Reprint | **NO.38**

ATMOSPHERIC CORROSION IN NEW ZEALAND

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Atmospheric corrosion in New Zealand

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SUMMARY

There is reason to regard chloride as the most important atmospheric corrosion stimulator for most areas of New Zealand except the central North Island and perhaps around Christchurch. The high atmospheric moisture levels will combine with the chloride to produce severe hazards on sheltered surfaces. No studies of steel corrosion rates appear to have been made. Data are presented from previously unpublished studies of atmospheric corrosion risks for zinc and aluminium in New Zealand, also a study of chloride deposition levels in support of these predictions of hazards.

THE ECONOMIC IMPACT OF ATMOSPHERIC CORROSION

There is no reliable knowledge regarding the cost of atmospheric corrosion to the New Zealand economy. A lot of circumstantial evidence indicates that it is high — special measures are needed in coastal areas to protect electricity reticulation systems (1) and in Rotorua to keep the telephone exchange working (2), fencing wire can have a short life (3), and perforation of metal claddings and gutters is common, to mention only a few examples. It is no exaggeration to claim that corrosion in the atmosphere is the most pervasive corrosion problem faced by New Zealand. Our engineered structures, such as buildings, bridges, production plants and railway systems, in general have the atmosphere as the major environment in which they must resist corrosion. Much of our equipment (such as tools or motor vehicles) spends a significant part of its life not in service, but always having to resist atmospheric corrosion.

It should be remembered, too, that a metallic component may be rendered totally unserviceable by the loss of a few per cent of its weight if the corrosion has attacked a section of critical dimensions or strength, or if the component is part of a safety mechanism. The costs of small amounts of corrosion can be disproportionately high.

MECHANISMS OF ATMOSPHERIC CORROSION

It is not intended in this paper to summarise the textbooks which are available on atmospheric corrosion. Special attention should be paid to those by Rosenfeld (4), Barton (5) and Ailor (6) which in turn summarise the state of the art in 1960, 1972 and 1980. However, it is essential to lay down a few guidelines to important theoretical points.

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The actual physical processes in which metals are converted to metallic ions in atmospheric corrosion are reasonably well characterised. In general we can place metals into one of four categories:

(a) Noble metals, which remain unattacked in the presence of atmospheric electrolytes. Examples are platinum and gold.

(b) Passivating metals, on which a tenacious, thin, unreactive oxide layer is formed under normal atmospheric conditions, so that corrosion is generally slow, and localised at weak points in the oxide film. Examples are aluminium, chromium, titanium, or stainless steel. Provided dust deposits do not occur (to produce differential aeration cells) these metals are generally fairly resistant to acidic pollutants in the air, but they can be quite severely attacked by chloride ions, especially under prolonged contact conditions such as occur on unwashed surfaces.

(c) Convertible oxide metals, which form a near-insoluble oxide/hydroxide layer which reacts with atmospheric impurities to form salts of greater solubility. Zinc, copper and lead fall into this category. The attack is general across the surface of these metals, with the rate-determining process occurring at the oxide/air interface.

(d) In a class of its own comes the most technically important metal, iron (or mild steel). This typically corrodes 10-100 times as fast as zinc over a two-year exposure period in the atmosphere (7). In contrast to zinc, the rate of iron corrosion is determined by the process at the rust/metal interface.

The involvement of water in providing the electrolytic path for atmospheric corrosion is essential but severe atmospheric corrosion can occur even in the absence of visible water film formation on surfaces. The rate of exchange of water is often so great that rain will wash away more salts or other surface contaminants such as corrosion products than it delivers to the surface. When the surface builds up a visible liquid film due to exposure to fog, or in dew formation, the corrosion problems can be much more severe. The amount of water exchange in the surface film is much lower, yet the film will be saturated with any corrosion-promoting species present in the atmosphere, so that when it evaporates it may leave behind larger amounts of salts on the surface than were originally present. If the surface is contaminated by salts, the formation of surface electrolyte films can be significant even at humidities below 100% RH. Several sources (e.g. 8) have tabulated "critical" relative humidity values for relevant salts. The "critical" value is the equilibrium humidity over a saturated solution of the salt; if the humidity of the atmosphere exceeds this value the saturated salt solution takes up water until equilibrium is achieved. The salt which takes up the water may be a corrosion product; this is particularly true of the metal chlorides which may form in a marine environment.

