Wind Corrosion Index

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Introduction

Seaside wind corrosion is a major problem for cars, causing premature rusting and damage to the paintwork and bodywork. This is due to the presence of salt in the air, which is carried by the wind and deposited on the car's surface. When salt and moisture come into contact with metal, they cause an electrochemical reaction that leads to rust.

This report seeks to quantify the corrosion risk of living near the seaside.

This paper offers a methodology by using Bureau of Meteorology’s wind roses.

> **Axiom 1:** Seaside corrosion risk is proportional to the distance to the shoreline. This is because salt spray from the ocean is more concentrated closer to the shoreline.
>
> **Axiom 2:** Seaside corrosion risk is proportional to wind velocity. This is because stronger winds carry more salt spray and cause it to travel further inland.
>
> **Axiom 3:** The number and size of wave generated aerosols increase with wind velocity. This is because stronger winds generate larger and more forceful waves, which produce more salt spray.
>
> **Axiom 4:** Only on-shore winds carry aerosols over land. This is because other wind directions will blow the salt spray back out to sea.

These axioms are used to develop a model to predict seaside corrosion risk. Such a model could be used to identify areas that are at high risk of corrosion and to develop strategies to mitigate that risk.

Salt Air

Ocean wave aerosols are formed when ocean waves break and release bubbles into the air. These bubbles then burst, releasing tiny droplets of seawater into the atmosphere. The droplets are so small that they can remain suspended in the air for long periods of time, forming a mist or haze.

The formation of ocean wave aerosols is influenced by a number of factors, including:

- Wind speed: Stronger winds generate larger waves and more whitecaps, which produce more aerosol.
- Wave height: Larger waves break with more force, producing more aerosol.
- Water temperature: Warmer water produces more aerosol than colder water.
- Sea surface salinity: Saltier water produces more aerosol than less salty water.

- Presence of organic matter: Organic matter, such as phytoplankton and bacteria, can act as surfactants, which help to stabilize bubbles and increase aerosol production.

Ocean wave aerosols are composed of a variety of substances, including sea salt, organic matter, and other trace gases. Sea salt is the most abundant component of ocean wave aerosols,

Here is a more detailed explanation of the process of ocean wave aerosol formation:

1. Wind blows across the ocean surface, creating waves.
2. As the waves break, they trap air and form bubbles.
3. The bubbles rise to the surface and burst, releasing tiny droplets of seawater into the air.
4. The droplets evaporate quickly, leaving behind a solid particle of sea salt.
5. These particles are then carried away by the wind.

The size of ocean wave aerosols ranges from a few nanometers to a few hundred micrometers. The smallest particles can remain suspended in the air for weeks or even months, while the larger particles fall out of the atmosphere more quickly.

The deposition distance of ocean wave aerosols is highly variable and depends on a number of factors, including the size of the aerosol particles, the wind speed, the atmospheric stability, the terrain, the vegetation, and the presence of obstacles. As a result, it is difficult to quantify aerosol deposition distances that are universally applicable.

Corrosion along the wind path of ocean wave aerosols can be measured directly, without the need to measure deposition distance first. This is a more direct and accurate way to assess the corrosivity of ocean wave aerosols.

