

Reprint

NO.41

CI/SfB

(Y7)

UDC

69.003.12

DEGRADATION OF BUILDING MATERIALS IN NEW ZEALAND ATMOSPHERES

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Reprinted from the conference paper presented at
*IDEA 85: Investment and design, their effects
on your assets.* October 14th and 15th 1985
Michael Fowler Centre, Wellington.

DEGRADATION OF BUILDING MATERIALS IN NEW ZEALAND ATMOSPHERES

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ABSTRACT

The four main atmospheric factors which affect the durability of building materials in New Zealand are:

1. high relative humidity
2. sea salt carried inland on the wind
3. high sunshine hours, leading to high total solar radiation
4. sulphur-containing gases, especially in geothermal regions

The available information on these factors is reviewed, and some ways to minimise degradation problems are discussed.

High relative humidity is the greatest problem because it is the most difficult to design against. Appropriate choice of material and careful design can often reduce the effects of the other factors to manageable levels. But water vapour is a universal hazard, menacing virtually all building materials in one way or another as well as increasing the damage caused by the other factors.

INTRODUCTION

The New Zealand Meteorological Service (1983a) distinguishes 17 different climate types in New Zealand. Each has a particular combination of temperature, rainfall and humidity characteristics, but a factor common to nearly all is a significant level of atmospheric moisture with its important implications for the degradation of building materials. Martin and Price (1982) have pointed out how water is involved in the destruction of almost all such materials, ranging from the obvious effects on corrosion of metals, through strength loss of timber composites to its less obvious involvement in accelerated breakdown of plastics and paints by solar radiation.

The other atmospheric factors superimpose their own degradation processes on top of that caused by atmospheric moisture: for example, rot in timber advances faster in moderately warm conditions (Beesley et al. 1983) and atmospheric corrosion problems are greater the closer buildings are to surf beaches or to geothermal sources of sulphur-containing gases (Duncan 1984). It is important for those involved in the design of buildings to have an awareness of all the possible degrading influences of the atmosphere where the building will stand and to select construction materials accordingly.

It is impossible in a short paper such as this to examine all the adverse reactions which may be encountered; the purpose, instead, is to highlight some of the important differences that may occur between New Zealand and other countries, especially Australia, from which opinions are frequently sought or given on the likely durability of materials which are unfamiliar to the New Zealand building industry.

ATMOSPHERIC MOISTURE

The most immediately evident causes of wet surfaces - rain and snow - are not very important in the context of this paper; the excess runs off from non-absorbent materials.

But water vapour in the atmosphere is ever present and constitutes a more persistent source of wetting - condensing and remaining on surfaces when they are colder than the surrounding air, such as in dew formation, to give a visible water layer. These conditions, however, usually occur at night (so the interaction with sunlight is minimal) and at lower temperatures (so the rates of chemical reaction are lower). The most important cause of water-promoted degradation is adsorption of water in an invisible film only a few molecular layers thick, which can occur even in bright sunshine if the atmospheric humidity is high enough.

Relative humidities in the more densely populated parts of New Zealand - and, thus, those with the highest levels of building activity - are often high. "Relative humidity" is an expression, in percentage, of the level to which the atmosphere is saturated with water vapour; with 100% representing complete saturation - the point beyond which additional vapour immediately condenses out of the atmosphere. The relative humidity is affected by the temperature; at a constant atmospheric water content, a decrease in temperature causes an increase in relative humidity. Trethowen (1976) has published data on the frequency of occurrence of relative humidity/temperature combinations at a few NZ sites. Figure 1 shows the relative humidity as a function of time and month for a selection of New Zealand cities, based on data supplied by the New Zealand Meteorological Service.