There are two possible mechanisms of loss of water from the electrolyte layer. These are evaporation (which is the chief mechanism) and reaction of the water at the surface. Evaporation can occur only at relative humidites below 100%. Both the temperature of the ambient air (which determines how much moisture the air can hold at 100% RH) and any temperature differences between the surface and its surroundings have effects on the evaporation rate. Thus, while the likelihood of electrolyte layer formation may be reasonably predictable from humidity and rainfall duration data, the "time of wetness' of the surface (i.e. the lifetime of the electrolyte layer which forms) is much less predictable.

The world's worst atmospheric corrosion problems are attributable to pollution by industry generated sulphur-containing gases. In addition to their naturally-occuring instances, such as in geothermal zones, they are generated by combustion of fossil fuels, and their impact on the environments of industrial zones overseas has been considerable. Not least of the consequent problems has been acidification of rainfall. Rain saturated with CO_2 at its atmospheric partial pressure would have a pH of approximately 5.6. Absorption of other atmospheric pollutants can change the pH, and Likens et al (9) have noted the widespread acidifcation of rainfall over Northwest Europe and North America. Even more insidious is the phenomenon of acid fog (10) because acid rain will affect only those surfaces exposed to rain (which can therefore be selectively protected), but acid fogs will reach to all surfaces.

The chief naturally-occurring chemical with significant atmospheric corrosion impact is the chloride ion. Most of the data collected on chloride in the atmosphere has been from rainfall analysis, and Brierly (11) summarised much of it in the course of defining four zones of hazard from corrosion by sea salt. These ranged in severity from oceanic islands and coastal areas (worst) to sub humid and humid areas long distances inland (least). Brierly categorised these areas in terms of a total salt-fall level; it should be noted that total salt-fall includes both that in rainfall and that due to dry deposition of wind-borne chloride, which can be significant (12).

Interactions between two or more

TABLE 1: METEOROLOGICAL PARAMETERS FOR SOME NEW ZEALAND TOWNS AND CITIES

		Rainfall			9am R.H.			Temperature		
	Sunshine hours	Total Annual mm	Feb mm	Aug mm	Mean Annual	Mean Feb	Mean Aug	Mean Annual	Mean Feb	Mean Aug
Kaitaia	2113	1418	109	160	82	79	87	15.6	20.0	12.0
Auckland	2102	1185	87	135	78	74	82	15.3	19.7	11.5
Hamilton	2006	1201	81	110	81	77	85	13.3	18.1	9.4
Whakarewarewa	1948	1439	103	131	81	78	85	12.6	17.7	8.3
New Plymouth	2114	1539	107	142	78	77	79	13.5	17.5	10.1
Gisborne	2204	1058	69	116	74	70	81	14.0	18.8	9.9
Wellington	2019	1271	84	124	81	80	84	12.5	16.6	8.9
Greymouth	1701	2451	167	199	82	83	80	12.3	16.2	9.0
Christchurch	1974	666	42	53	78	73	86	11.6	16.3	7.0
Dunedin	1685	784	61	55	74	72	78	11.0	15.1	7.3
Invercargill	1621	1037	75	66	83	81	87	9.7	13.6	6.2

pollutants can produce unexpected corrosion effects. Walton et al (13) have discussed the interactions of sulphur dioxide and a range of active and inert particulate types in initiation of corrosion. The importance of chloride in the particulate, both in its own right in involvement in corrosion and also under some conditions in producing a low critical relative humidity for moisture uptake onto the surface, emerges from their experiments.

