Emission Inventory: Emission Factors & Methodology

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Emission inventory (EI)

- is a comprehensive listing by sources of air pollutant emissions in a geographic area during a specific time period.

- Fundamental components of Air Quality Management Plans

- Useful in air quality model applications

Robustness of inventories depends upon:

- Methodology
- Measurements
  - Calibration & Standardization

Emission Inventory Development Approaches

1. Top-down approach

- **Uses general emission factors combined with gross level activity data**

(<u>emission factor</u> x <u>national fuel consumption</u>)

- **National- or regional-level emissions estimates scaled to the inventory domain based on surrogate data (geographic, demographic, economic data etc.)**

- **Used when the detailed data are not available**

- **Requires minimum resources but the emissions generally have high level of uncertainty**

Emission Inventory Development Approaches

2. Bottom-up approach

- Uses source-specific data and category-specific data at the most refined spatial level
- Emission estimation for individual sources (and source categories) is summed to obtain domain level inventory
- Used when source/category-specific activity or emissions data are available
- Requires resources to collect site-specific information
- Estimates are more accurate than from top-down approach

Estimation Method

- The most common emission estimation method is to multiply emission factor by activity Data.
- This method estimates the rate at which a pollutant is released to the atmosphere as a result of some processes.

$$E = EF \times AD \times \frac{(1-CE)}{100}$$

Where,

E = Emission Load

EF = Emission Factor

AD = Activity Data

CE = Overall Control Efficiency (%)

Source Categories

- Energy
- Industrial Processes and Product Use (IPPU)
- Agriculture, Forestry and Other Land Use (AFOLU)
- Waste

(as per IPCC 2006)

General Issues in the Preparation of Emission Inventories

- Data collection
- Uncertainty assessment
- Key category analysis
- Time Series Consistency
- Quality Assurance (QA), Quality Control (QC) and Verification

The Methodological Principles of data collection that underpin good practice are:

- Focus on the collection of data which is needed to accurately estimate emissions or removals from the sources or sinks that are the largest, have the greatest potential to change (especially increase), or have the greatest uncertainty.

- Choose data collection procedures that iteratively improve the timeliness, comparability, completeness, accuracy and transparency of the inventory.

Continued from previous…

- Put in place data collection activities (resource prioritisation, planning, implementation, and documentation) that lead to a progressive enrichment of the data sets used in the inventory.

- Collect data/information at a level of detail that is comparable between the inventory datasets of an inventory sector and consistent with the inventory user's needs .

- Review data collection activities and methodological needs on an annual basis to guide progressive, and efficient, inventory improvement.

Uncertainty Assessment

- Uncertainty estimates are an essential element of a complete emission inventory and should be derived for both the national level and the trend estimate, as well as for the component parts.

Structured approach to estimating inventory uncertainty includes:

- Determination of uncertainties in individual data used in the inventory
- Aggregation of the component uncertainties to the total inventory
- Determination of uncertainty in the trend over time
- Identification of key sources of uncertainty in the inventory to help prioritize information gathering and efforts to improve the inventory.

An uncertainty analysis

…should be seen as a means to help prioritise national efforts to reduce the uncertainty of inventories in the future, and help guide decisions on methodological choice.

For this reason, the methods used to attribute uncertainty values must be practical, scientifically defensible, robust enough to be applicable to a range of source and sink categories, methods and national circumstances, and presented in ways comprehensible to inventory users

Reducing uncertainty

Depending on the type of uncertainty present, uncertainties could be reduced in five broad ways:

- *Improving representativeness:* This may involve stratification or other sampling strategies
- *Using more precise measurement methods*
- *Collecting more measurements* : Increase in sample size
- *Eliminating known risk of bias*
- *Improving state of knowledge*

KEY CATEGORIES

- A *key category* is one that is prioritised within the inventory system because its estimate has a significant influence on a country's total inventory

