CONVENTION ON LONG-RANGE TRANSBOUNDARY AIR POLLUTION

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Results from the multipollutant programme: Corrosion attack on zinc after 1, 2 and 4 years of exposure (1997-2001)

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EMPA

Swiss Federal Laboratories for Materials Testing and Research

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Contents

Summary and conclusions

Mass loss

Zinc specimens were exposed at 29 test sites within the UN/ECE exposure programme from 1997-2001. Samples were withdrawn and analysed after 1, 2 and 4 years of exposure under unsheltered and sheltered conditions. Material loss and the mass of corrosion products retained on the surface were determined by weighing test specimens before exposure, after exposure and after removal of the corrosion products. The chemical composition of the corrosion products was determined by x-ray diffraction (XRD) [3].

The results for **mass loss** for 1, 2 and 4 years exposure are presented in Table 8-11, 13-16 and below the mean values all in g/m^2.

	1 year sheltered	1 year unsheltered	2 years sheltered	2 years unsheltered	4 years sheltered	4 years unsheltered
Mean	4.14	7.84	7.28	13.25	8.94	24.46
S.D.	1.47	2.28	3.32	4.38	4.01	6.84
Min	2.02	4.23	3.55	7.61	2.99	15.72
Max	7.84	12.08	19.11	22.75	17.05	41.7

The results for **held back corrosion products** for 1, 2 and 4 years exposure are presented in Table 18-25 and below the mean values all in g/m^2.

	1 year sheltered	1 year unsheltered	2 years sheltered	2 years unsheltered	4 years sheltered	4 years unsheltered
Mean	6.12	7.41	9.85	11.02	12.79	18.19
S.D.	2.04	2.23	3.78	3.90	5.49	4.88
Min	2.94	3.38	5.42	6.45	4.13	10.15
Max	10.85	13.2	21.7	21.54	23.71	29.48

Runoff

The results for lost metal (runoff) for 1, 2 and 4 years exposure are presented in Table 26-28.

To calculate runoff values from corrosion data it was assumed that the predominantly corrosion product is hydrozincite $Zn_5(CO_3)_2 (OH)_6$ [3]. If other corrosion products with higher zinc content would be present all percentages given below will shift to lower numbers (negative values possible). In the case of negative percentages zinc (or other material) would be deposited.

Under sheltered conditions:
After one year of exposure 2-21% (mean = 11.8) of corroded zinc are carried into the environment. After two years the percentage ranges from 3-33% (mean = 17.8) and after four years 4-28% (mean = 13.11).

Under unsheltered conditions:
After one year 27-53% (mean = 43.7) after two years 35-63% (mean = 50.7) and after four years 39-69% (mean = 55.6) of corroded zinc are carried into the environment.

The results of mass losses in different exposure periods are presented in table 34 (sheltered samples) and in table 35 (unsheltered samples).
For the 2 years exposure the exposure period form 1997-1999 mass loss tends to be lower than during the exposure period from 1987-1989. This is true for sheltered and unsheltered samples.
For the 1 year exposure period the mass losses found during the exposure periods 1990-1991, 1992-1993, 1994-1995 and 1997-1998 were compared. The mass loss results don't significantly differ from one exposure period to the next.

Dose-response functions

The unified dose-response functions from the 8 year exposure programme 1987-1995 [4] were applied on the conditions of the exposure programme for zinc 1997-2001. The predicted and measured mass loss results for the 1, 2 and 4 years exposure period differ strongly. This means that the measured results for mass loss could not be predicted in a satisfying way compared to the earlier measurements [5].

Adapted dose-response functions for this time period to predict the mass loss concise have to be calculated taking into account the results of HNO_3 and particle measurements from the 5th Framework program Multi-Assess ending 2004.
To find these phenomenological functions the procedure described in [5] can be extended in the modelling part.
The restriction of maximal two additive parts for dry and wet corrosion attack complicates the mathematical form of the functions especially if one takes more environmental parameters into account.
In table 37 one sees that the contribution of the wet part is at most exposure sites marginal which means that the "dry" part of the unsheltered DRF includes the rain contribution to a certain amount which explains the difference to the sheltered DRF.
Therefore it seems possible to get better prediction of the corrosion attack if one tries out different mathematical functions with possibly more than two additive parts. In addition the sensitivity of the model to each parameter would be more visible.
These new functions have to accomplish the boundary conditions given by the corrosion process, the environmental parameters and should lead to stable functions in time as stated in [6].

Methods

Test Sites

Table 1 List of test sites

Site	No.	Country
Prague	1	CZ
Kopisty	3	CZ
Ähtäri	5	FIN
Waldhof Langenbrügge	7	D
Langenfeld	9	D
Bottrop	10	D
Rome	13	I
Casaccia	14	I
Milan	15	I
Venice	16	I
Oslo	21	NO
Birkenes	23	NO
Stockholm South	24	S
Aspvreten	26	S
Lincoln Cathedral	27	UK
Madrid	31	E
Toledo	33	E
Moscow	34	RU
Lahemaa	35	EE
Lisbon	36	P
Dorset	37	CA
Paris	40	F
Berlin	41	D
Tel Aviv	43	IL
Svanvik	44	NO
Chaumont	45	CH
London	46	UK
Los Angeles	47	US
Antwerpen	49	B
Warsow*)	50	PL

*) only 1 year Trend samples 2000/01

Material
Zinc plates (99.99% Zn) 100 x 150 mm in size and 2 mm in thickness were used. The samples were degreased in petrol and glass blasted (R_a ca. 2.9 μm) before exposure. Three zinc plates were exposed at each sampling site and each exposure duration under sheltered and unsheltered conditions. Chemical composition of the corrosion products was determined by X-ray diffraction (XRD).

Exposure
The specimens were exposed according to ISO 8565 (i.e. 45° facing to south).

Investigation methods
The evaluation is based on gravimetric measurements of the samples according to ASTM G1-90. The mass of corrosion products retained on the surface and material loss were determined by weighing test specimens before exposure (m_i), after exposure ($m_i$bp) and after removal of the corrosion products ($m_i$ap); (bp = before pickling, ap = after pickling). After exposure corrosion products were removed using 10% chromic acid as pickling solution at a temperature of 80 °C. Samples were left in the pickling solution for 2 to 5 minutes. This procedure was adapted from ISO 8407.

Lost metal and runoff
To estimate the ecological influence of zinc corrosion we need to know the effective loss of metallic material to the environment. The lost metal was calculated by comparing the held back corrosion products to the theoretical amount of corrosion products. The corrosion products in crystalline form were identified with X-ray diffraction as hydrozincite $Zn_5(CO_3)_2(OH)_6$ [3]. With this information the theoretical amount of corrosion products can be calculated from the total mass loss of metallic zinc. The mass of held back corrosion products was determined by weighing test specimen before pickling and after pickling.
From the lost metal it is possible to calculate the runoff expressed as metallic material in g/m^2. Runoff can only be established with unsheltered specimens. Because only the upper side of the specimen is exposed to the rain the value of lost metal gives only an approximation of the real runoff of metallic material.

Results

Raw data

Table 2 Sheltered samples 1 year exposure

Raw data, mass before exposure (m_i), after exposure ($m_i$bp) and after removal of the corrosion products ($m_i$ap).

Site No.	m_1	$m_1$bp	$m_1$ap	m_2	$m_2$bp	$m_2$ap	m_3	$m_3$bp	$m_3$ap
	g	g	g	g	g	g	g	g	g
1	221.8735	221.9222	221.7413	218.1295	218.1839	217.9857	221.0989	221.1501	220.9636
3	217.2275	217.3238	217.0239	216.8052	216.9014	216.6064	218.3683	218.4629	218.1735
5	217.0866	217.1456	216.9935	216.2551	216.3236	216.1596	216.3899	216.4478	216.2923
7	218.4011	218.4771	218.2682	221.1090	221.1908	220.9725	217.2414	217.3314	217.0947
9	221.6588	221.7107	221.5432	218.0114	218.0678	217.8909	220.7374	220.7921	220.6220
10	217.7127	217.7739	217.5539	216.6323	216.6959	216.4770	218.1941	218.2589	218.0309
13	216.8393	216.8868	216.7317	218.1211	218.1642	218.0166	219.5977	219.6435	219.4971
14	218.2919	218.3366	218.2118	220.7125	220.7546	220.6384	216.9530	216.9965	216.8733
15	missing	missing	missing	missing	missing	missing	missing	missing	missing
16	216.1253	216.2117	215.9737	217.9411	218.0206	217.7990	216.5315	216.6122	216.3884
21	218.5339	218.5665	218.4724	216.7600	216.7959	216.6923	217.8396	217.8756	217.7717
23	217.8770	217.9317	217.7933	217.5266	217.6025	217.4054	218.5006	218.5707	218.3960
24	218.5775	218.6169	218.4888	219.0342	219.0726	218.9470	219.8858	219.9260	219.7970
26	218.2319	218.2819	218.1588	216.7655	216.8160	216.6923	217.3467	217.4003	217.2741
27	219.6348	219.7361	219.4212	219.6606	219.7557	219.4665	217.8053	217.8917	217.6206
31	218.8988	218.9274	218.8346	218.0214	218.0488	217.9573	217.6644	217.6909	217.6108
33	220.1019	220.1328	220.0459	217.2621	217.2979	217.1972	218.7938	218.8307	218.7287
34	219.0961	219.1907	218.9187	221.0762	221.1732	220.8973	220.2319	220.3183	220.0657
35	216.5293	216.5894	216.4149	217.0080	217.0639	216.8929	217.3546	217.4145	217.2417
36	219.8348	219.9286	219.5886	218.0883	218.1764	217.8681	219.6274	219.7167	219.3882
37	217.7312	217.7735	217.6350	220.0252	220.0668	219.9339	218.0710	218.1141	217.9752
40	218.8947	218.9481	218.7783	217.7631	217.8103	217.6541	217.5429	217.5954	217.4305
41	219.7691	219.8337	219.6329	218.8125	218.8688	218.6901	218.9798	219.0324	218.8650
43	218.4478	218.4966	218.3220	217.9494	217.9996	217.8266	218.6434	218.7004	218.5074
44	217.1425	217.1930	217.0176	217.8317	217.8833	217.7026	221.4036	221.4534	221.2816
45	216.9073	216.9692	216.8043	217.0463	217.1135	216.9342	218.0286	218.0948	217.9197
46	218.2344	218.2892	218.0623	218.1054	218.1629	217.9359	218.5230	218.5800	218.3558
47	missing	missing	missing	missing	missing	missing	missing	missing	missing
49	217.9529	218.0107	217.8048	221.2493	221.3062	221.1020	219.6180	219.6732	219.4750

Table 3 Unsheltered samples 1 year exposure

Raw data, mass before exposure (m_i), after exposure ($m_i$bp) and after removal of the corrosion products ($m_i$ap)

Site No.	m_1	$m_1$bp	$m_1$ap	m_2	$m_2$bp	$m_2$ap	m_3	$m_3$bp	$m_3$ap
	g	g	g	g	g	g	g	g	g
1	218.6602	218.6371	218.4683	222.9200	222.8914	222.7174	221.5981	221.5739	221.3930
3	218.0405	218.0293	217.7420	219.2350	219.2126	218.9376	219.7907	219.7785	219.4744
5	216.9707	217.0214	216.7659	219.6352	219.6789	219.4326	215.4443	215.4904	215.2431
7	217.9545	217.9397	217.7705	221.9308	221.9192	221.7411	221.1894	221.1789	220.9950
9	218.1785	218.1531	217.8794	219.7104	219.6765	219.4672	218.6340	218.6041	218.3741
10	217.8065	217.7165	217.4486	218.8043	218.7214	218.4422	219.6249	219.5410	219.2575
13	217.6685	217.6279	217.4225	221.3022	221.2652	221.0429	222.4189	222.3820	222.1682
14	220.8868	220.8762	220.6573	217.5138	217.4994	217.2944	220.6385	220.6310	220.3987
15	220.0332	219.9908	219.8021	217.9316	217.6550	217.4765	216.9650	216.9118	216.7184
16	218.3905	218.3770	218.1961	219.8715	219.8628	219.6681	219.3052	219.2977	219.1011
21	218.1247	218.1089	217.9855	219.2254	219.2104	219.0843	218.1457	218.1329	218.0005
23	219.4758	219.4582	219.2469	219.1986	219.1808	218.9655	219.5204	219.4987	219.2830
24	219.7950	219.8009	219.5616	219.1537	219.1547	218.9274	218.3808	218.3834	218.1562
26	219.1392	219.2167	218.8582	217.2577	217.2902	217.0616	219.3946	219.4338	219.1757
27	219.5091	219.4788	219.1544	220.1293	220.1168	219.7850	218.9460	218.9300	218.5950
31	219.3624	219.3633	219.2259	220.5607	220.5628	220.4269	218.8471	218.8486	218.7114
33	218.8012	218.8068	218.6559	221.3138	221.3126	221.1807	219.4535	219.4504	219.3217
34	220.0637	220.0461	219.8512	218.8244	218.8088	218.6175	219.1734	219.1689	218.9696
35	219.7987	219.8101	219.5733	219.1550	219.1577	218.9387	218.5250	218.5291	218.3120
36	218.5471	218.5483	218.2765	220.5735	220.5780	220.3115	220.8189	220.8209	220.5468
37	217.4040	217.3885	217.2410	218.4694	218.4513	218.3101	220.1934	220.1757	220.0270
40	221.9020	221.9013	221.5752	220.3951	220.3961	220.0405	217.6673	217.6702	217.3279
41	220.0971	220.0946	219.9256	219.2922	219.2837	219.0895	219.3606	219.3590	219.1512
43	221.6785	221.7177	221.2875	218.8702	218.9073	218.5173	218.9520	218.9809	218.6128
44	218.4657	218.4927	218.2803	217.8949	217.9239	217.6991	219.8769	219.9060	219.6896
45	220.8571	220.8331	220.7225	219.3117	219.2856	219.1842	218.8958	218.8694	218.7773
46	218.6477	218.5953	218.3824	218.1716	218.1220	217.9076	219.3948	219.3440	219.1218
47	217.4764	217.4695	217.2579	221.3019	221.2977	221.0878	217.5749	217.5717	217.3673
49	217.2950	217.2685	216.9972	220.0291	220.0005	219.7202	220.1658	220.1298	219.8771

Table 4 Sheltered samples 2 years exposure

Raw data, mass before exposure (m_i), after exposure ($m_i$bp) and after removal of the corrosion products ($m_i$ap)

Site No.	m_1	$m_1$bp	$m_1$ap	m_2	$m_2$bp	$m_2$ap	m_3	$m_3$bp	$m_3$ap
	g	g	g	g	g	g	g	g	g
1	217.7262	217.8106	217.5358	217.5690	217.6495	217.3806	220.7065	220.7873	220.5123
3	219.5337	219.6483	219.3003	219.9798	220.1012	219.7428	219.7241	219.8519	219.4874
5	217.5738	217.6429	217.4628	219.7819	219.8499	219.6778	220.2148	220.2789	220.1105
7	219.8909	219.9835	219.7168	220.3784	220.4684	220.2174	219.9653	220.0539	219.8092
9	218.9913	219.0464	218.8384	218.8190	218.8751	218.6689	219.0541	219.1086	218.9099
10	217.0360	217.1566	216.7938	218.6482	218.7667	218.4131	218.7914	218.9095	218.5616
13	220.1014	220.1621	219.9559	219.6396	219.7005	219.4884	220.0369	220.0992	219.9007
14	219.8156	219.8688	219.7002	219.1252	219.1746	219.0208	217.8954	217.9472	217.7821
15	216.7636	216.8339	216.5865	216.4977	216.5685	216.3233	218.2244	218.2959	218.0459
16	218.0893	218.1839	217.9016	216.7015	216.7924	216.5279	216.2665	216.3604	216.0756
21	217.2373	217.2872	217.1125	218.0148	218.0711	217.8887	216.5053	216.5626	216.3851
23	219.2007	219.2719	219.0536	217.5960	217.6655	217.4497	216.2092	216.2852	216.0612
24	218.6378	218.7029	218.4384	217.5713	217.6336	217.3790	218.6447	218.7124	218.4579
26	218.0957	218.1503	217.9814	219.0652	219.1193	218.9502	219.2083	219.2643	219.0826
27	216.0046	216.1515	215.6773	216.9327	217.0844	216.6231	216.5939	216.7201	216.3065
31	215.8248	215.8638	215.6829	215.5382	215.5797	215.4044	216.0630	216.1077	215.9108
33	218.2904	218.3332	218.1708	219.6730	219.7162	219.5513	219.8171	219.8611	219.6891
34	218.0370	218.1205	217.7792	219.1391	219.2224	218.8730	217.4115	217.4930	217.1334
35	216.0471	216.1250	215.8495	216.1118	216.1905	215.9104	217.0264	217.1060	216.8125
36	218.5501	218.6551	218.2101	217.8756	217.9926	217.5029	216.3836	216.5225	215.9941
37	217.6878	217.7417	217.5028	217.0204	217.0787	216.8156	217.9796	218.0349	217.7902
40	218.7706	218.8475	218.4532	218.1971	218.2726	217.8906	218.8870	218.9323	218.5772
41	217.5699	217.6532	217.3170	218.3028	218.3814	218.0607	217.0038	217.0835	216.7481
43	219.7999	219.8626	219.5685	217.3779	217.4463	217.1226	219.0178	219.0816	218.7624
44	219.8920	219.9640	219.5949	217.5174	217.5897	217.2131	218.0393	218.1089	217.7261
45	217.9597	218.0339	217.7377	220.4163	220.4982	220.1810	217.6575	217.7271	217.4324
46	218.2508	218.3280	217.6603	220.4059	220.4841	219.8000	219.4802	219.5581	218.9569
47	missing	missing	missing	missing	missing	missing	missing	missing	missing
49	218.0146	218.1171	217.6843	217.6853	217.7867	217.3651	218.0090	218.1047	217.7125

Table 5 Unsheltered samples 2 years exposure

Raw data, mass before exposure (m_i), after exposure ($m_i$bp) and after removal of the corrosion products ($m_i$ap)