Most of New Zealand has relatively frequent rainfall, for most months of the year (New Zealand Meteorological Service 1983b). This brings positive effects in cleansing surfaces of contaminants (especially sea salt) which may promote degradation, and negative ones by increasing the duration of "wet" periods in wet/dry cycles which are important in the degradation of many materials. Rainfalls in New Zealand are generally not sufficiently acidic to cause extra materials degradation problems associated with the acidity, though Kennett (1978) 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 5.3 to 6.7. Stevenson (1980) reports a mean rainfall pH of 4.6 from a study in Christchurch in winter. Even this is relatively acidic compared with the pH of water in equilibrium with normal atmospheric pressures of carbon dioxide which would be around 5.5.

ATMOSPHERIC CHLORIDE

Chloride-containing salts are important corrosion promoters and can also act as hygroscopic generators of surface water layers. The "critical" relative humidity (i.e. the relative humidity at which water vapour is absorbed from the atmosphere by a deposit of salt over a surface) is relatively independent of temperature in the case of the salt sodium chloride, which has a critical value of around 78%. It can be deduced from Figure 1 that surfaces which are sea salt-contaminated are likely to have a moisture film over them for very long periods at a range of temperatures.

New Zealand, because of its position as an isolated island chain in a latitude band of relatively strong winds, undoubtedly falls in the "Area I" (worst) class proposed by Brierly (1965) in his categorisation of corrosion hazards due to atmospheric chloride. Strong winds not only act as carriers of sea salt particles, but also aid the sea wave breaking which generates the particles and the turbulence which raises them aloft. The best method of identifying the areas where salt fallout is most intense appears to be to use the maps of sodium distribution in grass, published by DSIR in 1962. Recent studies by BRANZ (the results of which have not yet been published) have examined the decrease in chloride deposition on to sheltered surfaces with increasing distance from the coast in Manawatu and Southland. Interpretation of the results at this stage suggests that the map proposed for steel corrosion hazard zones (Duncan and Whitney 1982), which was developed from theoretical principles using the DSIR maps as an important source of information, was basically correct. A study at BRANZ Judgeford site (Duncan, Cordner and McCartain 1984) showed the importance of periods of high winds off the sea in affecting the amount of chloride carried inland. Analysis by neutron activation of deposited salt suggests that it is sea salt, even as far inland as Palmerston North. Virtually all evidence produced so far for New Zealand indicates that heavier chloride deposition is found in west and south coast areas than in east coast areas (though, obviously, there is a heavy deposition zone adjacent to the sea on east coasts). The heaviest deposits would be predicted to occur in the Taranaki coastal regions, the Kaipara coastline, the area around Wellington, and the south coast of the South Island.

SULPHUR-CONTAINING GASES

The geothermal region of the central North Island, an area approximately bounded by Te Puke, Ohakune, Waiouru, and Kawerau, gives rise to sulphur-containing gases in the atmosphere, although there can be very great variations in concentrations of these gases within a few hundred metres, depending on closeness to fumaroles. In a month's monitoring at the Rotorua Telephone Exchange site, Burns et al (1972) found a median hydrogen sulphide content in the air of 8-15 microgrammes per cubic metre ($\mu\text{g}/\text{m}^3$) with about 2% of values exceeding $300 \mu\text{g}/\text{m}^3$. The threshold for corrosion promotion by hydrogen sulphide is about $1.5 \mu\text{g}/\text{m}^3$, and at the median values found the reaction with pigments, usually to produce blackening, is fast. This has caused problems at various times for paint formulators (Macdonald 1978) and local authorities (Shannon et al 1984).

Sulphur dioxide - a gas produced in almost all fossil fuel combustion processes, and a severe problem in many industrialised countries where its acidity attacks metals and building stones - is a lesser problem in New Zealand. In this country, the effects of sulphur dioxide tend to be restricted to "foot-prints" of enhanced attack close to roads and extending up to 100 metres downwind of flues. Even the local meteorology of the Christchurch urban area, with its smogs, produces monthly average values of only around $50-70 \mu\text{g}/\text{m}^3$ in the worst winter months (Department of Health 1982), compared to the "normal urban atmosphere level" quoted (presumably for Europe) of $110-2300 \mu\text{g}/\text{m}^3$ (Barton 1976).

