2006 IPCC Guidelines for National Greenhouse Gas Inventories: Waste Sector

WMO UNEP

INTERGOVERNMENTAL PANEL ON climate change

Introduction

- Volume 4 (Waste) gives methodological guidance for estimation of CO_2, CH_4 and N_2O emissions from following categories:
  - Solid waste disposal (4A)
  - Biological treatment of solid waste (4B)
  - Incineration and open burning of waste (4C)
  - Wastewater treatment and discharge (4D)
- Typically, CH_4 emissions from solid waste disposal sites (SWDS) are the largest source in the Waste sector
- Biogenic CO_2 emissions are not included in the Waste sector
- All greenhouse gas emissions from waste-to-energy should be estimated and reported under the Energy sector

Major Developments in the 2006 IPCC Guidelines: Waste Sector

- Improved accuracy
  - Updated methods and improved default values
  - The previous Tier 1 method is replaced by a first order decay (FOD) method including a simple spreadsheet model (IPCC Waste Model)

  http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol5.html

- More complete:
  - Guidance is given on more sources
    - Biological treatment of solid waste
    - Open burning of waste
  - Inclusion of methods to estimate N_2O emissions
    - Discharge of wastewater into waterways
    - Advanced wastewater treatment plants

Waste Sector Categories

2006 IPCC Guidelines Category			Revised 1996 IPCC Guidelines and GPG 2000 Category	
Managed Waste Disposal Sites	Anaerobic Semi-aerobic	4A1	6A1	Managed Waste Disposal on Land
Unmanaged Waste Disposal Sites		4A2	6A2	Unmanaged Waste Disposal Sites
Uncategorized Waste Disposal Sites		4A3	6A3	Other
Biological Treatment of Solid Waste		4B		
Waste Incineration		4C1	6C	Waste Incineration
Open Burning of Waste		4C2		
Domestic Wastewater Treatment and Discharge		4D1	6B2	Domestic and Commercial Wastewater
Industrial Wastewater Treatment and Discharge		4D2	6B1	Industrial Wastewater
Other		4E	6D	Other

Solid Waste Disposal on Land: CH_4 Emissions

- Decomposition of organic components in waste under anaerobic environment
- Overall decomposition can be approximated by first order decay (FOD) reaction
  - Amount of product is proportional to the amount of reactant (mass of degradable organic carbon (DOC) decomposable under anaerobic conditions)
- Methodology for estimating CH_4 emissions from SWDS is based on the FOD method
  - Degradable organic component in waste at landfills decays slowly throughout a few decades during which significant amount of CH_4 and CO_2 are formed (some N_2O, NMVOCs, NO_x and CO)
  - A simple spreadsheet model to assist countries in using the FOD method
- FOD method requires data for historical disposals of waste over a time period of 3 to 5 half-lives to achieve accurate emission estimates
  - The 2006 Guidelines provide guidance on how to estimate historical waste disposal data

Solid Waste Disposal on Land: CH_4 Emissions

- CH_4 emissions in year *T* from SWDS (Gg)

$$CH_4 Emissions = \left[\sum_x CH_4 generated_{x,T} - R_T \right] * \left(1 - OX_T\right)$$

T : inventory year

X : waste category or type/material

R_T : recovered CH_4 in year *T*, Gg

OX_T : oxidation factor in year *T*, fraction

Solid Waste Disposal on Land: CH_4 Generation

- CH_4 is generated as a result of degradation of organic material under anaerobic conditions
- Estimated on the basis of the amount of Decomposable Degradable Organic Carbon (DDOCm) which is the part of the organic carbon that will degrade under the anaerobic conditions in SWDS

$$DDOC_m = W \bullet DOC \bullet DOC_f \bullet MCF$$

DDOCm : mass of decomposable DOC deposited, Gg
W : mass of waste deposited, Gg
DOC : degradable organic carbon in the year of deposition, fraction, Gg C/Gg waste
DOC_f : fraction of DOC that can decompose (fraction)
MCF : CH_4 correction factor for aerobic decomposition in the year of deposition (fraction)

