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Atmospheric Corrosivity in New Zealand

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SUMMARY

Prior to 1980 little quantitative atmospheric corrosivity data had been published for New Zealand. Results from a number of studies, including a nation-wide survey of atmospheric corrosivity toward steel, aluminium and galvanised steel, have now been reported and a more confident evaluation of atmospheric corrosivity in New Zealand is possible.

The results show that atmospheric corrosion rates in New Zealand are not, in general, especially high in comparison to rates throughout the world, given the high chloride deposition levels and high relative humidities observed in this country. Further work is needed to investigate relationships between environmental characteristics and corrosion rates.

Corrosivity categorisations for steel, aluminium and galvanised steel are proposed, in accordance with the International Standards Organisation (ISO) classifications recently produced.

INTRODUCTION

Until the last decade little quantitative atmospheric corrosivity data had been published for New Zealand (1). There seemed to be, however, a widely held perception that the New Zealand atmosphere was relatively corrosive, and that this was attributable to both the humid and maritime character of the environment.

Results have now been published from a number of studies of atmospheric corrosivity in New Zealand, including a nation-wide survey (2), and a more confident evaluation of corrosivity in New Zealand can be made. This paper reviews the results of these studies, and reports the 1 year exposure results from some previously unpublished results. Corrosivity categorisations for steel, aluminium and galvanised steel are proposed, in accordance with the International Standards Organisation (ISO) corrosivity classifications recently produced (3).

REVIEW OF ATMOSPHERIC CORROSIVITY STUDIES IN NEW ZEALAND

The earliest work in New Zealand seems to be Fahy's studies of anodised and mill finished aluminium (4 and 5). Weight changes (corrosion products not removed) for test coupons exposed at five sites in Christchurch were reported in 1980, and results for sites in Auckland, Rotorua, New Plymouth, Wellington, Greymouth, Woodbury and Dunedin were reported later. At four of the Christchurch sites the mill finished coupons increased in weight by about 1 g/m^2 in the first year with the rate of increase generally slowing thereafter. After 12 years total weight gains of 3 to 6 g/m^2 were recorded. The remaining site in Christchuch was alongside a fertiliser and chemical manufacturing works. Here weight gains on the mill finished coupons were about 6 g/m^2 in the first year and 25 g/m^2 after 10 years. At the other sites little weight change was observed in the mill finished coupons. The anodised coupons gained weight mainly during the first year or two then stabilised or lost weight. The largest weight loss was of about 5 g/m^2 after 12 years in Rotorua.

In 1981 Christian and Thomson (6) reported galvanised steel corrosion rates of approximately 5 per cent zinc weight loss per year (equivalent to 10 g/m^2 of total coating weight of 200 g/m^2 each side), for two sites at Otaki and South Head, Manukau. These workers commented that while the corrosion rates they found were consistent with their field experience in New Zealand, they seemed low compared to rates for similar environments overseas.

The following year Duncan and Whitney's paper (7) containing their corrosivity map appeared, which included CLIMAT test results for New Zealand conducted by Alcan (NZ) Ltd and the New Zealand Ministry of Energy. Marine corrosivity index (MCI) aluminium wire on steel bolt data only were published, for 15 sites in New Zealand plus 5 sites in Australia. The New Zealand indices ranged from 1.2 to 30.3, which although higher than for Australian sites at similar distances inland, were not especially high compared with CLIMAT indices found in other countries.

Further MCI results were reported in 1983 by Barnett and Turner (8), for 10 sites in New Zealand. Indices were between 5.0 and 16.4. In this study chloride levels both on and in adjacent gorse plants were also measured, but no correlation with the CLIMAT results was found.

