Distance effects of corrosion in geothermal environments

Buildings constructed within 50 metres of a geothermal hot spot are outside the scope of NZS 3604:2011 *Timber-framed buildings* and require specific engineering design. How appropriate is the set 50 m distance? BRANZ research on metal corrosion at sites around Rotorua shows that a 50 m separation might not always be enough to lower atmospheric corrosivity to a safe range.

AS WELL AS considering exposure zones, NZS 3604:2011 addresses local environmental effects or microclimates. The standard states that: "A mildly corrosive atmosphere can be converted into an aggressive environment by microclimatic effects." Geothermal hot spots (within 50 m of a bore, mud pool, steam vent or other source) are one situation that could lead to faster corrosion of metallic components.

BRANZ investigated the effects of distance from geothermal hot spots on material deterioration as part of a wider corrosion research project. Three exposure sites were established in the grounds of Scion, a Crown research institute in Rotorua. One rack holding mild steel, zinc and copper samples (150 × 100 × 1–3 mm) was fixed approximately 5 m from an active small fumarole (a natural vent that emits sulphurous gases). The second was located approximately 50 m east of this fumarole and the third approximately 60 m southwest.

To minimise the influence of possible changes in climatic conditions and geothermal activity, metal corrosion rates were measured after three exposure periods:

- December 2014–December 2015
- June 2015–June 2016
- December 2015–December 2016.

The first finding is that a separation of 50–60 m from this geothermal source could significantly decrease the corrosion rate of all three metals tested (Figures 1–3). This decreased by up to 10 times in some cases. This is likely related to lower airborne concentrations of sulphur-containing gases, hydrogen sulphide (H_2S) and/or sulphur dioxide (SO_2). H_2S concentrations 50–60 m away from the fumarole could be 5–10 times lower than that at the fumarole itself (Figure 4).

Even the reduced concentrations away from the fumarole were still far higher than non-geothermal locations, however. For example, these lower concentrations were more than 25 times higher than atmospheric H_2S measurements taken at BRANZ's rural campus at Judgeford, Porirua.

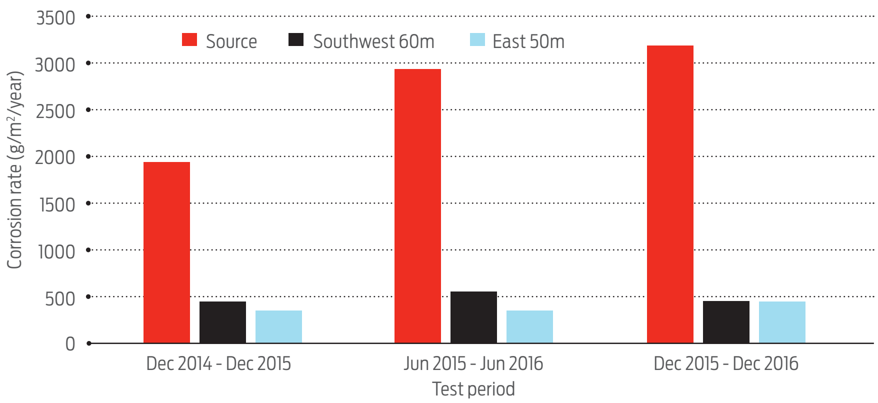


Figure 1. First-year corrosion rate of mild steel exposed at three locations around a fumarole in Scion campus.

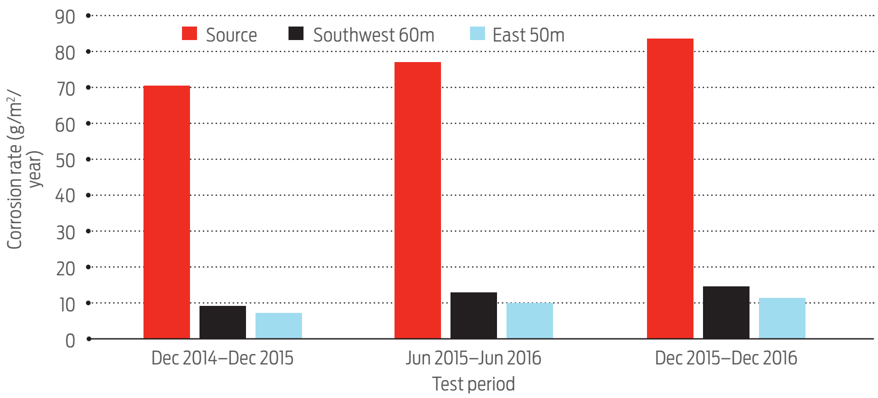


Figure 2. First-year corrosion rate of zinc exposed at three locations around a fumarole in Scion campus.

