determine MCFs. If no data are available, as a default, use 0 for *aerobic* systems, and 1.0 for *anaerobic*.[4]

Since aerobic and anaerobic handling are the only handling systems considered, the CH_4 conversion rate can be used to characterise a broad range of systems falling between aerobic and anaerobic handling systems.

Equation 10 presents the emission factor calculation for wastewater:

EQUATION 10

$$EF_i = B_{oi} \times \sum (WS_{ix} \times MCF_x)$$

where:

EF_i = emission factor (kg CH_4 /kg DC) for wastewater type (e.g., fertiliser industry, domestic, etc.)

B_{oi} = maximum methane producing capacity (kg CH_4/kg DC) for wastewater type i

WS_{ix} = fraction of wastewater type i treated using wastewater handling system x

MCF_x = methane conversion factors of each wastewater system x

Equation 11 presents the emission factor calculation for sludge:

EQUATION 11

$$EF_j = B_{oj} \times \sum(SS_{jy} \times MCF_y)$$

where:

EF_j = emission factor (kg CH_4 /kg DC) for sludge type j (e.g., fertiliser industry wastewater, domestic wastewater, etc.)

B_{oj} = maximum methane producing capacity (kg CH_4/kg DC) for sludge type j

SS_{jy} = fraction of sludge type j treated using sludge handling system y

MCF_y = methane conversion factors of each sludge handling system y (See footnote 4)

[4] If sludge is disposed of in landfills then the resulting emissions are already accounted for in the IPCC/OECD SWDS emission methodology (Section 6.2.4). If sludge is incinerated or burned as part of an energy recovery system, then the resulting emissions should be reported for in the Energy Chapter, classified as an industrial waste fuel. In these cases, to ensure that emissions are not counted twice an "MCF" of zero should be used in this methodology for sludge disposed in SWDSs or incinerated, or burned as part of an energy recovery system. In all other cases, an appropriate MCF value should be selected based on the specific characteristics of the system used to dispose of the sludge.

Step 3 - Wastewater Emissions

To estimate total emissions from wastewater, the selected emissions factors are multiplied by the associated organic wastewater production and summed. Subtract the amount of CH_4, if any, that is recovered and thus not emitted into the atmosphere for each handling method. If no data are readily available, the default assumption is that this amount is zero. Sum the results for each handling method to determine total CH_4 emissions from wastewater. In equation form, the estimate of total CH_4 emissions from wastewater handling is as follows:

EQUATION 12

$$WM = \Sigma_i \left(TOW_i \times EF_i - MR_i \right)$$

where:

WM	=	total methane emissions from wastewater in kg CH_4
TOW_i	=	total organic waste for wastewater type i in kg DC/yr. For domestic streams, the DC is BOD; for industrial streams it is the COD (Step 1)
EF_i	=	emission factor for wastewater type i in kg CH_4/kg DC (Step 2)
MR_i	=	total amount of methane recovered or flared from wastewater type i in kg CH_4. If no data are available, use the default value of zero

Step 4 - Sludge Emissions

To estimate total emissions from sludge, the selected emissions factors are multiplied by the associated organic sludge production and summed. Subtract the amount of CH_4, if any, that is recovered and thus not emitted into the atmosphere for each handling method. If no data are readily available, the default assumption is that this amount is zero. Sum the results for each handling method to determine total CH_4 emissions from wastewater. In equation form, the estimate of total CH_4 emissions from sludge handling is as follows:

EQUATION 13

$$SM = \Sigma_j \left(TOS_j \times EF_j - MR_j \right)$$

where:

SM	=	total methane emissions from sludge in kg CH_4
TOS_j	=	total organic waste for sludge type j in kg DC/yr. For domestic streams, the DC is BOD; for industrial streams it is COD (Step 1)
EF_j	=	emission factor for sludge type j in kg CH_4/kg DC (Step 2)
MR_j	=	total amount of methane recovered or flared from sludge type j in kg CH_4. If no data are available, the default is zero

Step 5 - Total Emissions

Total emissions from wastewater and sludge can be determined by summing the results of Steps 3 and 4. This is expressed as follows in Equation 14:

EQUATION 14

$$TM = WM + SM$$

where:

TM = total methane from wastewater and sludge handling in kg CH_4

WM = total methane emissions from wastewater in kg CH_4

SM = total methane emissions from sludge in kg CH_4

6.3.6 Uncertainties

The quality of CH_4 emissions estimates for wastewater handling is directly related to the quality and availability of the waste management data used to derive these estimates. Country specific data on wastewater quantities, characteristics, and wastewater management methods are very limited. The principal sources of uncertainty are described below.

