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ENVIRONMENTAL CORROSIVITY IN NEW ZEALAND: RESULTS AFTER 10 YEARS EXPOSURE

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ABSTRACT

A study of atmospheric corrosion of galvanised steel has been completed in New Zealand, using corrosion panels distributed across NZ at 181 sites. After 10 years, 51% of the sites returned panels, with the distribution of sites across the country remaining largely unaffected by the loss of the remaining 49%. Although only one panel was used at all sites, the 'within site' variation was assessed at a select number of sites using multiple panels exposed for both one year and 10 years. The results from these sites have shown that the variance in corrosion rates is sufficiently low for single panel exposures to produce accurate corrosion rate data across the country. It was found that at sites exposed to high levels of wind blown sea salts, the groundward face of the panels corroded faster than the skyward face. This is attributed to the accumulation of hygroscopic chloride-containing salts on the groundward faces of these panels. On close inspection of the results it was found that in New Zealand corrosion rate for zinc is generally in the ISO9223 "C2" classification for up to 100km from the coastline, and substantially higher at geothermal and coastal areas. There does not appear to be a strong relationship between rainfall, height above mean sea level, latitude and the corrosion rate of zinc. This may be due to the dominating effects from windborne salt and high relative humidities. This work is a continuation of the work which established the corrosion contours ('zones') for New Zealand used in AS/NZS 2312 "Guide to the protection of iron and steel against exterior atmospheric corrosion", and is a precursor to further studies on the refinement of these contours using measurements of microclimate-affecting parameters.

Keywords: zinc, rainfall, relative humidity, height, latitude, orientation, geothermal, coastal

1. INTRODUCTION

This work reports on the environmental corrosivity rates after one and ten years exposure across New Zealand for galvanized steel, and concludes a long-term steel, galvanised steel (zinc), and aluminium environmental corrosivity testing program. The weight loss panels were exposed at 181 sites across New Zealand with the Year 10 panels removed in June 1997. This work reports on the 10-year weight loss results and compares these to the one-year weight loss. Previous publications have reported on the one, two and six-year exposure results [1-4].

2. EXPERIMENTAL

The experimental procedures used throughout the corrosion survey have been previously described [4] and are briefly outlined in the following paragraphs. The research program was established in 1987, with the panel exposure sites requiring meteorological data, security, and wide distribution over New Zealand. A total of 92 meteorological sites maintained by the New Zealand Meteorological Services were chosen. In 1987 the exposure racks (Figure 1) were mounted facing north at each site. A number of independent sites were also selected to 'fill the gaps' between meteorological station sites. A larger and concurrent study was carried out at the BRANZ Judgeford site to evaluate the corrosion rate variability within one site, as shown in Figure 2. It should be noted that several sites were also in the geothermal area of the North Island.

The total number of sites established in 1987 was 181 and even with careful planning, an increasing number of the panels were stolen or vandalised each year. After one year there were 168 active sites remaining, after two years 156 sites, after six years 98 sites and after 10 years exposure there were 92 sites. The significant reduction cannot be blamed solely on theft or vandalism, because in 1992 the government of the day privatised the New Zealand Meteorological Service and subsequently many meteorological sites were closed down, automated, or relocated. This decision resulted in a substantial reduction in staff numbers and this had a significant impact on the outcomes of this work with nearly half the specimen racks being misplaced, lost, or disposed of, just prior to the completion of six years exposure.

Specimens

Figure 1: General exposure rack

Racks at all sites were placed (where practical) approximately 1.8 m above the ground facing north at a 45° angle, with each rack containing four sets of the three different panels (Figure 1). The dimensions of the panels were 150x100x3 mm (steel and aluminium) and 150x100x0.5 mm (galvanised steel). The Z300 galvanised steel panels were stamped with identification numbers on the skyward faces and the racks were assembled at BRANZ, prior to dispatch to the sites.

The final panel recovery rate of 51% (n=92) was obtained for the 10-year panels and was considered excellent given the unforseen circumstances surrounding climate station ownership. The distribution of panel sites across the country was not significantly affected by the 49% loss of samples over the 10-year period as shown in the return rate after 10 years exposure compared to the one-year exposure return rate (Figure 3).

Figure 2: Exposure rack at BRANZ

The panels were removed from the sites by the rack minders, sealed in plastic bags and dispatched to BRANZ. All panels were visually inspected prior to stripping and notable features were photographed. The metal panels were then stripped of corrosion products and the weight loss was determined. Weight loss measurements and the exposed area of the panels were then used to calculate the corrosion rate in $g.m^{-2}.yr^{-1}$ units. The exposed area was considered to be both sides of the panels, and the galvanised steel edges were not masked. The method of corrosion product removal prior to weight loss measurements was as per ASTM G1-90 “Standard practice for preparing, cleaning and evaluating test specimens” [5], as previously reported [1].