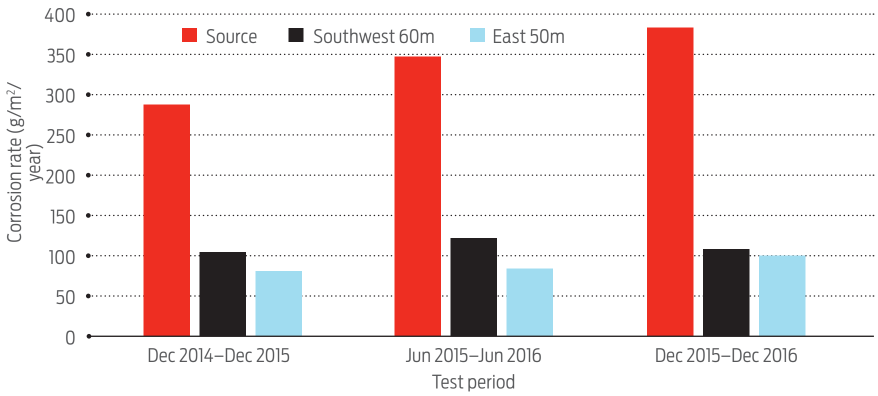


Figure 3. First-year corrosion rate of copper exposed at three locations around a fumarole in Scion campus.

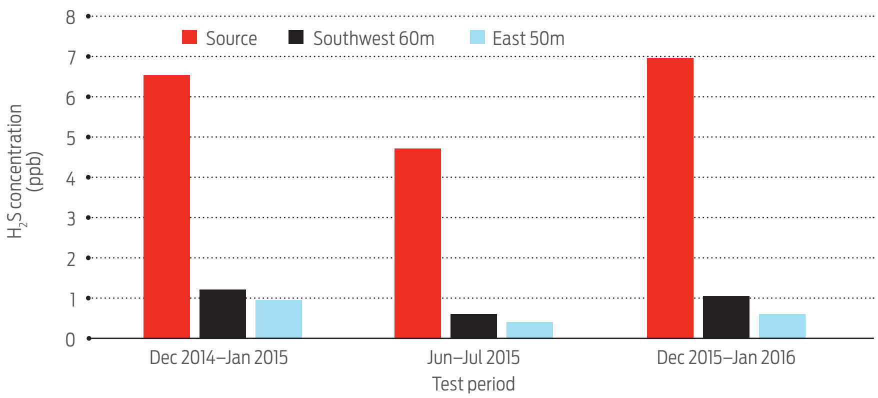


Figure 4. Averaged H_2S concentration measured at three locations around a fumarole in Scion campus.

Corrosion observed on the metal surface

After 1 year of exposure, the metal samples were examined. This showed that a separation of 50–60 m from the fumarole could lead to the formation of corrosion product layers with a better protective capability.

Mild steel samples exposed at 5 m from the fumarole suffered very severe corrosive attack (Figure 5a), with obvious cracking and spalling. By contrast, corrosion product layers on mild steel samples exposed 50–60 m away showed no significant detachment or spallation, although there were some cracks (Figure 5b).

The corrosion layer on the zinc sample 50–60 m from the fumarole (Figure 5d) was much thinner than that on the zinc sample 5 m from the source (Figure 5c).

Corrosion products on copper samples close to the fumarole also detached and spalled during exposure, with nodules/clusters formed (Figure 5e).

Spallation and/or detachment were not seen on the copper samples 50–60 m away. The surface showed clusters of smaller particles (Figure 5f). It was porous, and there were fine powder-like materials.

Highly corrosive atmosphere

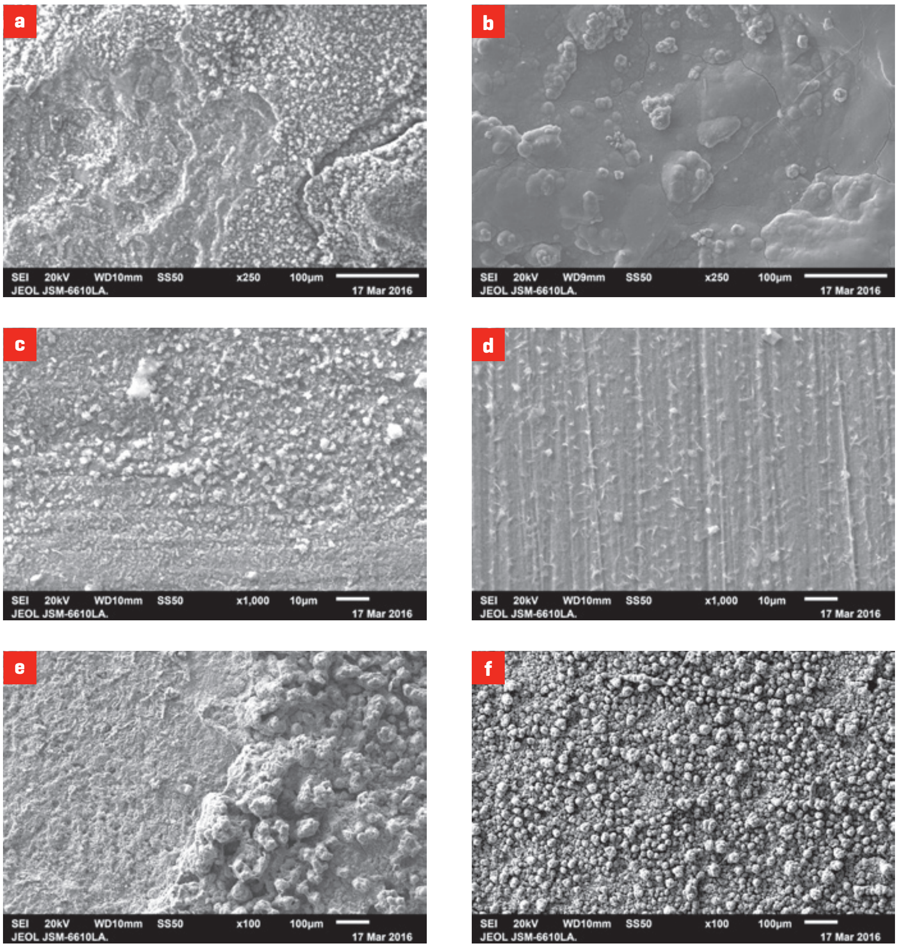
These findings do not mean that a 50–60 m separation would always put the local atmospheric environment into a relatively benign corrosivity category. (Categories are defined in ISO 9223:2012 *Corrosion of metals and alloys – Corrosivity of atmospheres – Classification, determination and estimation*.) For example, the corrosion rate of mild steel 60 m southwest of the fumarole was measured at 443–551 g/m²/year, placing the local environment into the C4 (High) corrosivity category (Table 1). For copper, corrosivity 50–60 m from the fumarole was even greater.