Site No.	m_1	$m_1$bp	$m_1$ap	m_2	$m_2$bp	$m_2$ap	m_3	$m_3$bp	$m_3$ap
	g	g	g	g	g	g	g	g	g
1	222.7760	222.6942	222.4903	217.8206	217.7434	217.5485	223.0595	222.9850	222.7831
3	220.1957	220.0935	219.7578	221.4307	221.2960	220.9690	220.6238	220.4929	220.1469
5	219.3700	219.3812	219.1124	218.8452	218.8561	218.5813	217.4246	217.4264	217.1592
7	222.2207	222.1671	221.9354	220.4598	220.4039	220.1829	220.1489	220.0967	219.8752
9	220.1927	220.0973	219.7995	218.0065	217.8939	217.5891	218.8924	218.7806	218.4791
10	217.3211	217.0700	216.6764	216.6678	216.4379	216.0473	219.6908	217.7799	217.3812
13	220.7838	220.7134	220.4496	220.6975	220.6265	220.3750	218.6992	218.6320	218.3842
14	222.0916	222.0480	221.7614	220.2446	220.2054	219.9202	218.9830	218.9444	218.6699
15	216.8987	216.8060	216.5748	217.7098	217.6121	217.3890	218.7768	218.6769	218.4583
16	217.7655	217.7315	217.4806	218.6591	218.6208	218.3777	218.2461	218.2271	217.9413
21	219.5394	219.4731	219.2736	218.5617	218.4974	218.2898	218.1330	218.0666	217.8607
23	219.4709	219.3468	219.0589	219.0576	218.9388	218.6599	218.5970	218.4663	218.1432
24	218.3382	218.2767	217.9676	218.2884	218.2236	217.9144	218.0993	218.0358	217.7298
26	222.3982	222.4244	222.0233	218.7782	218.8073	218.3981	220.8312	220.8602	220.4375
27	219.5773	219.4585	218.9752	220.6606	220.5430	220.0675	219.6434	219.5251	219.0405
31	221.2592	221.2176	221.0185	220.4562	220.4210	220.2292	220.8195	220.7832	220.5714
33	218.2135	218.1776	217.9849	218.1705	218.1366	217.9520	219.9824	219.9478	219.7443
34	216.0164	215.9548	215.6938	216.9528	216.8987	216.6194	218.0239	217.9662	217.6877
35	218.6754	218.6299	218.3721	217.5213	217.4812	217.2079	217.7364	217.6926	217.4135
36	220.2603	220.1957	219.7332	217.7168	217.6455	217.1749	220.4401	220.3748	219.8948
37	217.9891	217.9059	217.6515	219.8878	219.8050	219.5493	219.9380	219.8569	219.5699
40	220.4519	220.3586	219.8785	220.3900	220.3061	219.7917	218.8906	218.7926	218.2917
41	219.2580	219.2054	218.8394	218.5553	218.5085	218.1507	217.6078	217.5758	217.2374
43	220.4040	220.4635	219.8588	221.2399	221.2912	220.6563	218.9631	219.0268	218.3272
44	218.7980	218.7807	218.3917	219.4012	219.3904	218.9997	219.1205	219.1787	218.7899
45	218.4816	218.4051	218.1988	219.3428	219.2696	219.0928	218.1401	218.0641	217.8582
46	218.6536	218.4987	218.0704	220.2553	220.1049	219.6864	220.1807	220.0372	219.6038
47	220.9167	220.9290	220.4793	219.9677	219.9528	219.5630	219.7704	219.7630	219.3450
49	218.5439	218.3802	217.8190	219.1574	219.0146	218.4876	219.1511	219.0098	218.4982

Table 6 Sheltered samples 4 years exposure

Raw data, mass before exposure (m_i), after exposure ($m_i$bp) and after removal of the corrosion products ($m_i$ap)

Site No.	m_1	$m_1$bp	$m_1$ap	m_2	$m_2$bp	$m_2$ap	m_3	$m_3$bp	$m_3$ap
	g	g	g	g	g	g	g	g	g
1	219.8003	219.9298	219.4031	216.7933	216.9184	216.3630	215.4686	215.5991	214.9979
3	220.0599	220.2765	219.5665	218.4147	218.6070	217.9551	219.5061	219.6794	218.9639
5	219.6957	219.7773	219.4198	219.7866	219.8699	219.5094	218.0370	218.1185	217.7660
7	218.2180	218.3271	217.8071	216.9218	217.0262	216.4796	217.0845	217.1781	216.6774
9	218.0334	218.1333	217.6746	219.6401	219.7380	219.2460	217.0951	217.1909	216.6761
10	218.0378	218.2376	217.5312	217.3066	217.5124	216.7812	217.5678	217.7610	217.0649
13	missing	missing	missing	missing	missing	missing	missing	missing	missing
14	217.0549	217.1249	216.7020	218.4487	218.5021	218.2093	218.6196	218.6836	218.3003
15	216.6739	216.8287	216.3354	216.6722	216.8155	216.3771	217.4472	217.6020	217.1284
16	220.1173	220.3012	219.7485	219.1301	219.2933	218.7917	219.8326	220.0104	219.4886
21	218.3914	218.4642	218.2070	218.3626	218.4407	218.1800	217.9757	218.0575	217.7937
23	215.4589	215.5419	215.2796	219.4160	219.4957	219.2469	218.6952	218.7755	218.5250
24	218.1275	218.2363	217.8625	218.8410	218.9491	218.5930	218.7115	218.8218	218.4638
26	217.5240	217.5917	217.4031	218.0726	218.1416	217.9462	218.2528	218.3202	218.1294
27	220.0977	220.2654	219.7488	218.5344	218.7077	218.1937	218.7189	218.8988	218.3822
31	217.1171	217.1936	216.9770	218.1057	218.1775	217.9540	216.3346	216.4064	216.1869
33	217.8729	217.9323	217.7709	217.0447	217.0920	216.9564	220.6593	220.7185	220.5540
34	217.8505	217.9748	217.6282	219.4893	219.6366	219.2666	217.9940	218.1345	217.7714
35	216.9786	217.0804	216.8007	216.2288	216.3302	216.0541	217.2568	217.3584	217.0802
36	218.6282	218.8572	218.1915	217.9410	218.1891	217.5137	221.2458	221.5004	220.7741
37	218.2418	218.3238	218.0745	221.2130	221.2915	221.0545	219.6840	219.7707	219.5117
40	217.6879	217.8178	217.4675	217.4302	217.5441	217.2277	216.8576	216.9722	216.6338
41	217.4331	217.5853	217.1948	217.7447	217.8929	217.4986	215.9345	216.0901	215.6559
43	217.9514	218.0311	217.7848	218.8689	218.9442	218.7079	217.6700	217.7524	217.4914
44	216.5492	216.6797	216.3269	217.8710	218.0047	217.6330	217.8734	218.0010	217.6473
45	218.4417	218.5215	218.3026	218.9604	219.0363	218.8236	216.9385	217.0142	216.7978
46	220.8186	220.9683	220.5166	220.4260	220.5724	220.1162	215.8329	215.9802	215.5398
47	217.3259	217.3645	217.2327	219.9507	219.9823	219.8662	217.2491	217.2819	217.1581
49	217.2991	217.4590	217.0179	217.9706	218.1335	217.6920	219.4060	219.5656	219.1186

Table 7 Unsheltered samples 4 years exposure

Raw data, mass before exposure (m_i), after exposure ($m_i$bp) and after removal of the corrosion products ($m_i$ap)

Site No.	m_1	$m_1$bp	$m_1$ap	m_2	$m_2$bp	$m_2$ap	m_3	$m_3$bp	$m_3$ap
	g	g	g	g	g	g	g	g	g
1	222.1869	222.0374	221.6585	222.2186	222.0573	221.7299	221.6418	221.4906	221.1339
3	220.9219	220.6979	220.1694	220.2271	219.9350	219.4251	217.7606	217.4634	216.9195
5	215.7072	215.6356	215.2235	217.7466	217.6654	217.2620	218.6976	218.6177	218.2232
7	218.7042	218.5605	218.1310	218.2603	218.1214	217.6829	218.6351	218.5014	218.0372
9	221.1906	220.9421	220.2938	220.5532	220.3024	219.7134	221.0960	220.8509	220.3309
10	219.6906	219.1245	218.3811	216.8146	216.3194	215.6538	216.5142	215.9968	215.2312
13	missing	missing	missing	missing	missing	missing	missing	missing	missing
14	217.4754	217.3658	216.8026	216.8447	216.7289	216.1187	218.9663	218.8634	218.3285
15	217.1746	216.9254	216.3966	217.8258	217.5715	216.9538	217.8922	217.6313	217.0657
16	219.0420	218.9425	218.4719	218.4003	218.3374	217.8396	219.2663	219.1762	218.7161
21	217.0904	216.9161	216.5578	220.2742	220.0986	219.6963	220.3792	220.2010	219.7676
23	219.8281	219.4995	218.9847	219.0068	218.6860	218.1394	220.9203	220.6000	219.9967
24	219.6359	219.4259	218.8673	219.4157	219.2096	218.7015	218.8363	218.6230	218.1122
26	219.4358	219.3310	218.8563	218.4917	218.3780	217.8808	219.0402	218.9170	218.4189
27	217.5530	217.1863	216.4606	219.2877	218.9621	218.2369	219.8834	219.5742	218.8407
31	219.5429	219.4669	218.9707	220.2274	220.1509	219.7264	218.3568	218.2804	217.8327
33	219.4706	219.3707	218.9171	220.5524	220.4557	220.0260	219.7809	219.6824	219.1882
34	217.9753	217.8082	217.5167	218.8502	218.6813	218.3567	218.6332	218.4687	218.1708
35	218.5115	218.3624	217.8704	219.4045	219.2500	218.7327	217.1830	217.0304	216.5391
36	221.8238	221.6641	220.9572	219.4395	219.3031	218.4548	218.5503	218.4125	217.5173
37	219.3480	219.1693	218.7114	220.3817	220.1921	219.7284	220.0864	219.8957	219.4085
40	219.2630	219.0103	218.1302	219.0340	218.7322	217.8460	218.5681	218.2628	217.3758
41	219.4282	219.3106	218.6856	217.5125	217.3966	216.7153	221.2477	221.1518	220.5266
43	219.3142	219.2772	218.4850	219.2136	219.2287	218.3765	218.0965	218.1789	217.3312
44	218.9578	218.8750	218.3184	217.6809	217.5964	217.0122	218.2744	218.1870	217.5702
45	218.5792	218.4231	218.0648	220.9946	220.8458	220.4781	219.0860	218.9189	218.5578
46	222.1473	221.8034	221.2334	217.1331	216.7717	216.1354	221.2721	220.9051	220.4163
47	219.7116	219.6735	219.1101	220.9785	220.9350	220.3259	219.8961	219.8440	219.1791
49	217.0030	216.6347	216.1908	219.0390	218.6229	218.1879	219.0112	218.5994	218.1646

Calculations

1. Mass loss (g/exposed zinc plate) = $m_i - m_i ap$

2. Mean value of mass loss (g/m^2):

$$A = \frac{(m_1 - m_1 ap) + (m_2 - m_2 ap) + (m_3 - m_3 ap)}{3} * \frac{1}{0.03}$$

(area: $3 \cdot 10^4$ mm^2 = $3 \cdot 10^{-2}$ m^2)

3. Mass of held back corrosion product (g/exposed plate) = $m_i bp - m_i ap$

4. Mean value of mass of held back corrosion products (g/m^2):

$$B = \frac{(m_1 bp - m_1 ap) + (m_2 bp - m_2 ap) + (m_3 bp - m_3 ap)}{3} * \frac{1}{0.03}$$

5. Lost metal (runoff) (g/m^2)

$$C = A - \left(B * \frac{5 * MWZn}{MWHydrozincite}\right)$$

(MW_{Zn}: 65.39 g; $MW_{Hydrozincite}$: 549.01 g)

6. Corrosion rate (g/(m^2 * a)) = $\frac{A}{t}$ (A = mass loss, t = time of exposure in years)

7. Runoff rate (g/(m^2 * a)) = $\frac{C}{t}$ (C = lost metal (runoff), t = time of exposure in years)

Mass Loss

Table 8 Mass loss sheltered samples (1 year exposure)

Mass loss (g/exposed zinc plate) = $m_i - m_i ap$

Site	Site No.	m_1-$m_1$ap	m_2-$m_2$ap	m_3-$m_3$ap	mean	standard deviation	Rel. standard deviation
		g	g	g	g	g	%
Prague	1	0.1322	0.1438	0.1353	0.1371	0.0060	4.4
Kopisty	3	0.2036	0.1988	0.1948	0.1991	0.0044	2.2
Ähtäri	5	0.0931	0.0955	0.0976	0.0954	0.0023	2.4
Waldhof Langenbr.	7	0.1329	0.1365	0.1467	0.1387	0.0072	5.2
Langenfeld	9	0.1156	0.1205	0.1154	0.1172	0.0029	2.5
Bottrop	10	0.1588	0.1553	0.1632	0.1591	0.0040	2.5
Rome	13	0.1076	0.1045	0.1006	0.1042	0.0035	3.4
Casaccia	14	0.0801	0.0741	0.0797	0.0780	0.0034	4.3
Milan	15	missing	missing	missing	missing	missing	missing
Venice	16	0.1516	0.1421	0.1431	0.1456	0.0052	3.6
Oslo	21	0.0615	0.0677	0.0679	0.0657	0.0036	5.5
Birkenes	23	0.0837	0.1212	0.1046	0.1032	0.0188	18.2
Stockholm South	24	0.0887	0.0872	0.0888	0.0882	0.0009	1.0
Aspvreten	26	0.0731	0.0732	0.0726	0.0730	0.0003	0.4
Lincoln Cathedral	27	0.2136	0.1941	0.1847	0.1975	0.0147	7.5
Madrid	31	0.0642	0.0641	0.0536	0.0606	0.0061	10.0
Toledo	33	0.0560	0.0649	0.0651	0.0620	0.0052	8.4
Moscow	34	0.1774	0.1789	0.1662	0.1742	0.0069	4.0
Lahemaa	35	0.1144	0.1151	0.1129	0.1141	0.0011	1.0
Lisbon	36	0.2462	0.2202	0.2392	0.2352	0.0135	5.7
Dorset	37	0.0962	0.0913	0.0958	0.0944	0.0027	2.9
Paris	40	0.1164	0.1090	0.1124	0.1126	0.0037	3.3
Berlin	41	0.1362	0.1224	0.1148	0.1245	0.0108	8.7
Tel Aviv	43	0.1258	0.1228	0.1360	0.1282	0.0069	5.4
Svanvik	44	0.1249	0.1291	0.1220	0.1253	0.0036	2.8
Chaumont	45	0.1030	0.1121	0.1089	0.1080	0.0046	4.3
London	46	0.1721	0.1695	0.1672	0.1696	0.0025	1.4
Los Angeles	47	missing	missing	missing	missing	missing	missing
Antwerpen	49	0.1481	0.1473	0.1430	0.1461	0.0027	1.9

Table 9 Mass loss sheltered samples (2 years exposure)

Mass loss (g/exposed zinc plate) = $m_i - m_i ap$

Site	Site No.	m_1-$m_1$ap	m_2-$m_2$ap	m_3-$m_3$ap	mean	standard deviation	Rel. standard deviation
		g	g	g	g	g	%
Prague	1	0.1904	0.1884	0.1942	0.1910	0.0029	1.5
Kopisty	3	0.2334	0.2370	0.2367	0.2357	0.0020	0.8
Ähtäri	5	0.1110	0.1041	0.1043	0.1065	0.0039	3.7
Waldhof Langenbr.	7	0.1741	0.1610	0.1561	0.1637	0.0093	5.7
Langenfeld	9	0.1529	0.1501	0.1442	0.1491	0.0044	3.0
Bottrop	10	0.2422	0.2351	0.2298	0.2357	0.0062	2.6
Rome	13	0.1455	0.1512	0.1362	0.1443	0.0076	5.2
Casaccia	14	0.1154	0.1044	0.1133	0.1110	0.0058	5.3
Milan	15	0.1771	0.1744	0.1785	0.1767	0.0021	1.2
Venice	16	0.1877	0.1736	0.1909	0.1841	0.0092	5.0
Oslo	21	0.1248	0.1261	0.1202	0.1237	0.0031	2.5
Birkenes	23	0.1471	0.1463	0.1480	0.1471	0.0009	0.6
Stockholm South	24	0.1994	0.1923	0.1868	0.1928	0.0063	3.3
Aspvreten	26	0.1143	0.1150	0.1257	0.1183	0.0064	5.4
Lincoln Cathedral	27	0.3273	0.3096	0.2874	0.3081	0.0200	6.5
Madrid	31	0.1419	0.1338	0.1522	0.1426	0.0092	6.5
Toledo	33	0.1196	0.1217	0.1280	0.1231	0.0044	3.6
Moscow	34	0.2578	0.2661	0.2781	0.2673	0.0102	3.8
Lahemaa	35	0.1976	0.2014	0.2139	0.2043	0.0085	4.2
Lisbon	36	0.3400	0.3727	0.3895	0.3674	0.0252	6.9
Dorset	37	0.1850	0.2048	0.1894	0.1931	0.0104	5.4
Paris	40	0.3174	0.3065	0.3098	0.3112	0.0056	1.8
Berlin	41	0.2529	0.2421	0.2557	0.2502	0.0072	2.9
Tel Aviv	43	0.2314	0.2553	0.2554	0.2474	0.0138	5.6
Svanvik	44	0.2971	0.3043	0.3132	0.3049	0.0081	2.6
Chaumont	45	0.2220	0.2353	0.2251	0.2275	0.0070	3.1
London	46	0.5905	0.6059	0.5233	0.5732	0.0439	7.7
Los Angeles	47	missing	missing	missing	missing	missing	missing
Antwerpen	49	0.3303	0.3202	0.2965	0.3157	0.0174	5.5

Table 10 Mass loss sheltered samples (4 years exposure)