In 1984 Duncan (9) reviewed the atmospheric corrosion rate information available for New Zealand at that time, and reported the previously unpublished results of Shaw's surveys of zinc corrosion rates in New Zealand, which had been conducted in the early 1970s. A total of 44 sites were tested, and rates ranging from 4.8 to 15.6 g/m^2/yr were recorded. Confidence intervals were not given, but it is has been suggested by Duncan (personal communication) that due to high variability in replicates, little discrimination could be made among the sites, with the exception of the site at Rotorua which was significantly more corrosive than the others. It was noted that Shaw had found higher rates in much of Britain. More MCI results for New Zealand were also given in this paper, plus some early results from a programme of atmospheric corrosion studies being undertaken by the Building Research Association of New Zealand (BRANZ). These comprised CLIMAT results, including aluminium wire on plastic bolt (ACI) results, and chloride in rain and chloride dry deposition levels for the BRANZ exposure test site at Judgeford. The MCI indices were comparable with those previously reported. The ACI indices averaged about 0.17. The chloride dry deposition levels average 6.5 g/m^2/yr with the rain depositing 22 g/m^2/yr of chloride. Also in 1984 a galvanised steel corrosion rate of 6 g/m^2/year was separately reported (10) for the BRANZ site at Judgeford.

In 1985 the first steel corrosion rate measurements for New Zealand were reported by Ballance and Duncan (11). 'BSIRA' high copper content steel coupon corrosion rates, CLIMAT, and chloride dry deposition levels were concurrently measured at eighteen sites in Southland and the Manawatu, plus the BRANZ Judgeford site. The 'BISRA' steel coupons were from the same source as those used by King in the corrosion surveys of Melbourne (12), which were of nominally identical composition to material used in atmospheric corrosion studies in Britain and elsewhere. Steel corrosion rates ranged from 290 g/m^2/yr on the coastline to 50 g/m^2/yr 95 km inland. Average chloride dry deposition levels ranged from 34 down to 0.4 g/m^2/yr.

The average CLIMAT results were MCI 12.8 to 1.5 and ACI 0.27 to 0.06. In this study, chloride dry deposition levels were found to correlate closely with the steel corrosion rates, and with MCI. Chloride deposition and CLIMAT results for the Judgeford site were reported later (13); the 'BISRA' coupon corrosion rate (not previously reported) was 185 g/m^2/year.

Boulton in 1988 (14) published corrosion performance results of four types of welded stainless steel test panels exposed for three years at three sites. The alloys tested comprised AISI types 304L and 316L (austenitic), 444 (ferritic), and 3RE60 (duplex). In general the duplex alloy performed best at all three sites, although surface preparation was shown to have an important influence. Least corrosion was observed at the Rotorua (geothermal) site; most at the Manukau Heads (severe marine) site.

Earlier this year a study of corrosion rates of mild steel, galvanised steel and aluminium coupons exposed at five adjacent sites in Taranaki has been published (15). Average corrosion rates were 276 g/m^2/yr for steel, 6 g/m^{2}yr for galvanised steel and 1.6 g/m^2/yr for aluminium, with little difference found among the sites.

Very recently the first results from a comprehensive corrosion survey of atmospheric corrosivity in New Zealand have become available (2). Steel, galvanised steel and aluminium one-year corrosion rates have been determined for 168 sites located throughout most of the country. 'BISRA' steel coupons were exposed at the sites common to Duncan and Ballance's study. Excluding the results from the geothermal region, corrosion rates ranging from 18 to 511 g/m^2/yr for steel and 0.7 to 34 g/m^2/yr for galvanised steel were found. Few of the sites produced significant corrosion on the aluminium coupons and the maximum corrosion rate found was 2.6 g/m^2/yr. Tables 1 and 2 give the mild steel, aluminium and galvanised steel results in full. The 'BISRA' coupon corrosion rate at Judgeford was 172 g/m^2/year. Corrosion rates correspond with proximity to the sea, with increased rates observed in areas of geothermal activity and industry. These corrosion rates are low in comparison to rates observed in countries with significant industrial air pollution (corrosion rates being found to correspond to sulphur dioxide levels), but seem consistent with those in other predominantly marine-influenced environments.