ISO 9223:2012 uses the first-year corrosion rates of steel, zinc, copper and aluminium to determine corrosivity. The field trial observations suggest that ISO 9223:2012 might not be appropriate for atmospheric corrosivity classification where geothermal sulphur-containing gases are the major airborne pollutants. Different metals have quite different interactions with these pollutants – this study showed that copper is more prone to geothermal attack than mild steel or zinc.

This BRANZ research project also measured corrosion rates at the wastewater treatment plant site approximately 200 m south of Sulphur Bay, a location with many active geothermal features. First-year corrosion rates were 3,044–3,443 g/m²/year for mild steel, 65.6–88.6 g/m²/year for zinc and 443–517 g/m²/year for copper.

This is not the first time BRANZ has researched corrosion in this area. In the 1980s, BRANZ measured a first-year corrosion rate of mild steel of 2,293 g/m²/year at a site approximately 400 m southwest of Sulphur Bay.

These measurements indicate that the area around 200–400 m south or southwest from Sulphur Bay could be classified in the CX (Extreme) corrosivity category.



a) Mild steel at 5 m from a fumarole. b) Mild steel at 50 m. c) Zinc at 5 m. d) Zinc at 50 m. e) Copper at 5 m. f) Copper at 50 m.

Figure 5. Surface of metal samples exposed for 1 year.

Table 1. Corrosivity category determined according to ISO 9223:2012.

METAL	LOCATION	CORROSIVITY CATEGORY		
		DEC 2014–DEC 2015	JUN 2015–JUN 2016	DEC 2015–DEC 2016
Steel	Source (5 m)	CX Extreme	CX Extreme	CX Extreme
	Southwest (60 m)	C4 High	C4 High	C4 High
	East (50 m)	C3 Medium	C3 Medium	C4 High
Zinc	Source (5 m)	CX Extreme	CX Extreme	CX Extreme
	Southwest (60 m)	C3 Medium	C3 Medium	C3 Medium
	East (50 m)	C3 Medium	C3 Medium	C3 Medium
Copper	Source (5 m)	>CX Extreme*	>CX Extreme*	>CX Extreme*
	Southwest (60 m)	>CX Extreme*	>CX Extreme*	>CX Extreme*
	East (50 m)	CX Extreme	CX Extreme	>CX Extreme*

* When the first-year corrosion rate of copper is used for corrosivity category classification, the CX category indicates the corrosion rate will be in the range of 50–90 g/m²/year. In this study, the first-year corrosion rate of copper can be around five times higher than the upper limit.

Conclusion

A 50 m separation from geothermal hot spots required by NZS 3604:2011 might not always be enough to reduce atmospheric corrosivity into a safe range. This is based on two findings:

- The corrosion rate of a mild steel sample 60 m southwest of a fumarole placed it in the C4 (High) corrosivity category, while the corrosion rate of a copper sample 50–60 m away placed it above the top of the CX (Extreme) category.
- At 200 m south of Sulphur Bay, the corrosion rates for mild steel, zinc and copper could all be classified CX (Extreme).

For areas within approximately 500 m of an active geothermal feature, atmospheric corrosivity is strongly influenced by many factors, including size, emission capability, chemistry of the geothermal feature and weather. Atmospheric corrosivity could go up to CX (Extreme) with considerable variations.

More information

Li, Z., Marston, N. & Stokes, K. (2018). *Materials within geothermal environments.* BRANZ Study Report SR393. Judgeford, New Zealand: BRANZ Ltd.

Geothermal corrosion fact sheet 1 *Which metals are more sensitive to geothermal corrosion?*

Geothermal corrosion fact sheet 3 *Discolouration and deterioration of wood in geothermal environments*

Geothermal corrosion fact sheet 4 *The performance of aluminium-zinc alloy coating in geothermal environments*