Solid Waste Disposal on Land: CH_4 Generation

- Basic equations:

$$DDOCma_T = DDOCmd_T + \left(DDOCma_{T-1} \bullet e^{-k}\right)$$

$$DDOCmdecomp_T = DDOCma_{T-1} \bullet \left(1 - e^{-k}\right)$$

T : inventory year
$DDOCma_T$: DDOCm accumulated in the SWDS at the end of year T, Gg
$DDOCma_{T-1}$: DDOCm accumulated in the SWDS at the end of year (T-1), Gg
$DDOCmd_T$: DDOCm deposited into the SWDS in year T, Gg
$DDOCm_{decompT}$: DDOCm decomposed in the SWDS in year T, Gg
k : reaction constant, $k = \ln(2)/t_{1/2}$, (y^{-1})
$t_{1/2}$: half-life time (y)

FOD Spreadsheet Model (IPCC Waste Model)

- Most useful to Tier 1, but can be adapted for use with all tiers
  - Estimation of actual emissions of CH_4
- Two options for emission estimation from municipal solid waste (MSW) depending on data availability
  - Waste composition
  - Bulk waste
- Allows to define a delay time
  - Period between deposition of the waste and the start of CH_4 generation

FOD Spreadsheet Model (IPCC Waste Model)

- Selection of appropriate region in the *"Parameters"* sheet will adjust the IPCC defaults in other sheets
- Allows selection of *DOC* and *methane generation rate constant* (***k***) for modeling by waste composition or bulk waste options
- Allows selection of appropriate IPCC default ***k*** value for the selected climate zone
- The input parameters are entered into cells colored yellow in the worksheets with yellow colored tabs. Other sheets-calculated automatically
- Calculates the amount of CH_4 generated from each waste component on a different worksheet

Parameters

Country

Region Asia- Southeast

Please enter parameters in the yellow cells. If no national data are available, copy the IPCC default value.
Help on parameter selection can be found in the 2006 IPCC guidelines

	IPCC default value		Country-specific parameters	
			Value	Reference and remarks
Starting year		1950	1950	
DOC (Degradable organic carbon)	Waste by composition			
(weight fraction, wet basis)	**Range**	**Default**		
Food waste	0.08-0.20	0.15	0.15	
Garden	0.18-0.22	0.2	0.2	
Paper	0.36-0.45	0.4	0.4	
Wood and straw	0.39-0.46	0.43	0.43	
Textiles	0.20-0.40	0.24	0.24	
Disposable nappies	0.18-0.32	0.24	0.24	
Sewage sludge	0.04-0.05	0.05	0.05	
Industrial waste	0-0.54	0.15	0.15	
DOCf (fraction of DOC dissimilated)		0.5	0.5	
Methane generation rate constant (k)	Wet temperate			
(years^{-1})	**Range**	**Default**		
Food waste	0.1–0.2	0.185	0.185	
Garden	0.06–0.1	0.1	0.1	
Paper	0.05–0.07	0.06	0.06	
Wood and straw	0.02–0.04	0.03	0.03	
Textiles	0.05–0.07	0.06	0.06	
Disposable nappies	0.06–0.1	0.1	0.1	
Sewage sludge	0.1–0.2	0.185	0.185	
Industrial waste	0.08–0.1	0.09	0.09	
Delay time (months)		6	6	

Methane calculation from: Food waste

		National values
DOC	DOC	0.15
DOCf	DOCf	0.500
Methane generation rate constant	k	0.185
Half-life time ($t_{1/2}$, years):	h = ln(2)/k	3.7
exp1	exp(-k)	0.83
Process start in deposition year. Month M	M	13.00
exp2	exp(-k*((13-M)/12))	1.00
Fraction to CH4	F	0.500

