APPENDIX PART C: PRESENT AND FUTURE QUALITY OF SEDIMENTS IN THE RHINE CATCHMENT AREA - PAHS, PCBS

Chapter 1: Introduction

1.1 Individual PAHs and sum parameters

individual PAHs		*sum 6*	*sum 10*	*sum 16*
naphtalene			X	X
acenaphtalene				X
acenaphtene				X
fluorene				X
phenanthrene			X	X
anthracene			X	X
fluoranthene	Fl	X	X	X
pyrene				X
benz(a)anthracene			X	X
chrysene			X	X
benzo(b)fluoranthene	BbFl	X		X
benzo(k)fluoranthene	BkFl	X	X	X
benzo(a)pyrene	BaP	X	X	X
dibenz(ah)anthracene				X
benzo(ghi)perylene	BghiPe	X	X	X
indeno(1,2,3-cd)pyrene	Ind	X	X	X

sum 6 PAHs: also referred to as Borneff PAHs, most often used in German monitoring programmes and regulations

sum 10 PAHs: also referred to as VROM PAHs in Dutch regulations

sum 12 PAHs: also referred to as US-EPA PAHs

Chapter 3: Modelling of point and diffuse sources in the Rhine catchment area

3.1.2a PAH concentrations in influents and effluents of municipal wastewater treatment plants (LAU Hessen, 1989)

		Fl		BbFl		BkFl		BaP		BghiPe		Ind	
	n=12	1985 ng/L	1988 ng/L	1985 ng/L	1988 ng/L	1985 ng/L	1988 ng/L	1985 ng/L	1988 ng/L	1985 ng/L	1988 ng/L	1985 ng/L	1988 ng/L
influent	min	18	31	2	14	< 2	4	< 2	7	3	< 2	< 2	< 2
	25-percentile	52	97	18	28	2	14	2.8	27	5.5	< 2	4.8	< 2
	median	105	115	24	51	8.5	21	12	43	32	< 2	15	< 2
	75-percentile	180	188	51	76	23	34	21	69	82	2.8	29	< 2
	max	610	410	140	200	60	61	86	130	230	19.0	61	< 2
effluent	min	3	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
	25-percentile	6.5	9	2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
	median	11	15	3.5	< 2	1.5	< 2	< 2	< 2	2	< 2	< 2	< 2
	75-percentile	16	22	10	< 2	3	< 2	6.3	< 2	4.3	< 2	2	< 2
	max	88	190	31	< 2	5	3	8	3	13	< 2	8	< 2

Fl - fluoranthene, BbFl- benzo(b)fluoranthene, BkFl - benzo(k)fluoranthene,
BaP - benzo(a)pyrene, BghiPe - benzo(ghi)perylene, Ind - indeno(1,2,3-cd)pyrene

3.1.2b PCB concentrations in influents and effluents of municipal wastewater treatment plants (LAU Hessen, 1989)

		PCB 28	PCB 52	PCB 101	PCB 138	PCB 153	PCB 180
	n=12	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L
influent	min	< 5-50	< 10-50	< 10	< 10	< 10	< 10
	25-percentile	< 5-50	< 10-50	< 10	**10**	**8**	< 10
	median	< 5-50	< 10-50	< 10	**14**	**20**	< 10
	75-percentile	< 5-50	< 10-50	**11**	**18**	**27**	**3**
	max	< 5-50	**16**	**20**	**60**	**80**	**30**
effluent	min	< 5-50	< 2	< 1	< 1	< 1	< 1
	25-percentile	< 5-50	< 2	< 1	< 1	< 1	< 1
	median	< 5-50	< 2	< 1	< 1	< 1	< 1
	75-percentile	< 5-50	< 2	< 1	**0.3**	< 1	< 1
	max	< 5-50	< 2	< 1	**1**	< 1	< 1

3.1.2c PAH concentrations in sewage sludge of 53 WWTPs in Germany, 1994-1995 (UBA , 1998b)

n = 53	Fl mg/kg dw	BbFl + BkFl mg/kg dw	BaP mg/kg dw	sum 6 PAHs mg/kg dw	sum 16 PAHs mg/kg dw
min	0.12	0.08	0.09	0.6	1.0
median	1.0	0.37	0.35	2.5	6.1
max	4.3	2.1	3.4	12.5	25.6

3.1.2d PAH concentrations in sewage sludge of 29 WWTPs located at the Rhine, 1994-1995 (Vedewa, 2000)

n = 29	Fl mg/kg dw	BbFl + BkFl mg/kg dw	BaP mg/kg dw
min	0.12	0.1	0.09
25-percentile	0.74	0.24	0.18
median	0.98	0.37	0.35
75-percentile	1.3	0.51	0.6
max	4.3	2.1	3.4

3.1.2e PCB concentrations in sewage sludge from 11 WWTPs in Hessen, Germany, 1988 (LAU Hessen, 1989)

n=11	PCB 28 µg/kg dw	PCB 52 µg/kg dw	PCB 101 µg/kg dw	PCB 138 µg/kg dw	PCB 153 µg/kg dw	PCB 180 µg/kg dw
min	<3-5	<3-5	9	20	14	11
25-percentile	16	16	17	48	28	22
median	20	17	30	60	45	30
75-percentile	25	20	43	78	60	43
max	55	30	50	110	85	60

3.1.3a Atmospheric deposition of benzo(b)fluoranthene in Germany (Pacyna, 1999)

	NILU-EMEP Zingst Jan-Dec 95 *n*=10 ng/(m²*day)	McLachlan Zingst Oct 95 - Mar 96 *n*=6 ng/(m²*day)	McLachlan Berlin Oct 95 - Mar 96 *n*=6 ng/(m²*day)	McLachlan Bayreuth Oct 94 - Apr 96 *n*=13 ng/(m²*day)
min	0.7	28	152	22.7
mean	9.0	64	370	52.7
max	50.9	130	663	103.3

3.1.3b Atmospheric deposition of benzo(a)pyrene in Germany (Pacyna, 1999)

	NILU-EMEP Zingst Jan-Dec 95 *n*=8 ng/(m²*day)	McLachlan Zingst Oct 95 - Mar 96 *n*=6 ng/(m²*day)	McLachlan Berlin Oct 95 - Mar 96 *n*=4 ng/(m²*day)	McLachlan Bayreuth Oct 94 - Apr 96 *n*=13 ng/(m²*day)
min	0.8	13.5	152	8.3
mean	6.8	23.9	315	21.1
max	35.6	40.0	663	40.0