CHARACTERISATION OF THE NEW ZEALAND ATMOSPHERE

Cermakova and Barton (14) gave an extremely important review of philosophies of corrosiveness assessment of atmosphers. They commented that "For more complicated cases, however, even in the usual types of atmosphere, it is necessary to have specific experience or experimental data on the behaviour of materials in the type of location where it is used."

This is, of course, a counsel of perfection. Even in some relatively sophisticated economies, simple guidelines to assessing the possible corrosivity of the atmosphere in an unfamiliar location have been regarded as desirable. In accord with this philosophy and despite the absence of direct corrosion monitoring information, New Zealand was categorised into four zones for steel corrosion hazard (15) using zone definitions (developed from AS 2312 (16)) which rely heavily on meteorological data. Good meteorological data are available for New Zealand, and some long-term average data are shown in Table 1 (17).

The most important factors from an atmospheric corrosion viewpoint in New Zealand are the levels of atmospheric moisture and atmospheric chloride. There will also be local problems caused by acidic sulphur-containing gases in areas with geothermal activity (principally in the area around Rotorua).

Atmospheric moisture

Relative humidities in the more densely populated parts of New Zealand are high compared with those in other countries, such as Australia, from which opinions are normally sought on the likely durability of materials which are unfamiliar to New Zealand. There are long periods when salts (such as sea-salt) deposited onto surfaces may be exposed to humidities above

their critical values. The relatively high rainfalls across most of New Zealand will have a beneficial effect on metals by cleaning any such salt or dust deposits away. This may, however, heighten the problem of corrosion on sheltered surfaces to which rainwashing cannot reach, by reducing to a small value the surface area which is at risk, which is in turn neglected because it is small.

Rainfalls in New Zealand are generally not sufficiently acidic to cause materials degradation problems, though Kennett (18) reports pH values as low as 3.9 at Kawerau, which would be extremely aggressive. The average rainfall pH at the Kawerau sites monitored was in the range of 5.3 to 6.7; this latter value is surprisingly high in light of the equilibrium pH of an atmospheric partial pressure carbonic acid solution. Stevenson (19) reports a study of pH of precipitation in Christchurch in winter, in which a mean rainfall pH of 4.6 was found.

Atmospheric chloride

New Zealand, because of its position as an island chain in a strong westerly wind belt, undoubtedly falls in the "Area 1" (worst) class proposed by Brierly. Few measurements have been reported for salt fall in NZ, and the best approximation to determining places of highest chloride deposition has been through use of maps of sodium levels in grass (20). Most of the small amount of work reported on chloride deposition in New Zealand has been performed by DSIR Soil Bureau, and

concerns analysis of collected rain. The data are summarised in Table 2 (21-23). An assessment of the amount of chloride deposition to be expected on sheltered surfaces was made at the Building Research Association of New Zealand (BRANZ) Research site at Judgeford (24). The amounts of chloride deposited onto

TABLE 2: CHLORIDE LEVELS IN RAINFALL REPORTED FOR NEW ZEALAND LOCATIONS

Location	Distance from coast (km)*	Period	Deposition g/m²/yr
Rongotai	0.5	1947-48	23.5
Baring Head	0.5	1947-48	16.7
Kelburn	6.5	1947-50	11.2
Pirinoa	6.5	1949-50	12.5
Lincoln	8	1884-88	6.8
Levin	10	1949-50	5.4
Taita	16	1955-58	11.6
		1963-71	11.3
		1969-74	9.5
Palmerston North	32	1949-51	5.3
Te Awa	48	1949-51	3.7
Gore	51	1955-58	6.7
Waingawa	61	1949-50	4.0

* This distance was calculated by Blakemore for sites except Lincoln, Taita, and Gore, using the distance from ocean rather than from the nearest harbour shore.

the filter paper collectors and in rain are shown in Tables 3 and 4.