SOLAR RADIATION

There is a quite widely-held belief that sunshine reaching New Zealand has a higher UV component in its solar spectrum than other countries. This is almost certainly wrong. There may be some absorption of UV by more polluted atmospheres, and the ellipticity of the Earth's orbit brings this part of the

Southern Hemisphere closer to the sun in summer than corresponding latitudes of the Northern Hemisphere, such as Spain, during their summer (Basher 1981). These factors mean that there is probably a greater flux of ultraviolet radiation reaching New Zealand than those Northern Hemisphere counterparts which are of similar cloudiness. But there should be minimal, if any, difference between the percentage of solar radiation which lies in the UV waveband reaching the southern cities of Australia and the cities of New Zealand. The only published values for UV radiation levels in New Zealand appear to be 76 kWh/m² annually at Wellington (Fry and Whitney 1979) which is comparable to values in Sydney and Melbourne (Martin 1977), and measurements at Mangere Airport which suggest about 5.5% of incoming radiation is in the UV band (290 -380 nm), again comparable to values found in Australia (Basher 1981).

The belief in a higher New Zealand UV level seems to have arisen because of the unexpectedly rapid breakdown of paints and plastics in New Zealand compared with experience overseas. There is little conclusive scientific evidence in this respect, but such a phenomenon would be understandable in terms of a synergistic action of solar radiation and water on a surface, which has been seen in studies. For example, Clark and Roberts (1982) tested cover plate materials for solar collectors using natural exposure at three sites outdoors and in an artificial test regime with no water spray. The two outdoor sites with higher moisture levels (rain, dew, and humidity) gave higher transmittance loss for poly(methyl methacrylate) and fibre-reinforced plastics for equal total radiation than were found at the "dry" site (in Arizona) or in the artificial test. Martin and Price (1982) describe laboratory studies of chalking of paint and yellowing of polyester resins, using xenon arc irradiation under controlled atmospheric moisture conditions, which indicated that involvement of water was important. The study of chalking of paint found that above an apparent "critical" relative humidity of 60% the chalking rate was much faster.

AVOIDING PROBLEMS

The options available to a building designer to minimise atmospheric degradation of materials are far too numerous to list here. But there are some simple principles.

1. Don't regard any material as maintenance-free; it is an important responsibility on the designer to know the possible degradation behaviour of the specified materials, and to ensure that the means of avoiding it is "designed in". This will extend to ensuring that the client knows the maintenance procedures that will be required and providing the means of access for them to be carried out.
2. Beware of designs which result in surfaces sheltered from rain washing, especially in coastal towns and cities. The fine finishes on factory-coated claddings and anodised aluminium can be degraded within months if they are exposed to heavy salt deposition and never washed by rain or in maintenance.
3. Some polymers are more resistant to breakdown by solar radiation than others. Seek out these resistant materials and use them, even as surface protection layers for other polymers - such as acrylic lacquers over pvc, or polyvinylidene fluoride film over glass-reinforced plastic panels where aesthetics are important. If appearance is less of a concern, use polymers with UV stabilisers such as carbon black blended into them during manufacture.

4. The microclimate can be affected by the building itself and the materials from which it is built. Examples are
 - 4.1 Thermal storage by the building, so that the relative humidity in the thin layer adjacent to cladding materials is different from that in the bulk atmosphere.
 - 4.2 Surfaces close to equipment which is radiating heat may stay dry even when other surfaces nearby have thick condensation films on them.
 - 4.3 Radiation effects to a clear sky can lower cladding surfaces significantly below the air temperature under some conditions.
 - 4.4 The microclimate downwind from a flue may be quite different from that upwind.
5. Modification of the environment can sometimes be achieved, especially indoors; at Rotorua Telephone Exchange, for instance, activated carbon filters are used to remove hydrogen sulphide from the air as it enters the building, and there are airlocks on all external doors. But such adaptation can be very expensive - as in this case - and relies on a skilled building occupier to maintain the system and recognise very quickly if it is malfunctioning. For minimum trouble, it is probably better to use more durable materials from the outset than rely on a protection system that may break down.