Mass loss (g/exposed zinc plate) = $m_i - m_i ap$

Site	Site No.	m_1-$m_1$ap	m_2-$m_2$ap	m_3-$m_3$ap	mean	standard deviation	Rel. standard deviation
		g	g	g	g	g	%
Prague	1	0.3972	0.4303	0.4707	0.4327	0.0368	8.5
Kopisty	3	0.4934	0.4596	0.5422	0.4984	0.0415	8.3
Ähtäri	5	0.2759	0.2772	0.2710	0.2747	0.0033	1.2
Waldhof Langenbr.	7	0.4109	0.4422	0.4071	0.4201	0.0193	4.6
Langenfeld	9	0.3588	0.3941	0.4190	0.3906	0.0302	7.7
Bottrop	10	0.5066	0.5254	0.5029	0.5116	0.0121	2.4
Rome	13	missing	missing	missing	missing	missing	missing
Casaccia	14	0.3529	0.2394	0.3193	0.3039	0.0583	19.2
Milan	15	0.3385	0.2951	0.3188	0.3175	0.0217	6.8
Venice	16	0.3688	0.3384	0.3440	0.3504	0.0162	4.6
Oslo	21	0.1844	0.1826	0.1820	0.1830	0.0012	0.7
Birkenes	23	0.1793	0.1691	0.1702	0.1729	0.0056	3.2
Stockholm South	24	0.2650	0.2480	0.2477	0.2536	0.0099	3.9
Aspvreten	26	0.1209	0.1264	0.1234	0.1236	0.0028	2.2
Lincoln Cathedral	27	0.3489	0.3407	0.3367	0.3421	0.0062	1.8
Madrid	31	0.1401	0.1517	0.1477	0.1465	0.0059	4.0
Toledo	33	0.1020	0.0883	0.1053	0.0985	0.0090	9.1
Moscow	34	0.2223	0.2227	0.2226	0.2225	0.0002	0.1
Lahemaa	35	0.1779	0.1747	0.1766	0.1764	0.0016	0.9
Lisbon	36	0.4367	0.4273	0.4717	0.4452	0.0234	5.3
Dorset	37	0.1673	0.1585	0.1723	0.1660	0.0070	4.2
Paris	40	0.2204	0.2025	0.2238	0.2156	0.0114	5.3
Berlin	41	0.2383	0.2461	0.2786	0.2543	0.0214	8.4
Tel Aviv	43	0.1666	0.1610	0.1786	0.1687	0.0090	5.3
Svanvik	44	0.2223	0.2380	0.2261	0.2288	0.0082	3.6
Chaumont	45	0.1391	0.1368	0.1407	0.1389	0.0020	1.4
London	46	0.3020	0.3098	0.2931	0.3016	0.0084	2.8
Los Angeles	47	0.0932	0.0845	0.0910	0.0896	0.0045	5.1
Antwerpen	49	0.2812	0.2786	0.2874	0.2824	0.0045	1.6

Table 11 Mean value of mass loss sheltered samples (1, 2 and 4 years exposure)

Mean value of mass loss (g/m^2) = $\{\frac{(m_1 - m_1ap) + (m_2 - m_2ap) + (m_3 - m_3ap)}{3} * \frac{1}{0.03}\}$;

Site	Site No.	Mean value of mass loss (1 year)	Mean value of mass loss (2 years)	Mean value of mass loss (4 years)
		g/m^2	g/m^2	g/m^2
Prague	1	4.57	6.37	14.42
Kopisty	3	6.63	7.86	16.61
Ähtäri	5	3.18	3.55	9.16
Waldhof Langenbrügge	7	4.62	5.46	14.00
Langenfeld	9	3.91	4.97	13.02
Bottrop	10	5.30	7.86	17.05
Rome	13	3.47	4.81	missing
Casaccia	14	2.60	3.70	10.13
Milan	15	missing	5.89	10.58
Venice	16	4.85	6.13	11.68
Oslo	21	2.19	4.12	6.10
Birkenes	23	3.44	4.90	5.76
Stockholm South	24	2.94	6.43	8.45
Aspvreten	26	2.43	3.94	4.12
Lincoln Cathedral	27	6.58	10.27	11.40
Madrid	31	2.02	4.75	4.88
Toledo	33	2.07	4.10	3.28
Moscow	34	5.80	8.91	7.42
Lahemaa	35	3.80	6.81	5.88
Lisbon	36	7.84	12.25	14.84
Dorset	37	3.15	6.43	5.53
Paris	40	3.75	10.37	7.18
Berlin	41	4.15	8.34	8.48
Tel Aviv	43	4.27	8.24	5.62
Svanvik	44	4.18	10.16	7.63
Chaumont	45	3.60	7.58	4.63
London	46	5.65	19.11	10.05
Los Angeles	47	missing	missing	2.99
Antwerpen	49	4.87	10.52	9.41
Mean		4.14	7.28	8.94
S.D.		1.47	3.32	4.01
Min		2.02	3.55	2.99
Max		7.84	19.11	17.05

Table 12 Corrosion rate sheltered samples (1, 2 and 4 years exposure)

Corrosion rate ($g/(m^2 \cdot a)$)

Site	Site No.	Corrosion rate (0 - 1 year)	Corrosion rate (0 - 2 years)	Corrosion rate (0 - 4 years)
		$g/(m^2 \cdot a)$	$g/(m^2 \cdot a)$	$g/(m^2 \cdot a)$
Prague	1	4.57	3.18	3.61
Kopisty	3	6.63	3.93	4.15
Ähtäri	5	3.18	1.77	2.29
Waldhof Langenbrügge	7	4.62	2.73	3.50
Langenfeld	9	3.91	2.48	3.25
Bottrop	10	5.30	3.93	4.26
Rome	13	3.47	2.40	missing
Casaccia	14	2.60	1.85	2.53
Milan	15	missing	2.94	2.65
Venice	16	4.85	3.07	2.92
Oslo	21	2.19	2.06	1.52
Birkenes	23	3.44	2.45	1.44
Stockholm South	24	2.94	3.21	2.11
Aspvreten	26	2.43	1.97	1.03
Lincoln Cathedral	27	6.58	5.13	2.85
Madrid	31	2.02	2.38	1.22
Toledo	33	2.07	2.05	0.82
Moscow	34	5.80	4.46	1.85
Lahemaa	35	3.80	3.40	1.47
Lisbon	36	7.84	6.12	3.71
Dorset	37	3.15	3.22	1.38
Paris	40	3.75	5.19	1.80
Berlin	41	4.15	4.17	2.12
Tel Aviv	43	4.27	4.12	1.41
Svanvik	44	4.18	5.08	1.91
Chaumont	45	3.60	3.79	1.16
London	46	5.65	9.55	2.51
Los Angeles	47	missing	missing	0.75
Antwerpen	49	4.87	5.26	2.35
Mean		4.14	3.64	2.23
S.D.		1.47	1.66	1
Min		2.02	1.77	0.75
Max		7.84	9.55	4.26

Figure 1 Corrosion rate [g/(a m²)] sheltered samples 1, 2 and 4 years exposure

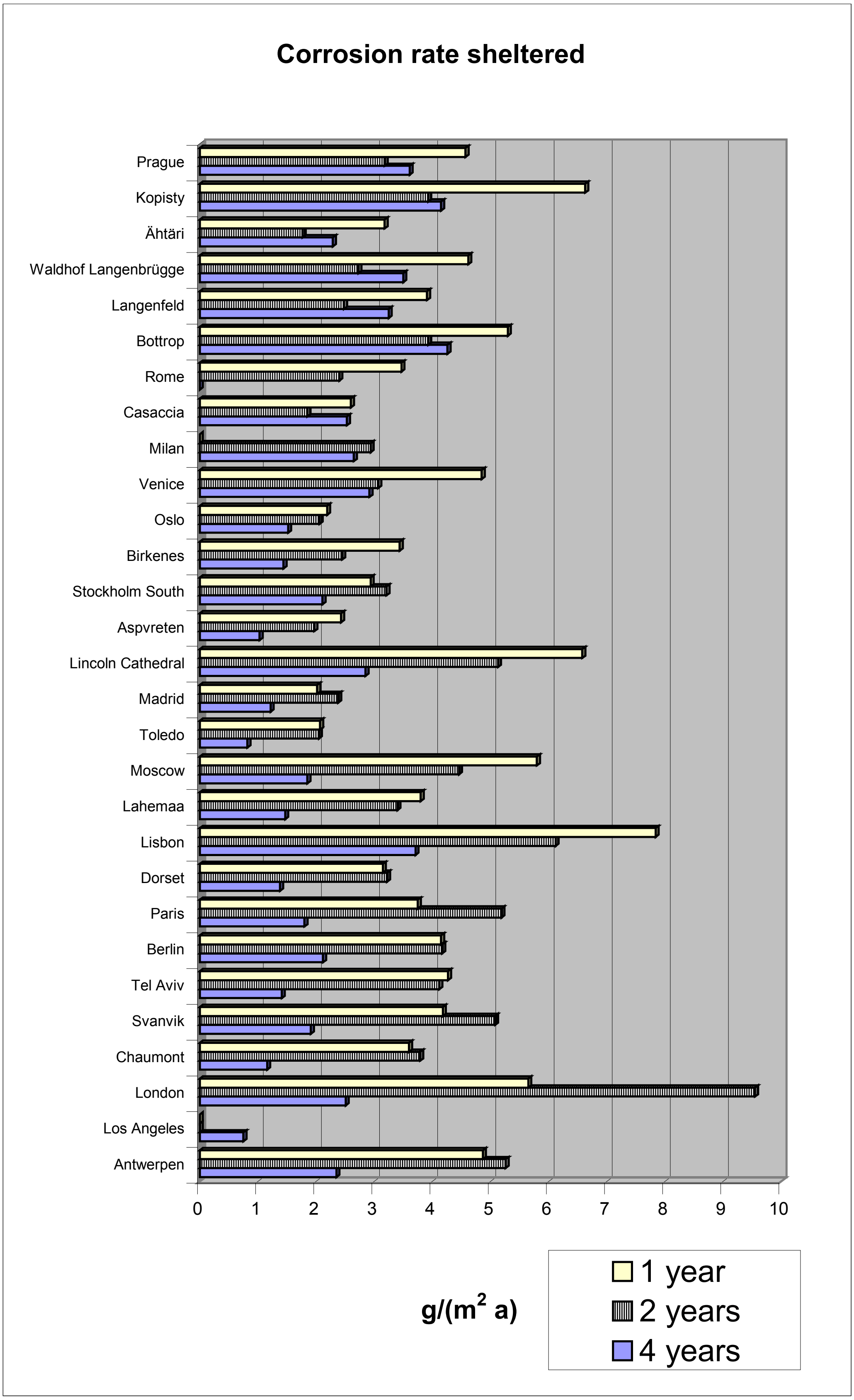


Table 13 Mass loss unsheltered samples (1 year exposure)

Mass loss (g/exposed zinc plate) = m_i-$m_i$ap

Site	Site No.	m_1-$m_1$ap	m_2-$m_2$ap	m_3-$m_3$ap	mean	standard deviation	Rel. standard deviation
		g	g	g	g	g	%
Prague	1	0.1919	0.2026	0.2051	0.1999	0.0070	3.5
Kopisty	3	0.2985	0.2974	0.3163	0.3041	0.0106	3.5
Ähtäri	5	0.2048	0.2026	0.2012	0.2029	0.0018	0.9
Waldhof Langenbr.	7	0.1840	0.1897	0.1944	0.1894	0.0052	2.8
Langenfeld	9	0.2991	0.2432	0.2599	0.2674	0.0287	10.7
Bottrop	10	0.3579	0.3621	0.3674	0.3625	0.0048	1.3
Rome	13	0.2460	0.2593	0.2507	0.2520	0.0067	2.7
Casaccia	14	0.2295	0.2194	0.2398	0.2296	0.0102	4.4
Milan	15	0.2311	0.4551	0.2466	0.3109	0.1251	40.2
Venice	16	0.1944	0.2034	0.2041	0.2006	0.0054	2.7
Oslo	21	0.1392	0.1411	0.1452	0.1418	0.0031	2.2
Birkenes	23	0.2289	0.2331	0.2374	0.2331	0.0043	1.8
Stockholm South	24	0.2334	0.2263	0.2246	0.2281	0.0047	2.0
Aspvreten	26	0.2810	0.1961	0.2189	0.2320	0.0439	18.9
Lincoln Cathedral	27	0.3547	0.3443	0.3510	0.3500	0.0053	1.5
Madrid	31	0.1365	0.1338	0.1357	0.1353	0.0014	1.0
Toledo	33	0.1453	0.1331	0.1318	0.1367	0.0074	5.4
Moscow	34	0.2125	0.2069	0.2038	0.2077	0.0044	2.1
Lahemaa	35	0.2254	0.2163	0.2130	0.2182	0.0064	2.9
Lisbon	36	0.2706	0.2620	0.2721	0.2682	0.0055	2.0
Dorset	37	0.1630	0.1593	0.1664	0.1629	0.0036	2.2
Paris	40	0.3268	0.3546	0.3394	0.3403	0.0139	4.1
Berlin	41	0.1715	0.2027	0.2094	0.1945	0.0202	10.4
Tel Aviv	43	0.3910	0.3529	0.3392	0.3610	0.0268	7.4
Svanvik	44	0.1854	0.1958	0.1873	0.1895	0.0055	2.9
Chaumont	45	0.1346	0.1275	0.1185	0.1269	0.0081	6.4
London	46	0.2653	0.2640	0.2730	0.2674	0.0049	1.8
Los Angeles	47	0.2185	0.2141	0.2076	0.2134	0.0055	2.6
Antwerpen	49	0.2978	0.3089	0.2887	0.2985	0.0101	3.4

Table 14 Mass loss unsheltered samples (2 years exposure)

Mass loss (g/exposed zinc plate) = m_i-$m_i$ap

Site	Site No.	m_1-$m_1$ap	m_2-$m_2$ap	m_3-$m_3$ap	mean	standard deviation	Rel. standard deviation
		g	g	g	g	g	%
Prague	1	0.2857	0.2721	0.2764	0.2781	0.0070	2.5
Kopisty	3	0.4379	0.4617	0.4769	0.4588	0.0197	4.3
Ähtäri	5	0.2576	0.2639	0.2654	0.2623	0.0041	1.6
Waldhof Langenbr.	7	0.2853	0.2769	0.2737	0.2786	0.0060	2.2
Langenfeld	9	0.3932	0.4174	0.4133	0.4080	0.0130	3.2
Bottrop	10	0.6447	0.6205	2.3096*)	0.6326	0.0171	2.7
Rome	13	0.3342	0.3225	0.3150	0.3239	0.0097	3.0
Casaccia	14	0.3302	0.3244	0.3131	0.3226	0.0087	2.7
Milan	15	0.3239	0.3208	0.3185	0.3211	0.0027	0.8
Venice	16	0.2849	0.2814	0.3048	0.2904	0.0126	4.3
Oslo	21	0.2658	0.2719	0.2723	0.2700	0.0036	1.3
Birkenes	23	0.4120	0.3977	0.4538	0.4212	0.0292	6.9
Stockholm South	24	0.3706	0.3740	0.3695	0.3714	0.0023	0.6
Aspvreten	26	0.3749	0.3801	0.3937	0.3829	0.0097	2.5
Lincoln Cathedral	27	0.6021	0.5931	0.6029	0.5994	0.0054	0.9
Madrid	31	0.2407	0.2270	0.2481	0.2386	0.0107	4.5
Toledo	33	0.2286	0.2185	0.2381	0.2284	0.0098	4.3
Moscow	34	0.3226	0.3334	0.3362	0.3307	0.0072	2.2
Lahemaa	35	0.3033	0.3134	0.3229	0.3132	0.0098	3.1
Lisbon	36	0.5271	0.5419	0.5453	0.5381	0.0097	1.8
Dorset	37	0.3376	0.3385	0.3681	0.3481	0.0174	5.0
Paris	40	0.5734	0.5983	0.5989	0.5902	0.0146	2.5
Berlin	41	0.4186	0.4046	0.3704	0.3979	0.0248	6.2
Tel Aviv	43	0.5452	0.5836	0.6359	0.5882	0.0455	7.7
Svanvik	44	0.4063	0.4015	0.3306	0.3795	0.0424	11.2
Chaumont	45	0.2828	0.2500	0.2819	0.2716	0.0187	6.9
London	46	0.5832	0.5689	0.5769	0.5763	0.0072	1.2
Los Angeles	47	0.4374	0.4047	0.4254	0.4225	0.0165	3.9
Antwerpen	49	0.7249	0.6698	0.6529	0.6825	0.0377	5.5

*) value omitted

Table 15 Mass loss unsheltered samples (4 years exposure)

Mass loss (g/exposed zinc plate) = m_i-$m_i$ap

Site	Site No.	m_1-$m_1$ap	m_2-$m_2$ap	m_3-$m_3$ap	mean	standard deviation	Rel. standard deviation
		g	g	g	g	g	%
Prague	1	0.5284	0.4887	0.5079	0.5083	0.0199	3.9
Kopisty	3	0.7525	0.8020	0.8411	0.7985	0.0444	5.6
Ähtäri	5	0.4837	0.4846	0.4744	0.4809	0.0056	1.2
Waldhof Langenbr.	7	0.5732	0.5774	0.5979	0.5828	0.0132	2.3
Langenfeld	9	0.8968	0.8398	0.7651	0.8339	0.0660	7.9
Bottrop	10	1.3095	1.1608	1.2830	1.2511	0.0793	6.3
Rome	13	missing	missing	missing	missing	missing	missing
Casaccia	14	0.6728	0.7260	0.6378	0.6789	0.0444	6.5
Milan	15	0.7780	0.8720	0.8265	0.8255	0.0470	5.7
Venice	16	0.5701	0.5607	0.5502	0.5603	0.0100	1.8
Oslo	21	0.5326	0.5779	0.6116	0.5740	0.0396	6.9
Birkenes	23	0.8434	0.8674	0.9236	0.8781	0.0412	4.7
Stockholm South	24	0.7686	0.7142	0.7241	0.7356	0.0290	3.9
Aspvreten	26	0.5795	0.6109	0.6213	0.6039	0.0218	3.6
Lincoln Cathedral	27	1.0924	1.0508	1.0427	1.0620	0.0267	2.5
Madrid	31	0.5722	0.5010	0.5241	0.5324	0.0363	6.8
Toledo	33	0.5535	0.5264	0.5927	0.5575	0.0333	6.0
Moscow	34	0.4586	0.4935	0.4624	0.4715	0.0191	4.1
Lahemaa	35	0.6411	0.6718	0.6439	0.6523	0.0170	2.6
Lisbon	36	0.8666	0.9847	1.0330	0.9614	0.0856	8.9
Dorset	37	0.6366	0.6533	0.6779	0.6559	0.0208	3.2
Paris	40	1.1328	1.1880	1.1923	1.1710	0.0332	2.8
Berlin	41	0.7426	0.7972	0.7211	0.7536	0.0392	5.2
Tel Aviv	43	0.8292	0.8371	0.7653	0.8105	0.0394	4.9
Svanvik	44	0.6394	0.6687	0.7042	0.6708	0.0324	4.8
Chaumont	45	0.5144	0.5165	0.5282	0.5197	0.0074	1.4
London	46	0.9139	0.9977	0.8558	0.9225	0.0713	7.7
Los Angeles	47	0.6015	0.6526	0.7170	0.6570	0.0579	8.8
Antwerpen	49	0.8122	0..8511	0.8466	0.8366	0.0213	2.5