Year	Amount deposited	MCF	Decomposable DOC (DDOCm) deposited	DDOCm not reacted. Deposition year	DDOCm decomposed. Deposition year	DDOCm accumulated in SWDS end of year	DDOCm decomposed	CH_4 generated
	W	MCF	D = W * DOC * DOCf * MCF	B = D * exp2	C = D * (1-exp2)	H = B + ($H_{last\ year}$ * exp1)	E = C + ($H_{last\ year}$ * (1 - exp1)	Q = E * 16/12 * F
	Gg	fraction	Gg	Gg	Gg	Gg	Gg	Gg
1950	693	0.71	37	37	0	37	0	0
1951	693	0.71	37	37	0	67	6	4
1952	693	0.71	37	37	0	92	11	8
1953	693	0.71	37	37	0	113	16	10
1954	693	0.71	37	37	0	131	19	13
1955	693	0.71	37	37	0	145	22	15
1956	693	0.71	37	37	0	158	25	16
1957	693	0.71	37	37	0	168	27	18
1958	693	0.71	37	37	0	176	28	19
1959	693	0.71	37	37	0	183	30	20
1960	693	0.71	37	37	0	189	31	21
1961	693	0.71	37	37	0	193	32	21
1962	693	0.71	37	37	0	197	33	22
1963	693	0.71	37	37	0	201	33	22
1964	693	0.71	37	37	0	203	34	23
1965	693	0.71	37	37	0	206	34	23
1966	693	0.71	37	37	0	208	35	23
1967	693	0.71	37	37	0	209	35	23
1968	693	0.71	37	37	0	210	35	24
1969	693	0.71	37	37	0	212	36	24
1970	693	0.71	37	37	0	212	36	24
1971	693	0.71	37	37	0	213	36	24

Biological Treatment of Solid Waste

- Composting and anaerobic digestion of organic waste (food waste, garden and park waste etc.)
  - reduced volume in the waste material
  - stabilisation of the waste
  - production of biogas for energy use
  - end product can be recycled as a fertilizer or soil amendment
- Composting
  - large fraction of DOC in waste is converted to CO_2
  - CH_4 and N_2O can both be formed during composting
- Anaerobic digestion
  - Biogas (CH_4 and CO_2)
  - N_2O is assumed to be negligible

Biological Treatment of Solid waste: CH_4 Emissions

- Default method for estimation of CH_4 emissions:

$$CH_4 Emissions = \sum_i \left(M_i \bullet EF_i\right) \bullet 10^{-3} - R$$

CH_4 Emissions: total CH_4 emissions in inventory year, Gg CH_4
M_i : mass of organic waste treated by biological treatment type *i*, Gg
EF_i : emission factor for treatment *i*, g CH_4/kg waste treated
i : composting or anaerobic digestion
R : total amount of CH_4 recovered in inventory year, Gg CH_4. **If the recovered gas is flared, the emissions should be reported in Waste Sector**

Biological Treatment of Solid Waste: N_2O Emissions

- Default method for estimation of N_2O emissions:

$$N_2O Emissions = \sum_i (M_i \bullet EF_i) \bullet 10^{-3}$$

N_2O Emissions: total N_2O emissions in inventory year, Gg N_2O

M_i : mass of organic waste treated by biological treatment type *i*, Gg

EF_i : emission factor for treatment *i*, g N_2O/kg waste treated

i : composting or anaerobic digestion

Biological Treatment of Solid Waste: Choice of Methods, AD and EFs

- Methodological tiers for estimation of CH_4 and N_2O emissions
  - Tier 1: Tier 1 uses the IPCC default emission factors
  - Tier 2: Country-specific EFs based on representative measurements
  - Tier 3: Facility or site-specific measurements data (on-line or periodic)
- When national data are not available
  - Regional default values for AD and EFs are given in Chapter 2 and 4
- It is *good practice* that countries use national, annually or periodically collected data, where available
  - National statistics
  - Data from municipal or regional authorities responsible for waste management, or from waste management companies

Incineration and Open Burning of Waste: CO_2 Emissions

- Based on the total amount of waste combusted:

$$CO_2 Emissions = \sum_i (SW_i \bullet dm_i \bullet CF_i \bullet FCF_i \bullet OF_i) \bullet 44/12$$

CO_2 Emissions: CO_2 emissions in inventory year, Gg/yr

SW_i : total amount of solid waste of type *i (wet weight) incinerated or open-burned, Gg/yr*

dm_i : dry matter content in the waste (wet weight) incinerated or open-burned, (fraction)

CF_i : fraction of carbon in the dry matter (total carbon content), (fraction)

FCF_i : fraction of fossil carbon in the total carbon, (fraction)

OF_i : oxidation factor, (fraction)

44/12 : conversion factor from C to CO_2

i : type of waste incinerated/open-burned such as MSW, industrial solid waste (ISW), sewage sludge, hazardous waste, clinical waste, etc.

