APPENDIXES

APPENDIX 1

A. Composition of the earth (total)

	Weight (%)
Fe	34.63
O	29.53
Si	15.20
Mg	12.70
Ni	2.39
S	1.93
Ca	1.13
Al	1.09
Na	0.57
Cr	0.29
Mn	0.22
Co	0.13
P	0.10
K	0.07
Ti	0.05
	100.00

B. Background concentration: Abundance in average crustal rock

Item	Value (% by weight)
Ag	0.000007
Al	8.1
Au	0.000004
Co	0.0025
Cr	0.010
Cu	0.0055
Fe	5.0
Hg	0.000008
Mg	2.1
Mn	0.10
Mo	0.00015
Ni	0.0075
Pb	0.0013
Pt	0.000001
Sb	0.00002
Sn	0.00020
Ti	0.44
U	0.00018
V	0.014
W	0.00015
Zn	0.0070

C. Background concentration: Biosphere

Item	Value (moles/hectare)
Al	4.12
C	6560
Ca	18.9
Cl	2.80
Fe	1.38
H	13,100
K	11.7
Mg	8.18
Mn	0.765
N	71.6
Na	1.65
O	6540
P	3.35
S	4.44
Si	8.62

D. Composition of the hydrosphere

element	mg/l	tons	element	mg/l	tons
Cl	19,000.0	$29.3 \cdot 10^{15}$	V	0.002	$3.0 \cdot 10^{9}$
Na	10,500.0	16.3 • -	Mn	0.002	3.0 * -
Mg	1,350.00	2.1 • -	Ti	0.001	1.5 • -
S	885.0	1.4 • -	Sb	0.0005	0.8 • -
Ca	400.0	0.6 * -	Co	0.0005	0.8 * -
K	380.0	0.6 • -	Cs	0.0005	0.8 * -
Br	65.0	0.1 * -	Ce	0.0004	0.6 • -
C	28.0	0.04 • -	Y	0.0003	0.5 * -
Sr	8.0	$12.0 \cdot 10^{12}$	Ag	0.0003	0.5 • -
B	4.6	7.1 • -	La	0.0003	0.5 • -
Si	3.0	4.7 * -	Kr	0.0003	0.5 * -
F	1.3	2.0 • -	No	0.0001	$15.0 \cdot 10^{7}$
A	0.6	0.93 • -	Cd	0.0001	15.0 • -
N	0.5	0.78 • -	W	0.0001	15.0 • -
Li	0.17	0.26 * -	Xe	0.0001	15.0 • -
Rb	0.12	0.19 • -	Ge	0.00007	11.0 • -
P	0.07	0.11 * -	Cr	0.00005	7.8 • -
I	0.06	$93.0 * 10^{9}$	Th	0.00005	7.8 • -
Ba	0.03	47.0 * -	Sc	0.00004	6.2 • -
In	0.02	31.0 * -	Pb	0.00003	4.6 • -
Zn	0.01	16.0 * -	Hg	0.00003	4.6 • -
Fe	0.01	16.0 • -	Ga	0.00003	4.6 • -
Al	0.01	16.0 • -	Bi	0.00002	3.1 * -
Mo	0.01	16.0 • -	Nb	0.00001	1.5 • -
Se	0.004	6.0 • -	Tl	0.00001	1.5 * -
Sn	0.003	5.0 • -	He	0.000005	0.8 * -
Cu	0.003	5.0 * -	Au	0.000004	0.6 * -
As	0.003	5.0 • -	Pa	$2 \cdot 10^{-9}$	3000
U	0.003	5.0 • -	Ra	$1 \cdot 10^{-10}$	150
Ni	0.002	3.0 * -	Rn	$0.6 \cdot 10^{-15}$	$1 * 10^{-3}$

E. Composition of the atmosphere

	Volume (ppm)	Weight (ppm)	Mass * 10^{20} g
N_2	780,900	755,100	38,648
O_2	209,500	231,500	11,841
A	9,300	12,800	0.665
CO_2	300	460	0.0233
Ne	18	12.5	0.000636
He	5.2	0.72	0.000037
CH_4	1.5	0.9	0.000043
Kr	1	2.9	0.000146
N_2O	0.5	0.8	0.000040
H_2	0.5	0.03	0.000002
O_3	0.4	0.6	0.000031
Xe	0.08	0.36	0.000018

F. The atomic composition of the four spheres

Element	Atoms % in (v.l. = very low)			
Element	Biosphere	Lithosphere	Hydrosphere	Atmosphere
H	49.8	2.92	66.4	v.l.
O	24.9	60.4	33	21
C	24.9	0.16	0.0014	0.03
N	0.27	v.l.	v.l.	
Ca	0.073	1.88	0.006	v.l.
K	0.046	1.37	0.006	v.l.
Si	0.033	20.5	v.l.	v.l.
Mg	0.031	1.77	0.034	v.l.
P	0.030	0.08	v.l.	v.l.
S	0.017	0.04	0.017	v.l.
Al	0.016	6.2	v.l.	v.l.
Na	v.l.	2.49	0.28	v.l.
Fe	v.l.	1.90	v.l.	v.l.
Ti	v.l.	0.27	v.l.	v.l.
Cl	v.l.	v.l.	0.33	v.l.
B	v.l.	v.l.	0.0002	v.l.
Ar	v.l.	v.l.	v.l.	0.93
Ne	v.l.	v.l.	v.l.	0.0018

APPENDIX 2

Pesticides: Degradation rate

Item	Conditions - in soil, time used to reach 70-100% of control
Heptachlor	90 weeks
IPA	5 -
Linuron	18 -
MPCA	12 -
Monuron	35 -
Picloram	80 -
Prometryn	10 -
Propazine	80 -
Simazine	40 -
TCA	12 -
Trifluralin	23 -
2,3,5-T	21 -
2,3,6-TBA	47 -
2,4-D	5 -

Pesticides: Half-life time in soil

Item	Conditions	
Akton	1.5 years	10 lbs/acre, spray, corn, sultan silt loam
Akton	1 year	2 lbs/acre, granules, corn, sultan silt loam
Akton	1.2 years	2 lbs/acre, spray, corn, sultan silt loam
Akton	32 weeks	LAB.
Aldicarb	7-17 days	Oxidation, value depending of soil
Aldrin	10 days	In irrigated soil, cotton, Gezira, Sudan
Aldrin	40% remaining after 14 years	Max value
Aldrin	28% remaining after 15 years	Max value
Azinphosmethyl	484 days	Sterile soil, dry, lag period included, 279 K
Azinphosmethyl	135 days	Sterile soil, dry, lag period included, 298 K
Azinphosmethyl	36 days	Sterile soil, dry, lag period included, 313 K

Pesticides: Half-life time in soil (continued)

Item	Conditions	
Benomyl	3-6 months	On turf, Delaware
Benomyl	6.12 months	Bare soil, Delaware
BHC	10% remaining after 14 years	Max. value
Bux	1-2 weeks	Hydrolysis, lab.
Carbaryl	8 days	Agricultural soil
Carbaryl	64 days	Sandy loam, Application = 25.4 kg/ha
Carbofuran	0.60 years	In soil, better drained, Application = 2.5 ppm, clay-muck, 1973
Carbofuran	0.92 years	In soil, poorly drained, Application = 2.5 ppm, clay, 1973
Carbofuran	0.56 years	In soil, well drained, Application = 2.5 ppm, clay-muck, 1973
Carbofuran	30 days	Hydrolysis, formation of phenol
Chlordane	40% remaining after 14 years	Max. value
Chlorobenzilate	21 days	In Leon and lakeland sands
DDT	8 months	P,P'-DDT, subtropical soil, fall and winter, Application = 5 kg/ha
DDT	14 days	In irrigated soil, cotton, Gezira, Sudan
DDT	39% remaning	Max. value after 17 years
Dicamba	3 weeks	On litter, Texas
Dicamba	2 weeks	On native grasses, Texas
Dieldrin	2.7 days	Loss by volatilization, grass, first 5 d
Dieldrin	7.5 months	P,P'-DDT, subtropical soil, fall and winter, Application = 5 kg/ha
Dieldrin	11 days	In irrigated soil, cotton, Gezira, Sudan
Dieldrin	31% remaining after 15 years	Max. value
Dioxathion	55 days	Soil dust 2(?069), pH = 7.3, org. matter = 2.1%
Dioxathion	45 days	Soil dust 3(?069), pH = 7.3, org. matter = 2.3%
Dioxathion	30 days	Soil dust 4(?069), pH = 7.6, org. matter = 1.8%

Pesticides: Half-life time in soil (continued)

Item	Conditions	
Endosulfan	7 days	In irrigated soil, cotton, Gezira, Sudan
Endrin	41% remaining after 14 years	Max. value
Ethion	420 days	None
Heptachlor	1.7 days	Loss by volatilization, grass, first 5 d
Heptachlor	16% remaining after 14 years	Max. value
Malathion	3 days	Basic silty loam, Illinois, Application = 10 ppm, pH = 6.2
Malathion	7 days	Basic silty loam, Illinois, Application = 10 ppm, pH = 8.2
Malathion	4.3 days	Basic silty loam, Illinois, Application = 10 ppm, pH = 7.2
Meobal	7 days	Field condition
Methomyl	30-42 days	None
Naproamide	54 days	Soil moisture content = 10.0%, 301 K, initial = 4.5 kg/ha
Naproamide	63 days	Soil moisture content = 7.5%, 301 K, initial = 4.5 kg/ha
Carbaryl	1.0 day	pH = 8.0, 301 K, seawater
Carbaryl	99 min	pH = 10.0, 285 K, init. concentration= $3 * 10^{-3}$ M, dark
Carbaryl	20 min	pH = 10.0, 298 K, init. concentration= $3 * 10^{-3}$ M, dark
Carbaryl	8 min	pH = 10.0, 308 K, init. concentration= $3 * 10^{-3}$ M, dark
Carbaryl	27 min	pH = 9.8, 298 K, init. concentration= $3 * 10^{-3}$ M, dark
Carbaryl	58 min	pH = 9.5, 298 K, init. concentration= $3 * 10^{-3}$ M, dark
Carbaryl	116 min	pH = 9.2, 298 K, init. concentration= $3 * 10^{-3}$ M, dark
Carbaryl	173 min	pH = 9.0, 298 K, init. concentration= $3 * 10^{-3}$ M, dark
Carbaryl	1 month	pH = 8.0, 276.5 K, seawater
Carbaryl	4.8 days	pH = 8.0, 290 K, seawater
Carbaryl	3.5 days	pH = 8.0, 293 K, seawater
Carbaryl	3.2 hours	Hydrolysis, pH = 9.0, 300 K
Carbaryl	1.3 days	Hydrolysis, pH = 8.0, 300 K
Carbaryl	13 days	Hydrolysis, pH = 7.0, 300 K
Carbaryl	4.4 months	Hydrolysis, pH = 6.0, 300 K
Carbaryl	3.6 years	Hydrolysis, pH = 5.0, 300 K

Pesticides: Half-life time in soil (continued)

