APPENDIX D

Tables of Environmental Impact Potentials

Table D-1 Global Warming Potentials for Greenhouse Gases (CO_2 is the benchmark).

Chemical	Formula	τ (yrs)	BI (atm^{-1} cm^{-2})	GWP[a]
Carbon dioxide	CO_2	120.0		1
Methane	CH_4			21
NOx				40
Nitrous oxide	N_2O			310
Dichloromethane	CH_2Cl_2	0.5	1604	9
Trichloromethane	$CHCl_3$			25
Tetrachloromethane	CCl_4	47.0	1195	1300
1,1,1-trichloroethane	CH_3CCl_3	6.1	1209	100
CFC (hard)				7100
CFC (soft)				1600
CFC-11	CCl_3F	60.0	2389	3400
CFC-12	CCl_2F_2	120.0	3240	7100
CFC-13	$CClF_3$			13000
CFC-113	CCl_2FCClF_2	90.0	3401	4500
CFC-114	$CClF_2CClF_2$	200.0	4141	7000
CFC-115	CF_3CClF_2	400.0	4678	7000
HALON-1211	$CBrClF_2$			4900
HALON-1301	$CBrF_3$			4900
HCFC-22	CF_2HCl	15.0	2554	1600
HCFC-123	$C_2F_3HCl_2$	1.7	2552	90
HCFC-124	C_2F_4HCl	6.9	4043	440
HCFC-141b	$C_2FH_3Cl_2$	10.8	1732	580
HCFC-142b	$C_2F_2H_3Cl$	19.1	2577	1800
HFC-125	C_2HF_5			3400
HFC-134a	CH_2FCF_3			1200
HFC-143a	CF_3CH_3			3800
HFC-152a	$C_2H_4F_2$			150
Perfluoromethane	CF_4			6500
Perfluoroethane	CF_6			9200
Perfluoropropane	C_3F_8			7000
Perfluorobutane	C_4F_{10}			7000
Perfluoropentane	C_5F_{12}			7500
Perfluorohexane	C_6H_{14}			7400
Perfluorocyclobutane	c-C_4F_8			8700
Sulfur hexafluoride	SF_6			23900

Adapted from 1995 IPCC Report (IPCC, 1996 and 1994).
[a] (100 year time horizon).
τ is the tropospheric reaction lifetime (hydroxyl radical reaction dependent) (WMO, 1990a - 1992b)
BI is the infrared absorbence band intensity (Pouchert, 1989)

mark).

^{2})	GWP[a]
	1
	21
	40
	310
	9
	25
	1300
	100
	7100
	1600
	3400
	7100
	13000
	4500
	7000
	7000
	4900
	4900
	1600
	90
	440
	580
	1800
	3400
	1200
	3800
	150
	6500
	9200
	7000
	7000
	7500
	7400
	8700
	23900

1990a - 1992b)

Table D-2 Ozone-Depletion Potentials for Several Industrially Important Compounds.

Chemical	Formula	τ (yrs)	k (cm^3 $molecule^{-1}$ s^{-1})	X	ODP
Methyl bromide	CH_3Br				0.6
Tetrachloromethane	CCl_4	47.0	3.1×10^{-10}	4	1.08
1,1,1-trichloroethane	CH_3CCl_3	6.1	3.2×10^{-10}	3	.12
CFC (hard)					1.0
CFC (soft)					.055
CFC-11	CCl_3F	60.0	2.3×10^{-10}	3	1.0
CFC-12	CCl_2F_2	120.0	1.5×10^{-10}	2	1.0
CFC-13	$CClF_3$				1.0
CFC-113	CCl_2FCClF_2	90.0	2.0×10^{-10}	3	1.07
CFC-114	$CClF_2CClF_2$	200.0	1.6×10^{-10}	2	0.8
CFC-115	CF_3CClF_2	400.0			0.5
HALON-1201	$CHBrF_2$				1.4
HALON-1202	CBr_2F_2				1.25
HALON-1211	$CBrClF_2$				4.0
HALON-1301	$CBrF_3$				16.0
HALON-2311	$CHClBrCF_3$				0.14
HALON-2401	$CHBrFCF_3$				0.25
HALON-2402	$CBrF_2$ $CBrF_2$				7.0
HCFC-22	CF_2HCl	15.0	1.0×10^{-10}	1	.055
HCFC-123	$C_2F_3HCl_2$	1.7	2.5×10^{-10}	2	.02
HCFC-124	C_2F_4HCl	6.9	1.0×10^{-10}	1	.022
HCFC-141b	$C_2FH_3Cl_2$	10.8	1.5×10^{-10}	2	.11
HCFC-142b	$C_2F_2H_3Cl$	19.1	1.4×10^{-10}	1	.065
HCFC-225ca	$C_3HF_5Cl_2$				.025
HCFC-225cb	$C_3HF_5Cl_2$				.033

τ is the tropospheric reaction lifetime (hydroxyl radical reaction dependent) (WMO, 1990a–1992b).
k is the reaction rate constant with atomic oxygen at 298 K (release of chlorine in the stratosphere).
X is the number of chlorine atoms in the molecule.

Table D-3 Acid Rain Potential for a Number of Acidifying Chemicals.