Table 16 Mean value of mass loss unsheltered samples (1, 2 and 4 years exposure)

Mean value of mass loss (g/m^2) = $\{\frac{(m_1 - m_1ap) + (m_2 - m_2ap) + (m_3 - m_3ap)}{3} * \frac{1}{0.03}\}$;

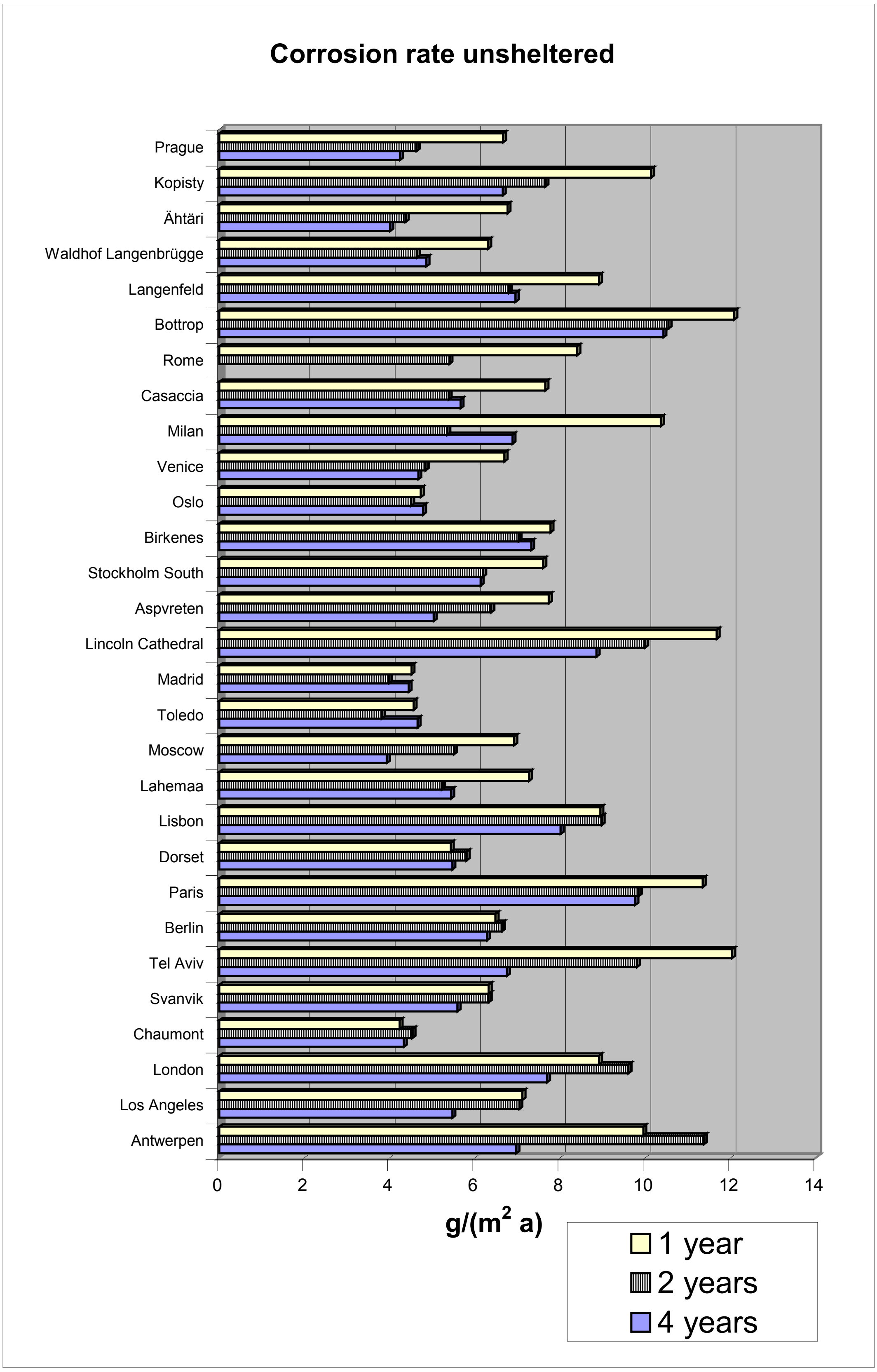
Site	Site No.	Mean value of mass loss (1 year)	Mean value of mass loss (2 years)	Mean value of mass loss (4 years)
		g/m^2	g/m^2	g/m^2
Prague	1	6.66	9.27	16.94
Kopisty	3	10.13	15.29	26.62
Ähtäri	5	6.76	8.74	16.03
Waldhof Langenbrügge	7	6.31	9.29	19.43
Langenfeld	9	8.91	13.60	27.79
Bottrop	10	12.08	21.08	41.70
Rome	13	8.40	10.80	missing
Casaccia	14	7.65	10.75	22.63
Milan	15	10.36	10.70	27.51
Venice	16	6.69	9.68	18.68
Oslo	21	4.73	9.00	19.13
Birkenes	23	7.77	14.04	29.27
Stockholm South	24	7.60	12.38	24.52
Aspvreten	26	7.73	12.76	20.13
Lincoln Cathedral	27	11.67	19.98	35.40
Madrid	31	4.51	7.95	17.75
Toledo	33	4.56	7.61	18.58
Moscow	34	6.92	11.02	15.72
Lahemaa	35	7.27	10.44	21.74
Lisbon	36	8.94	17.93	32.04
Dorset	37	5.43	11.60	21.86
Paris	40	11.34	19.67	39.03
Berlin	41	6.48	13.26	25.12
Tel Aviv	43	12.03	19.61	27.02
Svanvik	44	6.32	12.65	22.36
Chaumont	45	4.23	9.05	17.32
London	46	8.91	19.21	30.75
Los Angeles	47	7.11	14.08	21.90
Antwerpen	49	9.95	22.75	27.88
Mean		7.84	13.25	24.46
S.D.		2.28	4.38	6.84
Min		4.23	7.61	15.72
Max		12.08	22.75	41.7

Table 17 Corrosion rate unsheltered samples (1, 2 and 4 years exposure)

Corrosion rate ($g/(m^2 \cdot a)$)

Site	Site No.	Corrosion rate (0 - 1 year)	Corrosion rate (0 - 2 years)	Corrosion rate (0 - 4 years)
		$g/(m^2 \cdot a)$	$g/(m^2 \cdot a)$	$g/(m^2 \cdot a)$
Prague	1	6.66	4.63	4.24
Kopisty	3	10.13	7.65	6.65
Ähtäri	5	6.76	4.37	4.01
Waldhof Langenbrügge	7	6.31	4.64	4.86
Langenfeld	9	8.91	6.80	6.95
Bottrop	10	12.08	10.54	10.42
Rome	13	8.40	5.40	missing
Casaccia	14	7.65	5.38	5.66
Milan	15	10.36	5.35	6.88
Venice	16	6.69	4.84	4.67
Oslo	21	4.73	4.50	4.78
Birkenes	23	7.77	7.02	7.32
Stockholm South	24	7.60	6.19	6.13
Aspvreten	26	7.73	6.38	5.03
Lincoln Cathedral	27	11.67	9.99	8.85
Madrid	31	4.51	3.98	4.44
Toledo	33	4.56	3.81	4.65
Moscow	34	6.92	5.51	3.93
Lahemaa	35	7.27	5.22	5.44
Lisbon	36	8.94	8.97	8.01
Dorset	37	5.43	5.80	5.47
Paris	40	11.34	9.84	9.76
Berlin	41	6.48	6.63	6.28
Tel Aviv	43	12.03	9.80	6.75
Svanvik	44	6.32	6.32	5.59
Chaumont	45	4.23	4.53	4.33
London	46	8.91	9.60	7.69
Los Angeles	47	7.11	7.04	5.47
Antwerpen	49	9.95	11.37	6.97
Mean		7.84	6.62	6.12
S.D.		2.27	2.19	1.71
Min		4.23	3.81	3.93
Max		12.08	11.37	10.42

Figure 2 Corrosion rate [g/(a m^2)] unsheltered samples 1, 2 and 4 years exposure



Mass of held back corrosion products

Table 18 Mass of held back corrosion products sheltered samples (1 year exposure)

Mass of held back corrosion products (g/exposed plate) = $m_i bp - m_i ap$

Site	Site No.	$m_1bp - m_1ap$	$m_2bp - m_2ap$	$m_3bp - m_3ap$	mean	standard deviation	Rel. standard deviation
		g	g	g	g	g	%
Prague	1	0.1809	0.1982	0.1865	0.1885	0.0088	4.7
Kopisty	3	0.2999	0.2950	0.2894	0.2948	0.0053	1.8
Ähtäri	5	0.1521	0.1640	0.1555	0.1572	0.0061	3.9
Waldhof Langenbr.	7	0.2089	0.2183	0.2367	0.2213	0.0141	6.4
Langenfeld	9	0.1675	0.1769	0.1701	0.1715	0.0049	2.8
Bottrop	10	0.2200	0.2189	0.2280	0.2223	0.0050	2.2
Rome	13	0.1551	0.1476	0.1464	0.1497	0.0047	3.1
Casaccia	14	0.1248	0.1162	0.1232	0.1214	0.0046	3.8
Milan	15	missing	missing	missing	missing	missing	missing
Venice	16	0.2380	0.2216	0.2238	0.2278	0.0089	3.9
Oslo	21	0.0941	0.1036	0.1039	0.1005	0.0056	5.5
Birkenes	23	0.1384	0.1971	0.1747	0.1701	0.0296	17.4
Stockholm South	24	0.1281	0.1256	0.1290	0.1276	0.0018	1.4
Aspvreten	26	0.1231	0.1237	0.1262	0.1243	0.0016	1.3
Lincoln Cathedral	27	0.3149	0.2892	0.2711	0.2917	0.0220	7.5
Madrid	31	0.0928	0.0915	0.0801	0.0881	0.0070	7.9
Toledo	33	0.0869	0.1007	0.1020	0.0965	0.0084	8.7
Moscow	34	0.2720	0.2759	0.2526	0.2668	0.0125	4.7
Lahemaa	35	0.1745	0.1710	0.1728	0.1728	0.0018	1.0
Lisbon	36	0.3400	0.3083	0.3285	0.3256	0.0160	4.9
Dorset	37	0.1385	0.1329	0.1389	0.1368	0.0034	2.5
Paris	40	0.1698	0.1562	0.1649	0.1636	0.0069	4.2
Berlin	41	0.2008	0.1787	0.1674	0.1823	0.0170	9.3
Tel Aviv	43	0.1746	0.1730	0.1930	0.1802	0.0111	6.2
Svanvik	44	0.1754	0.1807	0.1718	0.1760	0.0045	2.5
Chaumont	45	0.1649	0.1793	0.1751	0.1731	0.0074	4.3
London	46	0.2269	0.2270	0.2242	0.2260	0.0016	0.7
Los Angeles	47	missing	missing	missing	missing	missing	missing
Antwerpen	49	0.2059	0.2042	0.1982	0.2028	0.0040	2.0

Table 19 Mass of held back corrosion products sheltered samples (2 years exposure)

Mass of held back corrosion products (g/exposed plate) = $m_i$bp - $m_i$ap

Site	Site No.	$m_1$bp - $m_1$ap	$m_2$bp - $m_2$ap	$m_3$bp - $m_3$ap	mean	standard deviation	Rel. standard deviation
		g	g	g	g	g	%
Prague	1	0.2748	0.2689	0.1942	0.2729	0.0035	1.3
Kopisty	3	0.3480	0.3584	0.2367	0.3570	0.0083	2.3
Ähtäri	5	0.1801	0.1721	0.1043	0.1735	0.0060	3.4
Waldhof Langenbr.	7	0.2667	0.2510	0.1561	0.2541	0.0113	4.5
Langenfeld	9	0.2080	0.2062	0.1442	0.2043	0.0049	2.4
Bottrop	10	0.3628	0.3536	0.2298	0.3548	0.0075	2.1
Rome	13	0.2062	0.2121	0.1362	0.2056	0.0068	3.3
Casaccia	14	0.1686	0.1538	0.1133	0.1625	0.0077	4.8
Milan	15	0.2474	0.2452	0.1785	0.2475	0.0024	1.0
Venice	16	0.2823	0.2645	0.1909	0.2772	0.0111	4.0
Oslo	21	0.1747	0.1824	0.1202	0.1782	0.0039	2.2
Birkenes	23	0.2183	0.2158	0.1480	0.2194	0.0042	1.9
Stockholm South	24	0.2645	0.2546	0.1868	0.2579	0.0057	2.2
Aspvreten	26	0.1689	0.1691	0.1257	0.1732	0.0073	4.2
Lincoln Cathedral	27	0.4742	0.4613	0.2874	0.4497	0.0319	7.1
Madrid	31	0.1809	0.1753	0.1522	0.1844	0.0112	6.1
Toledo	33	0.1624	0.1649	0.1280	0.1664	0.0050	3.0
Moscow	34	0.3413	0.3494	0.2781	0.3501	0.0092	2.6
Lahemaa	35	0.2755	0.2801	0.2139	0.2830	0.0094	3.3
Lisbon	36	0.4450	0.4897	0.3895	0.4877	0.0417	8.6
Dorset	37	0.2389	0.2631	0.1894	0.2489	0.0126	5.1
Paris	40	0.3943	0.3820	0.3098	0.3771	0.0200	5.3
Berlin	41	0.3362	0.3207	0.2557	0.3308	0.0087	2.6
Tel Aviv	43	0.2941	0.3237	0.2554	0.3123	0.0160	5.1
Svanvik	44	0.3691	0.3766	0.3132	0.3762	0.0069	1.8
Chaumont	45	0.2962	0.3172	0.2251	0.3027	0.0126	4.2
London	46	0.6677	0.6841	0.5233	0.6510	0.0439	6.7
Los Angeles	47	missing	missing	missing	missing	missing	missing
Antwerpen	49	0.4328	0.4216	0.2965	0.4155	0.0210	5.0

Table 20 Mass of held back corrosion products sheltered samples (4 years exposure)

Mass of held back corrosion products (g/exposed plate) = $m_i bp - m_i ap$

Site	Site No.	$m_1 bp - m_1 ap$	$m_2 bp - m_2 ap$	$m_3 bp - m_3 ap$	mean	standard deviation	Rel. standard deviation
		g	g	g	g	g	%
Prague	1	0.5267	0.5554	0.6012	0.5611	0.0376	6.7
Kopisty	3	0.7100	0.6519	0.7155	0.6925	0.0352	5.1
Ähtäri	5	0.3575	0.3605	0.3525	0.3568	0.0040	1.1
Waldhof Langenbr.	7	0.5200	0.5466	0.5007	0.5224	0.0230	4.4
Langenfeld	9	0.4587	0.4920	0.5148	0.4885	0.0282	5.8
Bottrop	10	0.7064	0.7312	0.6961	0.7112	0.0180	2.5
Rome	13	missing	missing	missing	missing	missing	missing
Casaccia	14	0.4229	0.2928	0.3833	0.3663	0.0667	18.2
Milan	15	0.4933	0.4384	0.4736	0.4684	0.0278	5.9
Venice	16	0.5527	0.5016	0.5218	0.5254	0.0257	4.9
Oslo	21	0.2572	0.2607	0.2638	0.2606	0.0033	1.3
Birkenes	23	0.2623	0.2488	0.2505	0.2539	0.0074	2.9
Stockholm South	24	0.3738	0.3561	0.3580	0.3626	0.0097	2.7
Aspvreten	26	0.1886	0.1954	0.1908	0.1916	0.0035	1.8
Lincoln Cathedral	27	0.5166	0.5140	0.5166	0.5157	0.0015	0.3
Madrid	31	0.2166	0.2235	0.2195	0.2199	0.0035	1.6
Toledo	33	0.1614	0.1356	0.1645	0.1538	0.0159	10.3
Moscow	34	0.3466	0.3700	0.3631	0.3599	0.0120	3.3
Lahemaa	35	0.2797	0.2761	0.2782	0.2780	0.0018	0.7
Lisbon	36	0.6657	0.6754	0.7263	0.6891	0.0326	4.7
Dorset	37	0.2493	0.2370	0.2590	0.2484	0.0110	4.4
Paris	40	0.3503	0.3164	0.3384	0.3350	0.0172	5.1
Berlin	41	0.3905	0.3943	0.4342	0.4063	0.0242	6.0
Tel Aviv	43	0.2463	0.2363	0.2610	0.2479	0.0124	5.0
Svanvik	44	0.3528	0.3717	0.3537	0.3594	0.0107	3.0
Chaumont	45	0.2189	0.2127	0.2164	0.2160	0.0031	1.4
London	46	0.4517	0.4562	0.4404	0.4494	0.0081	1.8
Los Angeles	47	0.1318	0.1161	0.1238	0.1239	0.0079	6.3
Antwerpen	49	0.4411	0.4415	0.4470	0.4432	0.0033	0.7

Table 21 Mean held back corrosion products sheltered samples (1, 2 and 4 years exposure)

Mean value of held back corrosion products (g/m^2):

$$B = \{ \frac{(m_1bp - m_1ap) + (m_2bp - m_2ap) + (m_3bp - m_3ap)}{3} * \frac{1}{0.03} \};$$

Site	Site No.	Mean value of held back corrosion products (1 year)	Mean value of held back corrosion products (2 years)	Mean value of held back corrosion products (4 years)
		g/m^2	g/m^2	g/m^2
Prague	1	6.28	9.10	18.70
Kopisty	3	9.82	11.90	23.08
Ähtäri	5	5.24	5.78	11.89
Waldhof Langenbrügge	7	7.38	8.47	17.41
Langenfeld	9	5.72	6.81	16.28
Bottrop	10	7.41	11.82	23.71
Rome	13	4.99	6.85	missing
Casaccia	14	4.05	5.42	12.21
Milan	15	missing	8.25	15.61
Venice	16	7.59	9.24	17.51
Oslo	21	3.35	5.94	8.68
Birkenes	23	5.67	7.31	8.46
Stockholm South	24	4.25	8.59	12.09
Aspvreten	26	4.14	5.77	6.39
Lincoln Cathedral	27	9.72	14.99	17.19
Madrid	31	2.94	6.14	7.33
Toledo	33	3.22	5.55	5.13
Moscow	34	8.89	11.67	12.00
Lahemaa	35	5.76	9.43	9.27
Lisbon	36	10.85	16.26	22.97
Dorset	37	4.56	8.30	8.28
Paris	40	5.45	12.57	11.17
Berlin	41	6.08	11.02	13.54
Tel Aviv	43	6.01	10.41	8.26
Svanvik	44	5.86	12.54	11.98
Chaumont	45	5.77	10.09	7.20
London	46	7.53	21.70	14.98
Los Angeles	47	missing	missing	4.13
Antwerpen	49	6.76	13.85	missing

Figure 3 Corroded zinc after 4 years of exposure under shelter. The retained zinc corrosion products and the entry to the environment (runoff, assuming predominantly hydrozincite as corrosion product [3]) are shown for each site (data for Rome is missing).