Item	Conditions	
Diazinon	0.49 days	Hydrolysis, pH = 3.1
Diazinon	31 days	Hydrolysis, pH = 5.0
Diazinon	185 days	Hydrolysis, pH = 7.5
Diazinon	136 days	Hydrolysis, pH = 9.0
Diazinon	6 days	Hydrolysis, pH = 10.4
Diazinon	0.017 days	Hydrolysis, pH = 3.1
Diazinon	1.27 days	Hydrolysis, pH = 5.0
Diazinon	29 days	Hydrolysis, pH = 7.5
Diazinon	18 days	Hydrolysis, pH = 9.0
Diazinon	0.42 days	Hydrolysis, pH = 10.4
Dimilin	22.9 days	pH = 7.7, 283 K, initial = 0.1 ppm
Dimilin	80.5 days	pH = 10.0, 283 K, initial = 0.1 ppm
Dimilin	28.7 days	pH = 7.7, 297 K, initial = 0.1 ppm
Dimilin	8.31 days	pH = 10.0, 297 K, initial = 0.1 ppm
Dimilin	8 days	pH = 7.7, 311 K, initial = 0.09 ppm
Dimilin	3.45 days	pH = 10.0, 311 K, initial = 0.1 ppm
Heptachlor	23.1 hour	299.8 K, for hydrolysis, in distilled water
Methoprene	30 hours	Freshwater pound, initial = 0.01 ppm, February, in sunlight, California
Methoxychlor	58 hours	Conc. in water = 10^{-7} M, NO H_2O_2 added, 338 K
Methoxychlor	58 hours	Hydls. water conc. = 10^{-6} M, 5% acetonitrile, NO H_2O_2 added, 338 K
Methoxychlor	<1 hour	Hydls. water conc. = 10^{-6} M, 5% acetonitrile, H_2O_2-conc. = 0.1 M, 338 K
Methoxychlor	<1.7 hours	Hydls. water conc. = 10^{-6} M, 5% acetonitrile, H_2O_2-conc. = 8 * 10^{-2} M, 338 K
Methoxychlor	2 hours	Hydls. water conc. = 10^{-6} M, 5% acetonitrile, H_2O_2-conc. = 8 * 10^{-3} M, 338 K

Rate of degradation: biological degradation in water

Item	Conditions	
Diethanolamine	19.5 mg COD/ gram-hour	Init. COD = 200 mg/l, no other source of C, aerob, 293 ± 3 K
Diethylene glycol	13.7 mg COD/ gram-hour	Init. COD = 200 mg/l, no other source of C, aerob, 293 ± 3 K
Dimethyl-cyclohexanol	21.6 mg COD/ gram-hour	Init. COD = 200 mg/l, no other source of C, aerob, 293 ± 3 K
Ethylene diamine	9.8 mg COD/ gram-hour	Init. COD = 200 mg/l, no other source of C, aerob, 293 ± 3 K
Ethylene glycol	41.7 mg COD/ gram-hour	Init. COD = 200 mg/l, no other source of C, aerob, 293 ± 3 K
Furfuryl alcohol	41.1 mg COD/ gram-hour	Init. COD = 200 mg/l, no other source of C, aerob, 293 ± 3 K
Furfuryl-aldehyde	37.0 mg COD/ gram-hour	Init. COD = 200 mg/l, no other source of C, aerob, 293 ± 3 K
Gallic acid	20.0 mg COD/ gram-hour	Init. COD = 200 mg/l, no other source of C, aerob, 293 ± 3 K
Gentisic acid	80.0 mg COD/ gram-hour	Init. COD = 200 mg/l, no other source of C, aerob, 293 ± 3 K
Glucose	180.0 mg COD/ gram-hour	Init. COD = 200 mg/l, no other source of C, aerob, 293 ± 3 K
Glucose	8 to > 26 days	Half-life time, 278 K, 5 stations at Southampton
Glucose	3 to 10 days	Half-life time, 295 K, 5 stations at Southampton
Glucose	21 to > 30 days	Half-life time, 300 K, Porto Novo 2 stations from River Vellar
Glucose	11 days	Half-life time, 300 K, Porto Novo Kille Backwater
Glucose	9 to 10 days	Half-life time, 300 K, 2 stations from Kille Backwater and Mangrove Swamp
Glucose	> 17 days	Half-life time, 300 K, Porto Novo Bay of Bengal
Glucose	45 days	Half-life time, 300 K, destilled water
Glycerol	85.0 mg COD/ gram-hour	Init. COD = 200 mg/l, no other sources of C, aerob, 293 ± 3 K
Hydroquinone	54.2 mg COD/ gram-hour	Init. COD = 200 mg/l, no other sources of C, aerob, 293 ± 3 K

Rate of degradation: biological degradation in water (continued)

Item	Conditions	
Iso-propanol	52.0 mg COD/ gram-hour	Init. COD = 200 mg/l, no other sources of C, aerob, 293 ± 3 K
Isophthalic acid	85.0 mg COD/ gram-hour	Init. COD = 200 mg/l, no other sources of C, aerob, 293 ± 3 K
Lineal alkyl benzen sulfonate in presence of:		
Activated sludge	0.79 mg surfact./l day	21 days, batch culture, initial conc. = 20 mg surfactant/l
Anabaena cylindrica	0.72 mg surfact./l day	21 days, batch culture, initial conc. = 20 mg surfactant/l
Anabaena variabilis	0.92 mg surfact./l day	21 days, batch culture, initial conc. = 20 mg surfactant/l
Anacystis nidulans	0.40 mg surfact./l day	21 days, batch culture, initial conc. = 20 mg surfactant/l
Ankistrodesmus braunii	0.35 mg surfact./l day	21 days, batch culture, initial conc. = 20 mg surfactant/l
Calothrix parietina	0.93 mg surfact./l day	21 days, batch culture, initial conc. = 20 mg surfactant/l
Chlorella pyrenoidosa	0.58 mg surfact./l day	21 days, batch culture, initial conc. = 20 mg surfactant/l
Chlorella vulgaris	0.42 mg surfact./l day	21 days, batch culture, initial conc. = 20 mg surfactant/l
Cylindrospernum sp.	0.84 mg surfact./l day	21 days, batch culture, initial conc. = 20 mg surfactant/l
Gloeocapsa alpicola	0.92 mg surfact./l day	21 days, batch culture, initial conc. = 20 mg surfactant/l
Nostoc Muscorum	0.46 mg surfact./l day	21 days, batch culture, initial conc. = 20 mg surfactant/l
Oscillatoria borneti	0.58 mg surfact./l day	21 days, batch culture, initial conc. = 20 mg surfactant/l
P-chloroantiline	5.7 mg COD/ gram-hour	Init. COD = 200 mg/l, no other sources of C, aerob, 293 ± 3 K
P-chlorophenol	11.0 mg COD/ gram-hour	Init. COD = 200 mg/l, no other sources of C, aerob, 293 ± 3 K
P-cresol	55.0 mg COD/ gram-hour	Init. COD = 200 mg/l, no other sources of C, aerob, 293 ± 3 K
P-hydroxybenzoic acid	100.0 mg COD/ gram-hour	Init. COD = 200 mg/l, no other sources of C, aerob, 293 ± 3 K
P-nitroacetophenone	5.2 mg COD/ gram-hour	Init. COD = 200 mg/l, no other sources of C, aerob, 293 ± 3 K
P-nitro aniline	No degradation	Init. COD = 200 mg/l, no other sources of C, aerob, 293 ± 3 K
P-nitrobenzaldehyde	13.8 mg COD/ gram-hour	Init. COD = 200 mg/l, no other sources of C, aerob, 293 ± 3 K
P-nitrobenzoic acid	19.7 mg COD/ gram-hour	Init. COD = 200 mg/l, no other sources of C, aerob, 293 ± 3 K

Rate of degradation: biological degradation in water (continued)

Item	Conditions	
P-nitrophenol	17.5 mg COD/ gram-hour	Init. COD = 200 mg/l, no other sources of C, aerob, 293 ± 3 K
P-nitro toluene	32.5 mg COD/ gram-hour	Init. COD = 200 mg/l, no other sources of C, aerob, 293 ± 3 K
P-phenylen-diamine	More degrad-able	Init. COD = 200 mg/l, no other sources of C, aerob, 293 ± 3 K
P-toluenesul-phonic acid	8.4 mg COD/ gram-hour	Init. COD = 200 mg/l, no other sources of C, aerob, 293 ± 3 K
Phenol	80.0 mg COD/ gram-hour	Init. COD = 200 mg/l, no other sources of C, aerob, 293 ± 3 K
Phloroglucinol	22.1 mg COD/ gram-hour	Init. COD = 200 mg/l, no other sources of C, aerob, 293 ± 3 K
Phosphorus	0.14 l/day	Potomac (Estuary), 293 K, org. P
Phosphorus	0.40 l/day	Lake Erie, 293 K, org. P
Phosphorus	0.14 l/day	Lake Ontario, 293 K, org. P
Phthalic acid	78.4 mg COD/ gram-hour	Init. COD = 200 mg/l, no other sources of C, aerob, 293 ± 3 K
Phthalimide	20.8 mg COD/ gram-hour	Init. COD = 200 mg/l, no other sources of C, aerob, 293 ± 3 K
Pyrocatechol	55.5 mg COD/ gram-hour	Init. COD = 200 mg/l, no other sources of C, aerob, 293 ± 3 K
Pyrogallol	No degradation	Init. COD = 200 mg/l, no other sources of C, aerob, 293 ± 3 K
Resorcnol	57.5 mg COD/ gram-hour	Init. COD = 200 mg/l, no other sources of C, aerob, 293 ± 3 K
Ribose	8 to > 30 days	Half-life time, 278 K, 5 stations at Southampton
Ribose	3 to 9 days	Half-life time, 295 K, 5 stations at Southampton
Ribose	> 36 days	Half-life time, 300 K, Porto Novo, River Vellar
Salicyloic acid	95.0 mg COD/ gram-hour	Init. COD = 200 mg/l, no other sources of C, aerob, 293 ± 3 K
Sec. butanol	55.0 mg COD/ gram-hour	Init. COD = 200 mg/l, no other sources of C, aerob, 293 ± 3 K
Si	0.0015 l/day	Detritus Si to dissolved Si
Sulphanilic acid	4.0 mg COD/ gram-hour	Init. COD = 200 mg/l, no other sources of C, aerob, 293 ± 3 K
Sulphosali-cylic acid	11.3 mg COD/ gram-hour	Init. COD = 200 mg/l, no other sources of C, aerob, 293 ± 3 K
Tert. butanol	30.0 mg COD/ gram-hour	Init. COD = 200 mg/l, no other sources of C, aerob, 293 ± 3 K
Tetrahydrofur-furyl alcohol	40.0 mg COD/ gram-hour	Init. COD = 200 mg/l, no other sources of C, aerob, 293 ± 3 K
Tetrahydro-phthalic acid	No degradation	Init. COD = 200 mg/l, no other sources of C, aerob, 293 ± 3 K