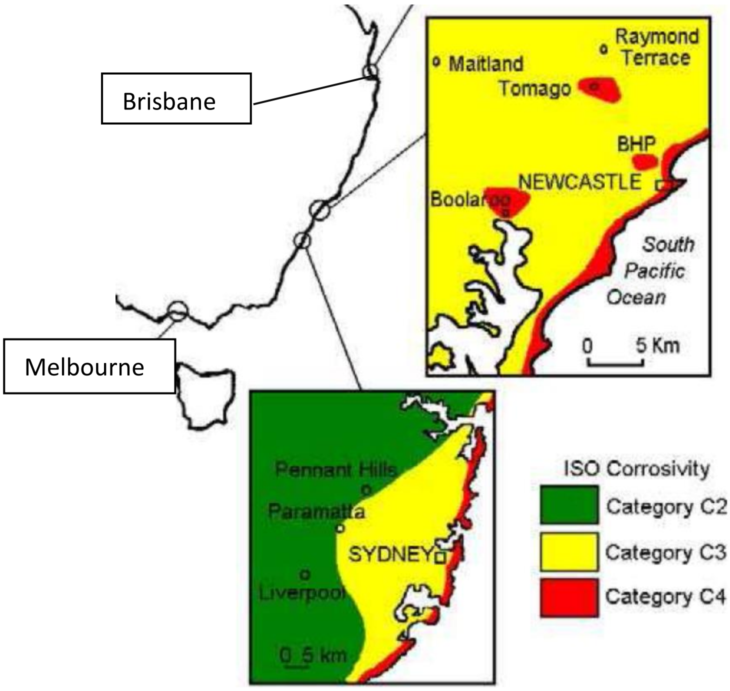
Atmospheric corrosion mapping of a large geographical area is a valuable tool for understanding and predicting the degradation of materials due to exposure to the atmosphere. By measuring and graphing the corrosion rate at different locations, researchers can create ISO-lines, which are lines of equal corrosion rate. These maps can be used to identify areas of high and low corrosion risk, and to select the most appropriate materials and corrosion protection methods for a given location. Santa[1] et al point out that there are 88 corrosion maps around the world at last count in 2022.

Figure 1 shows a typical atmospheric corrosion map, with different colours representing different corrosion rates. The map is delineated by changes in colour, with darker colours indicating higher corrosion rates. This type of map can be used to quickly and easily identify areas of high corrosion risk.

Figure 1 shows a snippet of a corrosivity map from AS4312. The AS4312 corrosivity map is a widely used tool for assessing corrosion risk in Australia, but it does not separately account for the effects of wind-driven aerosols. This paper aims to address this limitation by providing

[1] Santa, A. C., Tamayo, J. A., Correa, C. D., Gómez, M. A., Castaño, J. G., & Baena, L. M. (2022). ***Atmospheric corrosion maps as a tool for designing and maintaining building materials: A review***. Heliyon.

scope for a more detailed map of seaside corrosivity caused by wind-driven aerosols only. The highlighted red zone inwards corresponds with similar zones in **Figure 2** for the Newcastle area.



AS4312 Category	Corrosivity	Steel Corrosion Rate µm/yr	Typical Environment
C1	Very Low	<1.3	Dry Indoors
C2	Low	1.3-25	Arid/Urban Inland
C3	Medium	25-50	Coastal/Industrial
C4	High	50-80	Sea-Shore (Calm)
C5M	Very High (Marine)	80-200	Sea-Shore (Surf)
C5I	Very High (Industrial)	80-200	Severe Industrial
T	-	-	Tropical

Figure 1 - Corrosivity zones in some Australian centres according to AS 4312[2]

Australian Standard AS4312 provides a good general overview of corrosion risk for cars in Australia, but it does lack detail for the closer proximities to the shoreline. Also, the coverage is mainly for the higher car densities of Australian cities.

Figure 2 is a more detailed map of actual corrosion test sites, connected by ISO lines.

[2] RA Francis (2007) – ***Development and Use of an Atmospheric Corrosivity Standard*** - ACA Annual Conference Proceedings