An ISO working group has been active in the area of atmospheric corrosivity testing during the 1980s and is currently conducting an international atmospheric corrosivity survey, known as ISOCORRAG. Continuing work at BRANZ includes participation in ISOCORRAG, which involves exposure of both wire helix test units and flat panel test coupons. This work is being linked to previous studies in New Zealand by concurrently exposing surplus test coupons from those studies (ie BISRA coupons from Duncan and Ballance's study, and steel, galvanised steel and aluminium coupons from the nation-wide BRANZ corrosion survey). The first one-year results for the flat panels can now be presented: ISO steel 165 g/m^2/yr; New Zealand survey steel 158 g/m^2/yr; BISRA steel 167 g/m^2/yr; copper 11.7 g/m^2/yr; galvanised steel 4.1 g/m^2/yr; aluminium 0.2 g/m^2/yr.

CORROSIVITY CLASSIFICATION OF NZ

In the absence of atmospheric corrosivity test data, previous estimates of atmospheric corrosivity in New Zealand were performance based on theoretical grounds, generally relying on the air humidity and very limited chloride deposition information available (for example Rychtera (16)). In 1982 a map of 'suggested atmospheric corrosivity zones for iron and steel' in New Zealand was produced by Duncan and Whitney (7), based principally on sodium levels in grass, as a predictor of chloride deposition.

Table 1: One year Corrosion Rates ($gm^{-2}yr^{-1}$), North Island

SITE (LATITUDE, LONGITUDE)	STEEL	ZINC	ALUMINIUM
NORTHLAND			
Kaitaia A53125 (35.06, 173.15)	188	5.1	0.3
Kerikeri Aero A53293 (35.16, 173.55)	203	4.8	0.6
Waiotemarama A53541 (35.31, 173.25)	179	4.4	-0.3
Waipoua Forest A53651 (35.39, 173.33)	158	4.1	0.0
Dargaville A53982 (35.57, 173.50)	212	3.6	0.0
Whangarei Aero A54733 (35.46, 174.22)	234	5.1	0.0
Marsden Point A54842 (35.53, 174.28)	285	16.2	0.3
Leigh (36.18, 174.48)	304	9.2	1.4
Warkworth A64463 (36.26, 174.40)	191	5.7	0.3
Woodhill Forest A64741 (36.45, 174.26)	191	3.5	0.3
Muriwai (36.50, 174.27)	440	22.8	1.0
AUCKLAND			
Whenuapai A64761 (36.47, 174.38)	248	5.7	0.3
Takapuna (36.48, 174.45)	142	3.2	0.3
Albert Park A64878 (36.51, 174.46)	152	3.8	0.3
Auckland City A64878 (36.51, 174.46)	259	7.6	1.0
Parnell (36.52, 174.48)	165	3.2	-0.3
