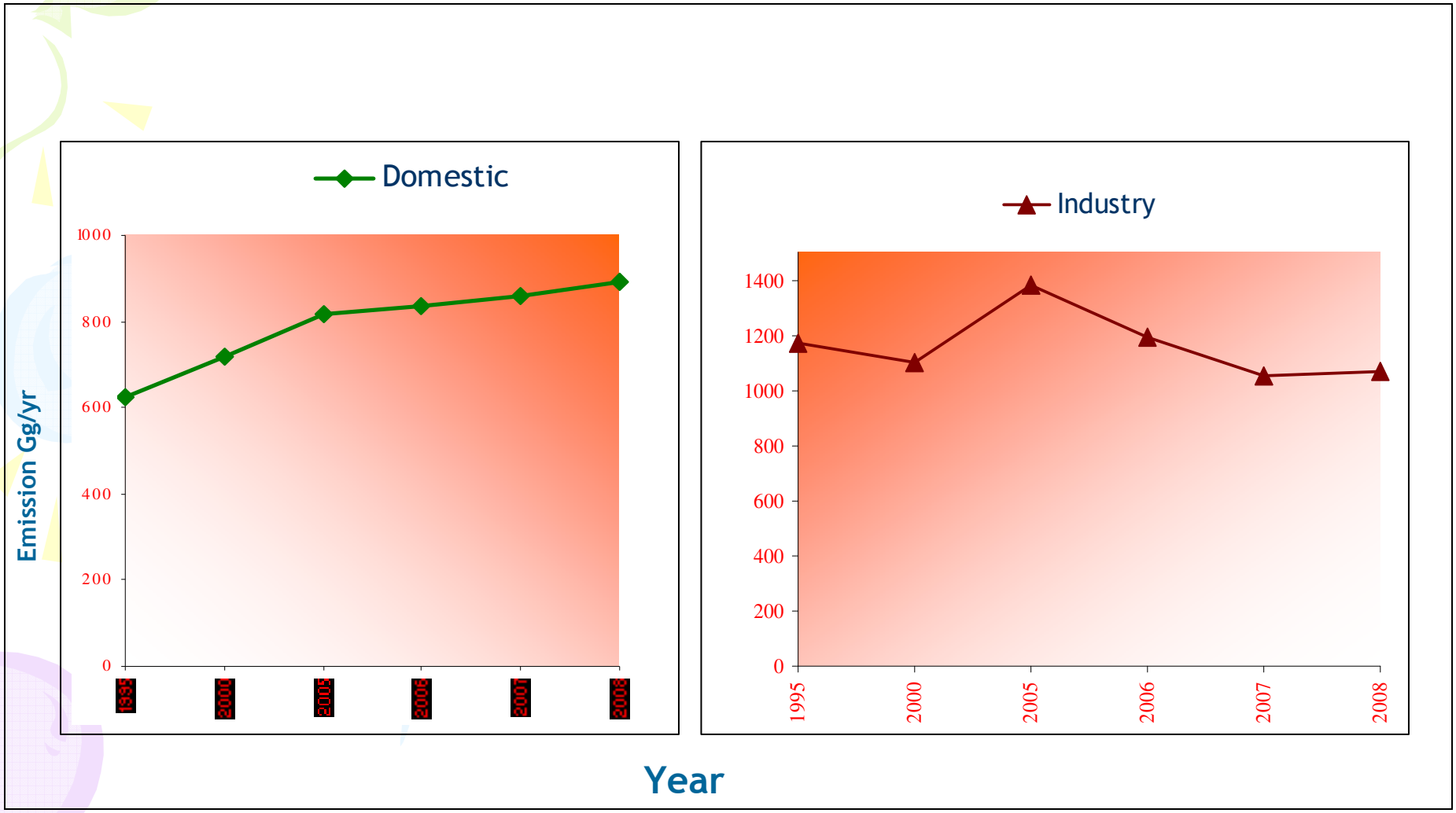
T_i	=	CH_4 emission in inventory year, kg CH_4/yr
i	=	Industrial sector
TOW_i	=	Total organically degradable material in waste water for industry i in inventory year, kg COD/year, $TOW = P \bullet W \bullet COD$
P	=	Total industrial production for industrial sector i, t/yr.
W	=	Wastewater generated m^3/tproduct.
COD	=	Chemical oxygen demand kg COD/m^3
S_i	=	Organic component removed as sludge in inventory year, kg COD/year (Default Value 0.35)
EF_i	=	Emission factor for industry i, kg CH_4 kg/COD for treatment/ discharge pathway or system used in inventory year. $EFj = Bo \times MCFj$
B_0	=	Maximum methane producing potential CH_4/kg COD (Default value 0.25)
MCF_i	=	Methane correction factor
R_i	=	Amount of CH_4 recovered in inventory year, kg CH_4/year

Industries (Category A)	Wastewater generated (m^3/t)	COD (kg COD /m^3)	MCF	EF
Pulp & paper	230[a]	5.9[a]	0.80	0.20
Sugar	1[a]	2.5[a]	0.80	0.20
Distillery	14 (m^3/m^3)[a]	100[a]	0.8	0.20
Tannery	32[b]	3.1[b]	0.20*	0.05*
Dairy	3[a]	2.24[a]	0.8*	0.2*

*Default value. a – Arun Kansal et.al., TERI information monitor on environmental science.,

b – J. Raghava Rao et. al. Cleaner production

Methane emission from domestic and industrial wastewater



For domestic emission only urban population is considered.