Variations within a testing site

A study of ‘within’ site variance was carried out at the BRANZ exposure site (Figure 2) using four sets of identical panels placed at the start of the survey and removed after 10 years exposure. At the Whangarei exposure site, three galvanised steel panels were found at the Year 10 panel recall date. In addition 18 sites were found where the exposed galvanised steel panels had not been retrieved at the Year 2 and/or Year 6 retrieval dates. All of these panels were returned to BRANZ and this provided the opportunity to assess the variability of results within a site, after 10 years exposure, as shown in Table 1.

3. RESULTS

The results for the galvanized steel panels from each site, after one and ten years exposure are shown in Appendix 1. Note that where more than one panel was recovered the result is the average.

The measurement errors in the corrosion rate found at the testing site were assessed and the average and the range of results listed. The test site at Judgeford was purposely established as a multiple sample exposure test site and recorded the corrosion rate results of 2.49 $g.m^{-2}.yr^{-1}$ with a range of 0.3 $g.m^{-2}.yr^{-1}$ for galvanised steel. Coincidently the panels from Whangarei recorded a similar result and range, as noted in Table 1.

Based on the International Organisation for Standardization ISO9223 Standard [6], which predicts corrosion rate classes for various materials including zinc, based on meteorological and pollution factors, the 'C2 Low' classification is for zinc (galvanized steel) values in the range of 0.7 $g.m^{-2}.yr^{-1}$ to 5 $g.m^{-2}.yr^{-1}$. Based on this range of corrosion rates, it is apparent that the 'within site' range of zinc results, 0.30 $g.m^{-2}.yr^{-1}$, is relatively insignificant.

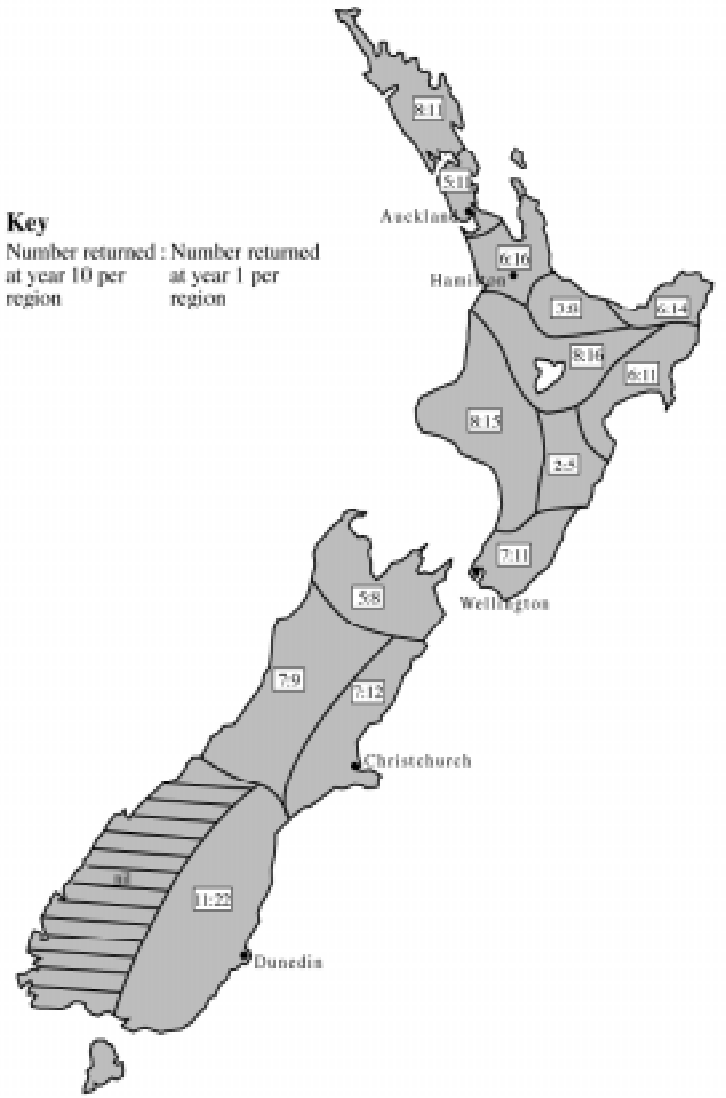

Figure 3: Specimen distribution as per regions indicating a ratio of panels retrieved after 10 years exposure compared to the number of panels retrieved after 1-year exposure.

The results from the other 18 sites indicate that the median range for the results is 0.10 $g.m^{-2}.yr^{-1}$. After ten years the galvanized panels were completely corroded on at least one face of the panel at Kaikoura, Wanganui Airport, Wellington Airport (Figure 4b) and Westport Airport so no result (N/R) was recorded for these panels as noted in Table 1. The range of results from Paraparaumu Airport was large for galvanized steel and was considered an outlier.