Auckland Harbour Bridge (36.51, 174.46)	390	19.0	2.2
Owairaka A64971 (36.54, 174.44)	152	4.1	0.6
Penrose (36.56, 174.51)	229	6.0	0.0
Ellerslie (36.55, 174.51)	190	3.2	0.0
Auckland Aero C74082 (37.01, 174.48)	298	13.0	0.3
Ardmore C74091 (37.02,174.58)	209	3.5	0.3
South Head (37.04, 174.33)	327	11.4	1.4
WAIKATO			
Pukekohe C74282 (37.12, 174.52)	192	4.1	0.0
Glenbrook (37.13, 174.45)	155	3.3	0.8
Maioro Forest C74371 (37.21, 174.43)	181	3.8	0.0
Hunua C75003 (37.04, 175.04)	180	4.1	0.0
Maramarua Forest C75321 (37.18, 175.15)	150	2.5	-0.3
Te Kauwhata C75412 (37.25, 175.08)	217	5.7	0.6
Thames B75152 (37.08, 175.32)	136	3.1	0.0
Paeroa B75361 (37.23, 175.40)	160	3.2	0.3
Te Aroha B75571 (37.33, 175.43)	115	2.9	0.3
Ruakura C75731 (37.47, 175.19)	130	1.6	0.6
Hamilton Aero C75832 (37.52, 175.20)	142	3.5	0.6
Cambridge C75953 (37.55, 175.30)	131	2.5	0.3
TAUPO			
Mohakatino C84761 (38.43, 174.37)	267	14.6	0.3
Arapuni C85061 (38.04, 175.39)	104	2.9	0.3
Waikeria C85132 (38.05, 175.23)	128	3.8	0.3
Te Kuiti C85314 (38.20, 175.09)	124	3.8	0.3
Wairere C85502 (38.32, 175.00)	163	2.2	0.3
Pureora Forest C85551 (38.31, 175.33)	107	3.2	0.6
Taumarunui C85821 (38.52, 175.16)	105	2.9	-0.3
Kinleith B85285 (38.17, 175.53)	308	5.4	1.3
Atiamuri B86403 (38.24, 176.01)	74	2.9	0.3
Taupo B86602 (38.41, 176.04)	120	2.9	0.6
Wairakei B86611 (38.38, 176.06)	155	4.8	0.0
Taupo Aero B86702 (38.45, 176.05)	104	4.1	0.0
Waimihia Forest B86821 (38.50, 176.16)	91	3.2	0.0
Turangi C95085 (39.00, 175.48)	107	2.5	0.3
Chateau, Mt Ruapehu C95152 (39.11, 175.32)	96	3.5	0.0
TARANAKI			
New Plymouth Aero C94011 (39.01, 174.11)	247	7.8	0.6
Stratford E94333 (39.20, 174.18)	188	3.8	0.3
Kapuni E94413 (39.28, 174.10)	230	4.8	0.6
Patea E94743 (39.45, 174.28)	218	14.6	1.0
Ohakune E95445 (39.24, 175.25)	85	3.4	0.0
Waiouru E95465 (39.28, 175.41)	155	2.7	0.0
Ahu Ahu E95614 (39.41, 175.06)	112	2.1	0.0
Taihape E95683 (39.41, 175.48)	71	0.9	0.0
Wanganui Aero E95903 (39.58, 175.01)	352	33.6	1.1
Paraparaumu Aero E04991 (40.54, 174.59)	240	9.1	0.6
Flockhouse E05221 (40.14,15116)	208	5.5	0.3
Kairanga E05343 (40.20, 175.28)	203	2.7	0.3
Palmerston North Aero E05361 (40.20, 175.37)	168	3.0	0.6
Waitarere Forest E05521 (40.33, 175.12)	224	5.5	0.6
Levin E05622 (40.39, 175.16)	194	4.0	0.6