3.1.3c PCB pattern in atmospheric deposition, re-calculated from data for Sweden and Finland (Pacyna, 1999)

PCB	28	52	101	138	153	180
% of Σ 6	15	14	13	23	20	15

3.1.4a Benzo(a)pyrene concentrations in top soils in Germany

Land use: agriculture (crops etc.), *density of population*: rural regions or not specified

	BaP µg/kg dw	BaP µg/kg dw	BaP µg/kg dw	BaP µg/kg dw	BaP µg/kg dw	BaP µg/kg dw	BaP µg/kg dw
land use	C	C	C+P	C	C	C	C
populat. density	III	III	III		III		III
State	Nordrhein-Westfalen	Nieder-sachsen	Bayern	Branden-burg	Sachsen	Thüringen	Saarland
reference	NRW 1993	NS 1996	GLA 1994	Brand 1995	Sachs 1997	Thür 1996	Saar 1999
no. of samples	*n*=94	*n*=84	*n*=53	*n*=162	*n*=306	*n*=63	
50 percentile	25	7	8	10	<10	18	14
90 percentile	70	20	49	36	28	91	29

Land use: agriculture (crops etc. or not specified), *density of population*: medium to high

	BaP µg/kg dw	BaP µg/kg dw	BaP µg/kg dw	BaP µg/kg dw	BaP µg/kg dw	BaP µg/kg dw	BaP µg/kg dw
land use	C	C	C			A	C
poluat. density	II	I	I-II	I	II		I
State	Nordrhein-Westfalen	Nieder-sachsen	Bayern	Hamburg	Hamburg	Hamburg	Sachsen
reference	NRW 1993	NS 1996	GLA 1994	HH 1996	HH 1996	HH 1996	Sachs 1997
no. of samples	*n*=238	*n*=20	*n*=44	*n*=90	*n*=18	*n*=21	*n*=68
50 percentile	60	27	23	360	30	90	19
90 percentile	260	57	142	1260	160	310	80

Land use: **A** - agriculture (not specified), **C** - crops etc., **P** - pasture

Population density: **I** - high density, **II** - medium density, **III** - rural

3.1.4b PCB concentrations in top soils in Germany

Land use: agriculture (crops etc.), *density of population*: rural regions or not specified

	PCBs sum 6 µg/kg dw	PCBs sum 6 µg/kg dw	PCBs sum 6 µg/kg dw	PCBs sum 6 ? µg/kg dw	PCBs sum 6 µg/kg dw	PCBs sum 6 µg/kg dw	PCBs sum 6 µg/kg dw	PCBs sum 7 µg/kg dw
land use	C	C (*vineyards*)	C	C	C	C	C	C
poluat. density			III	III	III	III		III
State	Rheinland-Pfalz	Rheinland-Pfalz	Baden-Württemberg	Nordrhein-Westfalen	Saarland	Nieder-sachsen	Branden-burg	Thüringen
reference	RLP 1996	RLP 1996	BW 1997	NRW 1993	Saar 1999	NS 1996	Brand 1995	Thür 1996
no. of samples	*n* =102	*n* =26	*n* =58	*n* =41		*n* =88	*n* =188	*n* =63
50 percentile	<1	4	-	4.5	-	<2	<1	-
90 percentile	12	23	7	10.1	11	2	<1	3

Land use: agriculture (crops etc. or pasture), *density of population*: medium to high

	PCBs sum 6 ? µg/kg dw	PCBs sum 6 ? µg/kg dw	PCBs sum 6 µg/kg dw	PCBs sum 6 µg/kg dw	PCBs sum 6 µg/kg dw	PCBs sum 6 µg/kg dw
land use	C	P	C	C	P	C
poluat. density	I	I	I-II	I-III	I-III	I
State	Nordrhein-Westfalen	Nordrhein-Westfalen	Saarland	Bayern	Bayern	Nieder-sachsen
reference	NRW 1993	NRW 1993	Saar 1999	GLA 1994	GLA 1994	NS 1996
no. of samples	*n* =61	*n* =28		*n* = 76	*n* = 60	*n* =16
50 percentile	6.5	4.3	1	20	-	<2
90 percentile	43.8	12.6	20	154	50	16

Land use: **A** - agriculture (not specified), **C** - crops etc., **P** - pasture

Population density: **I** - high density, **II** - medium density, **III** - rural

3.1.4c PCB pattern in agricultural top soils in the Netherlands, re-calculated from data from RIVM (1995)

PCB	28	52	101	138	153	180
% of Σ 6	10	8	18	24	24	14

3.2a Results of emission analysis for fluoranthene (present state, *BAU* and *Green* scenarios). Loads according to pathways/processes at selected stations along the Rhine and its tributaries

Fluoranthene loads / **kg·yr^{-1}**		*Rhine*	*Neckar*	*Main*	*Rhine*	*Rhine*	*Mosel*	*Rhine*	*Rhine*
	pathway/ process	Lauter-bourg	Mann-heim	Bischofs-heim	Mainz	Koblenz	Koblenz	Bad Honnef	Bimmen/ Lobith
Present	urban area	548	169	233	1060	1159	277	1458	2025
BAU	urban area	493	152	210	954	1043	249	1313	1822
GREEN	urban area	400	143	192	829	909	201	1129	1565
Present	erosion	120	28	77	235	252	31	285	300
BAU	erosion	120	28	77	235	252	31	285	300
GREEN	erosion	102	21	57	189	201	23	226	237
Present	atm. dep.	92	3	9	108	113	15	130	141
BAU	atm. dep.	83	3	8	98	102	13	117	127
GREEN	atm. dep.	74	3	7	87	91	12	104	113
Present	WWTPs	23	25	31	96	109	12	123	169
BAU	WWTPs	21	22	28	87	98	11	111	152
GREEN	WWTPs	13	14	18	55	62	7	70	96
Present	shipping	129	75	88	340	374	41	423	600
BAU	shipping	97	56	66	255	281	31	317	450
GREEN	shipping	65	37	44	170	187	20	211	300
Present	total	913	299	438	1840	2007	375	2419	3235
BAU	total	814	261	389	1629	1775	334	2142	2851
GREEN	total	654	217	319	1329	1450	263	1740	2312