The dry deposit at Judgeford is very close to pure sea salt, according to the neutron activation analysis results reported in Table 5, which it will be seen by comparison to Table 4 lists the analytical details for a month with relatively low salt deposition. The annual chloride deposition rates at Judgeford were assessed on the basis of 1982-3 measurement, as dry: 6.5 g/m²/yr, and in rain 22 g/m²/yr (24). As more data are collected these values will be able to be refined, but they suggest that salt deposition is higher at Judgeford than might have been expected from consideration of overseas studies. The first half of 1984 was an unusually calm period in Wellington, and this is the likely reason for the low 1984 values in Table 4.

A correlation of heavy chloride dry deposition to the occurrence of high winds is borne out by these data; as is the previously-reported effect of storms giving several months deposition in rain in a few days (see, for example May 1983). Further studies by BRANZ in Southland and the Manawatu are being done to test the hypothesis that at a particular distance inland the strength and origin of the prevailing wind have an overriding dominance in determining chloride deposition levels on oceanic islands such as New Zealand, but the available evidence clearly demonstrates the considerable potential hazard of chloride-mediated atmospheric corrosion of surfaces sheltered from direct rain-washing, even at distances many kilometres from the coast.

Hydrogen sulphide

Burns et al (2) claimed a threshold of corrosion problems of 1.5 microgrammes of hydrogen sulphide per cubic metre of air (μg/m³). In a months monitoring at the Rotorua telephone exchange site his group found a median value in the range 8-15

μg/m³, with about 2% of values exceeding 300 μg/m³, though quoting a "normal" value in the city of 15 μg/m³. Recent studies by the University of Auckland (25) have given similar results to those found by Burns et al (2). This University investigation found slightly lower values at sites away from bores at the Broadlands, Wairakei and Ohaki geothermal fields, but close to bores values exceeding 450 μg/m³ were frequent.

There can thus be considerable atmospheric corrosion dangers in the region around Rotorua due to the sulphur-containing gases in the atmosphere, but no general value can be ascribed. Locations close to fumaroles (which are distributed widely over the area bounded approximately by Te Puke, Ohakune, Waiouru and Kawerau) may be much more corrosive than locations only a few hundred metres distant.

Sulphur dioxide

Corrosion promotion by sulphur dioxide tends not to be a problem affecting regions of New Zealand the way hydrogen sulphide is. Microclimatic effects frequently lead to the area immediately around a flue being subject to this corrosion, and examples of "footprints" of enhanced corrosion reaching up to 100 metres down a prevailing wind have been seen in some industrial areas. The only urban centre whose meteorology makes its susceptible to enhanced sulphur dioxide levels in the atmosphere is Christchurch. Even here values are low by comparison with the "normal urban atmosphere value" of 110 to 2300 microgrammes of sulphur dioxide per cubic metre of air quoted by Barton (5). Health Department monitoring in central Christchurch in 1980-1 revealed maximum 24-hour SO₂ levels of 146 μg/m³ (1980) and 201 μg/m³ (1981) (both in the Manchester St area), with maximum monthly average of the 24-hour values (still in this same area) of

55 μg/m³ (1980) and 63 μg/m³ (1981) (26). In the industrial area of Penrose (Auckland) the respective maxima were 74 μg/m³ (1980) and 43 (1981) for a 24 hour average, and 31 μg/m³ (1980) and 24 μg/m³ (1981) for monthly average of the 24 hour values.

ACTUAL CORROSION MEASUREMENTS

No-one appears to have performed an analogous study of steel corrosion rates in New Zealand atmospheres to that reported by Martin and King (27), although the BRANZ studies now in progress include assessment of steel corrosion rates on panels from a batch shared with these CSIRO workers. The two widest based assessments of metal corrosion rates in New Zealand using uniform exposure methods appear to be those performed by Alcan (NZ) Ltd and by T. R. Shaw of Central Electricity Generating Board (UK), on aluminium and on zinc, neither of which has been the subject of any previously published data.

Climat studies by Alcan (NZ) Ltd.