Severity of environmental corrosivity

Shown in figures 4a-b are examples of the panels after the 10 years exposure showing the front (skywards) and the back (groundward) faces of the panels. Note that the weight loss assessment of several galvanized steel panels could not be carried out because of the excessive loss of zinc on the groundward side of the coating, leading to flaking and red rusting.

4. DISCUSSION

The final panel recovery rate of 51% (n=92) indicates that the theft of panels, panel racks and the tampering with the surfaces will always be an ongoing problem in environmental corrosivity experiments. This result indicates that site security and regular accountability of exposure sites is of prime importance in maximising the return of specimens. Close inspection of the ratio of retrieved Year 10 to Year 1 panels, as shown in Figure 3, indicates the loss was in general, widely distributed over New Zealand.

Table 1. Corrosion rate at sites returning two or more identical panels after 10 years.

Site	**Corrosion Rate** Zinc ($g.m^{-2}.yr^{-1}$)	
Judgeford	2.67, 2.37, 2.53, 2.37	
Average (Range)	= **2.49 (0.30)**	
Whangarei	3.87, 3.93, 4.10	
Average (Range)	= **3.97 (0.23)**	
	Average	Range
Appleby	1.9	0.17
Gracefield	2.6	0.20
Eskdale	1.9	0.03
Finegand	1.7	0.00
Havelock North	2.1	0.13
Invercargill Airport	2.0	1.0
Kaikoura	N/R	N/R
Kaingaroa	2.5	0.07
Paraparaumu Airport	7.1	2.37
Pukekohe	2.0	0.00
Taumaranui	2.0	0.06
Thames	2.6	0.10
Wainuiomata	2.7	0.00
Waiotermarama	2.2	0.10
Waiouru	1.9	0.27
Wanganui Airport	N/R	N/R
Wellington Airport	N/R	N/R
Westport Airport	N/R	N/R
	Median =	0.10

N/R No Results available

The variation in corrosion rates ‘within’ a site is not often reported. Site variations such as micro-variations in aerosol deposition, localised contamination, material variability and corrosion product removal can often be difficult to measure. ASTM G92-86 “Standard practice for characterization of atmospheric test site” [7] recommends that triplicate specimens should be exposed at a test site for each exposed period. However, for large surveys this results in a very high number of panels and a trade-off between accuracy and coverage must be made at the start of the project. The lack of knowledge on the ‘within’ site effect was investigated at the BRANZ site in Judgeford (Figure 2) and the results in Table 1 indicate that the variability was relatively low and possibly insignificant. By coincidence an exposure rack which contained the Year 2, Year 6, and Year 10 panels was found at Whangarei and this permitted a similar study to be carried out, which indicated a similar result. These two low variances, with panels exposed to different environmental conditions, gives substantial confidence in exposing only 1 specimen and not 3 specimens as recommended. Specific localised contamination on one panel is a possibility that may render the results invalid, and this appears to have happened for the galvanized steel specimen at Paraparaumu airport, where the zinc loss was far greater than expected. Further support for this original decision was found at Year 10, when all panels were recalled to BRANZ. Surprisingly 18 sites returned duplicate panels, which indicated that either the Year 1, 2, or 6 panel was not retrieved at the appropriate time. Table 1 lists these results and excluding the extremely high results from Paraparaumu Airport, the variations in the range of results are generally lower than the BRANZ Judgeford result. This again supports the concept of single panel exposure.

Corrosion Values - Year 10 Results

The absolute corrosion rate across all of the panels after atmospheric exposure for 10 years ranged from 0.8 $g.m^{-2}.yr^{-1}$ at Omarama to 8.27 $g.m^{-2}.yr^{-1}$ at Musselburgh, although several panels had red rust or were perforated. In these cases it was believed to be likely that some highly corrosive localised effect had influenced the performance of the coating.

The corrosion rate for galvanized steel was in the range of 0.8 to 16.9 $g.m^{-2}.yr^{-1}$ excluding one outlying result. It was observed that when red rust was present, it appeared on the groundward side of the panel, as shown in Figure 4b. This is explained by the rain-washing the corrosive salts from the skyward side more frequently than the groundward side. The accumulation of airborne contaminants on the groundward face results in longer dew formation and possibly a more aggressive electrolyte on the groundward face, effectively increasing the groundward corrosion process [8].