***Present*:** present state (1994-1996)

BAU: 'business as usual' scenario until 2015

GREEN: 'green environment' scenario until 2015

urban area: paved urban areas

erosion: erosion from top soils

atm. dep.: direct atmospheric deposition to surface waters

WWTPs: wastewater treatment plants

shipping: shipping related activities

3.2b Results of emission analysis for benzo(b)fluoranthene (present state, *BAU* and *Green* scenarios). Loads according to pathways/processes at selected stations along the Rhine and its tributaries

Benzo(b)fluoranthene loads / **kg·yr^{-1}**		*Rhine*	*Neckar*	*Main*	*Rhine*	*Rhine*	*Mosel*	*Rhine*	*Rhine*
	pathway/ process	Lauter-bourg	Mann-heim	Bischofs-heim	Mainz	Koblenz	Koblenz	Bad Honnef	Bimmen/ Lobith
Present	urban area	202	62	86	391	428	102	538	747
BAU	urban area	182	56	77	352	385	92	484	672
GREEN	urban area	148	53	71	306	336	74	417	578
Present	erosion	133	31	85	261	280	34	317	333
BAU	erosion	133	31	85	261	280	34	317	333
GREEN	erosion	114	23	64	210	223	26	251	264
Present	atm. dep.	35	1	3	41	43	6	49	54
BAU	atm. dep.	32	1	3	37	39	5	44	48
GREEN	atm. dep.	28	1	3	33	34	4	39	43
Present	WWTPs	9	9	12	36	40	4	46	62
BAU	WWTPs	8	8	10	32	36	4	41	56
GREEN	WWTPs	5	5	7	20	23	2	26	36
Present	shipping	129	75	88	340	374	41	423	600
BAU	shipping	97	56	66	255	281	31	317	450
GREEN	shipping	65	37	44	170	187	20	211	300
Present	total	509	178	274	1069	1165	187	1372	1796
BAU	total	452	152	242	937	1020	166	1203	1560
GREEN	total	359	119	188	739	803	127	944	1220

***Present*:** present state (1994-1996)

BAU: 'business as usual' scenario until 2015

GREEN: 'green environment' scenario until 2015

urban area: paved urban areas

erosion: erosion from top soils

atm. dep.: direct atmospheric deposition to surface waters

WWTPs: wastewater treatment plants

shipping: shipping related activities

3.2c Results of emission analysis for benzo(a)pyrene (present state, *BAU* and *Green* scenarios). Loads according to pathways/processes at selected stations along the Rhine and its tributaries

Benzo(a)pyrene loads / **kg·yr^{-1}**		*Rhine*	*Neckar*	*Main*	*Rhine*	*Rhine*	*Mosel*	*Rhine*	*Rhine*
	pathway/ process	Lauter-bourg	Mann-heim	Bischofs-heim	Mainz	Koblenz	Koblenz	Bad Honnef	Bimmen/ Lobith
Present	urban area	196	60	83	379	414	99	521	723
BAU	urban area	176	54	75	341	373	89	469	651
GREEN	urban area	141	50	62	283	309	64	379	527
Present	erosion	67	15	43	131	140	17	158	167
BAU	erosion	67	15	43	131	140	17	158	167
GREEN	erosion	57	12	32	105	112	13	126	132
Present	atm. dep.	33	1	3	39	41	5	47	51
BAU	atm. dep.	30	1	3	35	37	5	42	46
GREEN	atm. dep.	27	1	2	31	33	4	38	41
Present	WWTPs	8	9	11	34	39	4	44	60
BAU	WWTPs	7	8	10	31	35	4	40	54
GREEN	WWTPs	5	5	7	21	23	3	27	37
Present	shipping	86	50	59	227	249	27	282	400
BAU	shipping	65	37	44	170	187	20	211	300
GREEN	shipping	43	25	29	113	125	14	141	200
Present	total	390	135	199	810	883	153	1052	1401
BAU	total	345	116	175	708	771	135	920	1218
GREEN	total	273	92	132	554	601	98	710	937

***Present*:** present state (1994-1996)

BAU: 'business as usual' scenario until 2015

GREEN: 'green environment' scenario until 2015

urban area: paved urban areas

erosion: erosion from top soils

atm. dep.: direct atmospheric deposition to surface waters

WWTPs: wastewater treatment plants

shipping: shipping related activities

3.2d Results of emission analysis for PCB 52 (present state, *BAU* and *Green* scenarios). Loads according to pathways/processes at selected stations along the Rhine and its tributaries

PCB 52 loads / **kg·yr^{-1}**		*Rhine*	*Neckar*	*Main*	*Rhine*	*Rhine*	*Mosel*	*Rhine*	*Rhine*
	pathway/ process	Lauter-bourg	Mann-heim	Bischofs-heim	Mainz	Koblenz	Koblenz	Bad Honnef	Bimmen/ Lobith
Present	urban area	1.45	0.46	0.59	2.79	3.04	0.70	3.80	5.29
BAU	urban area	0.97	0.31	0.39	1.86	2.03	0.47	2.54	3.54
GREEN	urban area	0.45	0.16	0.18	0.88	0.95	0.19	1.15	1.61
Present	erosion	0.53	0.12	0.34	1.05	1.12	0.14	1.27	1.33
BAU	erosion	0.53	0.12	0.34	1.05	1.12	0.14	1.27	1.33
GREEN	erosion	0.45	0.09	0.26	0.84	0.89	0.10	1.00	1.05
Present	atm. dep.	3.68	0.13	0.34	4.33	4.52	0.58	5.17	5.64
BAU	atm. dep.	2.43	0.09	0.23	2.86	2.98	0.39	3.41	3.72
GREEN	atm. dep.	1.21	0.04	0.11	1.43	1.49	0.19	1.71	1.86
Present	WWTPs	0.54	0.35	0.43	1.55	1.72	0.18	1.94	2.74
BAU	WWTPs	0.40	0.26	0.31	1.14	1.26	0.14	1.43	2.02
GREEN	WWTPs	0.26	0.16	0.20	0.72	0.79	0.09	0.90	1.27
Present	total	6.20	1.07	1.70	9.71	10.39	1.61	12.17	15.00
BAU	total	4.33	0.78	1.28	6.91	7.40	1.13	8.64	10.60
GREEN	total	2.37	0.46	0.74	3.86	4.13	0.57	4.76	5.79