Organic Wastewater Quantity and Composition

Often the amount of degradable organic wastewater that is produced and the volumes handled in the various systems is not well known. Consequently, limitations exist for quantifying the fraction of wastewater subject to specific systems.

Physical and Chemical Data

Country-specific data on wastewater characteristics are very limited. For example, reported organic component values in industrial source categories are averages from several processes. Accurate and detailed data on the chemical characteristics and volumes of process wastewater streams could improve the emissions estimates.

Wastewater Handling Facility Efficiency and Output

Aerobically treated wastewater by handling plants may be subject to anaerobic conditions due to poorly managed and functioning facilities. This contributes to an underestimate of emissions. Additionally, current estimates from wastewater handling lagoons are relatively uncertain due to the limited available data. Work is on-going to develop better emission factors from these sources.

TABLE 6-5
ESTIMATED BOD_5 VALUES IN DOMESTIC WASTEWATER BY REGION

Region	BOD_5 Value (kg/cap/day)	BOD_5 Value (kg/1000 persons/yr)
Africa	0.037	13,505
Asia, Middle East, Latin America	0.04	14,600
N. America, Europe, Former USSR, Oceania	0.05	18,250
Source: IPCC (1994)		

TABLE 6-6 INDUSTRIAL WASTEWATER DATA BY REGION			
Industry Type and Region	Wastewater Produced (m^3/tonnes of product)	COD Value (kg COD/m^3 wastewater)	Country
Beverage - Distilled & Industry			
Generic - ethanol	13 m^3/ m^3 ethanol	40	
Generic - ethanol	NAV	5,000 kg/ m^3 ethanol	
South America	NAV	22	Brazil
Western Europe	NAV	4.0 - 5.0	Netherlands
Beverage - Malt & Beer			
Generic	5 m^3/ m^3 beer	17	
Generic	5-9 m^3/ m^3 beer	2.0 - 7.0	
Western Europe	NAV	1.0 - 1.5	Netherlands
Food - Meat & Poultry			
Generic	1.4 m^3/animal	NAV	
Western Europe	NAV	2.9	Netherlands
North America	NAV	15.0	USA
Food - Fish			
North America	NAV	2.5	USA
Food - Coffee			
North America	NAV	3.0 - 14.0	USA
Food - Dairy Products			
Generic	2.8	NAV	
Western Europe	NAV	1.5	Netherlands
Food - Fruits & Vegetables			
Generic (cannery)	26	NAV	
Generic Tomato processing	26	NAV	
North America, potatoes	NAV	3.0	USA
Western Europe, bean blanching	NAV	5.2	Netherlands
Western Europe, sauerkraut	NAV	10.0 - 20.0	Netherlands
Food - Oils			
Generic - Vegetable oil	1.6	0.3	
Middle East	NAV	42	Turkey
Asia	NAV	25	Malaysia
Food - Sugar			
Central America (cane)	NAV	98	Mexico
Iron And Steel			
South America	0.1	NAV	Brazil
Organic Chemicals			
Western Europe	NAV	20- 40	Netherlands
Pharmaceuticals			
Middle East	NAV	1.3	Egypt

TABLE 6-6 (CONTINUED)
INDUSTRIAL WASTEWATER DATA BY REGION

Industry Type and Region	Wastewater Produced (m^3/tonnes of product)	COD Value (kg COD/m^3 wastewater)	Country
Starch			
Generic, potato starch	NAV	4.0 - 16	
Generic, wheat starch	NAV	2.0 - 42	
Generic, corn starch	NAV	10	
Petroleum Production			
North America	NAV	0.3 -0.4	USA
North America	NAV	1.8	Canada
Pulp & Paper			
Generic (pulp)	58	2.0 - 15	
North America pulp mill	140	NAV	USA
Generic (paper)	NAV	2.0 - 8.0	
North America (virgin paper)	97	1.6	USA
North America (recycled paper)	44	3.0	USA
Western Europe (paper)	NAV	1.0 - 3.0	Netherlands
Textiles			
Rayon	501	NAV	
Greece	NAV	0.09	
North America, textile mills	NAV	1.0	USA
Leather Tanning			
North America, generic	NAV	5.8	USA

Source: Doorn and Eklund (1995). For a detailed list of references for each wastewater category, see Doorn and Eklund (1995). Wastewater production of COD values are not available (NAV) for every country and region. Research is ongoing to develop wastewater production and COD values for these countries and regions. Note that these data are currently undergoing revision and updating.