Figure 4a): Front and back of galvanized steel panels exposed for 10 years at Paeroa

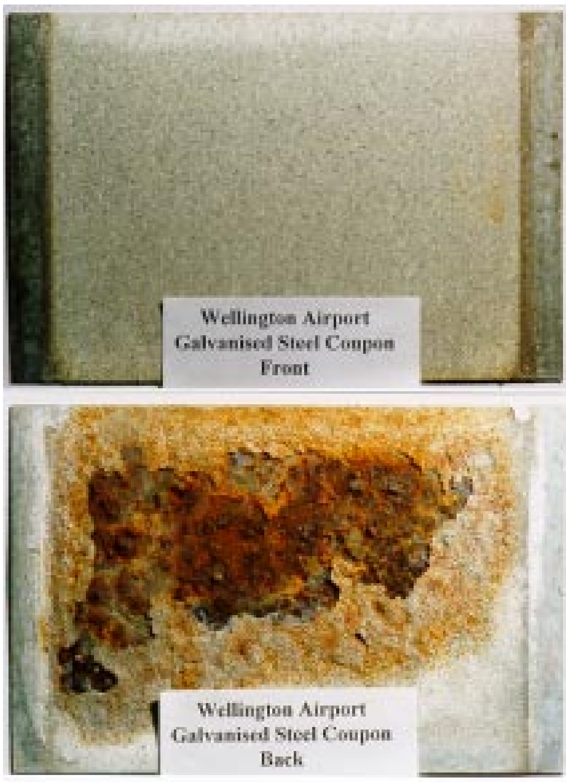

Figure 4b): Front and back of galvanized steel panels exposed for 10 years at Wellington airport

This appears to be contradictory to the results of long-term studies of zinc [9, 10], which report that the skyward surface corrodes at a significantly faster rate than the groundward-facing surface. The corrosion protection properties of zinc, under atmospheric conditions, are dependent on the formation of oxides, hydroxides and less soluble basic salts. If the panels were regularly subjected to an airborne contaminant, such as chloride salts, sulfates, etc., the basic salt layers (corrosion product) on the zinc would be transformed into more water-soluble layers, which offer significantly less corrosion protection [9, 10]. It has been reported that the ground-facing surface can have a corrosion rate of 40% of the rate on the skyward surface after 10 years exposure in a marine environment such as Kure Beach [9].

Thus there appear to be two different processes occurring, or a compromise. It has been noted [11] that, skyward surfaces of zinc corroded at a higher rate but that some panels corroded faster on the groundward facing surface depending upon the accumulation of hygroscopic salts on that surface. These salts are deposited by the onshore winds, and commonly require lower relative humidities to form condensed moisture on the surface, for example NaCl condensates moisture from the air at 77% relative humidity, which increases periods of surface wetness [12]. On this basis higher corrosion rates are attributed not only to the presence of corrosive salts on the surfaces, but to the extended periods of surface wetness.

It is interesting to note that only the galvanized panels exposed to severe or very severe [8] conditions corroded from the groundward side or the back. For example, Figure 4b) clearly shows the corrosion from the Wellington Airport panels occurred from the back, and the Year 1 corrosion rate was 18.3 g. $m^{-2}.yr^{-1,}$ which fits in ISO9223 classification of 'C4 High corrosivity'. In Figure 4a), corrosion occurred on the skyward side at the Paeroa site, and the Year 1 corrosion rate was 3.2 $g.m^{-2}.yr^{-1}$ resulting in an ISO9223 classification of environmental corrosivity of 'Low'. Note that these ISO classifications have been adopted in the latest version of AS/NZS 2312 [13].

Geothermal areas

High corrosion rates for the 10-year period were measured at Ngapuna and Lake Rotoatamaheke, in the Rotorua region. This region has an extremely corrosive geothermal environment, which has a very high concentration of hydrogen sulphide, as previously noted by Kane [3]. These two sites were considered to be anomalies due to the localised geothermal activities and were excluded from the overall general data analysis. This indicates that further studies in the geothermal regions are required.

Comparison of Year corrosion rates, and Meteorological and Geographical data

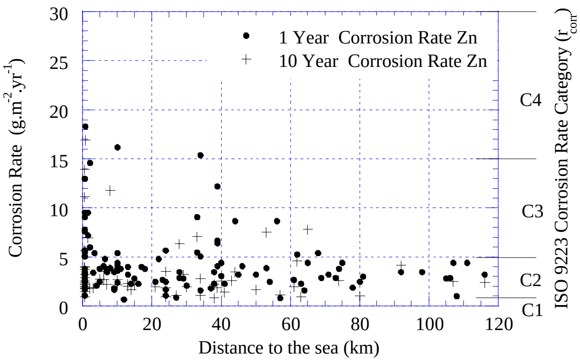

Figure 5: Corrosion rate of galvanized steel relative to the distance from the sea, including 'ISO 9223 category'.

By referring to a series of maps and the National Institute of Water and Atmospheric Research (NIWA) database, it was possible to obtain meteorological and geographical data for 128 of the Year 1 corrosion testing sites. As noted, Year 10 results are slightly lower than Year 1 results (see Figure 5), so Year 1 results have been used for these comparisons.