***Present*:** present state (1994-1996)

BAU: 'business as usual' scenario until 2015

GREEN: 'green environment' scenario until 2015

urban area: paved urban areas

erosion: erosion from top soils

atm. dep.: direct atmospheric deposition to surface waters

WWTPs: wastewater treatment plants

shipping: shipping related activities

3.2e Results of emission analysis for PCB 138 (present state, *BAU* and *Green* scenarios). Loads according to pathways/processes at selected stations along the Rhine and its tributaries

PCB 138 loads / **kg·yr^{-1}**		*Rhine*	*Neckar*	*Main*	*Rhine*	*Rhine*	*Mosel*	*Rhine*	*Rhine*
	pathway/ process	Lauter-bourg	Mann-heim	Bischofs-heim	Mainz	Koblenz	Koblenz	Bad Honnef	Bimmen/ Lobith
Present	urban area	2.78	0.91	1.09	5.29	5.76	1.29	7.15	10.00
BAU	urban area	1.88	0.62	0.73	3.58	3.90	0.86	4.83	6.76
GREEN	urban area	0.88	0.32	0.33	1.69	1.83	0.34	2.20	3.08
Present	erosion	1.60	0.37	1.02	3.14	3.35	0.41	3.80	4.00
BAU	erosion	1.60	0.37	1.02	3.14	3.35	0.41	3.80	4.00
GREEN	erosion	1.36	0.28	0.77	2.51	2.68	0.31	3.01	3.16
Present	atm. dep.	6.26	0.22	0.59	7.37	7.70	0.99	8.81	9.60
BAU	atm. dep.	4.13	0.15	0.39	4.87	5.08	0.66	5.81	6.34
GREEN	atm. dep.	2.07	0.07	0.19	2.43	2.54	0.33	2.91	3.17
Present	WWTPs	0.96	0.60	0.72	2.67	2.95	0.32	3.33	4.72
BAU	WWTPs	0.71	0.45	0.54	1.99	2.20	0.24	2.48	3.51
GREEN	WWTPs	0.47	0.29	0.35	1.29	1.42	0.16	1.61	2.28
Present	total	11.60	2.10	3.42	18.48	19.77	3.01	23.09	28.32
BAU	total	8.33	1.58	2.68	13.57	14.53	2.17	16.92	20.61
GREEN	total	4.78	0.96	1.63	7.93	8.47	1.13	9.73	11.69

***Present*:** present state (1994-1996)

BAU: 'business as usual' scenario until 2015

GREEN: 'green environment' scenario until 2015

urban area: paved urban areas

erosion: erosion from top soils

atm. dep.: direct atmospheric deposition to surface waters

WWTPs: wastewater treatment plants

shipping: shipping related activities

3.2f Results of emission analysis for PCB 180 (present state, *BAU* and *Green* scenarios). Loads according to pathways/processes at selected stations along the Rhine and its tributaries

PCB 180 loads / **kg·yr^{-1}**		*Rhine*	*Neckar*	*Main*	*Rhine*	*Rhine*	*Mosel*	*Rhine*	*Rhine*
	pathway/ process	Lauter-bourg	Mann-heim	Bischofs-heim	Mainz	Koblenz	Koblenz	Bad Honnef	Bimmen/ Lobith
Present	urban area	1.73	0.56	0.69	3.30	3.59	0.81	4.47	6.25
BAU	urban area	1.16	0.38	0.46	2.22	2.42	0.54	3.01	4.21
GREEN	urban area	0.54	0.20	0.21	1.05	1.13	0.22	1.37	1.92
Present	erosion	0.93	0.22	0.60	1.83	1.96	0.24	2.22	2.33
BAU	erosion	0.93	0.22	0.60	1.83	1.96	0.24	2.22	2.33
GREEN	erosion	0.80	0.16	0.45	1.47	1.56	0.18	1.76	1.84
Present	atm. dep.	4.09	0.14	0.38	4.81	5.02	0.65	5.74	6.26
BAU	atm. dep.	2.70	0.10	0.25	3.17	3.32	0.43	3.79	4.13
GREEN	atm. dep.	1.35	0.05	0.13	1.59	1.66	0.21	1.90	2.07
Present	WWTPs	0.49	0.31	0.37	1.37	1.51	0.16	1.70	2.41
BAU	WWTPs	0.36	0.23	0.28	1.01	1.12	0.12	1.26	1.79
GREEN	WWTPs	0.23	0.15	0.18	0.65	0.72	0.08	0.81	1.15
Present	total	7.23	1.23	2.04	11.30	12.08	1.86	14.14	17.25
BAU	total	5.16	0.92	1.58	8.24	8.81	1.33	10.28	12.46
GREEN	total	2.92	0.55	0.96	4.75	5.07	0.69	5.84	6.98

***Present*:** present state (1994-1996)

BAU: 'business as usual' scenario until 2015

GREEN: 'green environment' scenario until 2015

urban area: paved urban areas

erosion: erosion from top soils

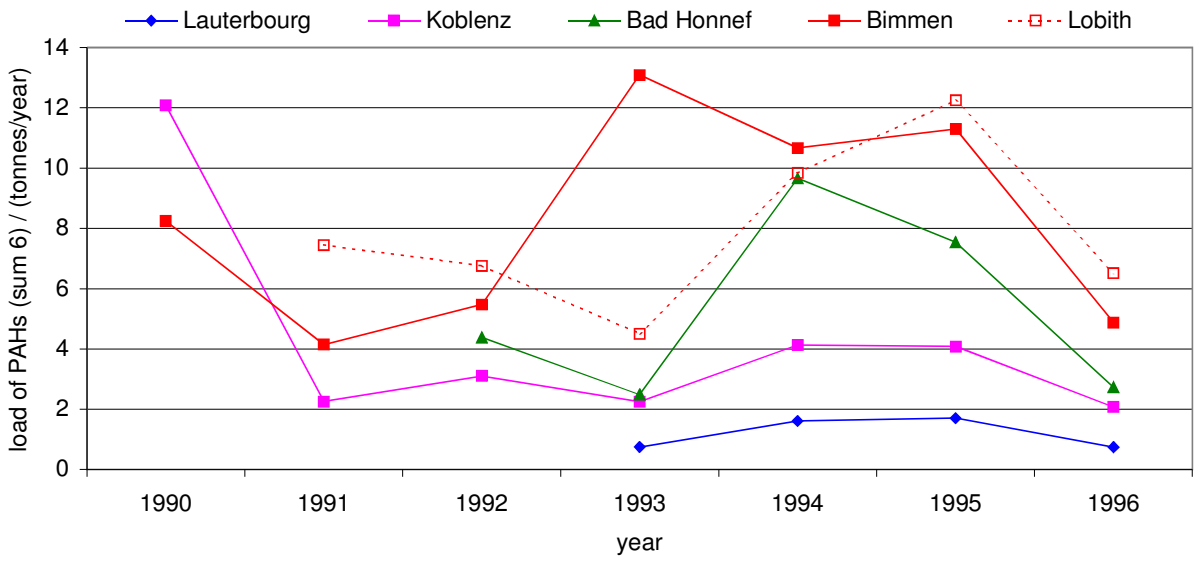
atm. dep.: direct atmospheric deposition to surface waters