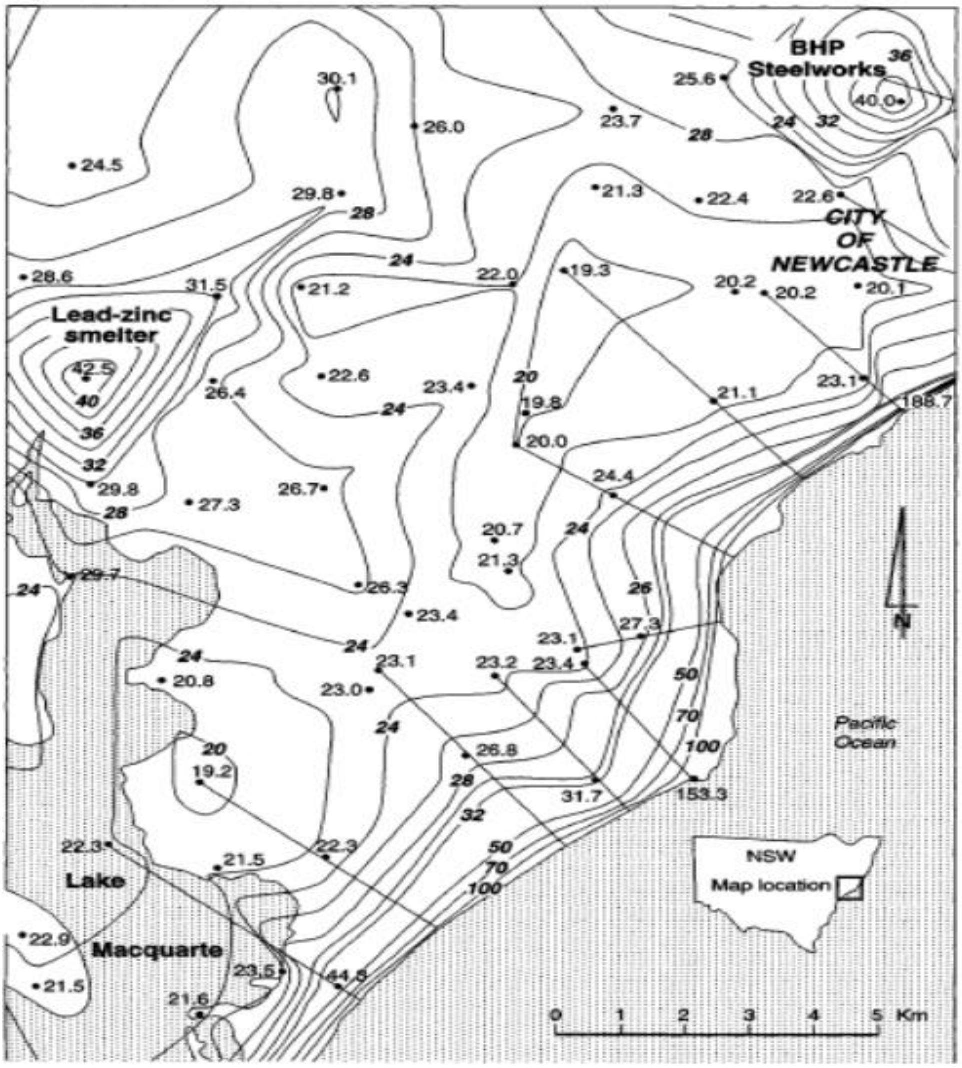


Figure 2 – Atmospheric corrosivity Map of Newcastle area[3].

Ocean shoreline corrosion rates are much higher than those around Lake Macquarie, due to the effect of wave aerosols. Corrosion rates also decrease rapidly away from the shoreline.

Towards a Corrosion Risk Index

Wind is the primary driver of seaside corrosion. It transports salt-laden air to the ground, where it can corrode metal and other materials. There are many factors that influence the amount of seaside corrosion, including wind speed, direction, duration, and frequency. A measure that combines all of these factors into a single damaging measure would be useful for assessing the risk of seaside corrosion.

[3] King, G. A., & Carberry, B. (1992). ***Atmospheric corrosivity of the greater Newcastle region.*** CSIRO Division of Building, Construction and Engineering.

An index of the form ***event X frequency*** is a good starting point for developing such a measure. This index would multiply the wind speed, wind direction, wind duration, and wind frequency together to give a single measure of the damaging potential of the wind for seaside corrosion.

Wind Roses

The Bureau of Meteorology (BOM) publishes wind data from hundreds of stations around the Country spanning a time period of at least 15 years, giving good averages of wind history for the area.

These data are published in the concise format of wind roses backed by numerical data which fit into a spreadsheet. Wind roses can be used to understand the direction and frequency of winds in a coastal area, which can be helpful for predicting the areas that are most likely to be affected by aerosol corrosion.