Key Categories in the Energy Sector for Indian GHG Emissions based on Indian INC

Category	Gg	Cumulative Emissions (Gg)	Level Assessment (%)
Power generation	349438.3	349438.3	57.6
Iron and steel	57029.2	406467.5	67.1
Residential	43794.0	450261.5	74.3
All other Sectors	31963.0	482224.5	79.6
Fertilisers	26793.9	509018.5	84.0
Cement	25834.3	534852.7	88.2
Commercial and Institutional	20509.0	555361.7	91.6
Gas Production and Handling	10858.3	566220.0	93.4
Petroleum refining	10702.9	576922.9	95.2
Railways	6599.5	583522.4	96.3
textile	6238.8	589761.2	97.3
Paper	5917.6	595678.8	98.3
Civil aviation	3039.2	598717.9	98.8
Bricks	2939.6	601657.6	99.3
Water ways	1186.7	602844.2	99.5
2W/3W	1016.9	603861.2	99.6
MCV/HCV	758.0	604619.1	99.7
Cars/Taxi	556.0	605175.2	99.8
Sugar	368.8	605544.0	99.9
LCV	324.9	605868.8	99.95
Oil Production and Handling	280.4	606149.2	99.998
Underground Mining	7.9	606157.1	99.999
Surface Mining	5.7	606162.8	100.000
Total	**606163**	.	.

TIME SERIES CONSISTENCY

- The time series is a central component of the inventory because it provides information on historical emissions trends and tracks the effects of strategies to reduce emissions.
- Emission trends should be neither over nor underestimated as far as can be judged.
- All emissions estimates in a time series should be estimated consistently, which means that as far as possible, the time series should be calculated using the same method and data sources in all years.
- Using different methods and data in a time series could introduce bias because the estimated emission trend will reflect both real changes and also the pattern of methodological refinements.

Issues with data availability

- ***Periodic data***
- ***Changes and gaps in data availability***
- ***Non-calendar year data***

QUALITY ASSURANCE / QUALITY CONTROL AND VERIFICATION

Quality Assurance (QA)

..is a planned system of review procedures conducted by personnel not directly involved in the inventory compilation/development process. Reviews, preferably by independent third parties, are performed upon a finalised inventory following the implementation of QC procedures. Reviews verify that data quality objectives were met, ensure that the inventory represents the best possible estimates of emissions given the current state of scientific knowledge and data availability, and support the effectiveness of the QC programme.

QUALITY CONTROL (QC)

- *Quality Control* (QC) is a system of routine technical activities, to measure and control the quality of the inventory as it is being developed. It is performed by personnel compiling the inventory. The QC system should be designed to:
  - Provide routine and consistent checks to ensure data integrity, correctness, and completeness;
  - Identify and address errors and omissions;
  - Document and archive inventory material and record all QC activities.

Indian Emission Factors

Coal

Categorization of Indian Coking and Non-Coking Coal

Sl. No	Class	Grade	Grade Specification
1.	Coking Coal on the basis of ash contents	Steel Gr I	Ash content < 15%
		Steel Gr. II	15% <= Ash content < 18%
		Washery Gr. I	18% <= Ash content < 21%
		Washery Gr. II	21% <= Ash content < 24%
		Washery Gr. III	24% <= Ash content < 28%
		Washery Gr. IV	28% <= Ash content < 35%
2.	Non-coking coal on the basis of Useful Heat Value (UHV) kcal/kg	A	UHV > 6200
		B	6200 >= UHV > 5600
		C	5600 >= UHV > 4940
		D	4940 >= UHV > 4200
		E	4200 >= UHV > 3360
		F	3360 >= UHV > 2400
		G	2400 >= UHV > 1300

Comparison of NCV & CEF

	IPCC Default 1996		India Specific Values 1994	
	NCV (TJ/kt)	CEF (tC/TJ)	NCV (TJ/kt)	CEF (tC/TJ)
Coking Coal	19.98	25.8	24.18	25.53
Non-coking Coal	19.98	25.8	19.63	26.13

Refinement of NCV & CEF from Coal in India

- Development of Coal Variety Specific NCV & CEF
- Development of Predictive Equations
- Comparison of Computed & Measured CO2 Emissions for Thermal Power Plants

Emissions from Thermal Power Plants

Average emission coefficient of different category of thermal power plants

Plant (MW)	Emission coefficient	Emission per kg coal				Emission per unit (kWh) electricity			
		CO_2 (kg)	CO (g)	SO_2 (g)	NO (g)	CO_2 (kg)	CO (g)	SO_2 (g)	NO (g)
60	Average value	1.550	0.493	10.918	4.235	0.804	2.510	5.670	2.210
	S.D.	0.091	0.446	0.964	0.927	0.020	3.224	0.432	0.559
	Range	1.480–1.670	0.147–13.07[b]	9.530–11.720	3.120–5.320	0.776–0.824	0.080–7.140[b]	5.210–6.211	1.540–2.910
67.5	Average value	1.734	0.353	12.14	4.590	1.079	0.220	7.550	2.855
	Range[a]	1.652–1.819	0.088–0.353	9.712–15.77	4.250–5.244	1.028–1.132	0.055–0.220	6.043–9.812	2.644–3.263
210	Average value	1.705	1.663	19.23	3.61	1.197	10.680	13.460	2.525
	S.D.	0.295	1.521	3.572	0.595	0.208	11.345	2.500	0.415
	Range	1.481–2.12	0.283–34.98[b]	15.29–22.85	2.84–4.27	1.037–1.49	0.198–24.49[b]	10.70–15.99	1.99–2.99
250	Average value	1.565	0.272	13.835	3.635	0.911	0.161	8.104	2.091
	S.D.	0.035	0.182	0.488	0.926	0.083	0.116	0.932	0.395
	Range	1.540–1.590	0.400–0.143	13.49–14.18	2.98–4.29	0.852–0.969	0.079–0.243	7.445–8.763	1.812–2.370