WWTPs: wastewater treatment plants

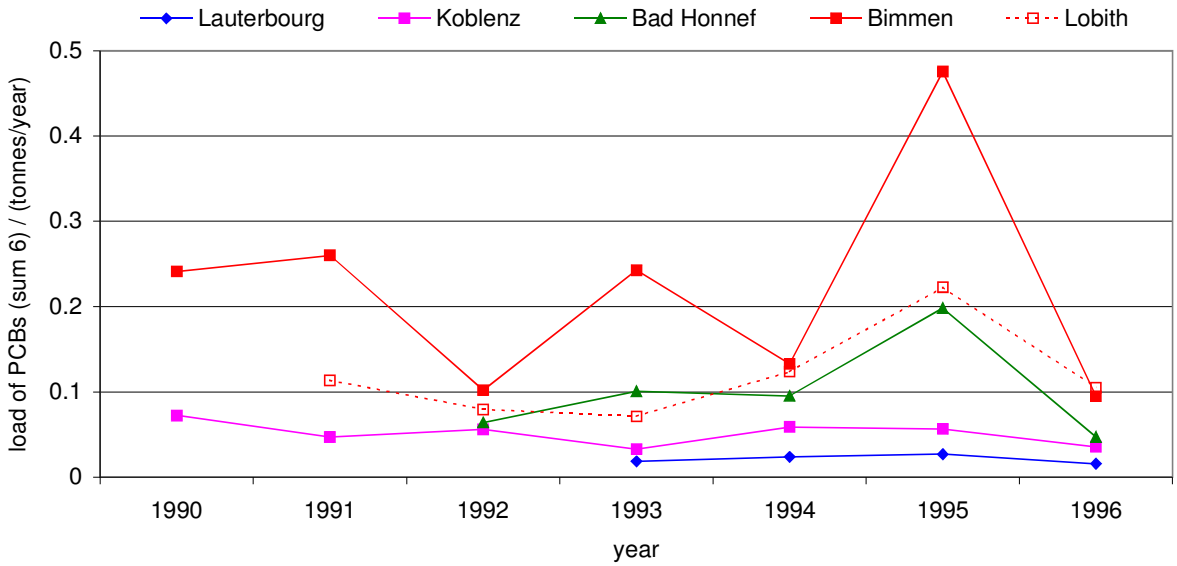
shipping: shipping related activities

Chapter 4: Trends in the quality of suspended particulate matter in the Rhine and link to the quality of dredged material in Rotterdam

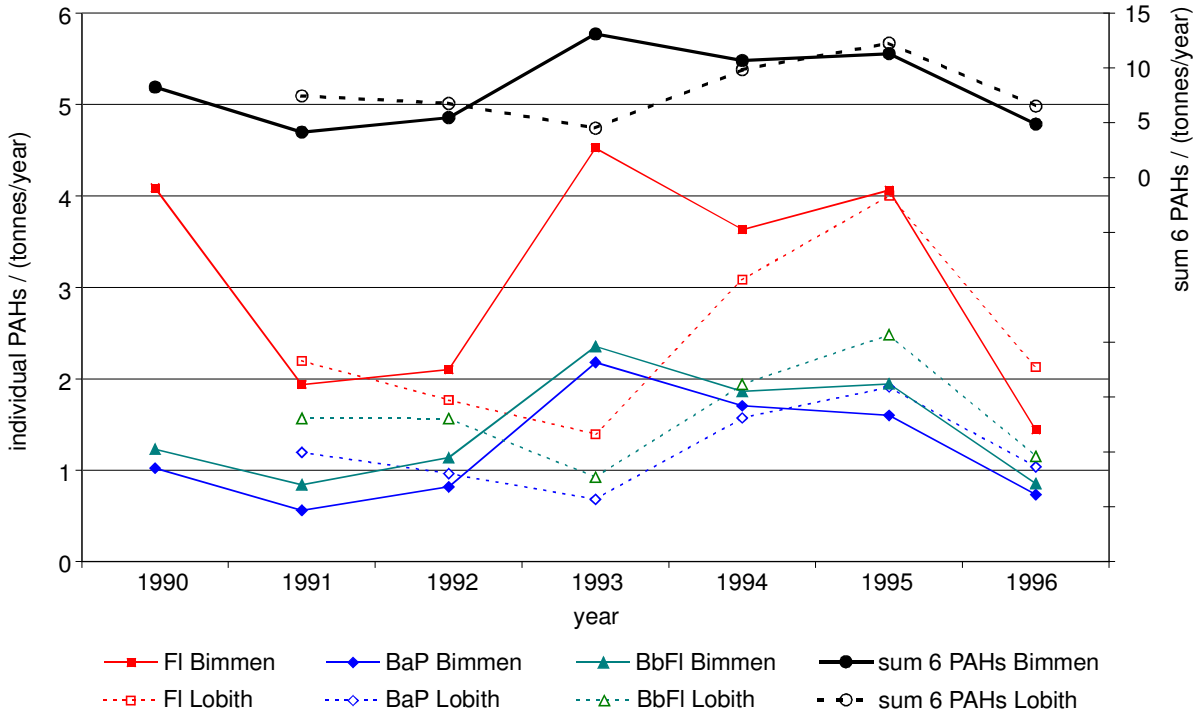
4.1a Annual loads of sum 6 PAHs along the Rhine river