Wind roses are diagrams that show the direction and frequency of winds at a particular location. They can be used to identify the prevailing winds, which are the winds that blow most often. Wind roses can also be used to identify the strongest winds and the winds that blow from different directions.

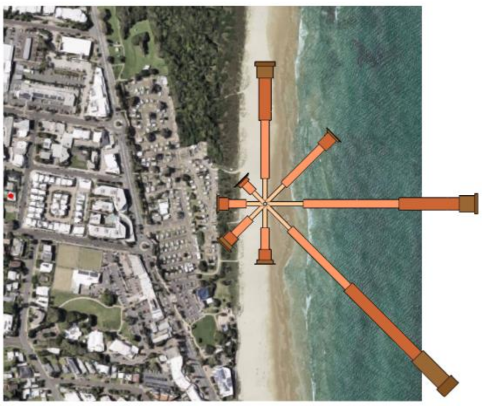


Figure 3 – Maryborough (Qld) Wind Rose superimposed on a Peregian Beach Shoreline.

Aerosol transport on a beach with an oblique onshore wind.

The angle of the ocean edge can also play a role in seaside wind corrosion. When the wind blows at an angle to the beach, the aerosol path will have a vector velocity with components along the beach and into the beach. The component into the beach will be proportional to the wind speed and the cosine of the angle between the wind direction and the normal to the beach. The component along the beach will be product of the wind speed and the sine of the angle of the wind.

For example, if the wind speed is 10 m/s and the wind blows at an angle of 45 degrees to the beach, then the aerosol path will have a nominal vector velocity of 7 m/s along the beach and 7 m/s into the beach. This is illustrated in Figure 4.

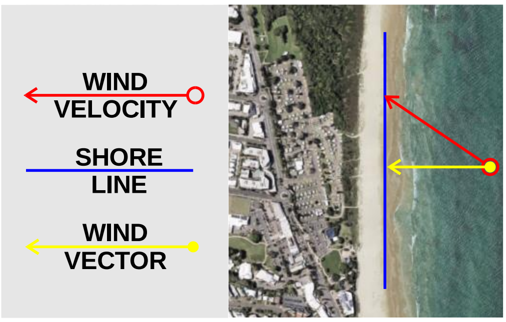


Figure 4 - Wind Shoreline Velocity Vector

Table 1 presents wind data from the Bureau of Meteorology (BOM) that is used to create wind roses. The table shows wind speed and direction data versus what percentage the speed and direction has occurred over at least the previous15 years.

Table 1 shows for example that 10.5% of all winds in Maryborough come from the North East (NE) and 1.0% of all wind comes from the South West (SW) at speeds between 20 and 30 km/h.

Table 1 Percentages of wind events at the velocity range (from BOM wind rose for Maryborough.)

Velocity Range	N	NE	E	SE	S	SW	W	NW	Calms	Rows Totals
>= 0 and < 10	2.6	2.8	4.0	3.7	2.5	2.1	1.9	1.7	0.7	22.0
>= 10 and < 20	6.4	5.9	10.6	9.1	2.4	2.5	1.9	1.3	0.0	40.1
>= 20 and < 30	4.6	1.6	6.6	10.8	1.1	1.0	1.0	0.4	0.0	27.2
>= 30 and < 40	1.3	0.2	1.7	4.1	0.4	0.4	0.2	0.1	0.0	8.4
>= 40	0.4	0.0	0.4	1.2	0.1	0.2	0.1	0.0	0.0	2.3
Column Totals	15.4	10.5	23.2	28.8	6.5	6.3	5.1	3.4	0.7	**100**

The study uses the midway point of each range of wind speeds provided by the BOM wind roses to simplify analysis. For wind speeds greater than 40 km/h, the study uses 45 km/h. These assumptions were made to empower the analysis and to present the results as they are, with all their limitations. The author acknowledges that this may have resulted in errors, but they believe that the benefits of presenting the results in this way outweigh the risks.

This version acknowledges the limitations of the BOM wind roses and the assumptions that were made in the study, but it also emphasizes the importance of presenting the results as they are, with all their limitations. This is important because it allows readers to understand the uncertainties in the results and to make their own judgments about their reliability.