SITE (LATITUDE, LONGITUDE)	STEEL	ZINC	ALUMINIUM
BAY OF PLENTY			
Whangapoua Forest B65761 (36.46, 175.36)	158	5.7	0.0
Tairua Forest B75182 (37.10, 175.51)	170	3.5	0.6
Waihi B75381 (37.23, 175.51)	163	4.4	0.0
Katikati B75592 (37.35, 175.58)	146	3.8	0.3
Tauranga aero B76621 (37.40, 176.12)	195	4.4	0.3
Te Puke B76835 (37.49, 176.19)	154	2.8	0.0
Rotoehu Forest B76951 (37.54, 176.31)	155	3.2	0.3
Edgecumbe B76984 (37.55, 176.55)	146	2.2	-0.6
Whakatane Aero B76994 (37.55, 176.55)	196	5.1	0.3
Kawerau B86071 (38.05, 176.43)	294	9.5	0.6
Kaingaroa Forest B86451 (38.24, 176.34)	109	2.5	0.3
Murupara B86471 (38.27, 176.42)	96	1.8	0.3
Ohaaki D.S.I.R (38.30, 176.20)	391	12.4	0.0
Ohaaki Power Station (38.31, 176.19)	109	3.5	0.3
HAWKES BAY			
Manutuke D87683 (38.41, 177.53)	141	2.2	0.0
Gisborne Aero D87692 (38.40, 177.59)	194	2.8	-0.3
Onepoto D87811 (38.51, 177.08)	90	2.8	0.6
Wharerata Forest D87881 (38.52, 177.52)	175	3.2	0.3
Esk Forest D95272 (39.15, 176.42)	86	2.5	0.3
Napier Aero D96481 (39.28, 176.52)	153	3.2	0.6
Havelock North D96689 (39.40, 176.53)	101	5.4	0.3
Taradale (39.35, 176.53)	82	1.6	0.0
Mohaka Forest D97004 (39.04, 177.02)	114	2.5	0.0
Frasertown D97042 (39.00, 177.24)	153	3.2	0.0
Waipukurau D06051 (40.00S, 176.32)	119	1.9	0.0
ROTORUA			
Tikitere B86034 (38.04, 176.21)	243	9.5	-0.3
Rotorua Aero B86131 (38.07, 176.19)	207	5.7	0.3
Lynmore (38.12, 176.18)	153	4.4	0.0
Koutu (38.10, 176.16)	117	4.4	0.0
Ngapuna (38.11, 176.18)	2293	71.6	0.3
Springfield (38.12, 176.16)	218	6.7	0.0
Ohinemutu (38.11, 176.16)	222	5.4	-0.3
Lake Rotoatamaheke (38.12, 176.16)	4800	141.6	*
Waitapu Forest B86341 (38.19, 176.25)	111	3.2	0.3
WAIRARAPA			
Dannevirke D06212 (40.13, 176.07)	114	3.2	-0.3
Castlepoint D06921 (40.54, 176.13)	232	15.5	0.3
Tauherenikau D15134 (41.07, 175.23)	124	2.9	-0.3
Mt Bruce D05765 (40.32, 175.38)	128	3.5	0.0
Waingawa D05964 (40.59, 175.37)	142	3.5	0.0
WELLINGTON			
Avalon E14195 (41.11, 174.56)	164	5.1	0.3
Judgeford (41.07, 174.56)	153	5.5	0.0
Kelburn E14272 (41.17, 174.46)	128	2.5	0.0
Thorndon (41.17, 174.47)	173	13.0	0.9
Thorndon, sheltered (41.17, 174.47)	194	12.2	0.4
Somes Island E14285 (41.16, 174.52)	243	4.4	0.6
Gracefield E14290 (41.14, 174.55)	167	7.0	0.6
Wainuiomata E14296 (41.17, 174.57)	165	4.1	-0.3
Wellington Aero E14387 (41.20S, 174.49)	268	18.3	2.6
Kaitoke E15011 (41.05, 175.11)	146	3.8	0.3
Wallaceville E15102 (41.08, 175.03)	145	4.1	0.3