Rate of degradation: biological degradation in water (continued)

Item	Conditions			
Tetrahydro-phthalimide	No degradation	Init. COD = 200 mg/l, no other sources of C, aerob, 293 ± 3 K		
Thymol	15.6 mg COD/ gram-hour	"	"	"
Triethylene	27.5 mg COD/ gram-hour	"	"	"
1-Napthalene-sulfonic acid	18.0 mg COD/ gram-hour	"	"	"
1-Naphtol	38.4 mg COD/ gram-hour	"	"	"
1-Naphthol-2-sulfonic acid	18.0 mg COD/ gram-hour	"	"	"
1-Naphthyl-amine	No degradation	"	"	"
1-Naphthylamine 6-sulfonic acid	No degradation	"	"	"
1,2-Cyclo-hexanediol	66.0 mg COD/ gram-hour	"	"	"
1,3-Dinitro-benzene	No degradation	"	"	"
1,4-Butanediol	40.0 mg COD/ gram-hour	"	"	"
1,4-Dinitro-benzene	No degradation	"	"	"
2-Chloro-4-nitrophenol	5.3 mg COD/ gram-hour	"	"	"
2-Naphthol	39.2 mg COD/ gram-hour	"	"	"
2,3-Dimethyl-aniline	12.7 mg COD/ gram-hour	"	"	"
2,3-Dimethyl-phenol	35.0 mg COD/ gram-hour	"	"	"
2,4-Diamino-phenol	12.0 mg COD/ gram-hour	"	"	"
2,4-Dichlor-phenel	10.5 mg COD/ gram-hour	"	"	"
2,4-Dimethyl-phenol	28.2 mg COD/ gram-hour	"	"	"
2,4-Dinitri-phenol	6.0 mg COD/ gram-hour	"	"	"
2,4-Trinitro-phenol	No degradation	"	"	"
2,5-Dimethyl-aniline	3.6 mg COD/ gram-hour	"	"	"
2,5-Dinitri-phenol	10.6 mg COD/ gram-hour	"	"	"

Rate of degradation: biological degradation in water (continued)

Item	Conditions			
2,5-Dinitro-phenol	No degradation	Init. COD = 200 mg/l, no other sources of C, aerob, 293 ± 3 K		
2,6-Dimethyl-phenol	9.0 mg COD/ gram-hour	"	"	"
2,6-Dinitro-phenol	No degradation	"	"	"
3,4-Dimethyl-aniline	30.0 mg COD/ gram-hour	"	"	"
3,4-Dimethyl-phenol	13.4 mg COD/ gram-hour	"	"	"
3,5-Dimethyl-phenol	11.1 mg COD/ gram-hour	"	"	"
3,5-Dinitro-benzoic acid	No degradation	"	"	"
4-Methylcyclo-hexanol	40.0 mg COD/ gram-hour	"	"	"
4-Methylcyclo-hexanone	62.5 mg COD/ gram-hour	"	"	"

APPENDIX 3

Concentration factors (CF), ww in brackets means that CF is based upon wet weight

Component	Species	CF	Concentration in water	Conditions
Ag	Daphnia magna	26 (ww)	0.5 mg l^{-1}	-
Ag	Phytoplankton	620-15,000 (ww)	wide range	-
Aldrin	Buffalo fish	30,000 (ww)	0.007 µg l^{-1}	-
Aldrin	Catfish	1590 (ww)	0.044 µg l^{-1}	-
Aldirn	Oyster	10 (ww)	0.05 µg l^{-1}	-
As	Salmo gardneri egg	18.5 (ww)	0.05 mg l^{-1}	279.5°K 33 days
Au	Brown algae	270 (ww)	wide range	-
Cd	Brown algae	890 (ww)	wide range	-
Cd	Zooplankton	6000 (ww)	10^{-4} mg m^{-3}	-
Cd	32 Freshwater plant species	1620	wide range	-
Chlordane	Algae	302 (ww)	6.6 ng l^{-1}	-
Chlorinated naphthalene	Chloroccum sp.	120 (ww)	100 µg l^{-1}	24 h
Co	32 Freshwater plant species	4425	wide range	-
Cr	Fish species	10 (ww)	wide range	Freshwater
Cr	Molluscs	21,800 (ww)	wide range	Marine sp.
Cs	Salmo trutta	1020 (ww)	wide range	Soft water 6.6 g fish
Cu	Chorda filum	560	$2.5*10^{-7}$ g l^{-1}	Seawater
Cu	Ulva sp.	47,000-56,000	low	Seawater
DDT	Algae	500 (ww)	0.016 ng l^{-1}	-
DDT	Crab	144 (ww)	50 µg l^{-1}	Seawater
DDT	Crayfish	97 (ww)	0.1 µg l^{-1}	-
DDT	Oyster	70,000	0.1 µg l^{-1}	-
DDT	Sea squirt	160,000 (ww)	0.1 µg l^{-1}	Seawater
DDT	Snail	480	50 µg l^{-1}	-
DDT	Trout	200 (ww)	20 µg l^{-1}	-
Dieldrin	Algae	4091	0.011 ng l^{-1}	-
Dieldrin	Catfish	4444 (ww)	0.009 µg l^{-1}	-

Concentration factors (CF), ww in brackets means that CF is based upon wet weight (continued)

Component	Species	CF	Concentration in water	Conditions
Dieldrin	Trout	3300 (ww)	2.3 µg l^{-1}	-
Fe	Brown algae	17,000 (ww)	-	-
Fe	Zooplankton	144,000 (ww)	0.01 mg m^{-3}	Seawater
Heptachlor	Bluegill	1130 (ww)	50 µg l^{-1}	-
Hexabromobiphenyl	Salmo salar	1.73 (ww)	all	5.3 g fish 48 h
Hexachlorobenzene	Salmo salar	690 (ww)	all	288°K 6 g fish
Hg	Daphnia magna	50 (ww)	2 mg m^{-3}	10 weeks
Hg	Zooplankton	650 (ww)	0.02 mg m^{-3}	Freshwater
Trimethylnaphthalene	Rangia cuneata	26.7 (ww)	0.03 mg l^{-1}	24 h
Pb	Brown algae	70,000 (ww)	all	-
Pb	Fucus vesiculosus	870	Very low	Seawater
Pb	Zooplankton	1500 (ww)	2 mg m^{-3}	-
PCB	Salmo salar	282 (ww)	wide range	5.29 g fish, 24 h
PCB	Yellow perch	17,000 (ww)	1.0 µg l^{-1}	Freshwater
Ra	Brown algae	370 (ww)	wide range	-
Se	Phytoplankton	900-5500 (ww)	wide range	-
W	Brown algae	87 (ww)	wide range	-
Zn	Phytoplankton	8900-75,000 (ww)	all	-
Zn	Pike	1250 (ww)	low	Freshwater

APPENDIX 4

A - mg per kg dry matter, elements in dry plant tissues

Element	Plankton*)	Brown algae	Ferns	Bacteria	Fungi
Ag	0.25	0.28	0.23		0.15
Al	1,000	62		210	29
As		30			
Au		0.012			
B		120	77	5.5	5
Ba	15	31	8		
Be					<0.1
Br		740			20
C	225,000	345,000	450,000	538,000	494,000
Ca	8,000	11,500	3,700	5,100	1,700
Cd	0.4	0.4	0.5		4
Cl		4,700	6,000	2,300	10,000
Co	5	0.7	0.8		0.5
Cr	3.5	1.3	0.8		1.5
Cs		0.067			
Cu	200	11	15	42	15
F		4.5			
Fe	3,500	690	300	250	130
Ga	1.5	0.5	0.23		1.5
H	46,000	41,000	55,000	74,000	55,000
Hg		0.03			
I	300	1,500			
K		52,000	18,000	115,000	22,300
La		10			
Li		5.4			
Mg	3,200	5,200	1,800	7,000	1,500
Mn	75	53	250	30	25
Mo	1	0.45	0.8		1.5
N	38,000	15,000	20,500	96,000	51,000
Na	6,000	33,000	1,400	4,600	1,500
Ni	36	3	1.5		1.5
O	440,000	470,000	430,000	230,000	340,000
P	4,250	2,800	2,000	30,000	14,000
Pb	5	8.4	2.3		50
Ra	$4 \cdot 10^{-7}$	$9 \cdot 10^{-8}$			
Rb		7.4			
Re		0.014			
S	6,000	12,000	1,000	5,300	4,000
Se		0.84			2
Si	200,000	1,500	5,500	180	
Sn	35	1.1	2.3		5
Sr	260	1,400	13		320
Ti	80	12	5.3		
U					0.25
V	5	2	0.13		0.67
W		0.035			
Y			0.77		0.5
Zn	2,600	150	77		150
Zr	20	2.3		5	

*) Mainly diatoms

B - mg per kg dry matter elements in dry animal tissues *)

Element	Coelenterata	Annelida	Mollusca	Crustacea	Insecta	Pisces	Mammalia
Ag	5?				≤0.07	11?	0.006
Al		340	50	15	100	10	<3
As	30	6	0.005	0.08		0.3	0.2
Au	0.007		0.008	0.0005		0.0003	<0.0009
B		2.1?	20	15		20	<2
Ba			3	0.2			2.3
Bi	0.3?					0.04?	
Br	1,000	100?	1,000	400		400	4
C	436,000	402,000	399,000	401,000	446,000	475,000	484,000
Ca	1,300	11,000	1,500	10,000	500	20,000	85,000
Cd	1		3	0.15		3	
Cl	90,000		5,000	6,000	12,000	6,000	3,200
Co	4?	5?	2	0.8	<0.7	0.5	0.3
Cr	1.3					0.2	<0.3
Cs							0.06
Cu	50	4?	20	50	50	8	2.4
F			2	2		1,400	500
Fe	400	630	200	20	200	30	160
Ga	0.5?					0.15?	
Ge	1.5?					0.3?	
H	45,000	59,000	60,000	60,000	73,000	68,000	66,000
Hg			1?			0.3?	0.05
I 15	160	4	1	0.9	1	0.43	
K	3,000	16,000	19,000	13,000	11,000	12,000	7,500
La							0.09
Li			1?		≤7		<0.02
Mg	5,500	6,000	5,000	2,000	750	1,200	1,000
Mn	30?	0.06?	10	2?	10	0.8	0.2
Mo	0.7		2	0.6	0.6	1	<1
N	63,000	99,000	85,000	84,000	123,000	114,000	87,000
Na	48,000		16,000	4,000	3,000	8,000	7,300
Ni	26?	11?	4	0.4	9	1	<1
O	271,000	340,000	390,000	400,000	323,000	290,000	186,000
P	14,000	8,100	6,000	9,000	17,000	18,000	43,000
Pb	35?		0.7	0.3	≤7	0.5	4
Pa			$1.5*1^{-7}$	$7*10^{-9}$		$1.5*10^{-8}$	$7*10^{-9}$
Rb			20				18
Re			0.006	0.0005		0.0008	
S	19,000	14,000	16,000	7,500	4,400	7,000	5,400
Sb	0.2					0.2	0.14
Sc							0.006
Se							1.7
Si		150	1,000	300	6,000	70	120
Sn	23?		15?	0.2		3?	<0.16
Sr		20	60	500			21
Th	0,03						
Ti	7		20	17	160	0.2	<0.7
U						≤0.06	0.023
V	2.3	1.2	0.7	0.4	0.15	0.14	<0.4
W			0.05	0.0005		0.0014	
Zn	1500?	6?	200	200	400	80	160