The Climat test involves assessment of the weight loss of a length of aluminium wire wrapped onto a threaded plastic, steel or copper stud and exposed outdoors for a 90-day period (28). The Alcan results reported in Table 6 cover only the data from the mild steel stud, because it is this stud which best codifies the marine aggressiveness of the location. Values above 5 are regarded as moderately severe, above 10 as severe, and above 20 as very severe. To demonstrate the relative values obtained on the studs, and the seasonal variations that can occur, Table 7 gives data collected by BRANZ at its Judgeford site. It will be seen that there are small variations between periods, but levels remain generally the same.

Fahy (29) has performed an assessment of the durability of anodised aluminium in New Zealand.

TABLE 3: CHLORIDE IN RAINFALL AT JUDGEFORD

Collection period		Rainfall (mm)	Chloride deposition g/m²/yr
1982	1 Nov - 29 Nov	139	45.1
	2 Dec - 5 Jan	250	4.6
1983	5 Jan - 2 Feb	18	12.3
	2 Feb - 2 Mar	12	6.4
	2 Mar - 30 Mar	96	18.0
	30 Mar - 28 Apr	168	20.0
	28 Apr - 25 May	353	212.0
	25 May - 22 Jun	80	30.9
	22 Jun - 20 Jul	249	41.3
	20 Jul - 17 Aug	111	32.3
	17 Aug - 14 Sep	146	12.6
	14 Sep - 12 Oct	152	5.5
	12 Oct - 10 Nov	283	4.3
	10 Nov - 7 Dec	47	7.2
	7 Dec - 4 Jan	187	11.6
1984	4 Jan - 1 Feb	74	10.0
	1 Feb - 29 Feb	42	0.7
	29 Feb - 28 Mar	106	3.5
	28 Mar - 26 Apr	54	5.5
	26 Apr - 23 May	107	24.3

TABLE 4: CHLORIDE DEPOSITION ONTO SHELTERED-SURFACE COLLECTORS AT JUDGEFORD

Period collection	Open field g/m²/yr	Hill Top g/m²/yr	Hill Bottom g/m²/yr	On Combined Labs Bldg g/m²/yr
1982				
3 Nov - 1 Dec		14.2	13.3	2.2
1 Dec - 29 Dec		3.5	2.5	4.4
29 Dec - 26 Jan		5.1	3.9	15.9
1983				
26 Jan - 23 Feb	1.8	1.6	1.1	3.2
23 Feb - 23 Mar	10.3	4.9	3.9	3.0
23 Mar - 20 Apr	13.3	8.3	4.4	9.3
20 Apr - 18 May	16.9	24.5	10.2	19.1
18 May - 15 Jun	7.5	3.1	1.0	3.1
15 Jun - 13 Jul	4.9	12.1	5.5	9.9
13 Jul - 10 Aug	7.4	5.5	3.9	6.9
10 Aug - 7 Sep	4.6	6.2	3.9	5.3
7 Sep - 5 Oct	9.6	7.2	3.4	13.2
5 Oct - 2 Nov	—	6.1	2.4	—
2 Nov - 30 Nov	1.4	2.6	1.2	2.2
30 Nov - 25 Jan	2.8	8.4	3.8	3.0
1984				
25 Jan - 22 Feb	2.9	2.9	1.6	3.4
22 Feb - 21 Mar	1.7	1.1	0.7	1.0
21 Mar - 26 Apr	2.7	2.7	1.3	1.3
26 Apr - 16 May	6.5	3.1	1.7	4.7

TABLE 5: NEUTRON ACTIVATION ANALYSIS RESULTS FOR FILTER PAPERS EXPOSED NOVEMBER 2-30, 1983
(courtesy of Graduate School of Oceanography, University of Rhode Island)

Collector Position	Weight Deposited (g/m²/yr)				Ratios*		
	Cl	Na	Mg	Ca	Na/Cl	Mg/Cl	Ca/Cl
Hill Top	6.6	3.7	0.6	nd	0.55	0.09	—
Hill Foot	0.9	0.5	0.06	0.02	0.52	0.06	0.02
Open Paddock	1.1	0.6	0.1	0.03	0.52	0.12	0.03
On Combined Labs	2.1	1.1	0.2	0.08	0.55	0.12	0.04
Blank	0.07	0.02	nd	nd	0.27	—	—
Doped with seawater by analyst	2.8	1.5	0.2	0.09	0.55	0.07	0.03

*Ratios do not agree with weights because weight values were rounded.