- Estimation of the amount of fossil carbon is the most important factor determining the CO_2 emissions as only CO_2 emissions of fossil origin (e.g., plastics, certain textiles, rubber, liquid solvents, and waste oil) should be included

Incineration and Open Burning of Waste: CO_2 Emissions

- For municipal solid waste:

$$CO_2 Emissions = MSW \bullet \sum_j (WF_j \bullet dm_j \bullet CF_j \bullet FCF_j \bullet OF_j) \bullet 44/12$$

CO_2 Emissions: CO_2 emissions in inventory year, Gg/yr

MSW : total amount of municipal solid waste as wet weight incinerated or open-burned, Gg/yr

WF_j : fraction of waste type/material of component ***j*** in the MSW (as wet weight incinerated or open-burned)

dm_j : dry matter content in the component j of the MSW incinerated or open-burned, (fraction)

CF_j : fraction of carbon in the dry matter (i.e., carbon content) of component ***j***

FCF_j : fraction of fossil carbon in the total carbon of component ***j***

OF_j : oxidation factor, (fraction)

44/12 : conversion factor from C to CO_2

j : component of the MSW incinerated/open-burned such as paper/cardboard, textiles, food waste, wood, garden (yard) and park waste, disposable nappies, rubber and leather, plastics, metal, glass, other inert waste

Incineration and Open Burning of Waste: CH_4 Emissions

- CH_4 emissions result from incomplete combustion of waste and can be affected by temperature, residence time, and air to waste ratio

$$CH_4 Emissions = \sum_i (IW_i \bullet EF_i) \bullet 10^{-6}$$

CH_4 Emissions: CH_4 emissions in inventory year, Gg/yr

IW_i : amount of solid waste of type ***i*** *incinerated or open-burned, Gg/yr*

EF_i : aggregate CH_4 emission factor, kg CH_4/Gg of waste

10^{-6} : conversion factor from kilogram to gigagram

i : category or type of waste incinerated/open-burned (MSW, ISW, hazardous waste, clinical waste, sewage sludge, etc.)

- The amount and composition of waste should be consistent with the activity data used for estimating CO_2 and N_2O emissions from incineration/open burning

Incineration and Open Burning of Waste: N_2O Emissions

- The N_2O emissions are mainly determined by technology, combustion temperature (emitted at relatively low combustion temperatures 500-950 °C) and waste composition

$$N_2O Emissions = \sum_i (IW_i \bullet EF_i) \bullet 10^{-6}$$

N_2O Emissions: N_2O emissions in inventory year, Gg/yr

IW_i : amount of incinerated/open-burned waste of type *i* , *Gg/yr*

EF_i : N_2O emission factor (kg N_2O/Gg of waste) for waste of type *i*

10^{-6} : conversion from kilogram to gigagram

i : category or type of waste incinerated/open-burned (MSW, ISW, hazardous waste, clinical waste, sewage sludge, etc.)

Incineration of Fossil Liquid Waste: CO_2 Emissions

- Fossil liquid waste - industrial and municipal residues, based on mineral oil, natural gas or other fossil fuels. It includes waste formerly used as solvents and lubricants.
- If, fossil liquid waste is not included in other types of waste (e.g., industrial waste, hazardous waste), the emissions need to be calculated separately.

$$CO_2 Emissions = \sum_i \left(AL_i \bullet CL_i \bullet OF_i \right) \bullet 44/12$$

CO_2 Emissions: CO_2 emissions from incineration of fossil liquid waste, Gg

AL_i : amount of incinerated fossil liquid waste type *i, Gg*

CL_i : carbon content of fossil liquid waste type *i, (fraction)*

OF_i : oxidation factor for fossil liquid waste type *i, (fraction)*

44/12 : conversion factor from C to CO_2

Amount of Waste Open-burned

• Statistics may not be available. Where the data on waste amount are not available, total amount of MSW open-burned can be estimated

$$MSW_B = P \bullet P_{frac} \bullet MSW_P \bullet B_{frac} \bullet 365 \bullet 10^{-6}$$

MSW_B : Total amount of municipal solid waste open-burned, Gg/yr

P : population (capita)

P_{frac} : fraction of population burning waste, (fraction)

MSW_P : per capita waste generation, kg waste/capita/day

B_{frac} : fraction of the waste amount that is burned relative to the total amount of waste treated