*) Most of the figures for marine animals were derived from the compilation by Vinogradov (1953)

C - mg elements per kg dry mammalian tissues

Element	Brain	Heart	Kidney	Liver	Muscle	Skin	Hair
Ag	0.04	0.01	<0.005	0.03	<0.004	0.022	
Al	0.92	0.8	1.1	1.7	0.67	4.4	30
As	0.08	0.01	0.34	0.5	0.16	0.36	1.1
Au	<0.5	0.00013	<0.5	<0.0001	<0.4	<0.2	
B	<0.6	0.2	<0.5	0.48	0.31	<0.2	
Ba	0.012	0.08	0.06	<0.007	0.013	0.15	
Be	<0.002	<0.002	0.002	0.0009	<0.003	<0.04	
Bi	<0.1	<0.08	<0.09	<0.07	<0.08	<0.03	
Br	3	8	16	10	4	10	6
Ca	320	150	390	140	105	360	200
Cd	<3	0.05	130	6.7	<0.06	<1	
Ce		0.0064			0.00003		
Cl	8,000	6,000	9,000	4,800	2,800	11,000	20,000
Co	0.0055	0.05	0.05	0.23	0.016	<0.03	15
Cr	0.12	0.025	0.05	0.026	0.042	0.29	2
Cs	0.03	0.05	0.03	0.05	0.09	<0.04	
Cu	22	14	12	196	3.1	1.7	80
Eu					0.00012		
F	2	2	3.2	4	5		
Fe	200	190	290	520	140	29	130
Ga	<0.04	<0.04	<0.04	<0.04	<0.04	<0.02	
Hf					<0.04		
Hg		0.17	0.25	0.022	0.02		
I0.4		0.09	0.0015	0.12	1.7		
In					0.016		
Ir					0.00002		
K	11,600	9,200	7,800	7,400	10,500	1,900	
La		0.00012					
Li	<0.03	<0.03	<0.03	<0.02	<0.02	0.084	
Lu					0.00012		
Mg	550	640	550	480	630	150	
Mn	1.1	0.8	3.8	3.7	0.21	0.22	1
Mo	<0.2	0.2	1.4	2.8	<0.2	<0.07	
N	99,000	132,000	115,000	112,000	108,000	161,000	
Na	10,000	4,500	800	5,500	4,000	9,300	
Ni	<0.3	<0.2	<0.2	<0.2	0.008	0.8	6
P	12,200	6,000	6,900	7,400	6,300	680	800
Pb	0.24	0.2	4.5	4.8	<0.2	0.78	35
Pd					0.002		
Pt					0.002		
Ra			$4*10^{-9}$	$8*10^{-9}$	10^{-10}		
Rb	15	13	17	30	24	8	
Ru	<0.5	<0.4	<0.4	<0.4	0.002	<0.2	
S	6,700	9,500	6,600	8,400	6,800	3,200	38,000
Sb		0.006					
Sc		0.00006			0.008		
Se	2.1	0.7	2.1	2.1	2.5		0.3-13
Si	80	100	95	70	130	450	
Sm		0.01					

C - mg elements per kg dry mammalian tissues (continued)

Element	Brain	Heart	Kidney	Liver	Muscle	Skin	Hair
Sn	<2	0.2	0.74	0.85	<0.2	0.36	
Sr	0.085	0.1	0.24	0.06	0.05	0.15	
Te					0.02		
Ti	<0.3	<0.2	<0.2	<0.2	<0.2	0.54	3
Tl	<0.5	<0.4	<0.4	<0.4	<0.4	<0.2	
Tm					0.0004		
U		0.03	0.03	0.04	0.03		0.13
V	<0.3	<0.04	<0.05	<0.04	<0.04		0.02
W		0.005					
Yb					0.00012		
Zn	46	110	210	130	180	13	170
Zr	<5	<4	<4	<4	<0.3	<2	

References for tables A, B and C:

Aten et al., 1961; Arrhenius, 1963; Beharrell, 1942; Baumeister, 1958; Bowen and Dymond, 1955; Bertrand, 1950; Bowen, 1963; Boirie et al., 1962; Brooksbank and Leddicotte, 1953; Black and Mitchell, 1952;Bowen and Cawse, 1963; Bowen, 1956; Bertrand, 1942; H.J.M. Bowen, unpublished; Bowen, 1960; Bertrand and Levy, 1931; Cannon, 1960; Cannon, 1963; Chau and Riley, 1965; Chilean Iodine Educational Bureau, 1952; Dye et al., 1963; Fukai and Meinke, 1959 and 1962; Fore and Morton, 1952; Forbes et al., 1954; Hunter, 1953; Hunter, 1942 and 1953; Ferguson and Armitage, 1944; Moon and Pall, 1944; Hamaguchi et al., 1960; Henderson et al., 1962; Harrison et al., 1963; International Commission on Radiological Protection, 1964; Johnson and Butler, 1957; Jervis et al., 1961; Koczy and Titze, 1958; Kehoe et al., 1940; King, 1957; Koch et al., 1956; King and Belt, 1938; Koch and Roesmer, 1962; Kringsley, 1959; Long, 1961; Lounamaa, 1956; Leddicotte, 1959; Leroy and Koksoy, 1962; Low, 1949; Lux, 1938; Mayer and Gorham, 1957; Matsumura et al., 1955; McCance and Widowson, 1960; McConnell, 1961; Muth et al., 1960; Mitchell, 1944; Moiseenko, 1959; Mackle et al., 1939; Monier-Williams, 1950; Mullin and Riley, 1956; Neufeld, 1936; Newman, 1949; Porter, 1946; Pavlova,1956; Parr and Taylor, 1963, 1964; Smales and Salmon, 1955; Stitch, 1956; Soremark and Bergman, 1962; Schofield and Hackin, 1964; Shacklette, 1965; Schwartz and Foltz, 1958; Shimp et al., 1957; Shibuya and Nakai, 1963; Stock, 1940; Smales and Pate, 1952; Sowden and Stitch, 1957; Spector, 1956; Soremark, 1964; Samsahl and Soremark, 1961; Stamm and Fernandez, 1958; Suzuki and Hamada, 1956; Tipton and Cook, 1963; Turner et al., 1958; Thompson and Chow, 1956; Thomas, Hendricks and Hill, 1950; Tyutina et al., 1959; Vinogradow, 1953; Vinogradova and Kobalsky, 1962; Wester, 1965; Wakita and Kigoshi, 1964; Young and Langille, 1950; Yamagata, 1950, 1962; Yamagata, Murata and Toril, 1962.

Amounts of elements *) in the diet of adult mammals in mg day^{-1}

Species		Man (Homo sapiens)				Rat (Ratus norvegicus)		
Mean weigth		70 kg				0.3 kg		
Wt. of dry diet		750 g/day				10 g/day		
Element/ state	Defi-cient	Normal	Toxic	Lethal	Defi-cient	Normal	Toxic	Lethal
Ag^{+}		0.06-0.08	60	1300				
Al^{3+}		10-100			0.001		200	220
As^{III} or V		0.1-0.3	5-50	100-300	0.002		0.6	1.3-5
B Borate		10-20	4000		0.0006		0.15	130-270
Ba^{2+} soluble		(1-5)	200					70-100
Bi^{3+}		(0.06)					1.5	
Br^{-}		1-10	3000		0.005			800
Ca^{2+}		400-1500			1	45-60		>400
Cd^{2+}		(0.6)	3				0.5	16
Cl^{-}	70	2400-4000			0.4	5-30		>900
Co^{2+}		0.0002	500				0.7	
Cr^{VI} Chromate		(0.05)	200	3000			5	
Cu^{2+}		2-5	250-500			0.05-0.2		20
F^{-}		0.5	20	2000	0.0007	0.001	0.1	30
Fe^{II} or III		12-15				0.1-0.5		>60
Ga^{3+}		(0.02)					10	
Hg^{II}		0.005-0.02		150-300				8
I^{-}	0.015	0.2	10,000			0.001-0.002		
In^{3+}		(0.01)					30	200-300
K^{+}		1400-3700	6000		0.3	50		>400
Li^{+}		2	200					
Mg^{2+}		220-400			0.1	2-5		
Mn^{2+}		3-9			0.003	0.03-0.2		
Mo^{VI} Molybdate		(0.7)			0.0005	0.0005-0.001	5	50
N Organic		8000-22,000						
Na^{+}	45	1600-2700			0.2	5-50		
Ni^{2+}		0.3-0.5					50	
P Phosphate		1200-2700				35-45		
Pb^{2+}		0.3-0.4		10,000				270
Rb^{+}		(10)				0.5	10	
S Sulphate, etc.		420-3000						
Sb^{III} or V		(0.1)	100					11-75
Se^{IV} Selenite		(0.2)	5		0.0007		0.06	1-2
Si Silicate		600						
Sn^{2+}		17-45	2000					
Sr^{2+}		1.5-5					8	900
Ta^{V} Tantalate		(1)						300
Te^{VI} Tellurate		(0.02)		2000			0.25	1-9
Ti TiO_2		(1-10)						
Tl^{+}		(0.1)		600				7.5
$U^{VI}UO_2^{2+}$		(0.05)						36
V^{V} Vanadate		(0.3)					0.5	1.5
W^{VI} Tungstate		(0.05)						30-50
Zn^{2+}		10-15			0.016	0.02-0.04	50	150
Zr^{IV}		(0.1)						250-700

*) For comparative purpose, and for order of magnitude estimates for other species of mammals, the amounts in mg per kg body weight are more useful than the absolute amounts given above. Figures given in parantheses are provisional.

APPENDIX 5

A: Effects of Trace Amounts of Methyl Mercury Hydroxide (MMH) on the Growth of Tomato Seedlings after Thirteen Days. Six replications

Treatment (ppm) MMH	Mean shoot growth (cm)	% inhibition of mean shoot growth	Mean seedlings wet weight (mg)	% inhibition of mean wet weight	Mean seedlings dry weight (mg)	% inhibition of mean dry weight
0.05	0.6	88.8	42	95.8	5	94.3
0.04	0.8	83.6	61	93.9	8	89.3
0.03	1.3	75.5	141	86.5	15	81
0.02	3.2	37.9	320	68.4	28	64
0.01	3.9	25.3	353	65.1	30	60.6
0	5.2	-	1013	-	77	-

B: Growth response of loblolly Pine (LP) and Red Maple (RM) versus Lead Concentration (pb) in mole/l.