Note : * Implies missing data

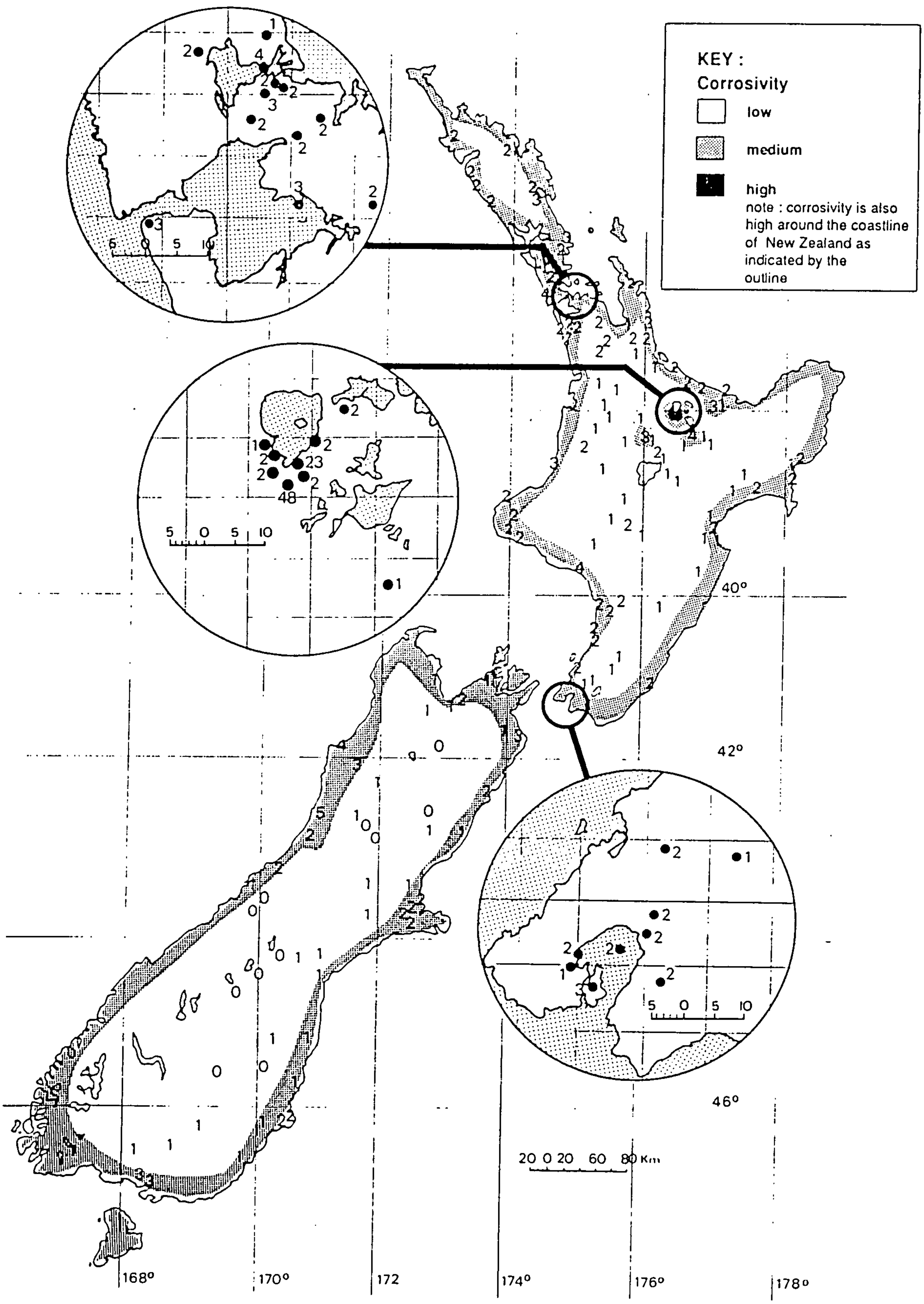

Figure 1: Corrosivity Zones and Steel Corrosion Rates for New Zealand. Rates mapped by location, g × 10⁻¹/M⁻¹/year. Rates rounded for clarity.

Duncan and Whitney's zone names were purposely similar to the atmospheric classifications defined in Australian Standard AS 2312 (17). In AS 2312 the zones are defined in terms of amount of rainfall, average relative humidity and levels of industrial pollution and marine influence, but with data on corrosion rates found in the various atmospherid classes appended. Interpretation of this information is not straightforward, but seems to indicate one-year corrosion rates of up to 160 g/m²/year for 'mild' environments, above 230 g/m²/year in 'very severe' environments, with rates in 'moderate' and 'severe' environments being intermediate. Duncan and Whitney's paper reproduced that corrosion rate information and thus implied similar steel corrosion rates for the New Zealand zones. According to their categorisation the corrosion hazard in much of New Zealand, including all major urban areas, is 'severe' or 'very severe'. This categorisation has been published by the Standards Association of New Zealand (SANZ) (18), as a commentary on the Australian standard.

With the advantage of the quantitative corrosion rate data that has subsequently become available, it appears that although steel corrosion rates are closely related to chloride deposition levels, the corrosion rates are somewhat lower than would be predicted from Duncan and Whitney's classification. The New Zealand corrosion survey found steel corrosion rates less than 160 g/m²/yr in much of New Zealand, and while rates above 230 g/m²/year were found at some sites, these were generally within a few kilometres of the sea. There is also a problem with terminology used in AS 2312, in that the corrosion rates implied by 'severe' etc are not high when considered globally.

The ISO, as part of their recent work on atmospheric corrosion testing, have produced definitions of corrosivity categories for steel, zinc, aluminium and copper (3). Based on the considerable data now accumulated for steel in New Zealand, and using the ISO categorisation, Figure 1 is constructed. This map may be considered to provide a reasonably reliable guide, as the evidence indicates similar corrosion rates for different grades of steel in New Zealand, with little variation in corrosivity from year to year. Local environmental characteristics, as found at Kinleith for instance, and microclimatic effects must naturally be borne in mind.