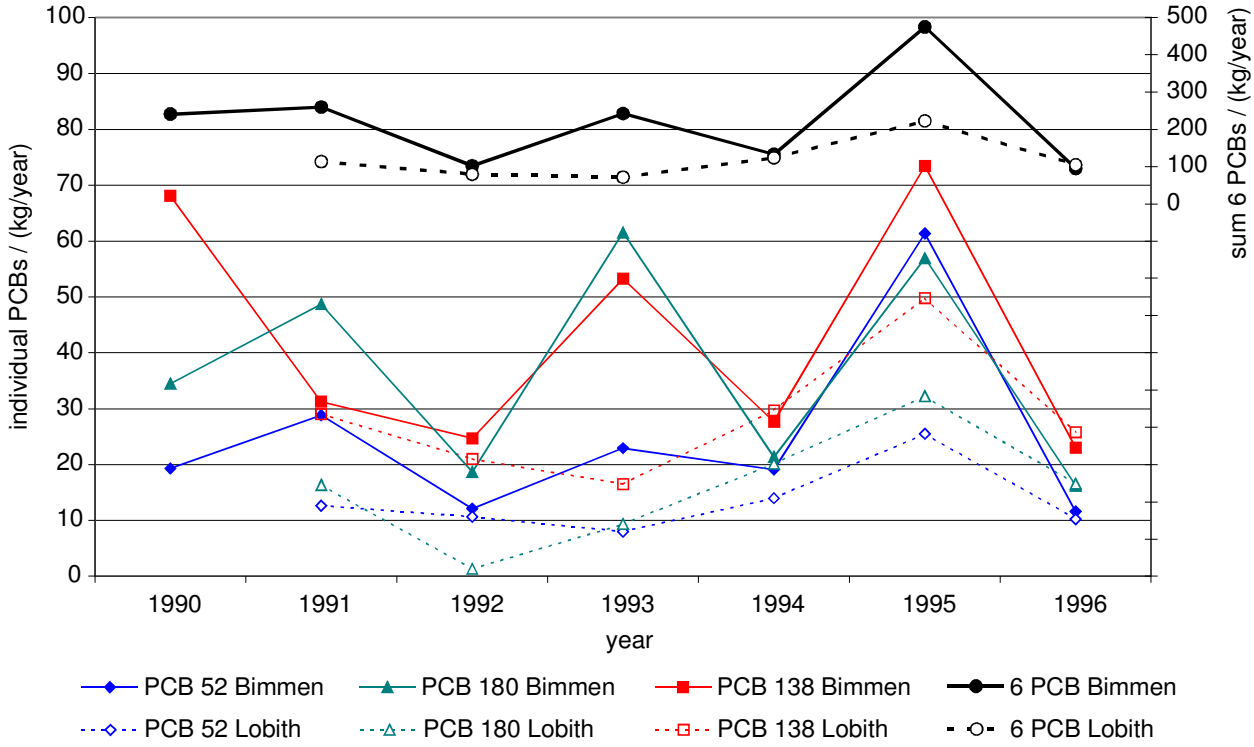
4.1b Annual loads of sum 6 PCBs along the Rhine river



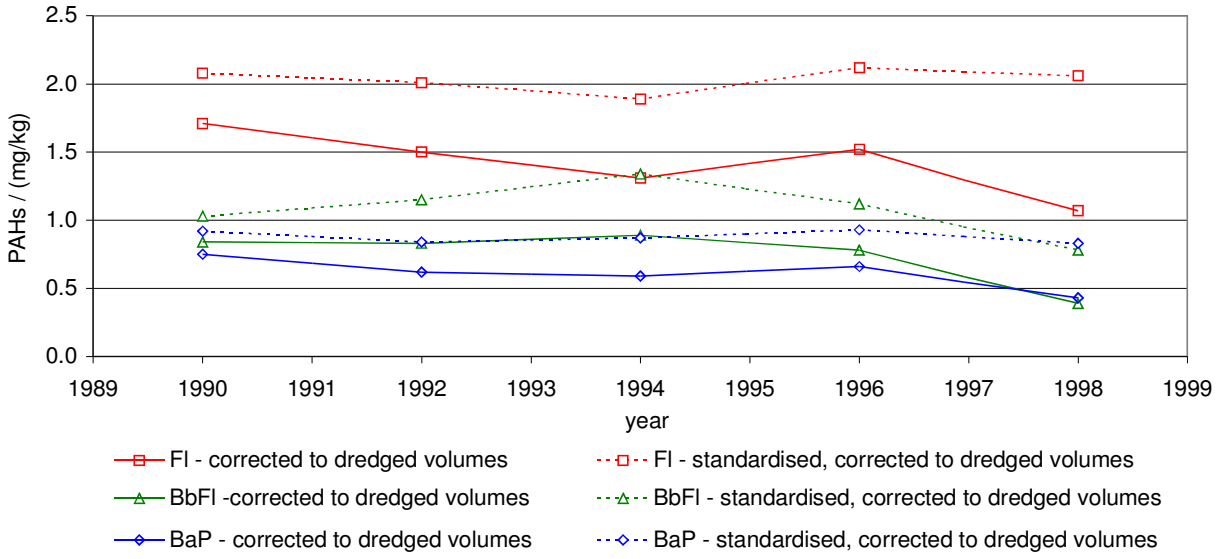
4.1c Annual loads of individual PAHs in comparison to sum 6 PAHs at Bimmen and Lobith