[a]This range was measured at only one thermal power plant. As data on other units are not available, figure for S.D. has not been calculated.

[b]Due to oil support in these thermal power plants, the CO emission is high, which has been reflected in the range of emission for CO.

Chakraborty N., Mukherjee I., Santra A.K., Chowdhury S., Chakraborty S., Bhattacharya S., Mitra A.P. & Sharma C., 'Measurement of CO2, CO, SO2, and NO emissions from coal-based thermal power plants in India', Atmospheric Environment, doi:10.1016/j.atmosenv.2007.10.074

Emission rates of pollutants from different thermal power generating units

Generator unit	Installed in year	Installed capacity (MW)	Electricity generation and corresponding emission						Flue gas temperature (°C)
			Generation (MW)	CO_2 (kg h^{-1})	CO (kg h^{-1})	SO_2 (kg h^{-1})	NO (kg h^{-1})		
S1U1	1982–1983	60	60	48456.84	428.53[a]	312.51	130.210		127
S1U2	1982–1983	60	60	48508.67	4.823	372.64	174.41		128
S1U3	1982–1983	60	60	46550.96	33.99	327.45	92.36		139
S1U4	1982–1983	60	60	49420.8	135.14[a]	347.07	133.99		154
S2U1	1995	250	250	242232.40	60.85	2155.75	453.10		137
S2U2	1997	250	250	213002.82	19.79	1861.95	592.58		127
S3U1	1987–1988	210	175	260099.25	4285.32[a]	2106.71	523.52		133
S3U3	1987–1988	210	140	167914.63	375.97	2238.86	369.96		126
S3U5	1987–1988	210	175	181389.27	34.63	2643.67	434.72		127
S3U6	1987–1988	210	200	211836.74	3067.13[a]	2139.92	397.53		143
S4U2	1990	67.5	67.5	72821.31	14.842	509.681	192.71		144

[a] Due to oil support in these thermal power plants, the CO emission is high, which has been reflected in the range of emission for CO.

Chakraborty N., Mukherjee I., Santra A.K., Chowdhury S., Chakraborty S., Bhattacharya S., Mitra A.P. & Sharma C., 'Measurement of CO2, CO, SO2, and NO emissions from coal-based thermal power plants in India', Atmospheric Environment, doi:10.1016/j.atmosenv.2007.10.074

Comparison of emission coefficients

Gaseous type	Range of measured emission coefficient		Emission coefficients	
	Present study for the year 2003–2004	Study by OSC in the year 1997–1998	Gurjar et al. (2004)	Present study
CO_2	0.776–1.49 ($kg\,kWh^{-1}$)	0.8–1.8 ($kg\,kWh^{-1}$)	1.739 ($kg\,kg^{-1}$ of coal)	1.639 ($kg\,kg^{-1}$ of coal)
SO_2	5.210–15.99 ($g\,kWh^{-1}$)	4–18 ($g\,kWh^{-1}$)	14.767 ($g\,kg^{-1}$ of coal)	14.031 ($g\,kg^{-1}$ of coal)
NO	1.540–3.263 ($g\,kWh^{-1}$)	6–13.1 ($g\,kWh^{-1}$)	0.824[a] ($g\,kg^{-1}$ of coal)	4.018 ($g\,kg^{-1}$ of coal)
CO	0.055–24.49[b]	Not available	0.253 ($g\,kg^{-1}$ of coal)	5.153 ($g\,kg^{-1}$ of coal)

[a]NO_x as NO_2 measured by Gurjar as 1.263, converted to NO multiplying with a factor of 0.652.
[b]Additional oil support.