The corrosion rate as previously noted is strongly influenced by the presence of airborne sea salts which deposit on the surface and it has been reported that the corrosion rate of galvanized steel rapidly reduces 100m from the shore line [14] and this can vary substantially depending upon the prevailing wind. New Zealand is exposed to strong winds and chloride from sea salt is carried considerable distances. Studies have found chlorides at distances of 20 to 50km inland [15, 16]. The plot shown as Figure 5 indicates the corrosion rate after the first year of exposure in relation to distance from the sea and indicates at least 10km before a significant reduction occurs, but the rate still does not level out until 80km, which is further than expected.

If the galvanized steel was continually washed with rain and the corrosion product (which normally develops to form a protective passivating layer) was regularly washed away by rain, then the rainfall experienced at the site should show an effect on corrosion rates. The plot shown as Figure 6 indicates the corrosion rate after the first year of exposure in relation to annual rainfall (average of 10 years data). The high rainfalls do not appear to have any major effect on the corrosion rate.

A study into developing a predictive equation for relative humidity (80% RH, 85% RH, 90% RH levels which are all significant for corrosion studies), was based on altitude above mean sea level (MSL), latitude, distance to a large body of water, and housing density [17]. The study found that when developing a linear regression that the significant factors were housing density, distance to the water, and latitude for 80% RH and 85% RH.

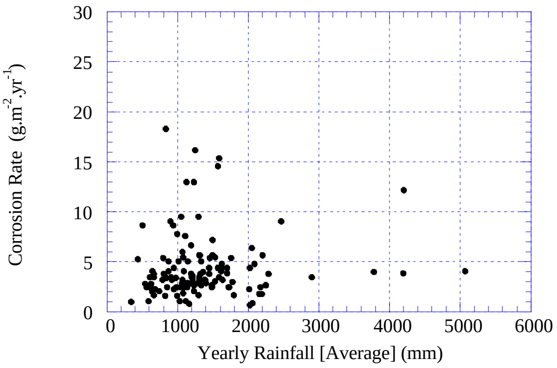

Figure 6: Corrosion rate of galvanised steel relative to the annual rainfall.

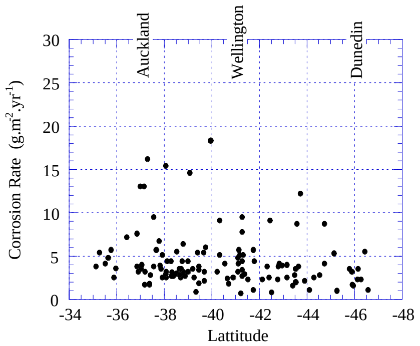

Figure 7: Corrosion rate of galvanised steel relative to latitude.

The plot shown as Figure 7 indicates the corrosion rate after the first year of exposure in relation to latitude. The results do not indicate a significant change in the corrosion rate as the latitude increases (negative sign indicates south). It is also known that increasing the latitudes significantly decreases the mean temperature of the environment. Decreasing the mean temperature does not appear to have a significant effect on corrosion rates of galvanized steel. Figure 7 also indicates the even distribution of the exposure racks over New Zealand.

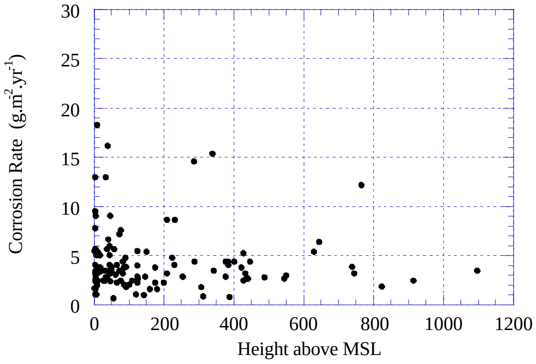

Figure 8: Corrosion rate of galvanised steel relative to height above sea level.

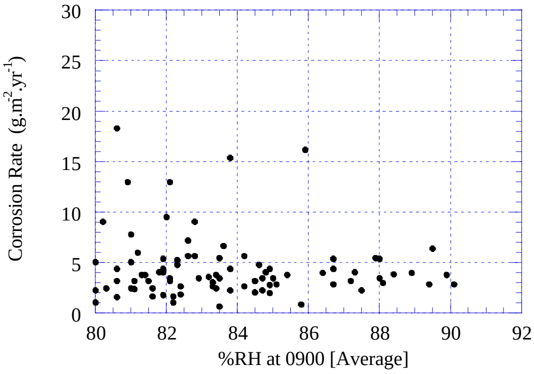

Figure 9: Corrosion rate of galvanised steel relative to relative humidity at 0900hrs

New Zealand has the geographical features of being relatively large islands with numerous mountains. The effect of a mountain range, and in particular, the height above the mean sea level would affect such environmental conditions as time of wetness and rainfall. The plot shown as Figure 8 indicates the corrosion rate after the first year of exposure in relation to altitude. As noted in the USA study [17], the height above sea level does not appear to have significant effect.