365 : number of days by year

10^{-6} : conversion factor from kilogram to gigagram

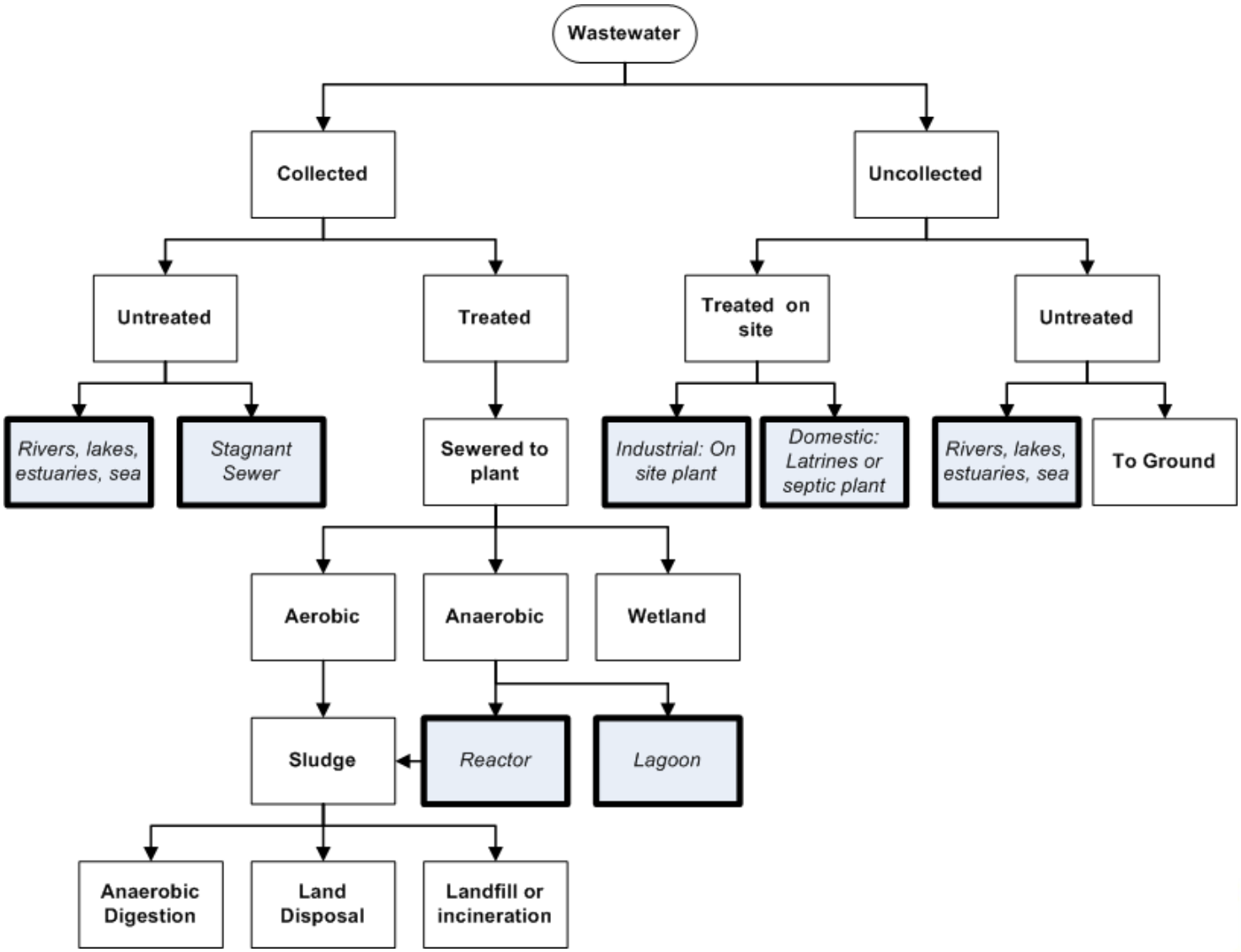
Incineration and Open Burning of Waste: Choice of Methods, AD and EF/Parameters