TABLE 6: ALUMINIUM ON IRON STUD DATA FROM CLIMAT TESTS IN NEW ZEALAND BY ALCAN (NZ) LTD

General location	Specific location	Value	General location	Specific location	Value
NORTH ISLAND			**SOUTH ISLAND**		
Kaitaia	Town centre	11.2	Marlborough	D'Urville Is	6.9
	1 km from sea	12.6			
			Westland	Karamea	10.3
Auckland	Henderson	8.8		Haast township	10.0
	New Lynn	4.5		Birchfield	5.6
	Waiau Creek	6.6		Ngakawau River	22.7
	Otahuhu	5.0			
	Penrose	6.5	Timaru	Seadown	5.1
	Piha	15.7			
	Wiri (Alcan plant)	7.5	Oamaru	13 km from sea	5.5
				15 km from sea	3.4
Manukau	Kariotahi Beach	30.8			
Peninsula	South Heads Rd	21.0	Dunedin	Aramoana Bay	9.5
				Halfway Bush	1.2
Coromandel	Waihi Beach	25.4		Gas works	3.8
	Whangamata	31.0			
			Tiwai Point	1.6 km from sea	13.6
Napier	Whirinaki substation	4.3			
			Orepuke	Beach 300 m from sea	30.3
Taranaki	Opunake substation	8.5		Riverferry Rd	21.0
	Waitara	11.1		6 km from sea	
	Huirangi substation	9.4		Council Rd	12.3
				18 km from sea	
	New Plymouth Power Station	16.1	Invercargill	Makarewa Substation	8.3
	200 m of coast	14.3		City 14 km from sea	8.2
	800 m	6.9			
	1.9 km	6.9			
	3.1 km	6.5			
	3.8 km	7.4			
	5.4 km	6.4			
	7.1 km	4.5			
Manawatu	500 m from coast	21.5			
	1 km	12.8			
	1.7 km	9.0			
	7 km	11.2			
	15 km	9.5			
	20 km	8.9			
Wellington	MWD Central Lab	5.6			
	Oteranga Bay	16.4			

Zinc corrosion studies

Shaw (30) has devised a test using zinc dry-cell cases as exposure specimens, and used it to produce a map of the corrosivity of the atmosphere towards zinc in U.K. He applied the same method to a study of New Zealand in 1970-75. Thus, zinc dry cell battery cases were exposed for approximately 2-year periods at sites selected by the New Zealand Meteorological Service and the New Zealand Department of Health. Results for the weight loss, expressed in g/m²/yr, are shown in Table 8. Overall, the results

suggest that for inland New Zealand the corrosion rate of zinc is 7 to 10 g/m²/yr, though in Rotorua the rate is twice that at cites at comparable distances inland. In light industrial areas, or close to the sea, the rates were higher. (These latter rates were also found to vary from period to period; data for this is not given.) An important point to emerge is that, while this technique revealed many areas of UK to have corrosion rates exceeding 30 g/m²/yr (and some exceeding 60) no areas with such high rates were found in New Zealand. The differences between locations within New Zealand should be meaningful; the U.K. vs N.Z. differences probably reflect different air pollution levels, and especially rainfall acidity.