Chakraborty N., Mukherjee I., Santra A.K., Chowdhury S., Chakraborty S., Bhattacharya S., Mitra A.P. & Sharma C., 'Measurement of CO2, CO, SO2, and NO emissions from coal-based thermal power plants in India', Atmospheric Environment, doi:10.1016/j.atmosenv.2007.10.074

Total estimated emission of pollutants from Indian thermal power plants in the year 2003–2004

	Emission per unit (kWh) of electricity			
	CO_2	CO	SO_2	NO
Range of emission from all power plants	0.776–1.49 kg	0.055–24.49 g	5.21–15.99 g	1.54–3.263 g
Average emission coefficient	0.998 kg	3.393 g	8.696 g	2.420 g
Total estimated emission during year 2003–2004[a] (Tg)	465.667	1.583	4.058	1.129

Note: 1 Tg = 1 Mton = 1 million metric ton.

Chakraborty N., Mukherjee I., Santra A.K., Chowdhury S., Chakraborty S., Bhattacharya S., Mitra A.P. & Sharma C., 'Measurement of CO2, CO, SO2, and NO emissions from coal-based thermal power plants in India', Atmospheric Environment, doi:10.1016/j.atmosenv.2007.10.074

Transport Sector

Table 1 – Net calorific values, carbon emission factors and emission coefficients used for different fuel types

Fuel types	NCV (TJ/10^3 tonnes)	CEF (tC/TJ)	CH_4 (kg/TJ)	N_2O (kg/TJ)	CO (kg/TJ)	NO_x (kg/TJ)	NMVOC (kg/TJ)
Gasoline	44.80	18.9	20	0.6	8000	600	1500
Diesel oil	43.33	20.2	5	0.6	1000	800	200
LDO	43.33	20.2	5	0.6	1000	800	200
FO	40.19	20.2	5	0.6	1000	800	200
Lubricants	40.19	20.0	20	0.6	1000	600	1500

Singh A., Gangopadhyay S., Nanda P.K., Bhattacharya S., Sharma C. & Bhan C., 'Trends of greenhouse gas emissions from the road transport sector in India', Science of Total Environment, doi:10.1016/j.scitotenv.2007.09.027

Table 2 – Distribution of fuel consumption in road transport sector between 1980 to 2000 (10^3 tonnes)

Year	Gasoline 2W/3W	Gasoline car/taxi	Gasoline other uses [a]	Diesel MCV/HCV	Diesel LCV	Diesel other uses [b]	LDO	FO	Lubricants 2-Stroke 2W/3W
1980	964	542	8.1	5002	2144	3063	NA	NA	37
1985	1418	798	11.7	7148	3063	4376	NA	NA	54
1990	2281	1283	18.7	10376	4447	6353	1.3	36.0	87
1995	2882	1621	23.6	15140	6489	9269	1.8	9.5	110
2000	4099	2306	33.6	18772	8045	11493	3.0	5.3	130

NA = Not available; documentation began from 1990 onwards.

2W/3W = two wheelers and three wheelers.

[a] Gasoline other uses means gasoline consumption in railways and other take-away through network of retail outlets.

[b] Diesel other uses includes diesel consumption in railways, aviation, shipping, agriculture, energy and transformation industries and other industries.

Singh A., Gangopadhyay S., Nanda P.K., Bhattacharya S., Sharma C. & Bhan C., 'Trends of greenhouse gas emissions from the road transport sector in India', Science of Total Environment, doi:10.1016/j.scitotenv.2007.09.027

Wheat Straw Burning in Agriculture Fields

Atmospheric pollution due to FBCR in Rice & Wheat cultivation

Emission Factors (g/kg) of various emission species from the wheat straw burning and their comparison with existing EFs available in literature for various biomass types

Biomass type	CH_4	CO_2	CO	N_2O	NO_x	NO	NO_2	OC	BC	TC
Crop residue[a]									0.75	
Agricultural residue[b]*								3.3	1	
Crop residue[c] *								0.17–4.69	0.12–0.17	
Agricultural residue[d]	2.7	1515 ± 177	92 ± 84	0.07	2.5 ± 1.0			3.3	0.69 + 0.13	4
Wheat straw [e,†]	7.37± 2.72		156 ± 22	0.34 ± 0.21				2.38	1.59	
Rice straw [e,†]	5.32 ± 3.08		82 ± 20	0.48 ± 0.45						
Wheat straw[f]	**3.55 ± 2.66**	**1787 ± 35**	**28 ± 20**	**0.74 ± 0.46**	**1.70 ± 1.68**	**0.78± 0.71**	**0.56 ± 0.47**	**0.29 ± 0.12**	**0.16 ± 0.07**	**0.53 ± 0.21**
Wheat stubble[g]			21.1 ± 1.9							
Wheat fires[g]			38.2							
Wheat[g]			44.1 ± 7.4							
Wheat[g]			59							
Wheat[g]			35							
Cereal waste[h]		1400	35		3					
Wheat straw[i, ‡]								1.23 ± 0.03		
Rice straw[i,‡]								8.94 ± 0.42		
Wheat residue[j,]*	2.62 - 8.97	959 - 1320	61.1 - 179		0.23 - 1.14					
Wheat residue[k]	0.59-2.04	1540-1615	26-64							
Wheat Straw[l]	0.41		34.65		2.63					