Wind speeds are vectorized and multiplied by the frequency of occurrence to calculate an index. The indices are then summed to obtain an overall onshore index for the site under study, as defined:

- ***Vectorized:*** Wind speeds are converted into vectors, which are quantities that have both magnitude and direction.

- ***Multiplied by the frequency of occurrence:*** The vectorized wind speeds are multiplied by the frequency of occurrence, which is the percentage of time that the wind blows from a particular direction and at a particular speed.
- ***Calculate an index:*** The multiplication of the vectorized wind speeds and the frequency of occurrence gives an index, which is a measure of the wind energy potential at a particular site.
- ***Summed to obtain an overall onshore index:*** The indices for all wind directions and speeds are summed to obtain an overall onshore index for the site under study.

Table 2 Maryborough On-shore INDEX.

Wind Velocity	NE Vector	% ges From BOM: NE	E	SE	SE Vector	% ges x Vectors NE	E	SE	
5	3.5	2.8	4.0	3.7	3.5	9.9	14.1	13.1	
15	10.6	5.9	10.6	9.1	10.6	62.6	112.4	96.5	
25	17.7	1.6	6.6	10.8	17.7	28.3	116.7	190.9	
35	24.7	0.2	1.7	4.1	24.7	4.9	42.1	101.5	
45	31.8	0	0.4	1.2	31.8	0.0	12.7	38.2	TOTAL
						106	298	440	844

This overall onshore index [844] in Table 2 can be used to compare the wind energy potential of different sites. Sites with higher indices have more wind energy potential. Two more studies are presented, as follows:

- Williamtown (NSW)
- Broome (WA)

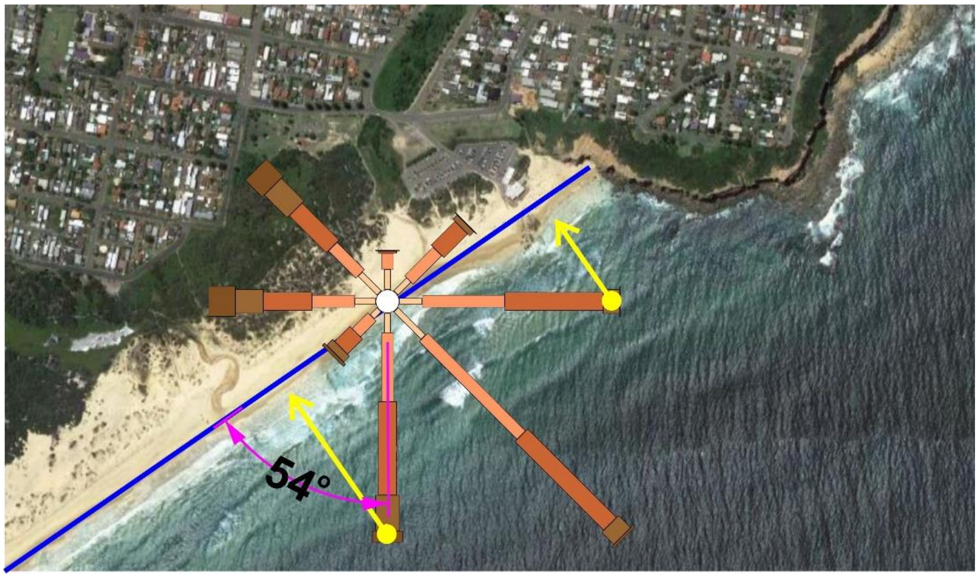


Figure 5 – Williamtown (NSW) Wind Rose onto Redhead Shoreline

Table 3 Williamtown On-shore INDEX.