Application of data on one metal to predict corrosion rates of another metal

It has already been discussed how different metals can have different mechanisms of corrosion, and so a direct transfer of corrosion rate from one metal to another is not often possible. As indicated earlier, however, if information on the climatic factors is available (including

microclimatic factors such as degree of shelter, and eddy effects introduced by adjacent land forms or man-made structures) the existence of data on corrosion rates of other metals can provide a valuable means of checking that the corrosion hazards which may be predicted do indeed exist. In this respect, the steel stud data from the Climat test in Table 6 provide evidence of the harsh marine character of the New Zealand atmosphere, especially in the North Island. The nylon stud values, on the other hand, which reflect the general atmosphere aggressiveness, are very low at the BRANZ site (see Table 7) compared with previously published data when viewed alongside the concurrent steel and copper stud values. These low values, and the low attack on zinc in most areas, suggest that in general rainfall in New Zealand is not aggressive and seems frequent enough to keep exposed non-ferrous metal surfaces washed of aggressive salt deposits. It is to be hoped that there can be a comprehensive study of the same type devised for exposure of steel, which is, after all, our most important technical metal. BRANZ studies now in progress may take us the first step, but there is a need for more work yet.

CONCLUSIONS

Though no survey of the financial impact of atmospheric corrosion has ever been reported for countries like New Zealand (with its relatively low level of industrialisation and its location many hundreds of miles from the nearest major land mass), there is reason to expect that this impact is high. There is considerable chloride carried inland on prevailing winds from west coasts to major population centres, and there are high relative humidity and rainfall levels across most of New Zealand. Additional problems are found due to sulphurous gases in one of the major tourist centres. There is a need for more characterisation of corrosion rates of metals exposed in New Zealand; in particular, there seems to have been no previous systematic study of steel corrosion rates. If this increased characterisa-

TABLE 7: CLIMAT TEST RESULT VALUES FOR SAMPLES COLLECTED AT BRANZ JUDGEFORD SITE

Unit	1	2	3
4/11/81-2/2/82			
Alon Fe	5.66	3.13	4.04
Cu	6.03	3.67	4.59
Nylon	0.24	0.15	0.24
4/2/82-5/5/82			
Alon Fe	5.80	4.51	5.32
Cu	5.18	4.38	5.06
Nylon	0.15	0.10	0.11
5/5/82-3/8/82			
Alon Fe	6.50	3.57	6.31
Cu	5.88	4.35	5.39
Nylon	0.15	0.11	0.19
3/8/82-1/11/82			
Alon Fe	6.50	4.80	6.30
Cu	4.96	4.02	6.27
Nylon	0.19	0.20	0.24

TABLE 8: ZINC CORROSION RATE DATA (G/M²/YR) FROM EXPOSURE OF ZINC DRY CELL CASES

a) NZ Meteorological Service site, 1970-74

Kaitaia	6.8	Wellington Airport	7.2
Auckland	8.0	Nelson	10.0
Rotorua	15.6	Kaikoura	7.0
Gisborne	7.2	Hokitika	5.6
Waiouru	7.4	Christchurch	6.9
New Plymouth	8.0	Wigram	8.2
Ohakea	5.6	Dunedin	4.8
Paraparaumu	6.4	Invercargill	7.0
Kelburn, Wellington	8.0		

b) NZ Department of Health Sites, 1972-74/5

Auckland City	5.5	Petone	9.6
New Lynn	11.2	Seaview	12.0
Penrose	8.8	Golden Bay	8.8
Pakuranga	5.7	Christchurch City	6.5
Takapuna	10.4	Hornby	9.7
Waiuku	9.0	Paparua	8.5
Glenbrook	9.6	Woolston	9.0
Kamo (Whangarei)	13.0	Dunedin	5.1
Ruakaka	10.4	Kaikourai	5.7
Marsden Point	8.8	Green Island	6.9
Hamilton	7.0	Awarua	5.7
Wanganui	12.5	Invercargill	6.3
Pt Howard	12.0	Bluff	7.8
Lower Hutt	7.2		

tion of corrosion risks was available, it could have beneficial economic effects through more appropriate levels of specification of protective coatings.

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