	Heigth (cm)		Root dry weight (g)		Root/shoot ratio		Anthocyanin (relative)	
Pb	LP	RM	LP	RM	LP	RM	LP	RM
0	7.26	10.02	0.8	1.89	2.8	2.86	0.99	3.18
$2*10^{-4}$	7.23	10.51	0.61	1.61	2.38	2.24	0.99	2.49
10^{-3}	5.03	5.71	0.46	0.84	2.58	2.15	0.73	7.18
$2*10^{-3}$	4.2	4.68	0.5	0.8	2.49	2.13	1.46	8.7
$5*10^{-3}$	3.18	3.33	0.33	0.43	1.76	1.57	1.42	11.75
Mean	5.38	6.87	0.54	1.11	2.4	2.18	1.12	6.66

C: Growth response of Loblolly Pine (LP) and Red Maple (RM) versus Fluoride Concentration.

	Heigth (cm)		Stem dry weight (g)		Root dry weight (g)		Root/shoot ratio	
mole/l	LP	RM	LP	RM	LP	RM	LP	RM
0	6.74	9.31	0.29	0.76	0.76	1.97	3.02	2.79
$2*10^{-4}$	6.56	9.07	0.3	0.68	0.69	1.88	2.28	2.83
10^{-3}	6.68	7.99	0.3	0.68	0.7	2.45	2.89	3.71
$2*10^{-3}$	6.15	8.35	0.27	0.58	0.59	1.76	2.26	2.78
$2*10^{-2}$	3.74	3.91	0.19	0.31	0.32	0.55	1.77	1.84
Mean	5.97	7.73	0.27	0.6	0.61	1.72	2.44	2.79

Lethal doses 50% Mortality (LD_{50})

Component	Concentration (mg per kg body)	Species
Ag	100	Mouse (oral)
Ag as oxide	2820	Rat -
Al	770	Mouse -
Al	3700	Rat -
As	9	Mouse -
As as As_2O_5	8	Rat -
As as As_2O_3	45	Rat -
B as borax	4500	Rat -
B as boric acid	2660	Rat -
Ba as chloride	500	Mouse -
Ba as chloride	150	Rat -
Ba as carbonate	800	Rat -
Be as chloride	86	Rat -
Bi	13	Rat (intraven.)
Ca as acetate	4280	Rat (oral)
Cu as chloride	4000	Rat -
CCl_4	4620	Mouse -
Cd as oxide	72	Rat -
Ce as nitrate	4200	Rat -
Co as chloride	80	Mouse -
Cr as chloride	1870	Rat -
Cu as chloride	140	Rat -
CN^- as Na-salt	3	Mouse -
Fe(III) as nitrate	3250	Rat -
Fe(II) as sulphate	1480	Rat -
Ge as oxide	750	Rat -
Hf as chloride	112	Mouse (intraven.)
Hg(II) as chloride	37	Rat (oral)
La	35	Rat (intraven.)
Li as carbonate	710	Rat (oral)
Mg as chloride	2800	Rat -
Ni as fluoride	130	Mouse (intraven.)
Pb as acetate	120	Rat (oral)
Se as sulphide	38	Rat -
Sn(II) as chloride	41	Mouse (intraven.)
Strychnine	0.98	Mouse (oral)
Te as Na-salt	20	Mouse (oral)
Th as chloride	114	Mouse (intraven.)
Tl as oxide	44	Rat (oral)
U as oxide	6	Mouse (intraven.)
V(II) as chloride	540	Rat (oral)
V(IV) as chloride	160	Rat -
Zn as acetate	2460	Rat -

Lethal Concentration 50% Mortality (LD_{50})

Component	Concentration $\mu g\ l^{-1}$	Duration	Species
Ag as nitrate	30	4 d	Daphnia magna
Al as chloride	3900	2 d	- -
Alkyl benzene sulphonate	25,000	38 h	Tilapia (fish)
Ammonia	280	24 h	Salmo salar
Ba as chloride	14,500	2 d	Daphnia magna
Cd as chloride	65	2 d	- -
Cd (hard water)	17	5 d	Salmo gairdneri
Chloramine (NH_2Cl)	100	24 h	Phytoplankton
Chlorine	100	24 h	- -
Co as chloride	1100	2 d	Daphnia magna
Cr(IV)	50	2 d	- -
Cr(IV)	32-6000	2 d	Phytoplankton
Cu as chloride	9.8	2 d	Daphnia magna
Dibutyl-phthalate	50,000	2 d	Goldfish
Hg as chloride	5	2 d	Daphnia magna
Mn(II) as chloride	9800	2 d	- -
Polyelectrolytes	345,000	48 h	- -
Polyelectrolytes	>8000	48 h	Salmonoid fish
Polyoxyethylene	14,500	48 h	- -
Sn(II) as chloride	55,000	2 d	Daphnia magna
Sr as chloride	125,000	2 d	- -
Zn as chloride	100	2 d	- -
Zn as chloride	6000	15 h	Salmonoid fish

APPENDIX 6

Water Quality Standards for Domestic Water

Water use	Sub-stances	Units	Int.WHO accept-able	Int.WHO allow-able	Euro-pean WHO	U.S.A.	Sweden	France	Bulgaria	Tanza-nia
Toxic effects	Lead	µg/l		50	100	50	20/50		100	100
Toxic effects	Arsenic	µg/l		50	50	50	10/50		50	50
Toxic effects	Selenium	µg/l		10	10	10	10/50		50	50
Toxic effects	Chromium	µg/l		50	50	50	20		50	50
Toxic effects	Cyanide	µg/l		200	50	10	10/20		10	200
Toxic effects	Cadmium	µg/l		10	10	10	10		50	50
Toxic effects	Barium	µg/l		1000	1000	1000			1000	1000
Toxic effects	Mercury	µg/l					1/5			
Toxic effects	Silver	µg/l				50				
Human health	Fluoride	mg/l		1.5	0.7	0.8-1.7	1.5		0.7-1.0	8.0
Human health	Nitrate	mg/l		30.0	50/100	45	30	44	30	(100)
General use	Colour	mg pt/l	5	50		15	10		15	50
General use	Turbidity	mg SiO_2/l	5	25		3	weak		30 cm	30
General use	pH		7.0-8.5	6.5-9.2			6.0-8.0		6.5-8.5	6.5-9.2
General use	Tot. dis. matter	mg/l	500	1500			200	2000		2000
General use	Tot. hard-ness	mg $CaCO_3$/l			500			300	450	600
General use	Calcium	mg/l	75	200					150	
General use	Magnesium	mg/l	50	150	125			125	50	
General use	Sulphate	mg/l	200	400	250	250	25/250	250	250	600
General use	Chloride	mg/l	200	600	600	250	25/250	250	250	800
General use	Iron	mg/l	0.3	1.0	1.0	0.3	0.2	0.2	0.2	1.0
General use	Manganese	mg/l	0.1	0.5	0.05	0.05	0.05	0.1	0.1	0.5
General use	Copper	mg/l	1.0	1.5	0.05	1.0	0.05/1.0	0.2	0.2	3.0
General use	Zinc	mg/l	5.0	15.0	5.0	5.0	0.3/5.0	3	3	15.0
General use	Phenol	µg/l	1	2	1	1			1	2

APPENDIX 7

Elements: Abundance and Biological Activity

Symbols used:

a = elements formed by radioactive decay of uranium and thorium. Have short physical half-lives and their crustal abundance are too low to be measured accurately.
b = very low, unmeasureable
ra = radioactive
cs = carcinogenic, suspected only.
s = stimulatory
cp = carcinogenic, proven
en = essential nutrient, established
ep = essential nutrient, probably or required under special conditions
t1 = toxic
t2 = very toxic

Element	Symbol	Atomic number	Crustal abundance weight (%)	Abundance in hydrosphere (mg/l)	Abundance in atmosphere (vol ppm)	Biological activity	Threshold limit (mg/m^3 in air in 8 hours)
Actinium	Ac	89	manmade	manmade		ra	
Aluminium	Al	13	8	0.01		cs	
Americum	Am	93	manmade	manmade		ra	
Antimony	Sb	51	0.00002	0.0005		s t2	
Argon	Ar	18	0	0.6	9300		
Arsenic	As	33	0.00020	0.003		cs s t2	
Astatine	At	85	manmade	manmade		ra	
Barium	Ba	56	0.0380	0.03		s t1	0.5
Berkelium	Bk	97	manmade	manmade		ra	
Beryllium	Be	4	0.0002	b		cp (s) t2	
Bismuth	Bi	83	4E-7	2E-5		t1	
Boron	B	5	0.0007	4.6			
Bromine	Br	35	0.00040	65		t1=Br2	
Cadmium	Cd	48	0.000018	0.001			0.2
Calcium	Ca	20	5.06	400		en	
Californium	Cf	98	manmade	manmade		ra	
Carbon	C	6	0.02	28	CO_2=330	en	
Cerium	Ce	58	0.0083	0.0004		s	
Cesium	Cs	55	0.00016	0.0005			
Chlorine	Cl	17	0.019	18,980		Cl(-)=en Cl_2=t1	
Chromium	Cr	24	0.0096	5E-5		en cp s t1	0.1(CrO_3)
Cobalt	Co	27	0.0028	0.0005		en cp	
Copper	Cu	29	0.0056	0.003		en s t1	
Curium	Cm	96	manmade	manmade		ra	
Dysprosium	Dy	66	0.00085	b		s	
Einsteinium	Es	99	manmade	manmade		ra	
Erbium	Er	68	0.00036	b		s	
Europium	Eu	63	0.00022	b			
Fermium	Fm	100	manmade	manmade		ra	
Fluorine	F	9	0.0460	1.3		ep s	

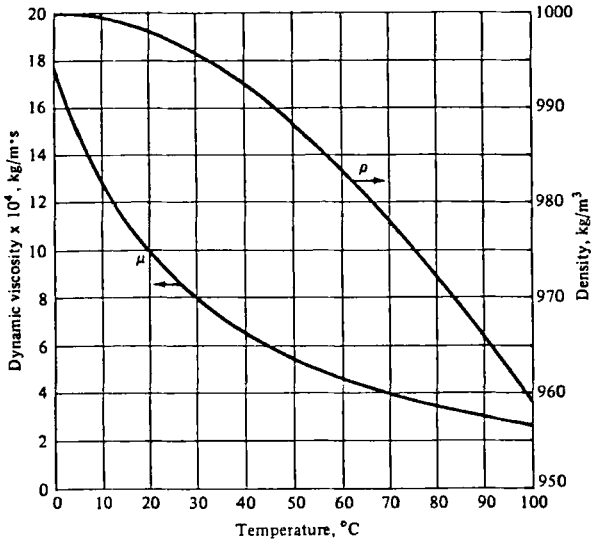
Elements: Abundance and Biological Activity (continued)