Wind Velocity	Vectors E	Vectors SE	Vectors S	% ges From BOM: E	% ges From BOM: SE	% ges From BOM: S	% ges x Vectors E	% ges x Vectors SE	% ges x Vectors S
5	4.0	4.9	2.9	1.7	2.8	1.4	6.9	13.8	4.1
15	12.1	14.8	8.8	6	10.1	5	72.8	149.6	44.1
25	20.2	24.7	14.7	7.2	9.2	6.8	145.6	227.2	99.9
35	28.3	34.6	20.6	1.2	1.2	2.6	34.0	41.5	53.5
45	36.4	44.4	26.5	0.1	0.2	0.8	3.6	8.9	21.2
							263	**441**	**223**

TOTAL
927

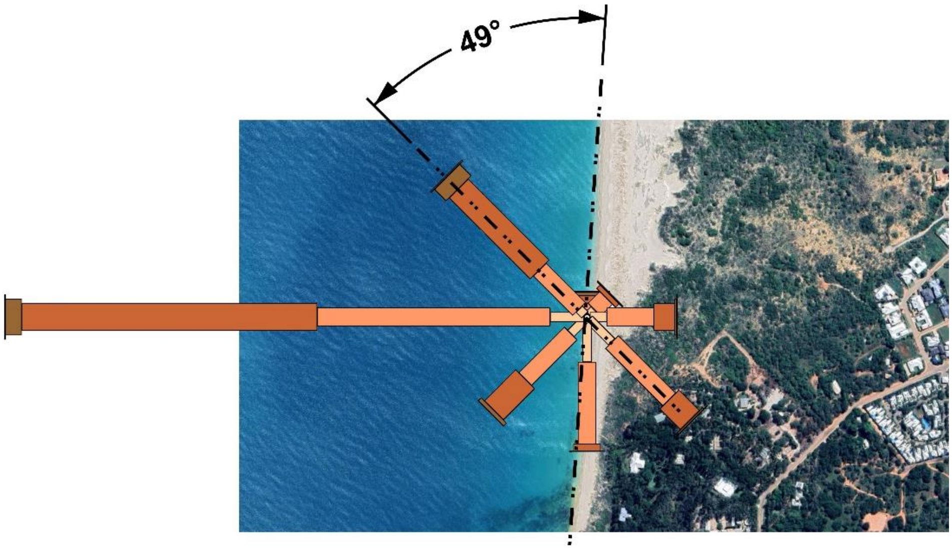


Figure 6 – Broome (WA) Wind Rose onto Cable Beach Shoreline

Table 4 - Cable Beach On-shore INDEX.

Wind Velocity	Vectors SW	Vectors W	Vectors NW	% ges From BOM: SW	% ges From BOM: W	% ges From BOM: NW	% ges x Vectors SW	% ges x Vectors W	% ges x Vectors NW
5	3.3	5.0	3.8	1.5	2.5	0.6	4.9	12.5	2.3
15	9.8	15.0	11.3	4.8	17.5	4.2	47.2	261.9	47.5
25	16.4	24.9	18.9	3.3	22.2	8.6	54.1	553.6	162.3
35	23.0	34.9	26.4	0.3	1.2	1.2	6.9	41.9	31.7
45	29.5	44.9	34.0	0	0	0.1	0.0	0.0	3.4
							113	**870**	**247**

TOTAL
1230

Conclusion

Methodology has been developed for a corrosion risk Index. The three examples follow:

6. Peregian Beach using a Maryborough wind rose = 844
7. Redhead Beach using a Williamtown wind rose = 927
8. Cable Beach using a Broome wind rose = 1230

The index purely reflects the likely reach of the airborne aerosols generated by the surf. It is important to note that the corrosion risk index is just one of many factors that should be considered when assessing the risk of corrosion at a particular site.

In conclusion, the corrosion risk index is a valuable tool that can be used to identify areas that are at high risk of corrosion at the shoreline. This information can then be used to develop strategies to mitigate the risk of corrosion, such as selecting appropriate materials for construction, applying protective coatings, installing cathodic protection systems, and inspecting and repairing structures regularly.

It is important to note that the corrosion risk index, though dominant, is just one of many factors that should be considered when assessing the risk of corrosion at a particular site. Other factors, such as the type of structure, the environment, and the expected lifespan of the structure, should also be taken into account.

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