CONCLUSION

The New Zealand atmosphere is relatively wet and this has implications for degradation of many building materials. High relative humidities can interact with other factors (such as pollutants) to worsen the problems caused by these factors. Careful selection of materials at the design stage and careful detailing of the way they are used, including provision for their maintenance, is therefore important.

REFERENCES

- Barton K. 1976. Protection against atmospheric corrosion: theories and methods. Wiley. Chichester.
- Basher R.E. 1981. Basic science of solar radiation and its ultraviolet components. In Proceedings of the seminar on solar ultraviolet radiation, March 26-27, 1980. New Zealand Meteorological Service. Wellington.
- Beesley J., Creffield J.W., and Saunders I.W. 1983. An Australian test for decay in painted timbers exposed to the weather. Forest Products Journal 33(5):57-63.
- Brierly W.B. 1965. Atmosphere sea salts - design criteria areas. J environmental sciences 8:15-23.
- Burns D.M., McPherson G.T., Mayes C.J. et al. 1972. An automatic telephone network in a hydrogen sulphide laden atmosphere. New Zealand Engineering (January):3-21.
- Clark E.J. and Roberts, W.E. 1982. Weathering performance of cover materials for flat plate solar collectors. National Bureau of Standards. Washington. (NBS TN1170).

DUNCAN

Department of Health. 1982. Air pollution control in New Zealand: 19th annual report of the Principal Air Pollution Control Officer. Wellington.

Department of Scientific and Industrial Research. 1962. Single factor map showing "available" sodium (sodium in sweet vernal grass) in unfertilised soils. Wellington.

Duncan J.R. 1984. Atmospheric corrosion in New Zealand. *Corrosion Australasia* 9(5):4-9.

Duncan J.R., Cordner R.J. and McCartain M.J. 1984. Chloride in the New Zealand atmosphere as a corrosive agent. In Extended abstracts, 9th International Congress on Metallic Corrosion, Toronto, 1984, 3:206-210.

Duncan J.R. and Whitney R.S. 1982. Suggested zones of steel corrosion hazard in New Zealand atmospheres. *IPENZ Transactions* 9(3/EMCh):65-75.

Fry J.I. and Whitney R.S. 1979. The natural weathering of sealants in cyclic movement testers. Building Research Association of New Zealand. Judgeford. Technical Paper P26.

Kennett A.C. 1978. Rotorua - the corrosion centre. In Living with corrosion. Australasian Corrosion Association. Auckland.

Macdonald A. 1978. Paint systems for the Rotorua area. In Living with corrosion. Australasian Corrosion Association. Auckland.

Martin K.G. 1977. Solar weathering indices for Australian sites. CSIRO Division of Building Research. Melbourne. Technical Paper 18.

Martin K.G. and Price R.E. 1982. Quantitative considerations of moisture as a climatic factor in weathering. *Durability of Building Materials* 1(2):127-140.

New Zealand Meteorological Service. 1983a. New Zealand climatic regions. Wellington. Miscellaneous Publication 175 Part 2.

New Zealand Meteorological Service. 1983b. Summaries of climatological observations to 1980. Wellington. Miscellaneous Publication 177.

Shannon R.J., Roberts G.S., Helsby C.R. and Pope J.L. 1984. An overview of corrosion problems in Rotorua. In Corrosion technology - 1984 and beyond. Australasian Corrosion Association. Auckland. Paper 53.

Stevenson D.J. 1980. The lead content and acidity of Christchurch precipitation. *NZ Journal of Science* 23:311-2.

Trethowen H.A. 1976. Indoor versus outdoor climate. *NZ Engineering* 31(3): 72-74.