Element	Symbol	Atomic number	Crustal abundance weight (%)	Abundance in hydrosphere (mg/l)	Abundance in atmosphere (vol ppm)	Biological activity	Threshold limit (mg/m^3 in air in 8 hours)
Francium	Fr	87	manmade	manmade		ra	
Gadolinium	Gd	64	0.00063	b			
Gallium	Ga	31	0.00063	b			
Germanium	Ge	32	0.00013	7E-5		s	
Gold	Au	79	2E-7	4E-6		s t1	
Hafnium	Hf	72	0.0004	b			
Helium	He	2	0	5E-6	5.2		
Holmium	Ho	67	0.00016	b		s	
Hydrogen	H	1	0.14	H2O	CH_4=1.5 H_2=0.5	en	
Indium	In	49	0.00002	0.02		s t2	
Iodine	I	53	0.00005	0.06		I(-)=en I_2=t1	
Iridium	Ir	77	2E-8	b		t1	
Iron	Fe	26	5.80	0.01		en	
Krypton	Kr	36	0	0.0003	1		
Lanthanium	La	57	0.0050	0.0003			
Lead	Pb	82	0.0010	3E-5		t2 cp s	0.2
Lithium	Li	3	0.0020	0.17		s	
Lutetium	Lu	71	8E-5	b			
Magnesium	Mg	12	2.77	1350		en	
Manganese	Mn	25	0.100	0.002		en cs	5
Mendelevium	Md	101	manmade	manmade		ra	
Mercury	Hg	50	2E-6	3E-5		s t2	
Molybdenium	Mo	42	0.00012	0.01		en	5-15
Neodymium	Nd	60	0.0044	b			
Neon	Ne	10	0	0.0001	18		
Neptunium	Np	93	manmade	manmade		ra	
Nickel	Ni	28	0.0072	0.002		ep cp s	
Niobium	Nb	28	0.0072	0.002		ep cp s	
Nitrogen	N	7	0.0020	0.5	780,900	en	
Nobelium	No	102	manmade	manmade		ra	
Osmium	Os	76	2E-8	b		ra	
Oxygen	O	8	45.2	H_2O	209,500	en	
Palladium	Pd	46	3E-7	b		cs	
Phosphorus	P	15	0.1010	0.07		en	
Platinum	Pt	78	5E-7	b		t1	0.002
Plutonium	Pu	94	manmade	manmade		ra	
Polonium	Po	84	a	b		ra	
Potassium	K	19	1.68	380		en	
Praseodymium	Pr	59	0.0015				
Promethium	Pm	61	manmade				Protachtinium
Radium	Ra	88	a	1E-10		ra	
Radon	Rn	86	a	0.6E-15		ra	

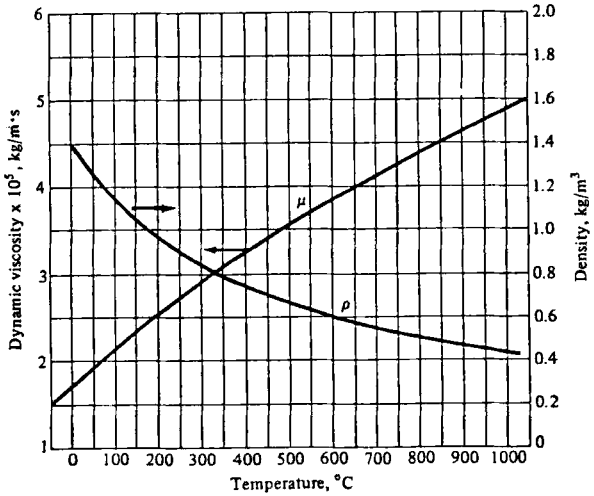
Elements: Abundance and Biological Activity (continued)

Element	Symbol	Atomic number	Crustal abundance weight (%)	Abundance in hydrosphere (mg/l)	Abundance in atmosphere (vol ppm)	Biological activity	Threshold limit (mg/m^3 in air in 8 hours)
Rhenium	Re	75	4E-8	b			
Rhodium	Rh	45	1E-8	b		cs	0.001
Rubidium	Rb	37	0.0070	0.12		s	
Rutherium	Ru	44	1E-8	b			
Samarium	Sm	62	0.00077	b			
Scandium	Sc	21	0.0022	4E-5		cs	
Selenium	Se	34	5E-6	0.004		cp s en t2	
Silicon	Si	14	27.2	3		ep cs	
Silver	Ag	47	8E-7	0.0003		cs t1	0.01
Sodium	Na	11	2.32	10,556		en	
Strontium	Sr	38	0.045	8			
Sulphur	S	16	0.030	885		en	
Tantalum	Ta	73	0.00024	b			5
Technetium	Tc	43	manmade	manmade		ra	

APPENDIX 8



Density and dynamic viscosity of liquid water as a function of temperature



Density and dynamic viscosity of pure air at 1.0 atm pressure as a function of temperature

APPENDIX 9

Ranger (1981) compared fertilized and non-fertilized stands at the ages of 15 and 18 years. The stem density was 4,500 stems per hectare. Half of the stand was fertilized at planting with additions of 9.3 g m^{-2} of nitrogen (27.5 g m^{-2} of urea), 16.3 g m^{-2} of phosphorus (38.0 g m^{-2} of P_2O_5) 57.1 g m^{-2} of calcium (80.0 g m^{-2} CaO), and 13.3 g m^{-2} of potassium (16.0 g m^{-2} of K_2O).

Fertilization largely increased the productivity of the stand (+ 122%) (Table 1). This increment was correlated with a higher uptake of nutrients. This effect changed with time. Between 15 and 18 years the biomass increased 39% in the unfertilized plot and only 30% in the fertilized one. At 18 years the biomass of the fertilized plot was only 107% greater than the control stand, whereas at 15 years it was 122% greater.

The same pattern was evident for nutrients. The fertilized stand, which produced 122% more biomass, used 153% more of the five nutrients studied than did the control plot. There was no direct relationship between biomass production and nutrient uptake. On the contrary, the increment of productivity was accompained by an "over-consumption" of some, but not all, nutrients. Potassium was not "over-consumed", and more surprising, neither was nitrogen.

Table 2 indicates the amounts of elements included in a thousand kilograms of woody biomass and in a thousand kilograms of 1-year-old needles, at 15 and 18 years, and also the amounts of these same nutrients found in the same quantity of litter.

Table 1
Biomass and the included nutrients in a fertilized (F) and control (C) plot of *Pinus laricio* after 15 and 18 years

Age of the stand	Site	Biomass kg m^{-2}	Mineral elements in biomass g m^{-2}				
			N	P	K	Ca	Mg
15	F	11.14	17.02	2.21	14.57	19.07	4.06
	C	5.01	7.05	0.46	7.15	6.40	1.47
	F-C	6.13	9.97	1.75	7.42	12.67	2.59
18	F	14.46	21.47	2.70	20.00	23.94	5.15
	C	6.98	9.61	0.62	9.90	8.64	2.00
	F-C	7.48	11.86	2.08	10.10	15.30	3.15

Table 2
Nutrients required to build up 1,000 kg of biomass in fertilized (F) and control (C) plots and in the yearly litter fall of a *Pinus laricio* stand (kg of nutrients)

Age	Type of material	Site	N	P	K	Ca	Mg	Total
15	Woody biomass	F	1.53	0.20	1.31	1.71	0.36	5.11
		C	1.41	0.09	1.43	1.28	0.29	4.50
	1-year-old needles	F	13.16	1.20	6.78	4.01	1.06	26.21
		C	13.74	0.77	6.81	3.10	1.16	25.58
18	Woody biomass	F	1.48	0.19	1.38	1.66	0.36	5.07
		C	1.38	0.09	1.42	1.24	0.29	4.43
	1-year-old needles	F	13.22	1.20	6.85	4.06	1.08	26.41
		C	13.89	0.76	6.87	3.20	1.16	25.88
	Litter	F	7.21	0.49	1.90	6.59	0.95	17.14
		C	8.00	0.23	1.31	5.35	1.00	15.89

Table 3
Losses of nutrients by various harvesting methods in a control and a fertilized stand of *Pinus laricio* (g m^{-2}). F - Fertilized plot; C - Control plot; I - Input

		N	P	K	Ca	Mg
Input with fertilizers		9.2	16.3	13.3	57.1	
Atmospheric inputs		0.5-1.0	0	0.2	0.2-0.5	0.1
Total harving	F	49.5	5.1	34.6	35.2	7.4
(boles, branches,	F-I	40.3	(+11.2)	21.3	(+21.9)	7.4
roots and leaves)	C	20.9	1.2	15.1	11.6	2.8
Harvesting total	F	46.1	4.8	32.5	32.8	6.7
aerial biomass	F-I	-36.9	(+11.5)	19.2	(+24.3)	6.7
	C	19.3	0.9	13.8	10.6	2.8
Boles harvested	F	5.1	0.9	6.7	5.2	1.5
(without bark)	F-I	(+4.1)	(+15.2)	(+6.6)	(+51.9)	1.5
	C	2.6	0.1	3.6	1.9	0.5

In contrast to forest fertilization, which involves an input of nutrients into the system, forestry practices have involved the increased utilization of forest products by harvesting all of the biomass. This management practice increases the output from the system.

Foresters have long respected the biological processes and mineral requirements of the forest ecosystems, and have used only a fraction of the biomass, such as boles or big branches, most often excluding leaves, small branches, bark and stumps.

Some utilization of forest litter as fertilizers of agricultural soils has been made in the past in Bavaria. After a few years, the productivity of the forests decreased so much that this method was prohibited.

Some recent projects for exploiting forest products have attempted to harvest not only the aerial part of forest, but also the root system, which can make up an appreciable part of the forest production. To study the effects of such practices, Ranger (1981) used the data of the stand discussed above to analyze the effect of different harvesting processes on the mineral budget. He compared total harvesting of aerial and root biomass, harvesting of the total aerial part and harvesting, by the old methods, of the boles, without bark and branches.

Table 3 indicates that on the control plot, the effect of the three harvesting procedures is always on the output of nutrients from the ecosystem, and that output could possible be matched for some nutrients, on a several year basis, by inputs from the atmosphere, by rain and by dry and wet deposition. However, when total input and output are considered, the final results is always a loss for succeeding plantations.