Industrial emission consists:

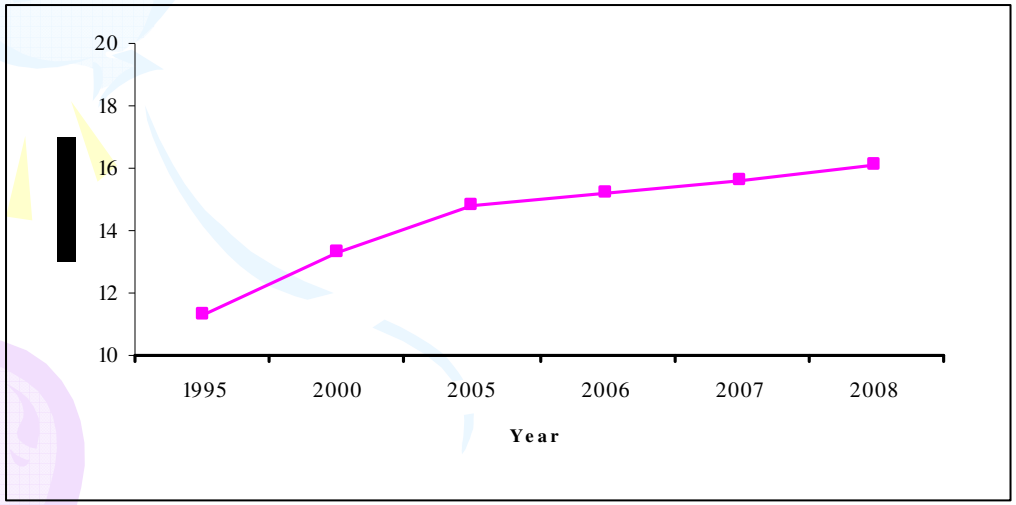
Pulp & paper, Sugar, Tannery, Fertiliser, Dairy, Iron & steel, petroleum and rubber industries, Beverage units (beer, coffee, soft drink, meat).

70% methane recovery from dairy & sugar industry , 80% methane recovery considered from distillery industry.

Methodology for N_2O Emissions from Wastewater (IPCC 2006 Guidelines)

$$N_2O_{Emissions} = N_{EFFLUENT} \cdot EF_{EFFLUENT} \cdot 44 / 28$$

$N_2O_{Emissions}$	=	N_2O emissions in inventory year, kg N_2O/yr
$N_{EFFLUENT}$	=	Nitrogen in the effluent discharged to aquatic environments, kg N/yr $NEFFLUENT = (P \cdot Pr \cdot F_{NPR} \cdot F_{NON-CON} \cdot F_{IND-COM}) - N_{SLUDGE}$
P	=	Human population
Pr	=	Annual per capita protein consumption, kg/person/yr
F_{NPR}	=	Fraction of nitrogen in protein, default = 0.16, kg N/kg protein
$F_{NON-CON}$	=	Factor for non-consumed protein added to the wastewater (1.4)
$F_{IND-COM}$	=	Factor for industrial and commercial co-discharged protein into the sewer system (1.25)
N_{SLUDGE}	=	Nitrogen removed with sludge (default = zero), kg N/yr
$EF_{EFFLUENT}$	=	Emission factor for N_2O emissions from discharged to wastewater, kg N_2O-N/kg N (0.005)
44 / 28	=	The conversion of kg N_2O-N into kg N_2O



Value of P_r

1995-1999 - 57.2 Gms capita^{-1}day^{-1}

2000-2004 - 58.5 Gms capita^{-1}day^{-1}

2005-2008 - 57.0 Gms capita^{-1}day^{-1}

Only Urban population is considered

Source:
Nutritional intake in India 2004-2005,
National Sample Survey Organization,
Ministry of Statistics & Programme Implementation,
Government of India, NSS 61ST Round July 2004- June 2005.

Conclusions

- Methane emissions from domestic & industrial sectors show increasing trend (861 & 1060 Gg/yr - 2007).
- Similar trend with Nitrous oxide emissions (15.8 Gg/yr - 2007).
- Necessary technologies available to mitigate methane from domestic and industrial sources.

Thank You