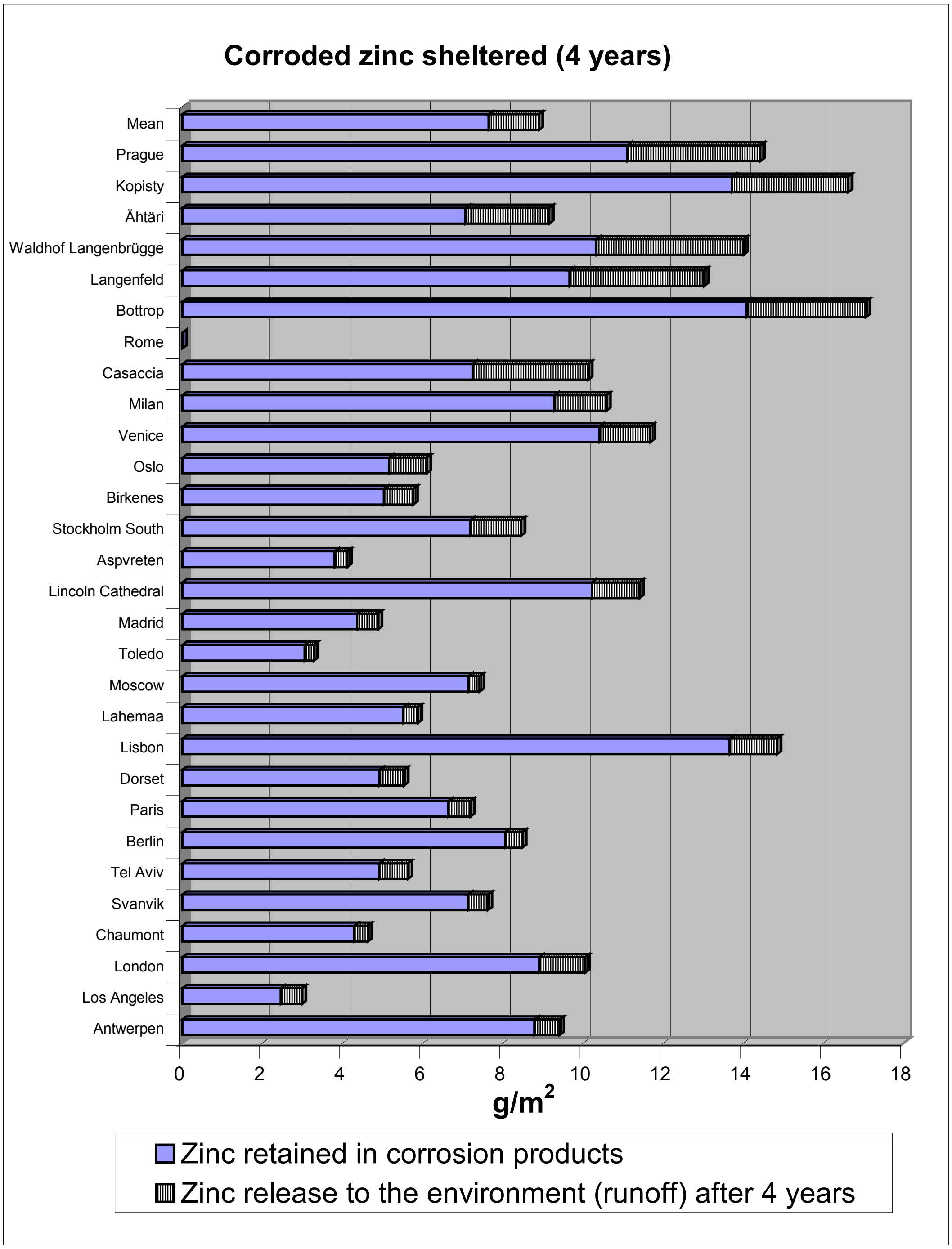


Table 22 Mass of held back corrosion products unsheltered samples (1 year exposure)

Mass of held back corrosion products (g/exposed plate) = $m_i$bp - $m_i$ap

Site	Site No.	$m_1$bp - $m_1$ap	$m_2$bp - $m_2$ap	$m_3$bp - $m_3$ap	mean	standard deviation	Rel. standard deviation
		g	g	g	g	g	%
Prague	1	0.1688	0.1740	0.1809	0.1746	0.0061	3.5
Kopisty	3	0.2873	0.2750	0.3041	0.2888	0.0146	5.1
Ähtäri	5	0.2555	0.2463	0.2473	0.2497	0.0050	2.0
Waldhof Langenbr.	7	0.1692	0.1781	0.1839	0.1771	0.0074	4.2
Langenfeld	9	0.2737	0.2093	0.2300	0.2377	0.0329	13.8
Bottrop	10	0.2679	0.2792	0.2835	0.2769	0.0081	2.9
Rome	13	0.2054	0.2223	0.2138	0.2138	0.0085	4.0
Casaccia	14	0.2189	0.2050	0.2323	0.2187	0.0137	6.2
Milan	15	0.1887	0.1785	0.1934	0.1869	0.0076	4.1
Venice	16	0.1809	0.1947	0.1966	0.1907	0.0086	4.5
Oslo	21	0.1234	0.1261	0.1324	0.1273	0.0046	3.6
Birkenes	23	0.2113	0.2153	0.2157	0.2141	0.0024	1.1
Stockholm South	24	0.2393	0.2273	0.2272	0.2313	0.0070	3.0
Aspvreten	26	0.3585	0.2286	0.2581	0.2817	0.0681	24.2
Lincoln Cathedral	27	0.3244	0.3318	0.3350	0.3304	0.0054	1.6
Madrid	31	0.1374	0.1359	0.1372	0.1368	0.0008	0.6
Toledo	33	0.1509	0.1319	0.1287	0.1372	0.0120	8.7
Moscow	34	0.1949	0.1913	0.1993	0.1952	0.0040	2.1
Lahemaa	35	0.2368	0.2190	0.2171	0.2243	0.0109	4.8
Lisbon	36	0.2718	0.2665	0.2741	0.2708	0.0039	1.4
Dorset	37	0.1475	0.1412	0.1487	0.1458	0.0040	2.8
Paris	40	0.3261	0.3556	0.3423	0.3413	0.0148	4.3
Berlin	41	0.1690	0.1942	0.2078	0.1903	0.0197	10.3
Tel Aviv	43	0.4302	0.3900	0.3681	0.3961	0.0315	8.0
Svanvik	44	0.2124	0.2248	0.2164	0.2179	0.0063	2.9
Chaumont	45	0.1106	0.1014	0.0921	0.1014	0.0093	9.1
London	46	0.2129	0.2144	0.2222	0.2165	0.0050	2.3
Los Angeles	47	0.2116	0.2099	0.2044	0.2086	0.0038	1.8
Antwerpen	49	0.2713	0.2803	0.2527	0.2681	0.0141	5.3

Table 23 Mass of held back corrosion products unsheltered samples (2 years exposure)

Mass of held back corrosion products (g/exposed plate) = $m_i bp - m_i ap$

Site	Site No.	$m_1bp - m_1ap$	$m_2bp - m_2ap$	$m_3bp - m_3ap$	mean	standard deviation	Rel. standard deviation
		g	g	g	g	g	%
Prague	1	0.2039	0.1949	0.2019	0.2002	0.0047	2.4
Kopisty	3	0.3357	0.3270	0.3460	0.3362	0.0095	2.8
Ähtäri	5	0.2688	0.2748	0.2672	0.2703	0.0040	1.5
Waldhof Langenbr.	7	0.2317	0.2210	0.2215	0.2247	0.0060	2.7
Langenfeld	9	0.2978	0.3048	0.3015	0.3014	0.0035	1.2
Bottrop	10	0.3936	0.3906	0.3987	0.3943	0.0041	1.0
Rome	13	0.2638	0.2515	0.2478	0.2544	0.0084	3.3
Casaccia	14	0.2866	0.2852	0.2745	0.2821	0.0066	2.3
Milan	15	0.2312	0.2231	0.2186	0.2243	0.0064	2.8
Venice	16	0.2509	0.2431	0.2858	0.2599	0.0227	8.7
Oslo	21	0.1995	0.2076	0.2059	0.2043	0.0043	2.1
Birkenes	23	0.2879	0.2789	0.3231	0.2966	0.0234	7.9
Stockholm South	24	0.3091	0.3092	0.3060	0.3081	0.0018	0.6
Aspvreten	26	0.4011	0.4092	0.4227	0.4110	0.0109	2.7
Lincoln Cathedral	27	0.4833	0.4755	0.4846	0.4811	0.0049	1.0
Madrid	31	0.1991	0.1918	0.2118	0.2009	0.0101	5.0
Toledo	33	0.1927	0.1846	0.2035	0.1936	0.0095	4.9
Moscow	34	0.2610	0.2793	0.2785	0.2729	0.0103	3.8
Lahemaa	35	0.2578	0.2733	0.2791	0.2701	0.0110	4.1
Lisbon	36	0.4625	0.4706	0.4800	0.4710	0.0088	1.9
Dorset	37	0.2544	0.2557	0.2870	0.2657	0.0185	6.9
Paris	40	0.4801	0.5144	0.5009	0.4985	0.0173	3.5
Berlin	41	0.3660	0.3578	0.3384	0.3541	0.0142	4.0
Tel Aviv	43	0.6047	0.6349	0.6996	0.6464	0.0485	7.5
Svanvik	44	0.3890	0.3907	0.3888	0.3895	0.0010	0.3
Chaumont	45	0.2063	0.1768	0.2059	0.1963	0.0169	8.6
London	46	0.4283	0.4185	0.4334	0.4267	0.0076	1.8
Los Angeles	47	0.4497	0.3898	0.4180	0.4192	0.0300	7.1
Antwerpen	49	0.5612	0.5270	0.5116	0.5333	0.0254	4.8

Table 24 Mass of held back corrosion products unsheltered samples (4 years exposure)

Mass of held back corrosion products (g/exposed plate) = $m_i$bp - $m_i$ap

Site	Site No.	$m_1$bp - $m_1$ap	$m_2$bp - $m_2$ap	$m_3$bp - $m_3$ap	mean	standard deviation	Rel. standard deviation
		g	g	g	g	g	%
Prague	1	0.3789	0.3274	0.3567	0.3543	0.0258	7.3
Kopisty	3	0.5285	0.5099	0.5439	0.5274	0.0170	3.2
Ähtäri	5	0.4121	0.4034	0.3945	0.4033	0.0088	2.2
Waldhof Langenbr.	7	0.4295	0.4385	0.4642	0.4441	0.0180	4.1
Langenfeld	9	0.6483	0.5890	0.5200	0.5858	0.0642	11.0
Bottrop	10	0.7434	0.6656	0.7656	0.7249	0.0525	7.2
Rome	13	missing	missing	missing	missing	missing	missing
Casaccia	14	0.5632	0.6102	0.5349	0.5694	0.0380	6.7
Milan	15	0.5288	0.6177	0.5656	0.5707	0.0447	7.8
Venice	16	0.4706	0.4978	0.4601	0.4762	0.0195	4.1
Oslo	21	0.3583	0.4023	0.4334	0.3980	0.0377	9.5
Birkenes	23	0.5148	0.5466	0.6033	0.5549	0.0448	8.1
Stockholm South	24	0.5586	0.5081	0.5108	0.5258	0.0284	5.4
Aspvreten	26	0.4747	0.4972	0.4981	0.4900	0.0133	2.7
Lincoln Cathedral	27	0.7257	0.7252	0.7335	0.7281	0.0047	0.6
Madrid	31	0.4962	0.4245	0.4477	0.4561	0.0366	8.0
Toledo	33	0.4536	0.4297	0.4942	0.4592	0.0326	7.1
Moscow	34	0.2915	0.3246	0.2979	0.3047	0.0176	5.8
Lahemaa	35	0.4920	0.5173	0.4913	0.5002	0.0148	3.0
Lisbon	36	0.7069	0.8483	0.8952	0.8168	0.0980	12.0
Dorset	37	0.4579	0.4637	0.4872	0.4696	0.0155	3.3
Paris	40	0.8801	0.8862	0.8870	0.8844	0.0038	0.4
Berlin	41	0.6250	0.6813	0.6252	0.6438	0.0324	5.0
Tel Aviv	43	0.7922	0.8522	0.8477	0.8307	0.0334	4.0
Svanvik	44	0.5566	0.5842	0.6168	0.5859	0.0301	5.1
Chaumont	45	0.3583	0.3677	0.3611	0.3624	0.0048	1.3
London	46	0.5700	0.6363	0.4888	0.5650	0.0739	13.1
Los Angeles	47	0.5634	0.6091	0.6649	0.6125	0.0508	8.3
Antwerpen	49	0.4439	0.4350	0.4348	0.4379	0.052	1.2

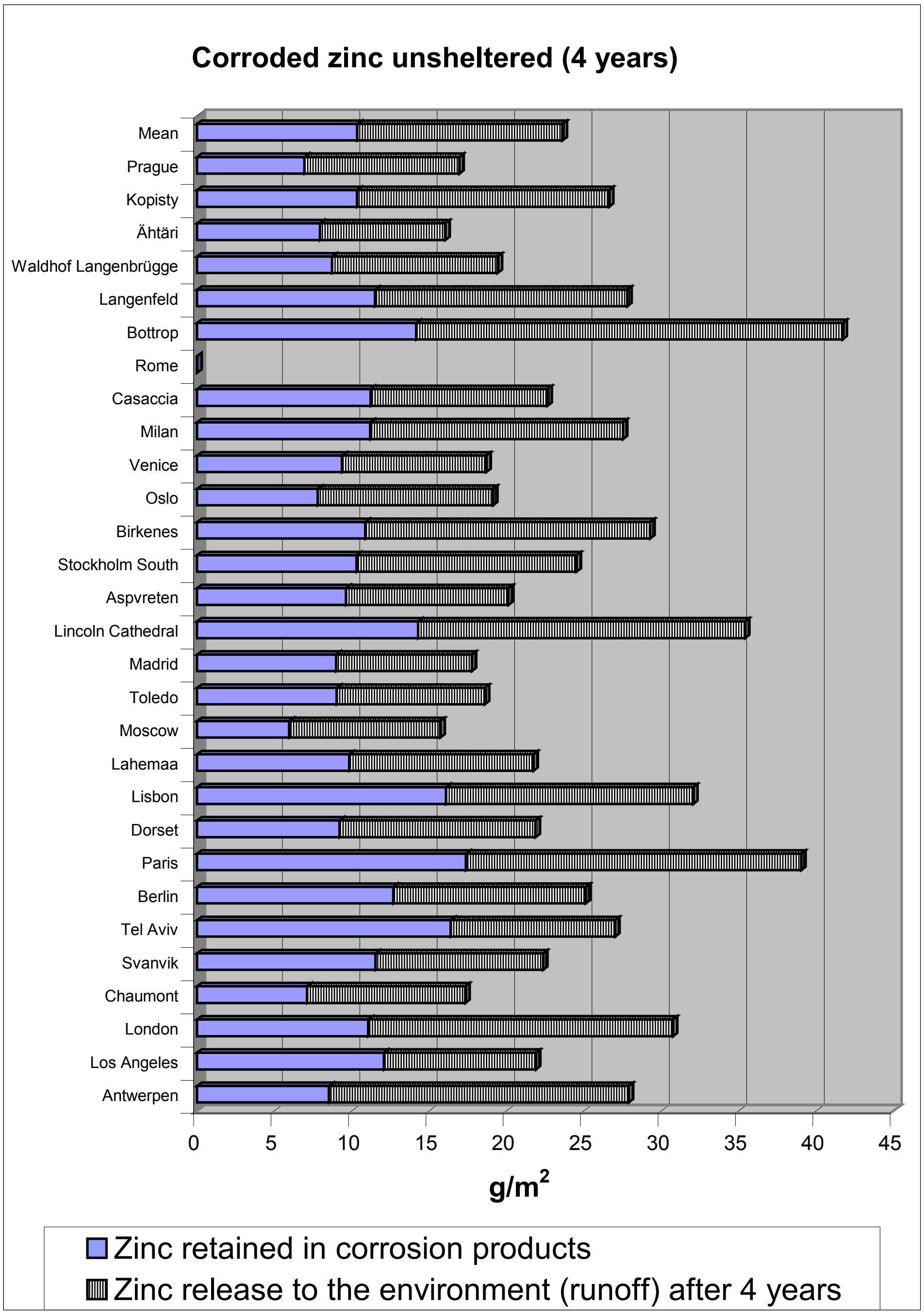
Table 25 Mean held back corrosion products unsheltered samples (1, 2 & 4 years exposure)

Mean value of held back corrosion products (g/m^2):

$$B = \left\{ \frac{(m_1bp - m_1ap) + (m_2bp - m_2ap) + (m_3bp - m_3ap)}{3} * \frac{1}{0.03} \right\}$$

Site	Site No.	Mean value of held back corrosion products (1 year) g/m^2	Mean value of held back corrosion products (2 year) g/m^2	Mean value of held back corrosion products (4 year) g/m^2
Prague	1	5.82	6.67	11.81
Kopisty	3	9.63	11.21	17.58
Ähtäri	5	8.32	9.01	13.44
Waldhof Langenbrügge	7	5.90	7.49	14.80
Langenfeld	9	7.92	10.04	19.52
Bottrop	10	9.23	13.14	24.16
Rome	13	7.13	8.48	missing
Casaccia	14	7.29	9.40	18.98
Milan	15	6.23	7.48	19.02
Venice	16	6.36	8.66	15.87
Oslo	21	4.24	6.81	13.27
Birkenes	23	7.14	9.89	18.49
Stockholm South	24	7.71	10.27	17.53
Aspvreten	26	9.39	13.70	16.33
Lincoln Cathedral	27	11.01	16.04	24.27
Madrid	31	4.56	6.70	15.20
Toledo	33	4.57	6.45	15.30
Moscow	34	6.50	9.10	10.15
Lahemaa	35	7.48	9.00	16.67
Lisbon	36	9.03	15.70	27.22
Dorset	37	4.86	8.86	15.65
Paris	40	11.38	16.61	29.48
Berlin	41	6.34	11.80	21.46
Tel Aviv	43	13.20	21.54	27.69
Svanvik	44	7.26	12.98	19.53
Chaumont	45	3.38	6.54	12.08
London	46	7.22	14.22	18.83
Los Angeles	47	6.95	13.97	20.41
Antwerpen	49	8.94	17.77	14.60

Figure 4 Corroded zinc after 4 years of exposure unsheltered exposure. The retained zinc corrosion products and the entry to the environment (runoff, assuming predominantly hydrozincite as corrosion product [3]) are shown for each site (data for Rome is missing).