APPENDIX 10

1. TEST GUIDELINES TO MEASURE PHYSICAL-CHEMICAL PROPERTIES

1.1 Test used to identity the chemical

Relative Molecular Mass
UV-VIS Absorption Spectra
Melting Point/Melting Range
Boiling Point/Boiling Range

1.2 Test used

(a) to obtain pre-requisite information for tests on degradation, accumulation, ecotoxicity, toxicity
(b) to evaluate environmental mobility and transport

Vapour Pressure Curve
* Water Solubility
* Adsorption/Desorption
* Partition Coefficient
Volatility from Aqueous Solutions
Complex Formation Ability
* Density of Liquids and Solids
* Particle Size Distribution
* Dissociation Constants
Viscosity of Liquids
Surface Tension of Aqueous Solution
Fat Solubility of Solids and Liquids
Permeability
Corrosiveness

1.3 Tests used to evaluate abiotic degradation

* Hydrolysis as a Function of pH
Storage Stability (thermal stability)

1.4 Tests used to obtain safety data

Determination of explosive properties
Determination of oxidizing effects of gases yielding oxygen
Determination of pyrophoric behaviour of solids & liquids
Determination of pyrophoric behaviour of gases & liquids
Determination of high inflammability of powdered granular and pasty substances
Determination of high inflammability
Inflammability of liquids
Determination of high inflammability of gases
Determination of substances, which give off highly inflammable gases in dangerous amounts on contact with water

2. GUIDELINES TO EVALUATE DEGRADATION AND ACCUMULATION IN THE ENVIRONMENT

2.1 Bio-Degradation in Water

Ready biodegradability (level I)
The following five tests are considered to be equally sensitive:
- French AFNOR test T 90/302
- Modified OECD screening test with DOC analysis
- Modified Sturm test, based on the measurement of CO_2 evolution
- MITI test
- Closed bottle test according to Fischer

Inherent biodegradability (level II)
- Modified semicontinuous activated sludge test for determination of inherent biodegradability (SCAS)
- Modified static method for testing the inherent biodegradability (Zahn-Wellens test)
- Test guideline for inherent biodegradability (MITI)

Simulation tests (level III)
OECD condirmatory test modified for the application of unspecific analysis (coupled units test)

2.2 Photodegradation

Laboratory gas phase photodegradation test
Laboratory solid surface photomineralisation test
Test on photochemical transformation in water

2.3 Bioaccumulation in organisms

Static tests
Bioaccumulation test with mussels
Static fish test on bioaccumulation

Semi-static test
Semi-static procedure for measuring bioconcentration of chemicals in fish
Sequential static procedure for measuring the bioaccumulation potential of chemicals with fishes

Dynamic flow-through test
Test guideline for testing the degree of accumulation of chemical substances in fish body

2.4 Degradation and accumulation in soil and sediments

Degradability of chemicals in soil
Leaching behaviour of chemicals in soil
Residue behaviour of chemicals in soil

3. GUIDELINES TO EVALUATE ECOTOXICOLOGICAL EFFECTS STUDIES TO EVALUATE ENVIRONMENTAL EFFECTS

- Acute toxicity LC_{50} of fish (96 hours, static)
- Reproduction study and LC_{50} with daphnia magna (14 days)
- Growth inhibition study with unicellular algae (4 days)

4. GUIDELINES TO EVALUATE TOXICOLOGICAL EFFECTS

4.1 Acute toxicity studies

- Acute oral toxicity
- Acute dermal toxicity
- Acute inhalation toxicity
- Acute dermal irritation/corrosivity
- Skin sensitisation

4.2 Subchronic toxicity studies

- Subchronic oral toxicity - rodent: 28 day or 14 day study
  Subchronic oral toxicity - rodent: 90 day study
  Subchronic oral toxicity - non-rodent: 90 day study
  Subchronic dermal toxicity: 21/28 day study
  Subchronic dermal toxicity: 90 day study
  Subchronic inhalation toxicity: 28 day or 14 day study
  Subchronic inhalation toxicity: 90 day study
  Subchronic neurotoxicity: 90 day study
  Teratogenicity

4.3 • Studies for the Evaluation of the Mutagenic and/or Carcinogenic Potential of Chemicals

4.4 Toxicolinetics

4.5 Chronic Toxicity Studies

Chronic toxicity
Combined Chronic Toxicity/Carcinogenicity
Carcinogenicity

2.3 Bioaccumulation in Organisms

Bioaccumulation is presented by the bioaccumulation factor (the ratio of concentration of a chemical in a test organism compared to that in the ambient medium at steady state conditions). Among the species tested, fish show the highest bioaccumulation factors for a given chemical. In view of the importance of water as a major carrier of envirnmental chemicals, it is recommended that fish should be **the** representative animal species in bioaccumulation testing.

Test procedures may be static (initial concentration of test chemical may decrease due to uptake by test organism) or **dynamic** (constant concentration of test chemical maintained in flow through system).

Eight **species**, for which there is considerable experience, are recommended (pelagic: zebrafish, carp, guppy, rainbow trout, fathead minnow, bluegill sunfish; bottom/filter feeders: mussel, catfish). Bottom and filter feeders ara the recommended test species for chemicals which have an octanol/water partition coefficient less than 1000, but are highly adsorbed on suspended matter and sediments/soils.

The dicision not to test a chemical for bioaccumulation will be based upon the assessment of its relevant physical-chemical properties and its degradability.

There will generally be no need for the determination of bioaccumulation of unionised organic chemicals, if

- the water solubility is greater than 2 g/litre;
- the n-octanol/water partition coefficient is less than 1000;
- the water/air partition coefficient (=volatility) is less than 10;
- the chemical is ready biodegradable

The following test stages are recommended:

Level I (Screening phase): Identifies chemicals with a significant bioaccumulation potential by performing phsysical-chemical tests (preferably the partition coefficient) and by taking into account their environmental stability. There may be cases where the physical-chemical testing yields an unequivocal result, in which case, a static test could be used as a screening test.

Level II and III: Confirmation of bioaccumulation as disclosed in the screening phase by means of studies with representative living organisms. The decision whether to use a dynamic or static test procedure depends on the reliability with which the bioaccumulation factor and the kinetics (uptake/depletion rate) can be measured.

Static tests

Bioaccumulation test with mussels.

Static fish test on bioaccumulation.

Semi-static tests

Semi-static procedure for measuring the bioaccumulation potential of chemicals in fishes.

Sequential static procedure for measuring the bioaccumulation potential of chemicals with fishes.

Dynamic flow-through test

Test Guideline for testing the degree of accumulation of chemical substances in fish body.

2.4 Degradation and Accumulation in Soils and Sediments

Soil tests should only be carried out on chemicals likely to reach the soil. Tests on soil/sediment should be run under aerobic/anaerobic conditions, respectively.

Chemicals readily biodegradable in water do not need to be tested for biodegradation in soils or sediments.

The likelihood of leaching of chemicals to deeper soil layers where anaerobic conditions prevail must be considered.

Due to the difficulties inherent in obtaining standardised soils, the use of the U.S. soil classification for tests on adsorption, biodegradation and/or leaching is recommended. Three types are described, which are common in temperature zones (but not representative of arid/tropical zones):

Nature	pH	Clay	Organic $CaCO_3$	Matter	Example
1. very strongly to strongly acid: sandy	4.5-5.5	5%		1-6%	Spodosol
2. moderately or slightly acid: loamy	5.6-6.5	15-25%		1-4%	Alfisol
3. neutral to slightly alkaline: loamy	6.6-8.0	11-25%	1-10%	1-4%	Entisol

In order to simulate sediments with anaerobic conditions, use of water-logged soils flushed with an inert gas may be used.

1. Biodegradability in soil

Level I: Ready Biodegradability
Tests on soils would be restricted to specialised substances as, for example, to chemicals directly applied to soil. Normally procedures for tests on soil/sediments will start at a level similar to level II for aquatic conditions.

Level II: Inherent Biodegradability
Such tests are recommended for chemicals which are not readily biodegradable in an aquatic screening test, and which may be expected to contaminate soils as a result of their anticipated use/disposal pattern.
A preliminary test guideline (C121/79) for degradability in soil requires use of ^{14}C labelled organic chemicals and is based on a technique developed for pesticides, monitoring $^{14}CO_2$ evolution for up to 64 days. No pass level is quoted. Techniques monitoring unlabelled CO_2 are usually not sensitive enough.

Level III: Simulation Tests
Currently available test methods relate to sewage treatment conditions. Tests at this level may be indicated for chemicals which are found to be nonbiodegradable, or have a low rate of biodegradation, or which are leaching and do not degrade easily anaerobically. Chemicals which degrade to recalcitrant metabolites are a special group for consideration.
In most cases, use of radiolabelled chemicals will be advantageous.

2. Abiotic Degradation in Soils

Where chemicals are disposed of in soils with low biological activity, tests for degradability by non-metabolic processes may be indicated. In such studies, use of sterilised soils could be involved.
Sterilisation of soil by irradiation or autoclaving is recommended. It should be noted that the remainder of the test must be carried out under aseptic conditions.

3. Accumulation in Soils (Adsorption/Desorption)

The n-octanol-water partition coefficient for unionised organic chemicals correlates empirically to leaching characteristics as a measure of the accumulation tendency. Direct measurements of

adsorption coefficient between water and soil may be used as a confirmatory test and also as an indicator of accumulation in soil of ionic materials.

4. Mobility of Chemicals in Soils/Sediments

Such tests are indicated for chemicals which are non-biodegradable and/or require simulation tests (see above); the tests allow an evaluation of the combined effects of specific adsorption properties and inherent degradability/persistence.

(a) Leaching

A test guideline presents a method (used for pesticides registration in Germany for assessment of leaching). Essentially the method consists of pouring a solution of the test chemical on to a column of water-saturated soil, followed by leaching water and analysing the eluate to detect the amount of test chemical washed through the soil column.

(b) Adsorption

Adsorption coefficient may also be used to predict leaching behaviour of a chemical in soil.

(c) Residue Behaviour

The test measures the degree to which the test substances is irreversibly adsorbed on soil.

3. Guidelines to Evaluate Ecotoxicological Effects

Three levels of testing are envisaged:

Level I (basic): Simple tests to indicate possible effects on a few functionally important types of organism. Tests with several species are judged to be more important than a single very accurate test with one organism.

[**Level II** (confirmatory): Tests which give more information than level I tests and confirm their results.

Any chemical which meets the following criteria should be submitted for level II tests:

1. Is not readily biodegradable
2. Bioaccumulates significantly
3. Is rated highly toxic in short/longterm toxicology tests and/or has an acute LC_{50} to an organism of less than 1 mg/litre
4. Is a positive mutagen
5. Does not show asymptotes in LC_{50} determinations
6. Undergoes change(s) in production volume/use/disposal pattern such that predicted environmental concentration (PEC) increases by an order of magnitude
7. Has a no-observed-effect concentration (NOEC) for fish, daphnia, algae less than 10 times the PEC
8. Demonstrates increased toxicity following chemical, physical or biological change in the environment.

For the time being, no test guidelines are presented for level II tests.]

[**Level III** (definitive): Restricted to special cases, e.g. where appreciable concentration of the chemical in the environment may exist, or possible environmental hazard has been identified.]

The objectives of level I testing are to indicate general types of ecotoxicologically significant effects (e.g., toxic effects, inhibition of growth, reproduction, photosynthesis) in a range of organisms with widely different physiological and biochemical properties. The tests recommended under level I are:

Fish LC_{50} (4 days)	LC = lethal concentration
Daphnia LC_{50} (14 days)	
Algae IC_{50} (4 days)	IC = inhibitory concentration
	EC = effect concentration

Acute Toxicity LC_{50} of fish (96h, static)

Duration	4 days (but may be extended to 14 days);
Applicability	Can be used for any chemical, volatile or non-volatile, which enters the fresh water environment;
Test species	Guppy, but one of several other suitable test species may be used;
Concentrations	Five concentrations (selection guided by solubility and

following range-finding test) plus blank, each one tested in duplicate;

No. of Fish — 10 per concentration;

Food — Only feed if duration exceeds 4 days;

Non-volatiles — Aerate solutions gently; transfer fish to freshly prepared solutions every 48 hours;

Volatiles — Do not aerate; transfer to fresh solutions every 24 hours;

Monitor — pH, and concentrations of oxygen and test substances throughout test (not necessarily on all solutions);

Record — Number dead after 3, 4, 24, 48, 72, 96 hours (dead fish are removed). If the last two observations suggest that mortality will continue, the test may be extended up to 14 days. Calculate LC_{50} for as many observation times as possible. Observe for effects other than mortality and calculate effect concentrations (EC_{50}) is possible.