- Methodological tiers for estimation of CO_2 emissions:
  - Tier 1: Default AD (amount, composition of waste incinerated/open-burned) and default parameters. The method is used when the emissions from incineration/open burning are not a key category
  - Tier 2: Country-specific AD, default and some country-specific parameters
  - Tier 3: Plant-/management-specific data
- Methodological tiers for estimation of CH_4 and N_2O emissions
  - Tier 1: Default AD (amount, composition of waste incinerated/open-burned) and EFs
  - Tier 2: Country-specific AD and EFs by waste type, technology or management practice
  - Tier 3: Plant-/management-specific data (e.g. flue gas concentrations for N_2O emissions)
- Default values are provided in Chapter 2 and 5

Wastewater Treatment and Discharge

- Wastewater (domestic, commercial and industrial) may be treated on site (uncollected), sewered to a centralized plant (collected) or disposed untreated
- Treatment and disposal of wastewater produce GHGs such as CO_2, CH_4 and N_2O
  - CO_2 is of biogenic origin and not included in the national totals
  - N_2O emissions from sludge and wastewater spread on agricultural land are considered in AFOLU sector
- Sludge produced in wastewater treatment is treated further. The CH_4 emissions from sludge sent to landfills, incinerated or used in agriculture are not included in this category

Wastewater Treatment Systems and Discharge Pathways



Wastewater treatment and discharge: CH_4 Emissions

- CH_4 production depends primarily on the amount of degradable organic material in the wastewater, the temperature and the type of treatment system.
- Common parameters used to measure the organic component of the wastewater :
  - Biochemical Oxygen Demand (BOD): amount of carbon that is aerobically biodegradable
  - Chemical Oxygen Demand (COD): total organic material available for chemical oxidation
- Methodological tiers for estimation of CH_4 emissions:
  - Tier 1 method applies default values for EFs (B_o, MCF, etc.) and AD
  - Tier 2 method allows for incorporation of a country specific EF and AD
  - Tier 3 method is a country specific method with measurements or other bottom-up data
- CH_4 generated can be recovered and combusted in a flare or energy device.
  - The flared or recovered for energy use should be subtracted from total emissions
  - CH_4 recovery for energy generation should be reported in the Energy Sector
  - The emissions (CH_4 and N_2O) from flaring should be reported under the Waste Sector

Domestic Wastewater Treatment: CH_4 Emissions

- Total CH_4 emissions from domestic wastewater:

$$CH_4 Emissions = \left[\sum_{i,j} \left(U_i \bullet T_{i,j} \bullet EF_j \right) \right] \left(TOW - S \right) - R$$

CH_4 Emissions: CH_4 emissions in inventory year, kg CH_4/yr

TOW : total organics in wastewater in inventory year, kg BOD/yr

S : organic component removed as sludge in inventory year, kg BOD/yr

U_i: fraction of population in income group i in inventory year

$T_{i,j}$: degree of utilisation of treatment/discharge pathway or system, j, for each income group fraction i in inventory year

i : income group: rural, urban high income and urban low income

j : each treatment/discharge pathway or system

EF_j : emission factor, kg CH_4 / kg BOD

R : amount of CH_4 recovered in inventory year, kg CH_4/yr

Domestic Wastewater Treatment: CH_4 Emissions

- Activity data is the total amount of organically degradable material in the wastewater (TOW).

$$TOW = P \bullet BOD \bullet 0.001 \bullet I \bullet 365$$

TOW : total organics in wastewater in inventory year, kg BOD/yr

P : country population in inventory year, (person)

BOD : country-specific per capita BOD in inventory year, g/person/day

0.001 : conversion from grams BOD to kg BOD

I : correction factor for additional industrial BOD discharged into sewers (for collected the default is 1.25, for uncollected the default is 1.00)

Domestic Wastewater: CH_4 Emissions

- Emission factor for each domestic wastewater treatment/discharge pathway or system

$$EF_j = B_0 \bullet MCF_j$$

EF_j : emission factor, kg CH_4 / kg BOD

j : each treatment/discharge pathway or system

B_o : maximum CH_4 producing capacity, kg CH_4/kg BOD.

MCF_j : CH_4 correction factor (fraction) and indicates the degree to which the system is anaerobic

Industrial Wastewater: CH_4 Emissions

- Industrial wastewater may be treated on-site or released into domestic sewer systems
- The CH_4 emissions from industrial wastewater treatment (on-site):

$$CH_4 Emissions = \sum_i \left[(TOW_i - S_i) \bullet EF_i - R_i \right]$$

CH_4 Emissions : CH_4 emissions in inventory year, kg CH_4/yr

TOW_i : total organically degradable material in wastewater from industry i in inventory year, kg COD/yr

i : industrial sector

S_i : organic component removed as sludge in inventory year, kg COD/yr

EF_i : emission factor for industry *i, kg CH_4/kg COD* for treatment/discharge pathway or systems. If more than one treatment practice is used in an industry this factor would need to be a weighted average.