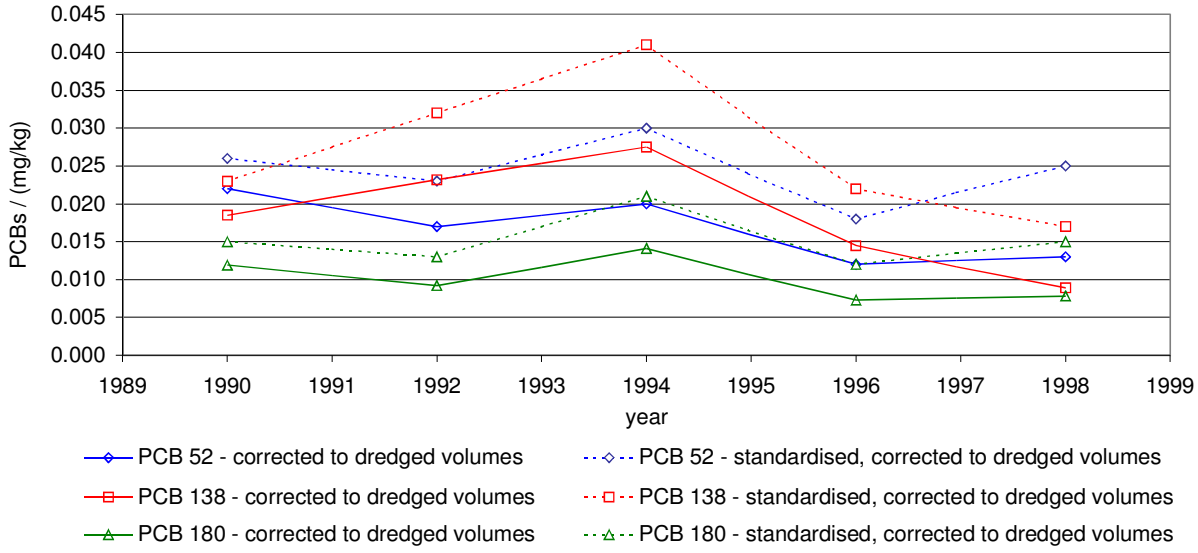
4.1d Annual loads of individual PCBs in comparison to sum 6 PCBs at Bimmen and Lobith



4.2a Averaged annual PAH concentrations in eastern parts of the port of Rotterdam



4.2b Averaged annual PCB concentrations in eastern parts of the port of Rotterdam



Chapter 5: Scenarios of future development in the Rhine catchment area and impact on dredged material quality in Rotterdam

5.1.a Estimated benzo(a)pyrene emissions to air for Germany 1994 and reduction potentials (adapted from UBA 1998a)

	1994				
	estimated emissions BaP t/yr	estimated emissions BaP %	est. reduced emissions BaP t/yr	absolute reduct.pot. BaP %	relative reduct. pot. BaP %
Total	**14**	**100**	**10**	**28**	**100**
Stationary combustion	**9.3**	**68**	**7.8**	**16**	**41**
Publ. power, cogen. & district heating	**0.0056**	**0.04**	**0.0056**	**0**	**0**
Public power etc. brown coal	0.0003		0.0003		
Public power etc. hard coal	0.00026		0.00026		
Public power etc. fuel oils	0.0050	0.04	0.0050		
Public power etc. other fuels	0.000075		0.000075		
Comm. instit. & resid. combustion	**9.3**	**68**	**7.8**	**17**	**41**
Commercial etc. brown coal	3.3	24	2.9	12	
Commercial etc. hard coal	0.69	5.0	0.61	12	
Commercial etc. fuel oils	3.4	25	2.8	16	
Commercial etc. other fuels	1.9	14	1.4	26	
Industrial combustion	**0.028**	**0.2**	**0.028**	**0**	**0**
Industrial combustion brown coal	0.0022		0.0022		
Industrial combustion hard coal	0.0057		0.0057		
Industrial combustion fuel oils	0.017	0.13	0.017		
Industrial combustion other fuels	0.0026		0.0026		
Production processes	**3.98**	**29**	**1.99**	**50**	**52**
Petroleum industries	n.q.				
Iron & steel industry					
Coke production	1.1	7.9	0.15	87	25
Electric arc furnace					
Production process	0.031		0.031		
Electrode production	0.23		0.23		
Sinter plants	0.053		0.0018	97	1.3
Non-ferrous metal industry					
Al industry					
Anode production	2.0	15	1.00	50	26
Primary Al production	0.58	4.2	0.58		
Organic chemical industry	n.q.				
Paper and pulp industry	n.q.				
Road paving with asphalt	n.q.				
Extraction & distribution of fossil fuels	n.q. 1)				
Solvent use	**0.16**	**1.1**	**0.016**	**90**	**3.7**
Wood preservation					
Production process	0.1		0.006	94	
Use	0.057		0.01	82	
Road transport	**0.27**	**1.9**	**0.13**	**50**	**3.5**
Other mobile sources & machinery	1)				
Waste treatment & disposal	**0.0078**	**0.06**	**0.0078**	**0**	**0**
Waste incineration	n.q.				
Landfill	0.0078		0.0078		

n.q.: not quantified, **1)** low relative emissions estimated

5.1.b Comparison of estimated benzo(a)pyrene emissions to air – Germany, the Netherlands, Europe

Estimated emissions for: country / countries	**GER**		**NL**		**EUR (25)**	
Estimated emissions for: year	**1994**		**1990**		**1990**	
Reference	UBA 1998a		TNO 1995		TNO 1995	
	BaP		BaP[1)]		BaP[1)]	
	t/yr	%	t/yr	%	t/yr	%
Total	**14**	**100**	**14.1**	**100**	**1138**	**100**
Stationary combustion	**9.3**	**68**	**3.3**	**23**	**425**	**37**
Publ. power, cogen. & district heating	**0.0056**	**0.04**	**0.065**	**0.46**	**1.0**	**0.09**
Public power etc. brown coal	0.0003					
Public power etc. hard coal	0.00026					
Public power etc. fuel oils	0.0050	0.04				
Public power etc. other fuels	0.000075					
Comm. instit. & resid. Combustion	**9.3**	**68**	**3.2**	**23**	**424**	**37**
Commercial etc. brown coal	3.3	24				
Commercial etc. hard coal	0.69	5.0				
Commercial etc. fuel oils	3.4	25				
Commercial etc. other fuels	1.9	14				
Industrial combustion	**0.028**	**0.2**				
Industrial combustion brown coal	0.0022					
Industrial combustion hard coal	0.0057					
Industrial combustion fuel oils	0.017	0.13				
Industrial combustion other fuels	0.0026					
Production processes	**3.98**	**29**	**2.4**	**17**	**235**	**21**
Petroleum industries						
Iron & steel industry	**1.4**	**10**	**2.1**	**15**	**117**	**10**
Coke production	1.1	7.9				
Electric arc furnace						
Production process	0.031					
Electrode production	0.23					
Sinter plants	0.053					
Non-ferrous metal industry	**2.6**	**19**	**0.33**	**2.3**	**118**	**10**
Al industry						
Anode production	2.0	15				
Primary Al production	0.58	4.2				
Organic chemical industry						
Paper and pulp industry						
Road paving with asphalt						
Extraction & distribution of fossil fuels						
Solvent use	**0.16**	**1.1**	**8**	**57**	**426**	**37**
Wood preservation			8		426	
Production process	0.1					
Use	0.057					
Road transport	**0.27**	**1.9**	**0.42**	**3.0**	**52**	**4.6**
Other mobile sources & machinery						
Waste treatment & disposal	**0.0078**	**0.06**				
Waste incineration						
Landfill	0.0078					

GER: Germany, **NL**: The Netherlands, **EUR (25)**: 25 European countries

1) The estimated emissions from publ. power, cogen. & district heating include industrial combustion.