For zinc and galvanised steel an analogous map could be produced, and would show essentially similar features. Less New Zealand data is available for aluminium but different alloys seem to perform generally alike in marine environments, excepting the Al-Cu alloys (AA-2000 series) which are less durable (19). Thus a corrosivity map for aluminium would show most of New Zealand to be of 'low' corrosivity with a band of 'medium' corrosivity around the coast reaching perhaps up to ten kilometres inland. With aluminium however, microclimatic effects can have an overrriding influence on corrosion performance, and so such a classification would probably be less used.

For other metals, apart from some very limited information for stainless steels (14), and the copper corrosion rate reported herein, no New Zealand data appears to have been published. Although the variation in relative corrosion rates exhibited by different metals in differing environments is not easy to predict precisely, particularly where the environment is not well characterised, the generally low corrosion rates observed for steel, zinc and aluminium might be taken as indicative.

CONCLUSIONS

Atmospheric corrosivity data for steel, aluminium and zinc now allows confident classification of New Zealand environments. Atmospheric corrosion rates for these metals in New Zealand seem comparable with rates found in other predominantly marine influenced environments. Further work is needed to investigate relationships between environmental characteristics and observed corrosion rates.

REFERENCES

1. Moresby, J.F., Reeves, F.M. and Spedding, D.J., (1982), in 'Atmospheric Corrosion', (ed W.H. Ailor), New York, Wiley; 745-754.
2. Cordner, R.J., Br. Corros. J. in press.
3. International Organisation for Standardisation: ISO.DIS 9223.
4. Fahy, F.W., Br. Corros. J, (1980), 15, (4), 203-207.
5. Fahy, F.W., Br. Corros. J, (1983), 18, (4), 179-183.
6. Christian, D.F. and Thomson, P.R., (1981), in Proceedings of Conference 21, Australasian Corrosion Association, ACA, 39-50.
7. Duncan, J.R. and Whitney, R.S., (1982), in Transactions, Institute of Professional Engineers of NZ, 9, (3/EMCh), IPENZ, 65-75.
8. Barnett, P.S. and Turner, K.S., (1983), in Annual Conference, Institute of Professional Engineers of NZ; Paper 80, IPENZ.
9. Duncan, J.R., Corros. Australasia, (1984), 9, (5), 4-8.
10. Cordner, R.J. and Whitney, R.S., (1984), in Proceedings of Conference 24, Australasian Corrosion Association; Paper 20, ACA.
11. Ballance, J.A. and Duncan, J.R., (1985), NZ J. of Technology, 1, 239-244.
12. King, G.A., Martin, K.G., and Moresby, J.F., (1982), A Detailed corrosivity survey of Melbourne, CSIRO, Melbourne.
13. Cordner, R.J., Wilson, R.G. and Duncan, J.R., (1987), NZ J. of Technology, 3, 219-225.
14. Boulton, L.H., Miller, N.A. and Sanders, M.C., (1988), Br. Corros. J. 23, (2), 117-121.
15. Cordner, R.J., Duncan, J.R. and Krouse, D.P., (1990), Corros. Australasia, 15, (1), 11-13.
16. Rychtera, M., (1970), Deterioration of Electrical Equipment in Adverse Environments, Academia/Iliffe Books Ltd, Prague.
17. Standards Association of Australia, (1984), Guide to the Protection of Iron and Steel against Exterior Atmospheric Corrosion, AS 2312-1984, Sydney.
18. Standards Association of New Zealand, (1987), Commentary on AS 2312:1984 Guide to the protection of iron and steel against exterior atmospheric corrosion, NZS MP 2312-1987, Wellington.
19. Godard, J.P., Jepson, W.B., Bothwell, M.R. and Kane, R.L., (1967), The Corrosion of Light Metals, John Wiley and Sons, New York, 23-24.