Sahai S., Sharma C., Singh D.P. et. al., 'A study for development of emission factors for trace gases and carbonaceous particulate species from insitu burning of wheat straw in agricultural fields in India' Atmospheric Environment, doi:10.1016/j.atmosenv.2007.07.054

Shifting Cultivation

- Still predominant in the North-Eastern Region of India and forest areas in Andhra Pradesh.
- The Shifting cultivation cycle has become more intense in recent times giving very little time for forest eco-system to recover resulting in poor soil quality and poor crop production

Slash and Burn Cultivation Site in Andhra Pradesh

Emission ratios of dCO/dCO_2 for different Shifting cultivation sites in A.P.

Ecosystem Location	ER (CO/CO_2)
Site 1	11.73±1.2
Site 2	11.23±1.3
Site 3	**12. 0 ± 1.2**

Comparison of Emission Ratios of Methyl Halides from Biomass Burning ($CH_3X/\Delta CO$) with Savanna Ecosystem

S.No.	Forest Fires – Ecosystem	ΔCH_3Cl /ΔCO	ΔCH_3Br /ΔCO	ΔCH_3I /ΔCO
1.	Savanna fires	$0.95 \pm 0.01 \times 10^{-3}$	$8.3 \pm 0.4 \times 10^{-6}$	$2.6 \pm 0.3 \times 10^{-6}$
2.	Tropical secondary mixed deciduous forests			
	Site1.	$7.3 \pm 2.0 \times 10^{-3}$	$1.7 \pm 0.29 \times 10^{-5}$	$2.2 \pm 0.26 \times 10^{-6}$
	Site2.	$4.1 \pm 0.36 \times 10^{-3}$	$1.8 \pm 0.275 \times 10^{-5}$	$1.54 \pm 0.21 \times 10^{-6}$
	Site3.	$3.8 \pm 1.95 \times 10^{-3}$	$1.6 \pm 3.4 \times 10^{-5}$	$1.47 \pm 3.2 \times 10^{-6}$

Analysis of methyl halides was done at NIAES, Tsukuba, Japan

Comparison of Emission ratios of Methyl halides from Biomass Burning ($\Delta CH_3X/\Delta CO_2$) with Savanna Ecosystem

S.No.	Forest Fires – Ecosystem	$\Delta CH_3Cl/\Delta CO_2$	$\Delta CH_3Br/\Delta CO_2$	$\Delta CH_3I/\Delta CO_2$
1.	Savanna fires	$20.2 \pm 2 \times 10^{-6}$	$0.11 \pm 0.04 \times 10^{-6}$	$0.09 \pm 0.05 \times 10^{-6}$
2.	Tropical secondary mixed deciduous forests			
	Site1.	$4.3 \pm 0.34 \times 10^{-8}$	$6.15 \pm 1.89 \times 10^{-7}$	$2.27 \pm 0.26 \times 10^{-5}$
	Site2.	$1.07 \pm 3.34 \times 10^{-7}$	$9.45 \pm 2.22 \times 10^{-7}$	$8.30 \pm 0.21 \times 10^{-6}$
	Site3.	$1.13 \pm 1.45 \times 10^{-7}$	$9.43 \pm 1.45 \times 10^{-7}$	$1.05 \pm 3.2 \times 10^{-5}$