Lost metal (Runoff)

To calculate runoff values from corrosion data it was assumed that the predominantly corrosion product is hydrozincite $Zn_5(CO_3)_2\,(OH)_6$ [3].

Table 26 Lost metal sheltered samples (1 year exposure)

Lost metal (g/m²) $C = A - (B^* \frac{5^*MWZn}{MWHydrozincite})$
(A = mean value of mass loss (g/m²);
B = mean value of mass of held back corrosion products (g/m²))

Site	Site No.	Lost metal	Lost metal (compared to total mass loss)
		g/m²	%
Prague	1	0.84	18.3
Kopisty	3	0.79	12.0
Ähtäri	5	0.06	1.9
Waldhof Langenbrügge	7	0.23	5.1
Langenfeld	9	0.51	13.0
Bottrop	10	0.90	17.0
Rome	13	0.51	14.6
Casaccia	14	0.19	7.4
Milan	15	missing	missing
Venice	16	0.34	6.9
Oslo	21	0.20	9.0
Birkenes	23	0.07	1.9
Stockholm South	24	0.41	14.1
Aspvreten	26	(-0.03)	(-1.4)
Lincoln Cathedral	27	0.80	12.2
Madrid	31	0.27	13.6
Toledo	33	0.15	7.4
Moscow	34	0.52	8.9
Lahemaa	35	0.38	10.0
Lisbon	36	1.39	17.7
Dorset	37	0.44	13.9
Paris	40	0.51	13.6
Berlin	41	0.54	12.9
Tel Aviv	43	0.70	16.5
Svanvik	44	0.69	16.6
Chaumont	45	0.17	4.6
London	46	1.18	20.8
Los Angeles	47	missing	missing
Antwerpen	49	0.85	17.6

Table 27 Lost metal sheltered samples (2 years exposure)

Lost metal (g/m^2) C = A- (B* $\frac{5*MWZn}{MWHydrozincite}$)
(A = mean value of mass loss (g/m^2);
B = mean value of mass of held back corrosion product (g/m^2))

Site	Site No.	Lost metal	Lost metal (compared to total mass loss)
		g/m^2	%
Prague	1	0.96	15.07
Kopisty	3	0.78	9.93
Ähtäri	5	0.11	3.00
Waldhof Langenbrügge	7	0.42	7.67
Langenfeld	9	0.92	18.57
Bottrop	10	0.82	10.49
Rome	13	0.74	15.31
Casaccia	14	0.48	12.99
Milan	15	0.99	16.73
Venice	16	0.64	10.44
Oslo	21	0.59	14.37
Birkenes	23	0.56	11.34
Stockholm South	24	1.32	20.56
Aspvreten	26	0.51	12.96
Lincoln Cathedral	27	1.36	13.22
Madrid	31	1.11	23.24
Toledo	33	0.81	19.68
Moscow	34	1.98	22.22
Lahemaa	35	1.20	17.68
Lisbon	36	2.59	21.15
Dorset	37	1.51	23.45
Paris	40	2.91	28.10
Berlin	41	1.79	21.49
Tel Aviv	43	2.06	25.04
Svanvik	44	2.72	26.77
Chaumont	45	1.59	20.96
London	46	6.24	32.66
Los Angeles	47	missing	missing
Antwerpen	49	2.30	21.82

Table 28 Lost metal sheltered samples (4 years exposure)

Lost metal (g/m^2) C = A- (B* $\frac{5*MWZn}{MWHydrozincite}$)
(A = mean value of mass loss (g/m^2);
B = mean value of mass of held back corrosion product (g/m^2))

Site	Site No.	Lost metal	Lost metal (compared to total mass loss)
		g/m^2	%
Prague	1	3.32	23.00
Kopisty	3	2.90	17.44
Ähtäri	5	2.09	22.86
Waldhof Langenbrügge	7	3.67	26.18
Langenfeld	9	3.35	25.77
Bottrop	10	2.97	17.39
Rome	13	missing	missing
Casaccia	14	2.88	28.47
Milan	15	1.30	12.27
Venice	16	1.27	10.84
Oslo	21	0.94	15.37
Birkenes	23	0.73	12.69
Stockholm South	24	1.27	14.99
Aspvreten	26	0.32	7.77
Lincoln Cathedral	27	1.18	10.35
Madrid	31	0.53	10.75
Toledo	33	0.23	7.13
Moscow	34	0.28	3.76
Lahemaa	35	0.37	6.24
Lisbon	36	1.18	7.93
Dorset	37	0.61	11.02
Paris	40	0.54	7.55
Berlin	41	0.42	4.94
Tel Aviv	43	0.71	12.66
Svanvik	44	0.50	6.55
Chaumont	45	0.35	7.47
London	46	1.15	11.40
Los Angeles	47	0.53	17.80
Antwerpen	49	0.62	6.64

Figure 5 "Runoff rate" [g/(m^2 a)] sheltered samples 1, 2 and 4 years exposure
To calculate runoff values from corrosion data it was assumed that the predominantly corrosion product is hydrozincite $Zn_5(CO_3)_2(OH)_6$ [3].

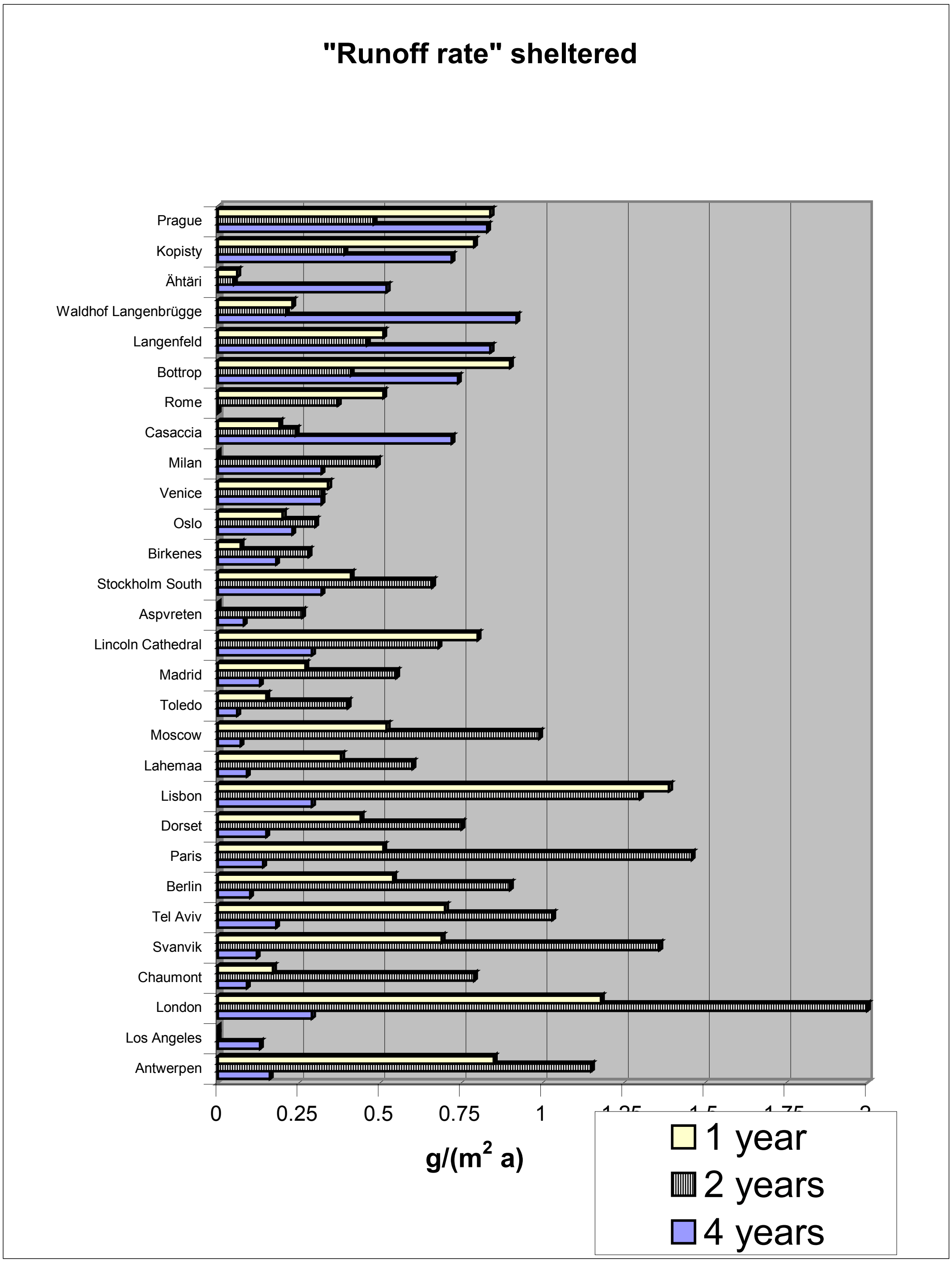


Table 29 Lost metal unsheltered samples (1 year exposure)

Lost metal (g/m^2) C = A- (B* $\frac{5*MWZn}{MWHydrozincite}$)
(A = mean value of mass loss (g/m^2);
B = mean value of mass of held back corrosion products (g/m^2))

Site	Site No.	Lost metal	Lost metal (compared to total mass loss)
		g/m^2	%
Prague	1	3.22	48.4
Kopisty	3	4.44	43.8
Ähtäri	5	1.82	27.0
Waldhof Langenbrügge	7	2.82	44.7
Langenfeld	9	4.23	47.5
Bottrop	10	6.64	55.0
Rome	13	4.19	49.9
Casaccia	14	3.34	43.6
Milan	15	6.71	64.7
Venice	16	2.93	43.8
Oslo	21	2.22	47.0
Birkenes	23	3.55	45.7
Stockholm South	24	3.04	40.0
Aspvreten	26	2.16	27.9
Lincoln Cathedral	27	5.15	44.2
Madrid	31	1.81	40.1
Toledo	33	1.85	40.6
Moscow	34	3.08	44.4
Lahemaa	35	2.85	39.1
Lisbon	36	3.60	40.2
Dorset	37	2.56	47.1
Paris	40	4.61	40.6
Berlin	41	2.73	42.1
Tel Aviv	43	4.21	35.0
Svanvik	44	2.01	31.8
Chaumont	45	2.24	52.9
London	46	4.66	52.2
Los Angeles	47	3.00	42.1
Antwerpen	49	4.67	46.9

Table 30 Lost metal unsheltered samples (2 years exposure)

Lost metal (g/m^2) C = A- (B* $\frac{5*MWZn}{MWHydrozincite}$)
(A = mean value of mass loss (g/m^2);
B = mean value of mass of held back corrosion products (g/m^2))

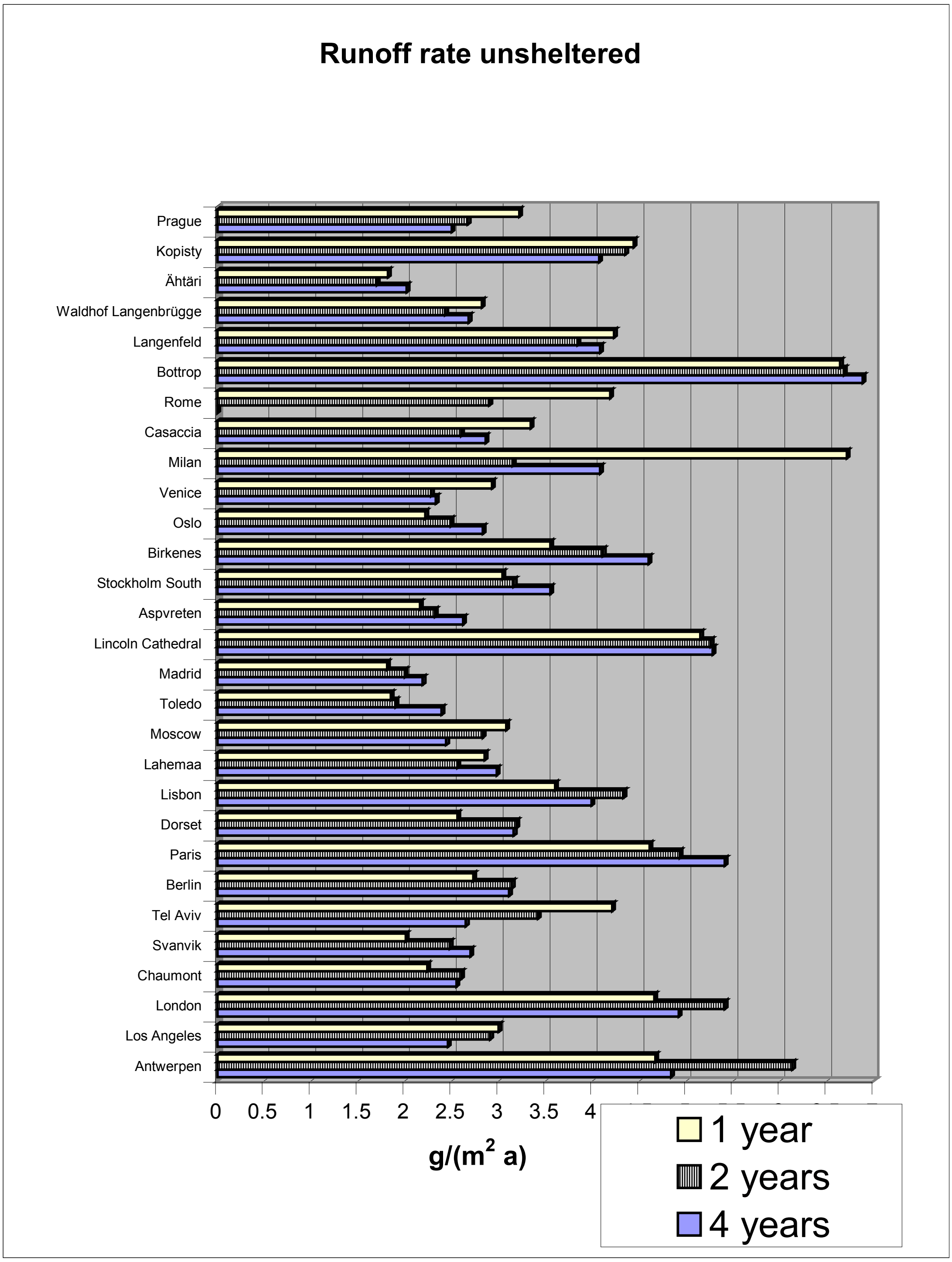
Site	Site No.	Lost metal	Lost metal (compared to total mass loss)
		g/m^2	%
Prague	1	5.34	57.59
Kopisty	3	8.69	56.83
Ähtäri	5	3.41	38.98
Waldhof Langenbrügge	7	4.87	52.41
Langenfeld	9	7.68	56.48
Bottrop	10	13.37	63.40
Rome	13	5.80	53.68
Casaccia	14	5.20	48.33
Milan	15	6.30	58.88
Venice	16	4.56	47.09
Oslo	21	4.98	55.39
Birkenes	23	8.22	58.54
Stockholm South	24	6.32	51.02
Aspvreten	26	4.64	36.40
Lincoln Cathedral	27	10.52	52.64
Madrid	31	4.00	50.28
Toledo	33	3.80	49.94
Moscow	34	5.65	51.29
Lahemaa	35	5.12	49.06
Lisbon	36	8.66	48.28
Dorset	37	6.38	55.00
Paris	40	9.86	50.13
Berlin	41	6.29	47.41
Tel Aviv	43	6.84	34.87
Svanvik	44	4.96	39.21
Chaumont	45	5.20	57.42
London	46	10.83	56.37
Los Angeles	47	5.81	41.27
Antwerpen	49	12.27	53.92

Table 31 Lost metal unsheltered samples (4 years exposure)

Lost metal (g/m^2) $C = A - (B * \frac{5*MWZn}{MWHydrozincite})$
(A = mean value of mass loss (g/m^2);
B = mean value of mass of held back corrosion products (g/m^2))

Site	Site No.	Lost metal	Lost metal (compared to total mass loss)
		g/m^2	%
Prague	1	9.99	58.98
Kopisty	3	16.28	61.17
Ähtäri	5	8.09	50.48
Waldhof Langenbrügge	7	10.70	55.09
Langenfeld	9	16.30	58.65
Bottrop	10	27.54	66.04
Rome	13	missing	missing
Casaccia	14	11.42	50.47
Milan	15	16.32	59.32
Venice	16	9.30	49.81
Oslo	21	11.33	59.20
Birkenes	23	18.41	62.89
Stockholm South	24	14.20	57.91
Aspvreten	26	10.49	52.12
Lincoln Cathedral	27	21.12	59.66
Madrid	31	8.77	49.40
Toledo	33	9.55	51.39
Moscow	34	9.75	62.03
Lahemaa	35	11.91	54.79
Lisbon	36	15.97	49.83
Dorset	37	12.65	57.84
Paris	40	21.66	55.48
Berlin	41	12.44	49.54
Tel Aviv	43	10.62	39.31
Svanvik	44	10.82	48.39
Chaumont	45	10.21	58.96
London	46	19.69	64.05
Los Angeles	47	9.83	44.87
Antwerpen	49	19.35	69.4

Figure 6 Runoff rate [g/(a m^2)] unsheltered samples 1, 2 and 4 years exposure.
To calculate runoff values from corrosion data it was assumed that the predominantly corrosion product is hydrozincite $Zn_5(CO_3)_2(OH)_6$ [3].