Compound	Reaction	α	MW_i (mol/kg)	η_i, (mol H^+/ kg "i")	ARP_i
SO_2	$SO_2 + H_2O + O_3 \rightarrow 2H^+ + SO_4^{2-} + O_2$	2	.064	31.25	1.00
NO	$NO + O_3 + 1/2\ H_2O \rightarrow H^+ + NO_3^- + 3/4\ O_2$	1	.030	33.33	1.07
NO_2	$NO_2 + 1/2\ H_2O + 1/4\ O_2 \rightarrow H^+ + NO_3^-$	1	.046	21.74	0.70
NH_3	$NH_3 + 2\ O_2 \rightarrow H^+ + NO_3^- + H_2O$	1	.017	58.82	1.88
HCl	$HCl \rightarrow H^+ + Cl^-$	1	.0365	27.40	0.88
HF	$HF \rightarrow H^+ + F^-$	1	.020	50.00	1.60

Adapted from Heijungs et al., 1992

Table D-4 Maximum Incremental Reactivities (MIR) for Smog Formation (O_3).

Alkanes	*normal*	**MIR**	*branched*	**MIR**
	methane	0.015	isobutane	1.21
	ethane	0.25	neopentane	0.37
	propane	0.48	iso-pentane	1.38
	n-butane	1.02	2,2-dimethylbutane	0.82
	n-pentane	1.04	2,3-dimethylbutane	1.07
	n-hexane	0.98	2-methylpentane	1.50
	n-heptane	0.81	3-methylpentane	1.50
	n-octane	0.60	2,2,3-trimethylbutane	1.32
	n-nonane	0.54	2,3-dimethylpentane	1.31
	n-decane	0.46	2,4-dimethylpentane	1.50
	n-undecane	0.42	3,3-dimethylpentane	0.71
	n-dodecane	0.38	2-methylhexane	1.08
	n-tridcane	0.35	3-methylhexane	1.40
	n-tetradecane	0.32	2,2,4-trimethylpentane	0.93
	Average	**0.55**	2,3,4-trimethylpentane	1.60
			2,3-dimethylhexane	1.31
	cyclic		2,4-dimethylhexane	1.50
	cyclopentane	2.40	2,5-dimethylhexane	1.60
	methylcyclopentane	2.80	2-methylheptane	0.96
	cyclohexane	1.28	3-methylheptane	0.99
	1,3-dimethylcyclohexane	2.50	4-methylheptane	1.20
	methylcyclohexane	1.80	2,4-dimethylheptane	1.33
	ethylcyclopentane	2.30	2,2,5-trimethylhexane	0.97
	ethylcyclohexane	1.90	4-ethylheptane	1.13
	1-ethyl-4-methylcyclohexane	2.30	3,4-propylheptane	1.01
	1,3-diethylcyclohexane	1.80	3,5-diethylheptane	1.33
	1,3-diethyl-5-methylcyclohexane	1.90	2,6-diethyloctane	1.23
	1,3,5-triethylcyclohexane	1.70	**Average**	**1.20**
	Average	**2.06**		
Alkenes	*primary*		*secondary*	
	ethene	7.40	isobutene	5.30
	propene	9.40	2-methyl-1-butene	4.90
	1-butene	8.90	trans-2-butene	10.00
	1-pentene	6.20	cis-2-butene	10.00
	3-methyl-1-butene	6.20	2-pentenes	8.80
	1-hexene	4.40	2-methyl-2-butene	6.40
	1-hepene	3.50	2-hexenes	6.70
	1-octene	2.70	2-heptenes	5.50
	1-nonene	2.20	3-octenes	5.30
	Average	**5.66**	3-nonenes	4.60
			Average	**6.75**
	others			
	1,3-butadiene	10.90		
	isoprene	9.10		
	cyclopentene	7.70		
	cyclohexene	5.70		
	α-pinene	3.30		
	β-pinene	4.40		
	Average	**6.85**		

	MIR
	1.21
	0.37
	1.38
e	0.82
e	1.07
	1.50
	1.50
ane	1.32
ne	1.31
ne	1.50
ne	0.71
	1.08
	1.40
tane	0.93
tane	1.60
e	1.31
e	1.50
e	1.60
	0.96
	0.99
	1.20
ıe	1.33
ane	0.97
	1.13
	1.01
	1.33
	1.23
	1.20
	5.30
	4.90
	10.00
	10.00
	8.80
	6.40
	6.70
	5.50
	5.30
	4.60
	6.75

Alcohols and Ethers		
	methanol	0.56
	ethanol	1.34
	n-propyl alcohol	2.30
	isopropyl alcohol	0.54
	n-butyl alcohol	2.70
	isobutyl alcohol	1.90
	t-butyl alcohol	0.42
	dimethyl ether	0.77
	methyl t-butyl ether	0.62
	ethyl t-butyl ether	2.00
	Average	**1.32**
Acetylenes		
	acetylene	0.50
	methylacetylene	4.10
	Average	**2.30**
Aromatics		
	benzene	0.42
	toluene	2.70
	ethylbenzene	2.70
	n-propylbenzene	2.10
	isopropylbenzene	2.20
	s-butylbenzene	1.90
	o-xylene	6.50
	p-xylene	6.60
	m-xylene	8.20
	1,3,5-trimethylbenzene	10.10
	1,2,3-trimethylbenzene	8.90
	1,2,4-trimethylbenzene	8.80
	tetralin	0.94
	naphthalene	1.17
	methylnaphthalenes	3.30
	2,3-dimethylnaphthalene	5.10
	styrene	2.20
	Average	**4.34**

Aromatic Oxygenates	
benzaldehyde	–0.57
phenol	1.12
alkyl phenols	2.30
Average	**0.95**
Aldehydes	
formaldehyde	7.20
acetaldehyde	5.50
C3 aldehydes	6.50
glyoxal	2.20
methyl glyoxal	14.80
Average	**7.24**
Ketones	
acetone	0.56
C4 ketones	1.18
Average	**0.87**
Others	
Methyl nitrite	9.50
Base Reactive Organic Gas Mixture	**3.10**

Adapted from Carter (1994)