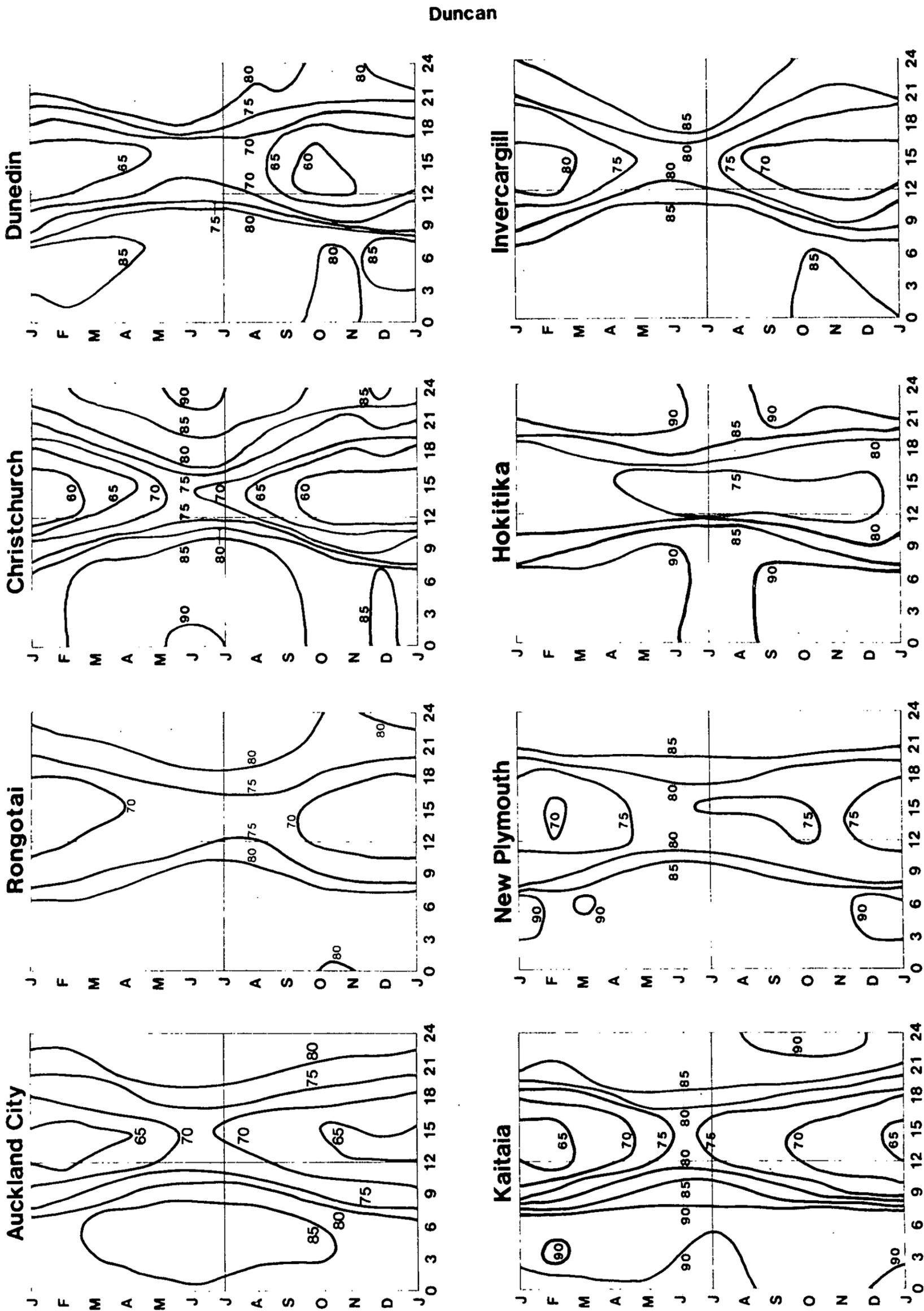


Figure 1: Plots of relative humidity at time of day on 24 hour clock versus month of year, for some New Zealand cities and towns

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