5.1.c Estimated PCB emissions to air in Germany

Estimated emissions for: year	1990	1980	1990	2000
Reference	UBA 1997	RIVM 1995	RIVM 1995	RIVM 1995
	PCBs[1)]	PCBs[2)]	PCBs[2)]	PCBs[2)]
	t/yr	t/yr	t/yr	t/yr
Total	**43**	**170**	**44**	**19**
Stationary combustion	**1.6**	**1.5**	**1.5**	**1.5**
Publ. power, cogen. & district heating	**0.94**	**1.2**	**1.2**	**1.2**
Public power etc. brown coal	0.78			
Public power etc. hard coal	0.15			
Public power etc. fuel oils	0			
Public power etc. other fuels	0.009			
Comm. instit. & resid. combustion	**0.14**	**0.26**	**0.26**	**0.26**
Commercial etc. brown coal	0.13			
Commercial etc. hard coal	0.010			
Commercial etc. fuel oils	0			
Commercial etc. other fuels	0			
Industrial combustion	**0.50**			
Industrial combustion brown coal	0.31			
Industrial combustion hard coal	0.18			
Industrial combustion fuel oils	0			
Industrial combustion other fuels	0.0010			
Production processes	**0.29**	**0.29**	**0.29**	**0.29**
Iron & steel industry				
Coke production		0.15	0.15	0.15
Open hearth furnace	0.015			
Basic oxygen furnace	0.13			
Sinter plants	0.15	0.14	0.14	0.14
Road transport				
Waste treatment & disposal		**0.033**	**0.033**	**0.033**
Waste incineration		0.032	0.032	0.032
Landfill		0.0008	0.0008	0.0008
Open uses		116		
Electrical equipment	**41**	**52**	**41**	**17**
Transformers		1.9	1.9	0.90
Large capacitors		33	33	16
Small capacitors		16	6.2	
Re-emission from soil		**0.062**	**0.062**	**0.062**
Re-emission from water		**0.57**	**0.57**	**0.57**

1) Data included as submitted by Germany for 1985-90, but most data incl. electrical equipm. estimated by TNO.
2) The estimated emissions from publ. power, cogen. & district heating include industrial combustion.

5.1.d Comparison of estimated PCB emissions to air - Germany, the Netherlands, Europe

Estimated emissions for: country / countries	**GER**	**NL**	**EUR (25)**	**EUR (38)**	**GER**	**NL**	**EUR (25)**
Estimated emissions for: year	**1990**	**1990**	**1990**	**1990**	**2000**	**2000**	**2000**
Reference	RIVM 1995	RIVM 1995	RIVM 1995	UBA 1997	RIVM 1995	RIVM 1995	RIVM 1995
	PCBs[2)] t/yr	PCBs[2)] t/yr	PCBs[2)] t/yr	PCBs[1)] t/yr	PCBs[2)] t/yr	PCBs[2)] t/yr	PCBs[2)] t/yr
Total	**44**	**0.50**	**144**	**119**	**19**	**0.38**	**70**
Stationary combustion	**1.5**	**0.030**	**5.0**	**5.7**	**1.5**	**0.030**	**5.0**
Publ. power, cogen. & district heating	**1.2**	**0.030**	**3.8**	**3.8**	**1.2**	**0.030**	**3.8**
Public power etc. brown coal				2.6			
Public power etc. hard coal				1.2			
Public power etc. fuel oils				0.001			
Public power etc. other fuels				0.009			
Comm. instit. & resid. combustion	**0.259**	**0**	**1.2**	**0.80**	**0.26**	**0**	**1.2**
Commercial etc. brown coal				0.24			
Commercial etc. hard coal				0.55			
Commercial etc. fuel oils				0			
Commercial etc. other fuels				0			
Industrial combustion				**1.1**			
Industrial combustion brown coal				0.37			
Industrial combustion hard coal				0.67			
Industrial combustion fuel oils				0			
Industrial combustion other fuels				0.0010			
Production processes	**0.29**	**0.042**	**1.3**	**1.8**	**0.29**	**0.042**	**1.3**
Iron & steel industry							
Coke production	0.15	0.019	0.65		0.15	0.019	0.65
Pig iron				0.030			
Open hearth furnace				0.25			
Basic oxygen furnace				0.50			
Electric arc furnace				0.006			
Rolling				0.025			
Sinter plants	0.14	0.023	0.65	0.65	0.14	0.023	0.65
Road transport				**0.08**			
Waste treatment & disposal	**0.033**	**0.0099**	**0.1360**	**0.060**	**0.033**	**0.0099**	**0.14**
Waste incineration	0.032	0.0097	0.13	0.045	0.032	0.0097	0.13
Landfill	0.0008	0.0002	0.006		0.0008	0.0002	0.006
Open uses							
Electrical equipment	**41**	**0**	**116**	**111**	**17**	**0**	**42**
Transformers	1.9	0.0	8.3		0.90	0.0	3.6
Large capacitors	33	0	87		16	0	39
Small capacitors	6.2	0.1	21				
Re-emission from soil	**0.062**	**0.006**	**3.8**		**0.062**	**0.006**	**3.8**
Re-emission from water	**0.57**	**0.26**	**17**		**0.57**	**0.26**	**17**

GER: Germany, **NL**: The Netherlands, **EUR (25)**: 25 European countries, **EUR (38)**: 38 European countries

1) Data included as submitted by Germany for 1985-90, but most data incl. electrical equipment estimated by TNO.

2) The estimated emissions from publ. power, cogen. & district heating include industrial combustion.