The last plot, Figure 9, indicates that environments with relative humidity levels between 80 and 84%, at 0900hrs, can have higher corrosion levels than environments, which experience higher humidity levels.

5. CONCLUSIONS

1) The corrosion rates obtained after 10 years of exposure have confirmed that single panel exposures can give reliable and accurate corrosion rate data. This is concluded from the multiple panels returned from two sites, and the duplicate panels returned from a further 18 sites in different locations around New Zealand, which when analysed have produced very low 'in-site' variation between panels.

2) The corrosion of galvanised steel facing groundward occurred at a faster rate than the skyward face at severe marine-influenced corrosivity sites. This is attributed to the accumulation of hygroscopic chloride-containing salts on the groundward surface, which create a high concentration electrolyte on the surface, which is not removed by rainwashing.

3) At geothermal sites, further work is required to understand the area of influence of the geothermal gases emitted from bores and fumaroles.

4) In New Zealand, the corrosion rate for zinc is generally in the ISO9223 "C2" category for up to 100km from the coastline, and substantially higher at geothermal and coastal areas.

5) There does not appear to be a strong relationship between rainfall, height above mean sea level, or latitude and the corrosion rates of zinc. This may be due to the dominating effects from windborne salt and high relative humidities.

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APPENDIX

Site	Year average %RH	Longitude	Latitude	Height above Mean Sea Level (m)	Yearly Rainfall (mm)	Distance to sea (km)	1Yr Zn Weight loss	10Yr Zn Weight loss
KAITAIA OBSERVATORY	85.4	173.26	-35.14	85	1324	7	3.80	2.23
KERIKERI AERO 2	86.7	173.92	-35.27	150	1759	3.5	5.40	
WAIOTEMARAMA	84.8	173.42	-35.52	229	1615	6	4.10	2.70
WAIPOUA FOREST	84.6	173.55	-35.65	88	1623	6.5	4.80	
DARGAVILLE	83.2	173.83	-35.95	15	1211	10	3.60	
WHANGAREI AERO	84.2	174.37	-35.77	37	1488	0.5	5.70	2.90
MARSDEN POWER STN	83.4	174.47	-35.88	3	2171	0.5	2.50	
WARKWORTH	82.6	174.67	-36.43	72	1493	1.5	7.20	
WOODHILL FOREST	85.4	174.43	-36.75	30	1293	6		
WHENUAPAI AERO	82.2	174.63	-36.78	26	1348	0.5		
AUCKLAND,ALBERT PARK	79.9	174.77	-36.85	49	1185	0.5	3.80	
AUCKLAND CITY	78.5	174.75	-36.85	75	1101	0.5	7.60	3.77
AUCKLAND,OWAIRAKA	81.1	174.73	-36.9	41	1304	0.5	3.20	1.93
THAMES 2	80.9	175.55	-37.15	3	1224	0.5	13.00	
TAIRUA FOREST	81.6	175.85	-37.17	3	1795	0.5	1.70	
PAEROA	82.2	175.67	-37.38	4	1297	24	1.70	0.97
WAIHI	79.0	175.85	-37.38	91	2155	9	1.80	
TE AROHA	81.3	175.72	-37.55	18	1444	18	3.80	
KATIKATI	82.0	175.95	-37.55	2	1293	1.5	9.50	6.93
TAURANGA AERO	79.8	176.2	-37.67	4	1311	0.5	5.70	
TE PUKE	79.4	176.32	-37.82	91	1704	8	3.90	3.80
WHAKATANE AERO	81.0	176.92	-37.92	6	1139	0.5	5.10	3.97
KINLEITH 2	84.9	175.88	-38.28	383	1563	75	4.40	
TIKITERE	83.8	176.35	-38.07	338	1584	34	15.40	
KAWERAU	80.3	176.72	-38.08	30	1729	24	2.50	1.90
ROTORUA AERO 2	81.9	176.32	-38.12	287	1443	40	4.40	
WAIOTAPU FOREST	83.3	176.42	-38.32	435	1335	61	2.70	1.93
ATIAMURI POWER STN	90.1	176.02	-38.4	253	1289	73	2.90	
KAINGAROA FOREST	84.2	176.57	-38.4	544	1480	61	2.70	
TAUPO N.Z.E.D.	85.1	176.07	-38.68	376	1147	106	2.90	
WAIRAKEI POWER STN	82.1	176.1	-38.63	342	1212	98	3.50	
TAUPO AERO	80.6	176.08	-38.75	400	945	111	4.40	
WAIMIHIA FOREST	84.5	176.25	-38.8	743	1635	116	3.20	2.43
AUCKLAND AERO	82.1	174.8	-37	33	1129	0.5	13.00	5.67
ARDMORE	88.0	174.97	-37.03	30	1300	9	3.50	
PUKEKOHE M.A.F.	80.6	174.87	-37.2	82	1320	13	3.20	2.27
WAIUKU FOREST	83.7	174.72	-37.35	52	1312	8	33.60	11.80
HUNUA EDL	86.4	175.07	-37.07	122	1364	13	4.00	2.03
MARAMARUA FOREST	85.9	175.25	-37.3	38	1244	10	16.20	
TE KAUWHATA M.A.F.	84.9	175.13	-37.42	32	1155	29	2.80	3.20
RUAKURA	83.6	175.32	-37.78	40	1189	39	6.70	
HAMILTON AERO	85.0	175.33	-37.87	50	1204	38	3.50	2.20
CAMBRIDGE	81.6	175.5	-37.92	76	1136	54	2.50	