Reproduction study and LC_{50} with Daphnia Magna (14 days)

Duration — 14 days (but may be extended)

Applicability — Can be used for any chemical, volatile or non-volatile, which enters the fresh water environment. Test substances which give highly coloured solutions, or consume oxygen at a rate necessitanting intensive aeration, will be more difficult to evaluate by this technique.

Concentrations — Three to five concentrations (selected following 48 hour range-finding test), plus blank, each one tested in duplicate.

No. of Daphnids — 25 per concentration, less than 24 hours old ("P generation").

Renew — Medium, standard water, test compound once every 48 hours (or Monday, Wednesday, Friday)

Food — Add specified algal suspension daily

Non-volatiles	Test in beakers or flasks
Volatiles	Tests in stoppered flasks
Monitor	pH/O_2 concentration before each renewal; concentration once per test;
Reproduction	When the mother daphnids are about 7 days old first new "brood" (F1 generation) appears, with further batches appearing every 2-3 days. Extend test duration past 14 days, if necessary for 3 broods of the F1 generation to appear in the blank concentrations
Record	Mortality: LC_{50} (at least) at 2, 4, 7, 14 days Effects: EC_{50} (where possible) for any other effects Reproduction: average young/female, and total young/female/test solution and calculate reproduction indicator "r".

For both the above tests, "conditions for the validity of the test" are presented, and recommendations are made to (1) include reference substances in the tests and (2) repeat the whole test (in the case of daphnia starting with the third batch of F1 animals).

Growth inhibition study with unicellular algae (4 days)

Duration	4 days;
Applicability	Can be used for all compounds that do not interfere with the counting of algae;
Test Organism	One of three specified green algal species (other may be used, with justification given);
Concentrations	Usually five concentrations (selected following range-finding test), plus blank, each one tested in duplicate. Highest concentration should at least give distinct inhibition of growth, lowest concentration should be no different from blank. Chemicals of low solubility can be predissolved in organic solvent;
Algal Suspension	$2*10^4$ cells/ml for readily water-soluble substances; 10^4 cells/ml for sparingly soluble substances;
Measure	algal concentration (by Coulter counter, counting chamber fluorimeter, spectro-photometer) at 1, 2, 3, 4 days in cells/ml;
Calculate	Growth rate, then per cent inhibition, derive IC_{50} and no-observed-effect concentration from graph of per cent inhibition against concentration.

4. Guidelines to Evaluate Toxicological Effects Relative to Human Health

Acute Tests assess responses of a test organism to a single dose/exposure. They identify chemicals of high toxicity and provide information on potential hazards to humans which could result from exposure to single doses. The data enable the hazard associated with exposure to a given chemical to be positioned relative to that of other chemicals.

1. Acute Toxicity: Guidelines are presented for tests involving administration by oral, dermal or inhalation routes. Such tests enable the hazard of poisoning by a single exposure to a chemical to be assessed.
   Test guidelines allow an LD_{50} or LC_{50} value to be calculated. For less

toxic chemicals test guidelines allow the assessment of lethality be a "limit value" test in which proposed dose levels are 5000 mg/kg (oral), 2000 mg/kg (dermal), 5 mg/litre (inhalation), and record all toxic responses observed during the 14 days following administration (note that properly conducted tests do not merely determine lethality.
Preferred species are rat (oral), rat, rabbit or guinea pig (dermal), rat (inhalation); test groups include equal numbers of both sexes.

2. Acute Dermal or Eye Irritation/Corrosivity: Irritation/corrosivity are defined as reversible/irreversible effects.
Effects of single applications to skin or eye should be assessed for chemicals which are likely to come into contact with skin or eye. After exposure, residual material is removed from skin and the application site is graded for up to 72 hours, although observation can continue for 14-21 days to evaluate e.g. reversibility of effects. Not all chemicals need to be assessed for eye irritation; substances found to be irritant to skin can be prejudged to be irritant to the eye.
Rabbits are the preferred species for both tests; sex is not considered to be important.

3. Sensitisation: Is not an acute test because it involves more than one exposure, but the period over which exposures take place is short.
Sensitisation tests are, however, usually carried out in the initial assessment phase. Any chemical which is likely to come into repeated contact with skin should be assessed for sensitisation potential.
Six test methods are considered acceptable, all of which use guinea pigs (sex not important).
Periodic use of a positive control substance is recommended to assess the reliability of the test system.

4.2 Subchronic Toxicity Studies

Subchronic Tests: Assess the toxic effects from repeated doses/exposures of a chemical for part of a lifespan. Tests which in duration do not exceed 10% of an average lifetime are termed "subchronic" in these Guidelines. The tests involve treatment of separate groups with different dose levels and provide information on the occurrence of abnormalities, target organs, dose response curves. and an estimate of a no-effect-level. Such studies should be helpful in selecting dose levels for longer term (i.e., chronic) studies and for establishing safety criteria for human exposure.

1. Guidelines are presented for oral, dermal and inhalation routes. Physical-chemical properties and likely human exposure route(s) need to be

considered in selecting the exposure route(s) to be tested. Recommended durations (14, 28, 90 days for oral and inhalation, 21/28 and 90 days for dermal) are those which are supported by experience or existing regulatory requirements. The longer the study, the greater is the amount of information likely to be obtained. For some chemicals the subchronic study will be the only repeated dose study to be carried out, therefore, it is important to obtain the maximum amount of information. The Guidelines recommend more detailed clinical chemistry, and histopathology in the 90 day compared with the 28 day studies, and the longer duration studies involve more animals per group. In the first instance, histopathology is restricted to control and high-dose groups. Use of satellite groups in which additional animals are treated with the highest dose level for the test duration and then maintained for a period without dosing to observe for reversibility, persistence, or delayed occurrence of toxic effects is recommended, as is the use of control groups which are handled in an identical manner to the test groups except for treatment with the test substance.

Preferred species are rat (oral), rat, rabbit or guinea pig (dermal), rat (inhalation). A separate guideline is included for a 90 day oral study in dogs sicne occasionally studies in non-rodent (in addition to rodent) species are advisable. In all cases, groups consist of equal numbers of each sex in order to establish whether there is a difference in toxic response between sexes.

2. Neurotoxicity: Has special importance because effects may be irreversible, and a guideline is included for a 90 day study involving oral administration to hens.

3. Teratogenicity: Is the property of a chemical which causes permanent structural or functional abnormalities during the period of embryonic development. It is assessed by administering the chemical daily to a pregnant animal through the period of organogenesis. Route of administration is usually oral but other routes more representative of likely human exposure can be used. Different dose levels are administered to separate groups of animals, with a control (and if necessary a vehicle control) group included in the test design. The study should detect any teratogenic potential; it this exists, the data should enable a no-effect level to be established so that appropriate measures may be taken.

4.3 Studies for the Evaluation of the Mutagenic and/or the Carcinogenic Potential of Chemicals

Mutagenicity: Is the property of a chemical which causes either mutations in genes or changes in chromosomes. The groups have presented a report outlining principles of testing for mutagenic potential, but expect to elaborate on the subject, and the use of short-term tests to detect carcinogenic potential, following a meeting in October 1980.]

4.4 Toxicokinetics

Studies of toxicokinetics give information on absorption, distribution, excretion and metabolism of a test chemical. Such data help to evaluate results of other toxicity studies. The time at which a toxicokinetic study may be carried out will vary according to the need for additional data to help assess the safety of a chemical. It may be done soon after tests for acute toxicity, but should definitely be carried out before chronic studies are initiated because it will provide data useful in selecting dose levels for long-term studies. If the study is to be used in such a way (or to evaluate other toxicity data), obviously the species tested must be the same. Alternatively, toxicokinetics studies in a range of species may help identify a species whîch metabolises the chemical in a similar pattern to man. This could help select a species for chronic studies which may be most predictive of effects in man.

4.5 Chronic Studies

Involve prolonged and repeated exposure of the test substances to animals for the major part of their lifespan and should enable effects which require a long latent period, or are cumulative, to be detected. For long-term studies the route(s) of administration will depend on the physical-chemical properties of teh test substance and teh route(s) typifying human exposure. The oral route is preferred, providing that it can be shown that the chemical is absorbed from the gastrointestinal tract. In all cases, selection of dose levels should be made following well-designed subchronic studies. For all the longterm studies, histopathology is restricted in the first instance to control and high-dose group animals only.

1. Chronic Toxicity: Guidelines are presented for chronic toxicity by oral, dermal or inhalation routes of exposure for at least 12 months. Such studies should identify the majority of chronic effects to establish dose-response relationships.
General toxicity (including neurological, physiological, biochemical, haemotological and pathological) effects should be detected. Guidelines for

both rodent and non-rodent species are presented, though it is noted that testing with a single species may provide sufficient data for assessing the hazard of a chemical. 20 rodents (4 non-rodents) of each sex are recommended group sizes.

2. Carcinogenicity: Guidelines are presented for carcinogenicity by oral, dermal or inhalation routes of exposure of animals to various doses of a test substance by an appropriate route of administration for the major part of their lifespan while observing for the development of neoplastic lesions during or after exposure. A test substance of unknown activity should be tested in both sexes in each of the animal species; of the three rodent species of choice the mouse and the rat have been more widely used than the hamster.
The number of animals tested have to be sufficient so that, at the end of the study, enough animals are available in every group for thorough biological and statistical evaluation; this is essential to support a negative conclusion. 50 animals of each sex are recommended for each test and control group; if interim sacrifice(s) are planned, then the initial number should be increased by the number of animals scheduled for interim sacrifice. Study duration is recommended to by 18 months for mice and hamsters and 24 months for rats, in animal strains of greater longevity and/or low spontaneous tunour rate, termination should be at 24/30 months for mice and hamsters/rats. Termination is acceptable when survival rate in control and lower-dose groups drops to 25%, but for a test which generates negative results to be acceptable, survival rate in all groups must exceed 50% after 18/24 months for mice and hamsters/rats.

3. Combined Chronic Toxicity/Carcinogenicity: Guidelines are presented for combined chronic toxicity/carcinogenicity study by oral, dermal or inhalation routes of exposure for 18-30 months. These guidelines for one species (typically the rat but other species may be used) are essentially a combination of those in (1) and (2) above, group size is 50 animals per sex in treatment and control groups for carcinogenicity assessment, with satellites of treated (20 per sex) and control (10 per sex) groups for toxicity assessment. Study duration constraints for carcinogenicity are as in paragraph 2 above; the satellite groups should be retained in the study for at least 12 months.