TABLE 6-7
DOMESTIC WASTEWATER TREATMENT EMISSIONS FACTOR DERIVATION DATA

Region	Type of Treatment	Fraction of Wastewater Treated (%)	MCF (%)
Africa			
Kenya	Lagoons	50	NAV
Tunisia	Lagoons	20	NAV
Zimbabwe	Activated Sludge	50	NAV
Other Africa	Lagoons	5	80
Asia			
Indonesia	not specified	1	NAV
Singapore	not specified	1	NAV
South Korea	not specified	1	NAV
Taiwan	not specified	1	NAV
Other Asia	not specified	5	75
Latin America And Caribbean	not specified	10	80
Australia And New Zealand	not specified	80	70

Source: Doorn and Eklund (1995). For a detailed list of references for each region, see Doorn and Eklund (1995). Methane correction factor (MCF) data are not available (NAV) for some countries and regions. Research is ongoing to provide MCF estimates for these countries and regions. Note that these data are currently undergoing revision and updating.

TABLE 6-8
INDUSTRIAL WASTEWATER TREATMENT EMISSIONS FACTOR DERIVATION

Region	Type of Industry	Type of Treatment	Fraction of Wastewater Treated (%)	MCF (%)
Africa				
Kenya	textiles	Lagoons	60	NAV
Kenya	coffee production	Lagoons	5	NAV
Other Africa	All	Lagoons	10	90
Asia				
Indonesia	All	not specified	10	NAV
Malaysia	palm oil	not specified	90	NAV
Singapore	All	not specified	10	NAV
South Korea	All	not specified	10	NAV
Taiwan	All	not specified	10	NAV
Thailand	breweries	activated sludge	50	NAV
Other Asia	All	not specified	20	90
North America				
Canada	All	not specified	90	70
USA	All	not specified	90	70
Latin America & Caribbean	All	not specified	20	90
Australia & New Zealand	All	not specified	95	70

Source: Doorn and Eklund (1995). For a detailed list of references for each region, see Doorn and Eklund (1995). Methane correction factor (MCF) data are not available (NAV) for some countries and regions. Research is ongoing to provide MCF estimates for these countries and regions. Note that these data are currently undergoing revision and updating.

TABLE 6-9
UNSPECIFIED WASTEWATER TYPE EMISSIONS FACTOR DERIVATION DATA

Region	Type of Treatment	Fraction of Wastewater Treated (%)	MCF (%)
Africa			
South Africa	not specified	10	NAV
Asia			
Afghanistan	not specified	1	NAV
Latin America And Caribbean			
Colombia	Lagoons	3	NAV
Argentina	Lagoons	3	NAV
Europe			
Albania	not specified	1-92	NAV
Austria	not specified	65	NAV
Belgium	not specified	85	NAV
Bulgaria	not specified	10-100	NAV
Belarus	not specified	10-80	NAV
Croatia	not specified	57	NAV
Czech Rep	not specified	10-5	NAV
Denmark	not specified	90	NAV
Estonia	not specified	10-80	NAV
Finland	not specified	68	NAV
France	not specified	50-85	NAV
Germany	not specified	90	NAV
Hungary	not specified	44	NAV
Ireland	not specified	66	NAV
Italy	not specified	92	NAV
Latvia	not specified	10-80	NAV
Lithuania	not specified	10-80	NAV
Moldavia	not specified	10-80	NAV
Netherlands	not specified	90	NAV
Norway	not specified	94	NAV
Poland	not specified	10-50	NAV
Portugal	not specified	42	NAV
Romania	not specified	10-46	NAV
Russia	not specified	10-80	NAV
Serbia	not specified	57	NAV
Slovenia	not specified	87	NAV
Spain	not specified	67	NAV
Sweden	not specified	98	NAV
Switzerland	not specified	88	NAV
Turkey	not specified	38	NAV
Ukraine	not specified	10-80	NAV
United Kingdom	not specified	90	NAV
Slovakia	not specified	10-65	NAV

Source: Doorn and Eklund (1995). Methane correction factor (MCF) data are not available (NAV). Research is ongoing to provide MCF estimates for these and other wastewater treatment systems. Note that these data are currently undergoing revision and updating.

6.4 Nitrous Oxide from Human Sewage

Since N_2O emissions from human sewage are closely linked to the agricultural N cycle, the method is further discussed in the Agriculture Chapter. For a detailed description of the proposed methodology, the reader is referred to Section 4.5.4 (on indirect N_2O emissions from nitrogen used in agriculture).