MOKAU	84.7	174.62	-38.72	46	1583	7	3.50	

Site	Year average %RH	Longitude	Latitude	Height above Mean Sea Level (m)	Yearly Rainfall (mm)	Distance to sea (km)	1Yr Zn Weight loss	10Yr Zn Weight loss
ARAPUNI POWER STN	89.4	175.65	-38.07	123	1395	69	2.90	
WAIKERIA	87.2	175.38	-38.08	46	1210	45	3.20	
TE KUITI	83.3	175.15	-38.33	61	1532	40	3.10	2.58
WAIRERE	87.9	175	-38.53	122	1530	33	5.50	
PUREORA FOREST	88.1	175.55	-38.52	549	1779	81	3.00	
NEW PLYMOUTH AERO	82.5	174.17	-39	27	1500	0.5		
TURANGI	79.8	175.81	-39	375	1622	107	4.40	2.47
MT RUAPEHU,CHATEAU	83.5	175.53	-39.18	1097	2896	92	3.50	4.17
MT BRUCE RES	81.9	175.63	-40.72	305	2191	37	1.80	
WAINGAWA	83.8	175.62	-40.98	114	965	43		2.60
DANNEVIRKE	82.1	176.12	-40.22	207	1065	50	3.20	1.70
TAUHERENIKAU	81.9	175.38	-41.12	43	1087	39	4.10	1.87
GISBORNE, MANUTUKE	76.9	177.88	-38.68	9	986	0.5	2.50	
GISBORNE AERO	75.9	177.98	-38.65	4	1061	0.5	2.80	
WAIKAREMOANA	89.5	177.12	-38.8	643	2050	39	6.40	
WHARERATA FOREST	79.3	177.87	-38.87	439	2249	23	2.70	
ESK FOREST	75.6	176.7	-39.25	427	1721	21	2.50	1.92
NAPIER AERO	73.9	176.87	-39.47	2	839	0.5	3.40	3.20
HAVELOCK NTH D.S.I.R.	81.9	176.88	-39.67	9	792	10	5.40	2.13
MOHAKA FOREST	76.9	177.03	-39.07	286	1565	2	14.60	1.83
WAIROA,FRASERTOWN	78.9	177.4	-39	8	1390	0.5	3.20	1.77
PARAPARAUMU AERO	79.0	174.98	-40.9	5	1043	0.5	2.50	
PALMERSTON NTH	80.0	175.47	-40.33	15	866	34	5.10	2.83
PALMERSTON N AERO	80.2	175.62	-40.33	45	899	33	9.10	7.08
WAITARERE FOREST	81.8	175.2	-40.55	3	872	6	4.10	3.57
LEVIN M.A.F.	81.1	175.27	-40.65	46	1078	10	2.40	
LOWER HUTT,AVALON	78.6	174.93	-41.18	15	1334	0.5	5.10	
WELLINGTON,KELBURN	82.4	174.77	-41.28	125	1231	0.5	2.70	
		174.78	-41.28	3	1052	0.5	9.50	
WAINUIOMATA COAST	83.8	174.95	-41.28	82	1702	10	4.40	2.18
WELLINGTON AERO	77.8	174.82	-41.33	43	1014	0.5	5.10	4.00
KAITOKE	82.3	175.18	-41.08	223	2089	22	4.80	
WALLACEVILLE	82.8	175.05	-41.14	56	1302	24	5.70	3.53
STRATFORD DEM FARM	85.8	174.3	-39.33	311	2063	27	0.90	1.07
KAPUNI	83.4	174.17	-39.47	173	1190	11	3.80	
PATEA HOSPITAL	81.2	174.47	-39.75	43	1067	2	6.00	
OHAKUNE JUNCTION 2	88.0	175.42	-39.4	629	1455	68	5.40	
WAIOURU MILITARY	82.4	175.68	-39.47	823	1077	78	1.90	
AHU AHU VALLEY	84.5	175.1	-39.68	85	1233	30	2.10	1.93
TAIHAPE REC	84.5	175.8	-39.68	433	914	71	3.20	
WANGANUI AERO	80.6	175.02	-39.96	8	834	0.8	18.30	16.90
WESTPORT AERO	82.6	171.58	-41.73	2	2198	0.5	5.70	
LAKE ROTOROA	86.7	172.58	-41.78	445	2024	65	4.40	7.83