Methane Emission from Rice Paddy Fields in India

Methane EF from Indian Rice Fields

Water regimes	RF-FP	RF-DP	IR-CF	IR-IF-SA	IR-IF-MA	DW
1991	19 ± 6.0* Koirapur	5 ± 3.2* Devoke,Cuttack	12.7 ± 1.6* Bhubaneswar, Cuttack, Chennai	5 ± 3.2* Devoke, Cuttack	0.56 ± 0.23* Allahabad, Faizabad, NPL	19 ± 6.0* Koirapur
1992			18.6 ± 9.3* Bhubaneswar			
1993					1.64 NPL	
1994					2.39 ± 0.8* IARI and NPL New Delhi	
1995			13.7 ± 2* Maruteru		1.82 ± 0.76* IARI and NPL New Delhi	
1996					2.05 IARI, New Delhi	
1997					1.48 IARI, New Delhi	
1998		8.7 ± 2.4* Pant Nagar and Karnal	16.1 ± 2.2* Chennai	.7 ± 2.4* 8Pant Nagar and Karnal	5.36 Pant Nagar	
1999			21.25 ± 10.01* CRRI, BHU			
NC-2002		7.14 AAU	22.53 ± 10.26* IRPE, CRRI, AAU, AU	6.17 AU, NRSA	0.78 ± 0.70* NPL, IARI, Meerut, AU, RRLT, NRSA	
NATCOM EFs	19 ± 6*	6.95 ± 1.86*	17.48 ± 4*	6.62 ± 1.89*	2.01 ± 1.49*	19 ± 6*
IPCC-1996 default values	16	8	20	10	4	16
MAC-1998 EFs	19 ± 6*	6.9 ± 4.3*	15.3 ± 2.6*	6.9 ± 4.3*	2.2 ± 1.5*	19 ± 6*

Gupta, P.K. et al., Development of methane emission factors for Indian paddy fields and estimation ...,Chemosphere (2008), doi:10.1016/j.chemosphere.2008.09.042

GHG emissions from Bovine Manure Management

CH_4 & N_2O emission factors and emission estimates from bovine manure management in India for year 2000 and comparison with NATCOM

Category		CH_4 EF (kg hd^{-1} $year^{-1}$)		CH_4 emission (Gg)		N_2O EF (mg hd^{-1} $year^{-1}$)	N_2O emission (kg)
		Present	NATCOM	Present	NATCOM		
Dairy cattle	Crossbred	3.3 ± 0.16	3.5 ± 0.8	23.5 ± 1.2	33.7 ± 7.1	8 ± 1.6	70.9 ± 14
	Indigenous	2.7 ± 0.13	3.8 ± 0.8	157 ± 7.7	167.6 ± 9.6	9.7 ± 1.9	465.2 ± 91.8
ND cattle (Crossbred)	0–1 year	0.8 ± 0.04	1.2	2.5 ± 0.1	3.6	3.3 ± 0.6	10.8 ± 2.1
	1–2.5 year	1.7 ± 0.08	2.8	6.3 ± 0.3	8.8	7.8 ± 1.5	29.6 ± 5.8
	Adult	2.3 ± 0.11	2.9 ± 1.4	8.9 ± 0.4	9.9 ± 3.5	10.8 ± 2.1	42.6 ± 8.4
ND cattle (Indigenous)	0–1 year	0.8 ± 0.04	1.1	14.7 ± 0.7	20	3 ± 0.6	52.2 ± 10.3
	1–3 year	2 ± 0.1	2.3	61.6 ± 3	79.7	6.5 ± 1.3	200.3 ± 39.5
	Adult	2.8 ± 0.14	2.5 ± 0.9	189 ± 9.4	172.9 ± 64.1	8.9 ± 1.7	605.5 ± 119.5
Dairy buffalo		3.3 ± 0.06	4.4 ± 0.6	145.9 ± 2.5	194.9 ± 26.6	11.0 ± 2.2	485.3 ± 95.7
ND buffalo	0–1 year	1.2 ± 0.02	1.8	17 ± 0.3	25.4	5.2 ± 1	73.6 ± 14.5
	1–3 year	2.3 ± 0.04	3.4	37.5 ± 0.6	55.6	9.9 ± 2	162.4 ± 32
	Adult	2.7 ± 0.05	4	33.6 ± 0.6	49.7	11.7 ± 2.3	145.5 ± 28.7
Total				697.8 ± 27	821.6 ± 110.9		2343.8 ± 462.4

ND = non-dairy, EF = emission factor, NATCOM = India's initial national communication of greenhouse gases to UNFCCC.

'Methane and nitrous oxide emission from bovine manure management practices in India' Prabhat K. Gupta P.K., Jha A.K., Koul S., Sharma P., Pradhan V., Gupta V., Sharma C., Singh N., Environmental Pollution, doi:10.1016/j.envpol.2006.04.039

National Physical Laboratory

National Metrology Institute responsible for maintaining national standards and providing traceability

Thanks