R_i : amount of CH_4 recovered in inventory year, kg CH_4/yr

Industrial Wastewater: CH_4 Emissions

- Emission factor for each industrial wastewater

$$EF_j = B_0 \bullet MCF_j$$

EF_j : emission factor, for each treatment/discharge pathway/systems, kg CH_4 / kg COD

j : each treatment/discharge pathway or system

B_o : maximum CH_4 producing capacity, kg CH_4/kg COD

MCF_j : CH_4 correction factor (fraction)

Industrial Wastewater: CH_4 Emissions

- Activity data is the amount of organically degradable material in the wastewater (TOW):

$$TOW_i = P_i \bullet W_i \bullet COD_i$$

TOW_i : total organically degradable material in wastewater for industry *i, kg COD/yr*

i : industrial sector

P_i : total industrial product for industrial sector *i, t/yr*

W_i : wastewater generated, m^3/t product

COD_i : chemical oxygen demand (industrial degradable organic component in wastewater), kg COD/m^3

Wastewater treatment and discharge: N_2O Emissions

- The N_2O emissions are associated with the degradation of nitrogen components in the wastewater (e.g., urea, nitrate and protein)
- The N_2O emissions can occur as direct emissions from treatment plants or from indirect emissions from wastewater after disposal of effluent into waterways, lakes or the sea
  - After treated at wastewater treatment plants, treated effluent is typically discharged to a receiving water environment (e.g., river, lake, estuary, etc.).
  - Centralized wastewater treatment systems may include processes for removing nitrogen compounds. The direct emissions from nitrification and denitrification at wastewater treatment plants may be considered as a minor source.
- The N_2O may be generated during
  - Nitrification: aerobic process converting nitrogen compounds such as ammonia and into nitrate (NO_3^-)
  - Denitrification: biological conversion of NO_3^- into dinitrogen gas (N_2) under anoxic environment
- The emissions from industrial sources are believed to be insignificant compared to emissions from domestic wastewater

Domestic Wastewater: N_2O Emissions

• Indirect N_2O emissions from wastewater effluent discharged into aquatic environments

$$N_2OEmissions = N_{EFFLUENT} \bullet EF_{EFFLUENT} \bullet 44/28$$

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

$EF_{EFFLUENT}$: emission factor for N_2O emissions from discharged to wastewater, kg N_2O-N/kg N

44/28 : conversion of kg N_2O-N into kg N_2O.

Domestic Wastewater: N_2O Emissions

- Total N in the effluent

$$N_{EFFLUENT} = (P \bullet PROTEIN \bullet F_{NPR} \bullet F_{NON-CON} \bullet F_{IND-COM}) - N_{SLUDGE}$$

$N_{EFFLUENT}$: total annual amount of nitrogen in the wastewater effluent, kg N/yr

P : human population

Protein : 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

$F_{IND-COM}$: factor for industrial and commercial co-discharged protein into the sewer system

N_{SLUDGE} : nitrogen removed with sludge (default = zero), kg N/yr

Domestic Wastewater: N_2O Emissions

- Emissions from advanced centralised wastewater treatment plants

$$N_2O_{PLANTS} = P \bullet T_{PLANT} \bullet F_{IND-COM} \bullet EF_{PLANT}$$

N_2O_{PLANTS} : total N_2O emissions from plants in inventory year, kg N_2O/yr

P : human population

T_{PLANT} : degree of utilization of modern, centralized WWT plants, %

$F_{IND-COMM}$: fraction of industrial and commercial co-discharged protein (default = 1.25)

EF_{PLANT} : emission factor, 3.2 g N_2O/person/year

- To include N_2O emissions from plants, the amount of nitrogen associated with these emissions (N_{WWT}) must be subtracted from the $N_{EFFLUENT}$.

Thank you

Guidelines in all UN languages
can be downloaded from
http://www.ipcc-nggip.iges.or.jp

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