Corrosion rate and runoff rate

Table 32 Corrosion rate and runoff rate sheltered samples (1, 2 and 4 years exposure),

Comparison of corrosion rate and "runoff rate" of zinc after 1, 2 and 4 years of exposure
To calculate runoff values from corrosion data it was assumed according to [3] that the predominantly corrosion product is hydrozincite $Zn_5(CO_3)_2(OH)_6$ with the metal proportion of 0.6. If one would take the (on open CO2 containing atmosphere unstable) wuelfingite, metal proportion 0.66, or zincite, metal proportion 0.8, the "runoff rate" diminishes or becomes negative due to the increased zinc proportion in the retained corrosion products.

Site	Site No.	corrosion rate (1 year)	"runoff rate" (1 year)	corrosion rate (2 years)	"runoff rate" (2 years)	corrosion rate (4 years)	"runoff rate" (4 years)
		$g/(m^2 \cdot a)$	$g/(m^2 \cdot a)$	$g/(m^2 \cdot a)$	$g/(m^2 \cdot a)$	$g/(m^2 \cdot a)$	$g/(m^2 \cdot a)$
Prague	1	4.57	0.84	3.18	0.48	3.61	0.83
Kopisty	3	6.63	0.79	3.93	0.39	4.15	0.72
Ähtäri	5	3.18	0.06	1.77	0.05	2.29	0.52
Waldhof Langenbrügge	7	4.62	0.23	2.73	0.21	3.50	0.92
Langenfeld	9	3.91	0.51	2.48	0.46	3.25	0.84
Bottrop	10	5.30	0.90	3.93	0.41	4.26	0.74
Rome	13	3.47	0.51	2.40	0.37	missing	missing
Casaccia	14	2.60	0.19	1.85	0.24	2.53	0.72
Milan	15	missing	missing	2.94	0.49	2.65	0.32
Venice	16	4.85	0.34	3.07	0.32	2.92	0.32
Oslo	21	2.19	0.20	2.06	0.30	1.52	0.23
Birkenes	23	3.44	0.07	2.45	0.28	1.44	0.18
Stockholm South	24	2.94	0.41	3.21	0.66	2.11	0.32
Aspvreten	26	2.43	(-0.03)	1.97	0.26	1.03	0.08
Lincoln Cathedral	27	6.58	0.80	5.13	0.68	2.85	0.29
Madrid	31	2.02	0.27	2.38	0.55	1.22	0.13
Toledo	33	2.07	0.15	2.05	0.40	0.82	0.06
Moscow	34	5.80	0.52	4.46	0.99	1.85	0.07
Lahemaa	35	3.80	0.38	3.40	0.60	1.47	0.09
Lisbon	36	7.84	1.39	6.12	1.30	3.71	0.29
Dorset	37	3.15	0.44	3.22	0.75	1.38	0.15
Paris	40	3.75	0.51	5.19	1.46	1.80	0.14
Berlin	41	4.15	0.54	4.17	0.90	2.12	0.10
Tel Aviv	43	4.27	0.70	4.12	1.03	1.41	0.18
Svanvik	44	4.18	0.69	5.08	1.36	1.91	0.12
Chaumont	45	3.60	0.17	3.79	0.79	1.16	0.09
London	46	5.65	1.18	9.55	3.12	2.51	0.29
Los Angeles	47	missing	missing	missing	missing	0.75	0.13
Antwerpen	49	4.87	0.85	5.26	1.15	2.35	0.16

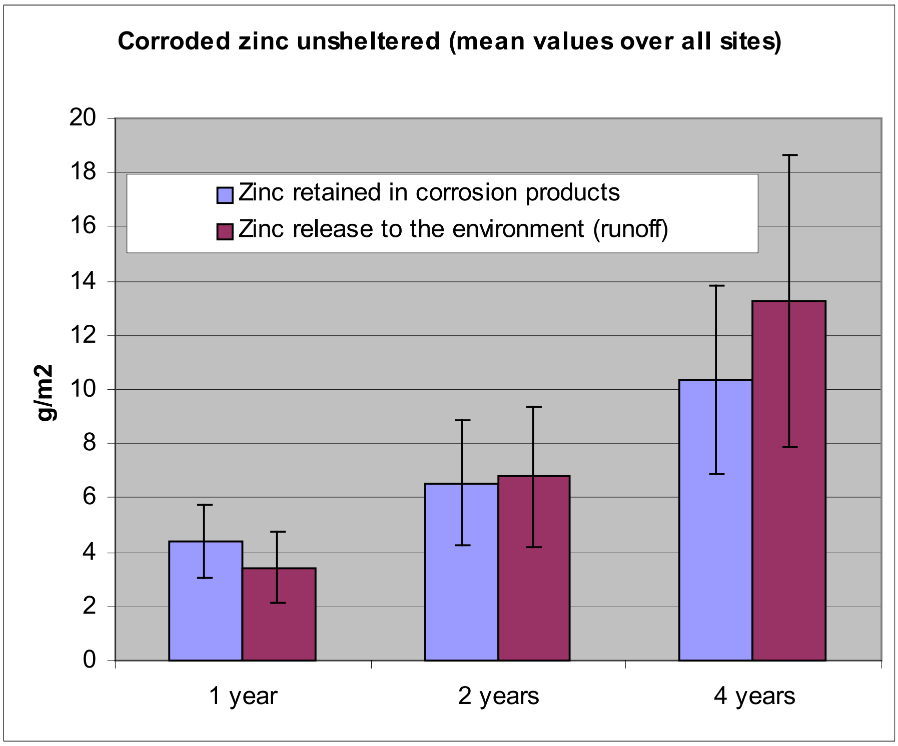
Table 33 Corrosion rate and runoff rate unsheltered samples (1, 2 and 4 years exposure)

Comparison of corrosion rate and runoff rate of zinc after 1, 2 and 4 years of exposure

Site	Site No.	corrosion rate (1 year)	runoff rate (1 year)	corrosion rate (2 years)	runoff rate (2 years)	corrosion rate (4 years)	runoff rate (4 years)
		$g/(m^2 \cdot a)$	$g/(m^2 \cdot a)$	$g/(m^2 \cdot a)$	$g/(m^2 \cdot a)$	$g/(m^2 \cdot a)$	$g/(m^2 \cdot a)$
Prague	1	6.66	3.22	4.63	2.67	4.24	2.50
Kopisty	3	10.13	4.44	7.65	4.35	6.65	4.07
Ähtäri	5	6.76	1.82	4.37	1.70	4.01	2.02
Waldhof Langenbrügge	7	6.31	2.82	4.64	2.43	4.86	2.68
Langenfeld	9	8.91	4.23	6.80	3.84	6.95	4.08
Bottrop	10	12.08	6.64	10.54	6.68	10.42	6.88
Rome	13	8.40	4.19	5.40	2.90	missing	missing
Casaccia	14	7.65	3.34	5.38	2.60	5.66	2.86
Milan	15	10.36	6.71	5.35	3.15	6.88	4.08
Venice	16	6.69	2.93	4.84	2.28	4.67	2.33
Oslo	21	4.73	2.22	4.50	2.49	4.78	2.83
Birkenes	23	7.77	3.55	7.02	4.11	7.32	4.60
Stockholm South	24	7.60	3.04	6.19	3.16	6.13	3.55
Aspvreten	26	7.73	2.16	6.38	2.32	5.03	2.62
Lincoln Cathedral	27	11.67	5.15	9.99	5.26	8.85	5.28
Madrid	31	4.51	1.81	3.98	2.00	4.44	2.19
Toledo	33	4.56	1.85	3.81	1.90	4.65	2.39
Moscow	34	6.92	3.08	5.51	2.83	3.93	2.44
Lahemaa	35	7.27	2.85	5.22	2.56	5.44	2.98
Lisbon	36	8.94	3.60	8.97	4.33	8.01	3.99
Dorset	37	5.43	2.56	5.80	3.19	5.47	3.16
Paris	40	11.34	4.61	9.84	4.93	9.76	5.41
Berlin	41	6.48	2.73	6.63	3.14	6.28	3.11
Tel Aviv	43	12.03	4.21	9.80	3.42	6.75	2.65
Svanvik	44	6.32	2.01	6.32	2.48	5.59	2.70
Chaumont	45	4.23	2.24	4.53	2.60	4.33	2.55
London	46	8.91	4.66	9.60	5.41	7.69	4.92
Los Angeles	47	7.11	3.00	7.04	2.91	5.47	2.46
Antwerpen	49	9.95	4.67	11.37	6.13	6.97	4.84

Figure 7 Pathways of corroded zinc on sheltered samples after samples 1, 2 and 4 years of exposure. The retained zinc (g/m2) of corrosion products and the runoff (g/m2) assuming predominantly hydrozincite as corrosion product [3] are shown with the standard deviation (error bar).

Figure 8 Pathways of corroded zinc on unsheltered samples after samples 1, 2 and 4 years of exposure. The retained zinc (g/m2) of corrosion products and the runoff (g/m2) are shown with the standard deviation (error bar).



Comparison of mass loss in different exposure periods

Table 34 Mass loss sheltered samples (1, 2 and 4 years) in different exposure periods

Comparison of mass loss (g/m^2) of zinc after 1, 2 and 4 years of exposure in different exposure periods

Site	No.	1 year	1 year	1 year	multipoll. progr. 1 year	2 years	multipoll. progr. 2 years	4 years	multipoll. progr. 4 years
		1990-91 [a]	1992-93 [a]	1994-95 [a]	1997-98	1987-89 [a]	1997-99	1987-91 [a]	1997-01
		g/m^2	g/m^2	g/m^2	g/m^2	g/m^2	g/m^2	g/m^2	g/m^2
Prague	1	11.8	1.7	4.4	4.57	13.3	6.37	15.9	14.42
Kopisty	3	10.5	11.8	6	6.63	14.3	7.86	18.7	16.61
Ähtäri	5	8.4	1.3	1.3	3.18	6.7	3.55	7.2	9.16
Waldhof Langenb.	7	20.6	7.1	2.6	4.62	21.6	5.46	9.1	14
Langenfeld	9	24	2.8	2.3	3.91	31.8	4.97	8	13.02
Bottrop	10	21	9.5	4.5	5.30	20.2	7.86	9.7	17.05
Rome	13	5.2		1.9	3.47	7.7	4.81	8.6	
Casaccia	14	5.1		0.9	2.60	7.0	3.70	7.9	10.13
Milan	15	7.8		2		10.6	5.89	15.2	10.58
Venice	16	5.6		1.5	4.85	9.3	6.13	12.1	11.68
Oslo	21	24.7	1.9	1.9	2.19	7.1	4.12	5.9	6.1
Birkenes	23	14	2.7	1.6	3.44	12.1	4.90	6.5	5.76
Stockholm South	24	8.2	2.7	2.6	2.94	19.8	6.43	8.6	8.45
Aspvreten	26	5	1.8	2	2.43	5.7	3.94	6.9	4.12
Lincoln Cathedral	27	7.1	8.6	3.6	6.58	10.1	10.27	9.6	11.4
Madrid	31	5.9	4.1	2.3	2.02	8.0	4.75	6.2	4.88
Toledo	33	2	1	0.6	2.07	2.3	4.10	3.7	3.28
Moscow	34	9.9	5.3	2.8	5.80	10.8	8.91	10.6	7.42
Lahemaa	35	5.7			3.80	6.2	6.81	8.1	5.88
Lisbon	36	5.3	6.3	2.9	7.84	6.2	12.25	7.7	14.84
Dorset	37	5.3	1.7	2.2	3.15	6.0	6.43	7.2	5.53
Paris	40				3.75		10.37		7.18
Berlin	41				4.15		8.34		8.48
Tel Aviv	43				4.27		8.24		5.62
Svanvik	44				4.18		10.16		7.63
Chaumont	45				3.60		7.58		4.63
London	46				5.65		19.11		10.05
Los Angeles	47								2.99
Antwerpen	49				4.87		10.52		9.41

a) Data for the exposure periods 1990-91, 1992-93, 1994-95 were extracted from [1]. Data for the exposure period 1987-89 from [2].

Figure 9 Comparison of mass loss (g/m^2) of zinc in different exposure periods – sheltered samples.
Data in table 34

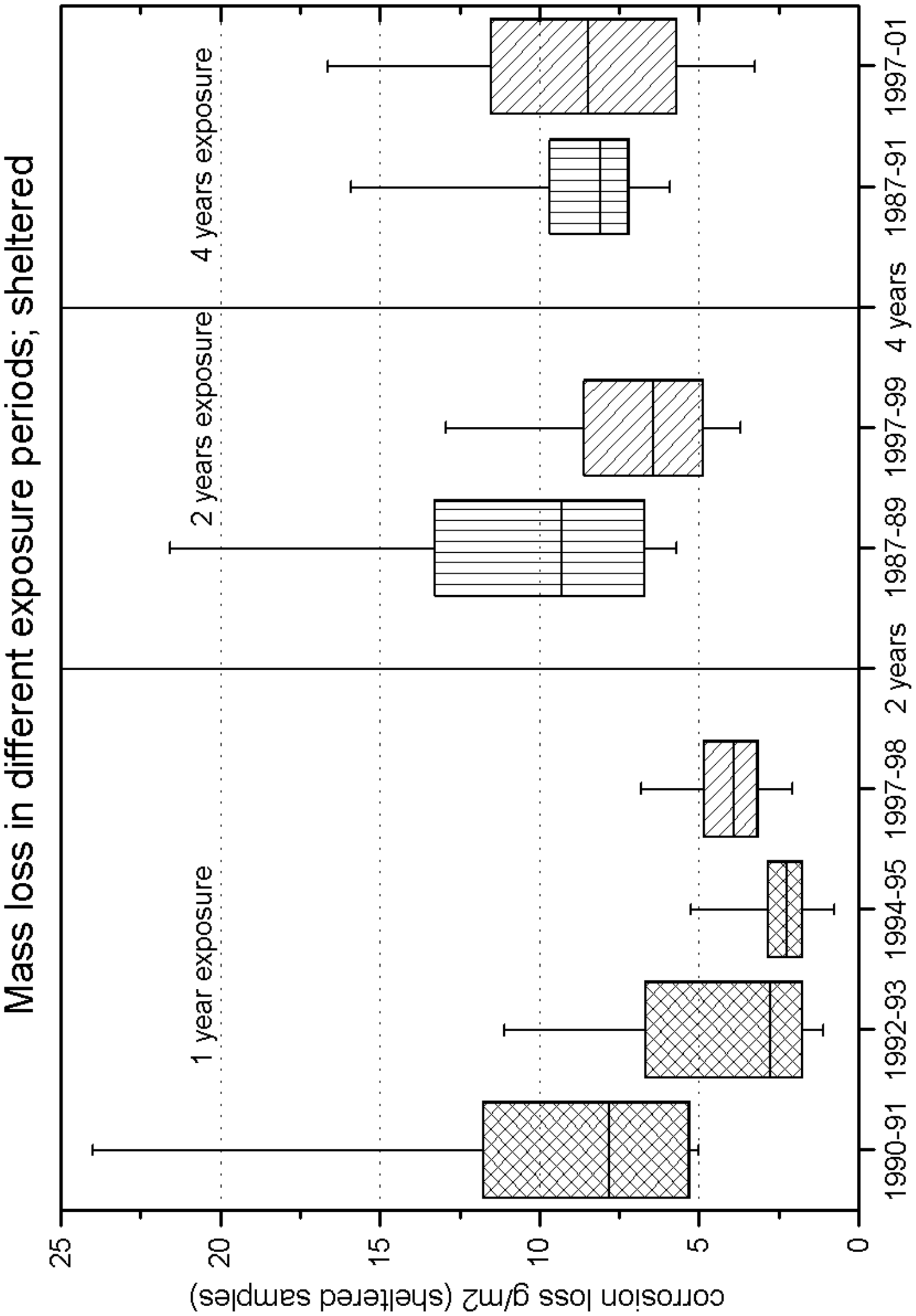
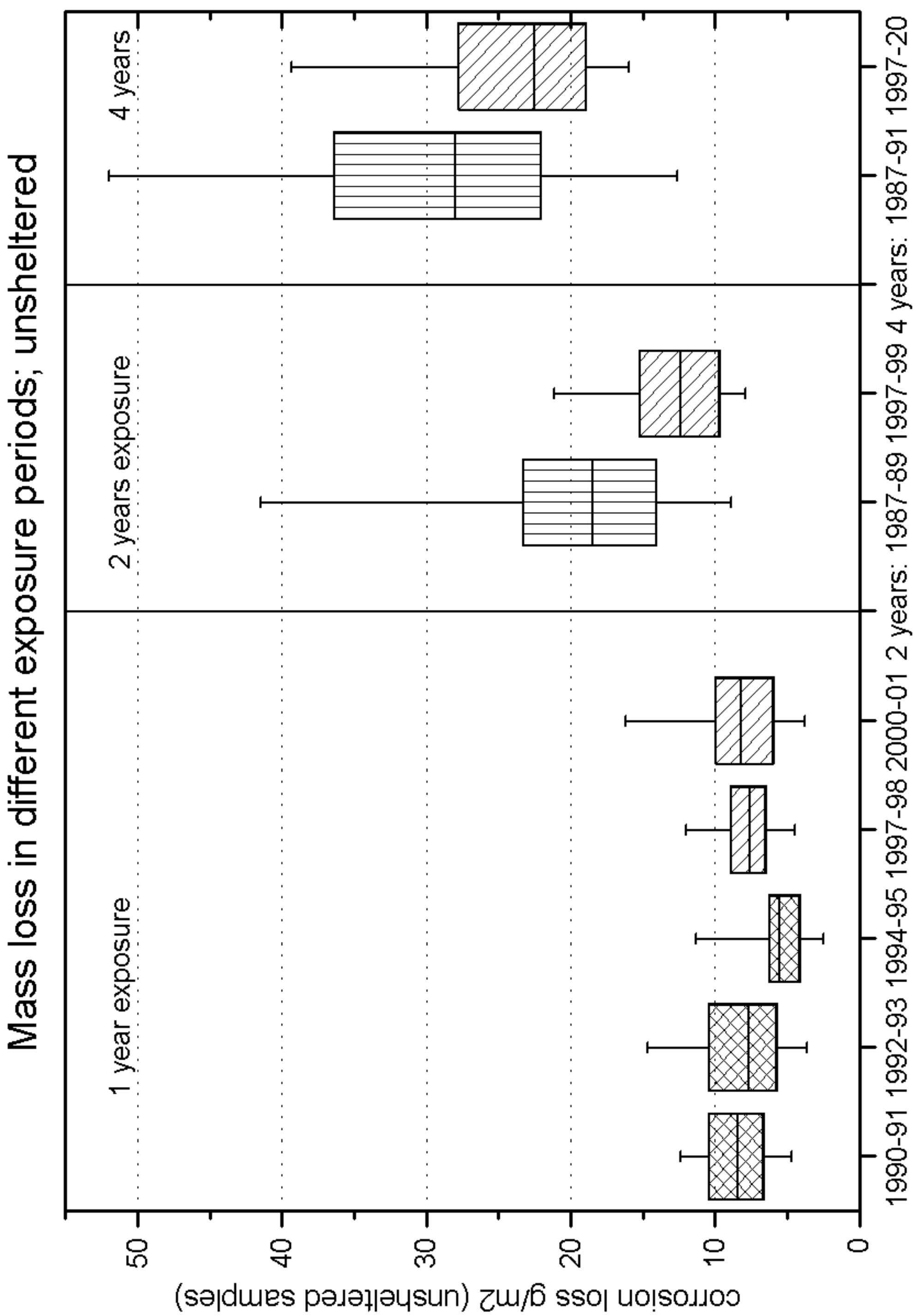