Table 2: One year Corrosion Rates ($gm^{-2}yr^{-1}$), South Island

SITE (LATITUDE, LONGITUDE)	STEEL	ZINC	ALUMINIUM
MARLBOROUGH			
Riwaka G12191 (41.06, 172.58)	95	2.3	0.0
Tapawera G12382 (41.23, 172.48)	97	2.6	0.4
Appleby G13211 (41.17, 173.06)	104	3.4	0.0
Nelson Aero G13222 (41.17, 173.14)	162	3.4	0.0
Rai Valley G13251 (41.14, 173.35)	105	3.0	0.0
Brancott Valley G13584 (41.32, 173.50)	58	2.3	0.0
Lake Grassmere G14711 (41.44, 174.9)	270	8.7	0.8
Lake Rotorua F12752 (41.47, 172.35)	34	4.9	0.4
WEST COAST			
Westport Aero F11752 (41.44, 171.35)	375	7.2	0.0
Hokitika Aero F20793 (42.43, 170.59)	235	8.7	-0.8
Reefton F21182 (42.07, 171.52)	253	5.3	0.0
Greymouth F21422 (42.28, 171.12)	511	9.1	0.8
Otira F21851 (42.50, 171.34)	102	6.4	0.0
Springs Junction F22311 (42.20, 172.11)	66	3.8	0.0
Harihari F30153 (43.09, 170.33)	150	4.0	-0.4
Franz Josef F30312 (43.23, 170.10)	118	9.1	0.0
CANTERBURY			
Hamner Forest G22581 (42.31, 172.51)	37	0.8	0.0
Kaikoura G23471 (42.25, 173.42)	223	4.2	0.8
Arthurs Pass H21951 (42.57, 171.34)	49	3.9	0.4
Culverden H22783 (42.46, 172.53)	76	2.3	0.0
Cheviot H23822 (42.48, 173.16)	108	3.8	0.0
Craigieburn Forest H31172 (43.09, 171.43)	25	2.5	0.4
Highbank H31572 (43.35, 171.44)	76	2.5	0.4
Ashburton H31971 (43.54, 171.45)	138	2.1	0.0
Eyrewell Forest H32424 (43.24, 172.17)	74	1.6	0.4
Christchurch Aero H32451 (43.29, 172.32)	206	2.8	0.4
Christchurch H32561 (43.32, 172.37)	152	2.0	0.0
Bromley H32573 (43.32, 172.42)	207	3.5	-0.4
Lincoln H32641 (43.39, 172.28)	175	2.4	0.0

	STEEL	ZINC	ALUMINIUM
SOUTHLAND AND OTAGO			
The Hermitage H30711 (43.44, 170.06)	30	3.9	0.0
Kelman Hut, 2450 m A.S.L (43.31, 170.22)	23	2.7	-0.6
Lake Tekapo H40041 (44.01, 170.28)	18	1.1	0.3
Fairlie H40183 (44.06, 170.50)	53	1.8	0.3
Twizel H40212 (44.15, 170.06)	22	1.1	0.3
Geraldine H41127 (44.06, 171.14)	75	1.1	0.0
Timaru Aero H41323 (44.18, 171.14)	144	1.8	-0.4
Waimate H41701 (44.44, 171.03)	74	1.8	0.7
Kurow I40742 (44.44, 170.28)	55	1.1	0.0
Omarama I49591 (44.32, 169.54)	17	1.4	0.0
Ranfurly I50113 (45.08, 170.06)	34	0.7	0.0
Palmerston I50147 (45.29, 170.43)	90	1.7	0.3
Taiaroa Head I50771 (45.47, 170.44)	239	4.4	0.3
Dunedin Aero I50921 (45.56, 170.12)	127	1.7	-0.3
Musselburgh I40951 (45.54, 170.31)	243	6.4	0.3
Alexandra I59234 (45.16, 169.23)	34	1.0	0.0
Tapuni I59921 (45.57, 169.17)	73	1.7	-0.3
Winton I68133 (46.09, 168.20)	148	2.7	0.0
Gore I68192 (46.07, 168.54)	121	2.3	0.0
Invercargill Aero I68433 (46.25, 168.20)	253	4.0	0.3
Tiwai Point I68533 (46.35, 168.23)	341	15.4	1.0
Finegand I69273 (46.16, 169.44)	145	2.3	0.3

Atmospheric corrosivity in New Zealand.
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