REEFTON EWS	87.5	171.87	-42.12	198	2011	41	2.30	1.43

Site	Year average %RH	Longitude	Latitude	Height above Mean Sea Level (m)	Yearly Rainfall (mm)	Distance to sea (km)	1Yr Zn Corrosion Data	10Yr Zn Corrosion Data
GREYMOUTH AERO	82.8	171.18	-42.45	4	2462	0.5	9.10	11.10
OTIRA SUBSTATION	87.3	171.57	-42.83	383	5069	46	4.10	
SPRINGS JUNCTION	89.9	172.18	-42.33	421	2282	74	3.80	2.63
HARIHARI N.Z.F.S.	88.9	170.55	-43.15	45	3773	17	4.00	
MOTUEKA, RIWAKA	81.5	172.97	-41.1	8	1377	0.5	3.20	
TAPAWERA	86.7	172.8	-41.38	146	1136	28	2.90	6.33
APPLEBY	79.4	173.1	-41.28	17	970	3	3.40	1.87
NELSON AERO	81.0	173.23	-41.28	2	989	0.5	7.80	13.90
RAI VALLEY	83.5	173.57	-41.22	55	2020	12	0.70	
BRANCOTT VALLEY	73.0	173.83	-41.53	64	684	16	2.30	
GRASSMERE SALT WK	70.6	174.15	-41.73	2	588	0.5	1.10	0.93
HANMER FOREST	76.7	172.85	-42.52	387	1164	57	0.80	1.17
KAIKOURA	74.2	173.7	-42.42	108	848	0.5	2.50	2.54
ARTHURS PASS	88.4	171.57	-42.95	738	4188	53	3.90	7.57
CULVERDEN	80.0	172.85	-42.77	173	632	38	2.30	0.80
CHEVIOT	81.4	173.27	-42.8	85	801	5	3.80	
MT COOK, HERMITAGE	76.0	170.1	-43.73	765	4198	39	12.20	
CRAIGIEBURN FOREST	78.8	171.72	-43.15	914	1486	80	2.50	1.03
HIGHBANK POWER STN	74.0	171.73	-43.58	230	933	44	8.70	3.50
ASHBURTON COUNCIL	74.0	171.75	-43.9	101	734	4	2.10	
EYREWELL FOREST	77.6	172.28	-43.4	158	826	34	1.60	1.07
CHRISTCHURCH AERO	79.3	172.53	-43.48	37	621	15	2.80	2.17
CHCHURCH GARDENS	84.9	172.62	-43.53	7	645	0.5	2.00	1.47
CHCHURCH,BROMLEY	77.3	172.7	-43.53	9	609	0.5	3.50	
LINCOLN	74.2	172.47	-43.65	11	664	10	3.80	
LAKE TEKAPO AERO	71.3	170.47	-44.02	762	605	75		
TWIZEL SUBSTATION	78.9						3.80	2.33
GERALDINE N.Z.F.S.	80.0	171.23	-44.1	119	1030	24	1.10	
TIMARU AERO	81.0	171.23	-44.3	25	560	5	2.50	2.73
WAIMATE	77.1	171.04	-44.74	64	640	10	4.10	2.70
KUROW	79.0	170.47	-44.73	207	503	56	8.70	
OMARAMA,TARA HILLS	75.2	169.9	-44.53	488	535	105	2.80	
RANFURLY MANIOTOTO	82.3	170.1	-45.13	427	439	62	5.30	4.60
TAIAROA HEAD	77.9	170.73	-45.78	72	660	0.5	3.50	2.37
DUNEDIN AERO	79.9	170.2	-45.92	1	658	9	1.70	
DUNEDIN,	75.8	170.52	-45.9	2	788	0.5	3.20	1.97
ALEXANDRA	78.1	169.38	-45.27	141	344	108	1.00	
TAPANUI	80.6	169.25	-45.95	180	988	64	1.60	
WINTON	82.9	168.33	-46.15	44	907	28	3.50	
GORE,GRASSLANDS.	83.8	168.9	-46.12	123	946	63	2.30	0.97
INVERCARGILL AERO	83.5	168.33	-46.42	0	1079	0.5	5.50	2.23
TIWAI POINT EWS	82.2	168.38	-46.58	5	1119	0.5	1.10	1.83
BALCLUTHA,FINEGAND	84.7	169.73	-46.27	6	680	14	2.30	1.67