Table 35 Mass loss unsheltered samples (1, 2 and 4 years) in different exposure periods

Site	No.	1 year	1 year	1 year	multipoll. progr. 1 year	multipoll. trend 1 year	2 years	multipoll. progr. 2 years	4 years	multipoll. progr. 4 years
		1990-91 [a]	1992-93 [a]	1994-95 [a]	1997-98	2000-01	1987-89 [a]	1997-99	1987-91 [a]	1997-01
		g/m^2	g/m^2	g/m^2	g/m^2	g/m^2	g/m^2	g/m^2	g/m^2	g/m^2
Prague	1	7	7.7	5.6	6.66	7.43	26.1	9.27	45.4	16.94
Kopisty	3	11.5	11.6	12.1	10.13	11.22	29.6	15.29	57.4	26.62
Ähtäri	5	7.6	6.6	4.6	6.76	11.1	8.8	8.74	15.4	16.03
Waldhof Langenb.	7	7.8	9	4.2	6.31	10.02	26.9	9.29	29.9	19.43
Langenfeld	9	6.6	9	7.6	8.91	8.96	42.6	13.6	34.1	27.79
Bottrop	10	10.6	15.2	7.8	12.08	15.7	20	21.08	32.2	41.7
Rome	13	9.7		3.4	8.4	4.5	11.8	10.8	30.7	
Casaccia	14	9.9		3.1	7.65	3.8	14.3	10.75	29.5	22.63
Milan	15	12.1		5.5	10.36	10.32	23.1	10.7	42.8	27.51
Venice	16	7.6		6.1	6.69	5.43	18.3	9.68	34.9	18.68
Oslo	21	5.6	6.6	3.5	4.73	6.2	16.2	9	25.4	19.13
Birkenes	23	8.4	10.5	5	7.77	21.33	20.5	14.04	27.4	29.27
Stockholm South	24	6	4.5	4.2	7.6	5.95	23.2	12.38	26.7	24.52
Aspvreten	26	6.7	4.8	6	7.73	9.03	9	12.76	18.6	20.13
Lincoln Cathedral	27	12.3	10.6	7	11.67	8.46	17	19.98	27.9	35.4
Madrid	31	4.8	3.5	2.3	4.51	4.83	9.6	7.95	15.7	17.75
Toledo	33	3.9	4.7	1.7	4.56	2.67	4.5	7.61	10	18.58
Moscow	34	8.6	6.5	4.6	6.92	8.13	14	11.02	23.4	15.72
Lahemaa	35	9.4			7.27	7.66	9.5	10.44	17.1	21.74
Lisbon	36		10.4	5.6	8.94	5.76	14.2	17.93	22.1	32.04
Dorset	37	6.2	5.2	6.1	5.43	7.36	14.2	11.6	24.1	21.86
Paris	40				11.34	5.94		19.67		39.03
Berlin	41				6.48	7.22		13.26		25.12
Tel Aviv	43				12.03	9.65		19.61		27.02
Svanvik	44				6.32	9.27		12.65		22.36
Chaumont	45				4.23	9.04		9.05		17.32
London	46				8.91	8.34		19.21		30.75
Los Angeles	47				7.11	5.11		14.08		21.9
Antwerpen	49				9.95	12.56		22.75		27.88
Warsaw	50					16.22				
Kaperske Hory	2	7.9	6.7	3.4			14		29.5	
Espoo	4	8.3	5.1	4.6			15.5		27	
Helsinki	6	9.2	5.7	5.5			20.6		27.7	
Aschaffenburg	8	4.6	5.2	4.1			40.1		19.9	
Essen	11	9.6	11.4	7			23.4		36.9	
Garmisch-Pat.	12	7.2	7.2	3.7			12.6		20	
Vlaardingen	17	11.3	10.6	5.8			25.9		37.2	
Eibergen	18	8.1	7.8	4.7			12.6		22	
Vredepeel	19	9	11	6.2			18.5		29.8	
Wijnandsrade	20	10.2	11.3	6.3			20		31.4	
Borregaard	22	16.7	15.8	12			48.3		80.1	
Stockholm Centre	25	5.6	3.5	3.5			14.4		21.9	
Wells Cathedral	28	6.4	7.7	8.6			16		28	
Clatteringshaws L.	29	11.6					23.7		42.5	
Stoke Orchard	30	8.4	9.9				23.1		37.3	
Bilbao	32	10.6	8.7	6.4			25.2		40.8	
Research Tri. Park	38	10.9	9.6				19		10.4	
Steubenville	39	12.4	7.3				20.1		38.7	

a) Data for the periods 1990-91, 1992-93, 1994-95 were extracted from [1]; 1987-91 from [2].

Figure 10 Comparison of mass losses (g/m^2) of zinc in different exposure periods – unsheltered samples.
Data in table 35



Dose–response functions

The unified dose response function after 8 years of exposure which were in [4], were applied to the results of mass loss for zinc in the exposure programme 1997-2001.

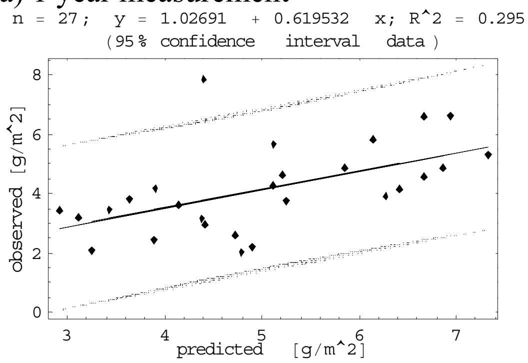
UNECE: Zinc sheltered 1, 2 and 4 years:

T>10°C: $ML=0.058*[SO2]^{0.16}*Rh*\exp\{-0.034(T-10)\}*t^{0.49}$

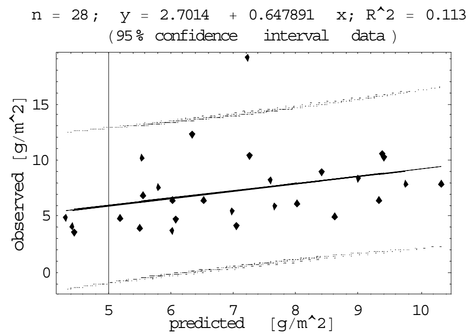
T≤10°C: $ML=0.058*[SO2]^{0.16}*Rh*\exp\{+0.039(T-10)\}*t^{0.49}$

Figures 11a, 11b, 11c and 11d Correlation of sheltered samples.
Correlation of mass loss observed and predicted by UN/ECE dose-response functions.
Exposure periods:
a) 1997-1998, b) 1997 - 1999, c) 1997 - 2001, d) 1997 - 2001

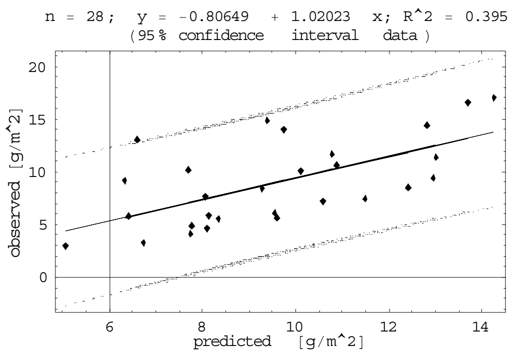
11a) 1 year measurement



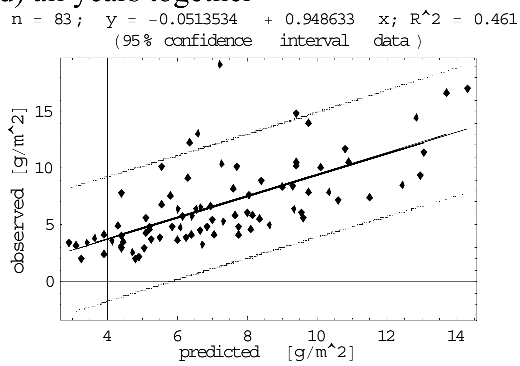
11b) 2 years measurement



11c) 4 years measurement



11d) all years together



Local differences of DRF Zn sheltered

Table 36 Statistical and local information of the UN/ECE DRF for sheltered zinc at different exposure sites. The ratio (predicted corrosion)/ (measured corrosion) ranges from over prediction of a factor two at Los Angeles to 1.8 times underestimation at Lisbon.
n = 83; RSquared -> 0.461, AdjustedRSquared -> 0.455; EstimatedVariance -> 7.40
y = -0.0051 + 0.949 x

Exposure site	Predicted/observed	StdDev % observed
Prague	1.27	0.25
Kopisty	1.04	0.14
Ähtäri	0.98	0.19
Waldhof Langenbrügge	1.03	0.23
Langenfeld	1.28	0.52
Bottrop	1.18	0.23
Rome	1.05	0.04
Casaccia	1.4	0.43
Milan	1.35	0.25
Venice	1.15	0.15
Oslo	1.84	0.27
Birkenes	0.95	0.11
Stockholm South	1.21	0.2
Aspvreten	1.63	0.17
Lincoln Cathedral	1.02	0.08
Madrid	1.75	0.42
Toledo	1.57	0.32
Moscow	1.18	0.24
Lahemaa	1.05	0.22
Lisbon	0.57	0.04
Dorset	1.28	0.23
Paris	1.19	0.33
Berlin	1.36	0.19
Tel Aviv	1.28	0.29
Svanvik	0.85	0.2
Chaumont	1.22	0.35
London	0.76	0.26
Los Angeles	2.02	0.35
Antwerpen	1.23	0.22

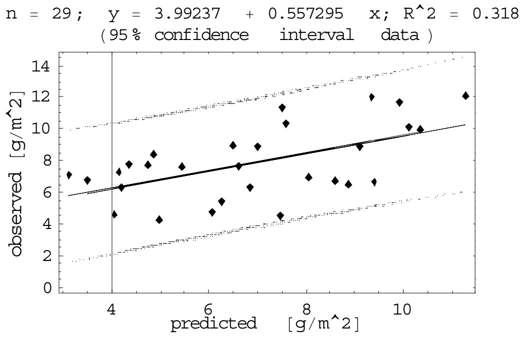
Zinc unsheltered 1, 2 and 4 years:

T>10°C: $ML=1.35*[SO_2]^{0.22}*\exp\{0.018Rh+0.021(T-10)\}*t^{0.85}+0.029Rain[H^+]*t$

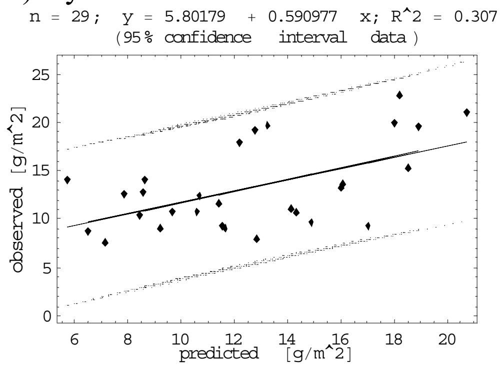
T≤10°C: $ML=1.35*[SO_2]^{0.22}*\exp\{0.018Rh+0.062(T-10)\}*t^{0.85}+0.029Rain[H^+]*t$

Figure 12a, 12b, 12c and 12d Correlation of unsheltered samples.
Correlation of mass loss observed and predicted by UNECE dose-response functions.
Exposure periods:
a) 1997-1998, b) 1997 - 1999, c) 1997 - 2001, d) 1997 - 2001

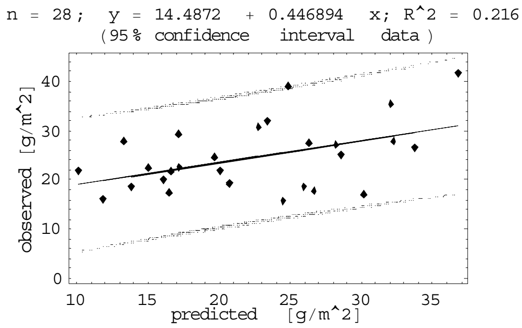
12a) 1 year measurement



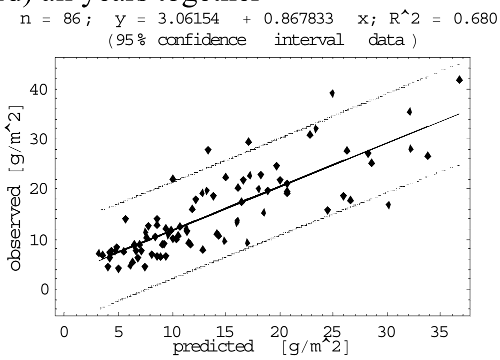
12b) 2 years measurement



12c) 4 years measurement



12d) all years together



Local differences of DRF Zn unsheltered

Table 37 Statistical information of the ratio predicted/observed corrosion and the contributions of the dry and wet part of the UN-ECE DRF for unshelterd zinc samples.

n = 86; RSquared -> 0.680, AdjustedRSquared -> 0.676; EstimatedVariance -> 22.6
y = 3.06 + 0.868 x

Exposure site	Predicted/observed	StdDev	Contribution of dry part of eq. %	Contribution of rain part of eq. %	StdDev of contributions
Prague	1.67	0.18	98	2	0.67
Kopisty	1.16	0.11	96.33	3.67	1.11
Ähtäri	0.67	0.1	87.67	12.33	0.44
Waldhof Langenbrügge	1.13	0.07	97	3	0
Langenfeld	0.89	0.28	94.67	5.33	2.44
Bottrop	0.93	0.03	97.33	2.67	0.44
Rome	0.76	0.12	100	0	0
Casaccia	0.87	0.08	100	0	0
Milan	1.01	0.22	100	0	0
Venice	1.4	0.09	100	0	0
Oslo	1.22	0.09	95	5	2
Birkenes	0.59	0.02	65.33	34.67	1.11
Stockholm South	0.79	0.05	94.33	5.67	0.44
Aspvreten	0.7	0.07	91	9	1.33
Lincoln Cathedral	0.89	0.02	94.33	5.67	0.44
Madrid	1.59	0.06	79	21	9.33
Toledo	0.86	0.08	99.33	0.67	0.44
Moscow	1.34	0.15	100	0	0
Lahemaa	0.72	0.1	93.67	6.33	1.11
Lisbon	0.71	0.02	99.67	0.33	0.44
Dorset	1.02	0.09	79.33	20.67	1.78
Paris	0.66	0.01	99.67	0.33	0.44
Berlin	1.24	0.09	100	0	0
Tel Aviv	0.93	0.1	100	0	0
Svanvik	0.65	0.02	95.67	4.33	0.89
Chaumont	1.05	0.09	93.33	6.67	1.11
London	0.73	0.04	99	1	0
Los Angeles	0.44	0.02	100	0	0
Antwerpen	1	0.13	97.33	2.67	0.44

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- BRE – Building Research Establishment Ltd., Watford, United Kingdom,
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