The emissions of N_2O from human sewage are calculated as follows:

EQUATION 15
$N_2O_{(S)} = \text{Protein} \times \text{Frac}_{NPR} \times NR_{PEOPLE} \times EF_6$

where:

$N_2O_{(s)}$ = N_2O emissions from human sewage (kg N_2O-N/yr)

Protein = annual per capita protein intake (kg/person/yr)

NR_{PEOPLE} = number of people in country

EF_6 = emissions factor (default 0.01 (0.002-0.12) kg N_2O-N/kg sewage-N produced) (See Table 4-18 in Agriculture Chapter)

$Frac_{NPR}$ = fraction of nitrogen in protein (default = 0.16 kg N/kg protein) (See Table 4-19 in Agriculture Chapter)

6.5 Emissions from Waste Incineration

6.5.1 Introduction

Waste incineration like other types of combustion, is a source of GHG emissions. Few data have been compiled on the global emissions from waste incineration. Preliminary indicators are that this source represents a small percentage of the total GHG output from the waste source category.

6.5.2 Emissions

Certainly waste incineration produces CO_2, but it is difficult to identify the portion which should be considered **net** emissions. A large fraction of the carbon in waste combusted (e.g., paper, food waste) is derived from biomass raw materials which are replaced by regrowth on an annual basis. These emissions should not be considered net anthropogenic CO_2 emissions in the IPCC Methodology. If the agricultural or forestry sources are not being sustainably managed, net CO_2 emissions (equivalent to reductions in biomass stocks) should be accounted for in those source categories. On the other hand, some carbon in waste is in the form of plastics or other products based on fossil fuel. Combustion of these materials, like fossil fuel combustion, releases net CO_2 emissions. In estimating emissions from waste incineration, the desired approach is to separate carbon in the incinerated waste into biomass and fossil fuel based fractions. Only the fossil based portion should be considered net carbon emissions. Any such detailed analysis should ensure that carbon emissions are not double counted in the treatment of stored carbon under energy emissions. See *Overview to the IPCC Guidelines*.

A recent Belgian analysis (Debruyn and Van Rensbergen, 1994) offers an example of a very detailed approach.

Other relevant gases released from combustion are net GHG emissions. Methane emissions from waste incineration are highly uncertain. An expert working group recognised waste incineration as a source of methane production, but was not able to give global estimates or default emissions factors. Although this source is considered to be relatively small compared to the other CH_4 sources in waste, it was recognised as an area for further research in the future (Berdowski et al., 1993).

Recent studies have also shown that N_2O may be an important GHG produced from incineration. Table 6-10 provides data from studies of several incineration plants and the N_2O produced from the waste incineration (de Soete, 1993). Studies in Belgium (IPCC, 1993), Japan (Tanaka et al., 1992) and Norway (Rosland, 1993) have estimated N_2O production from their waste incineration processes. It has also been found that the emission level depends on the nature of the waste burned. Research in Japan has noted that while all types of incineration produce N_2O, sludge incinerators produce the highest emissions rates (Tanaka et al., 1992).

Traditional air pollutants from combustion - NO_x, CO, NMVOC - are characterised in existing emissions inventory systems. The IPCC does not provide a new methodology for these gases, but recommends that national experts use existing published methods. Some key examples of the current literature providing methods are: Default Emission Factor Handbook (CORINAIR, 1994), as well as the US EPA's Compilation of Air Pollutant Emissions Factors (AP-42) (US EPA, 1985) and Criteria Pollutant Emission Factors for the 1985 NAPAP Emissions Inventory (Stockton and Stelling, 1987).

TABLE 6-10
NITROUS OXIDE EMISSIONS FROM WASTE INCINERATION

			N_2O Emission				
Nature of Waste (reference)	Facility	T°C	ppmv[a] min.	ppmv[a] average	ppmv[a] max.	O_2 (%)	g N_2O / tonne waste
Municipal refuse	10 furnaces (65-300 tonnes/day)		1.2	8	18		
Municipal refuse	Stepgrate	780-880	0.8		4.9	10	11-43
	Stepgrate	780-980	4		24	8-14	40-220
	Fluid. bed	830-850	6.7		10.5	13-15	14-123
Municipal solid waste	5 stokers (20-400 tonnes/day)		3	7	12		26-270
	3 Fluid. bed		5.6	9.8	17.1		97-293
	rot. koln (120 tonnes/day)		10.2	11.1	12.1		35-165
Sewage-sludge	4 incin. (150-300 tonnes/day)		57	87	125		
Sludge	Rotary grate	750		50.7			227
	Fluid. bed	770-812	270		600		580-1528
	Fluid. bed	838-854	135		292		684-1508
	Fluid. bed	834-844	100		320		275-886
	Fluid. bed	853-887	45		145		101-307

Source: de Soete, 1993.
[a] ppmv = parts per million by volume

6.6 References

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