Atmospheric corrosion mapping of South Africa and the Greater Johannesburg Metropolitan Area (GJMA)

ABSTRACT

The first corrosion map of South Africa (SA) was published in 1991. Since then only minor variations have been made to this map. However, due to the lack of differentiation of inland locations, overstatement of the corrosivity of environments, changes in international standards regarding the measurement of corrosive atmospheres, increased industrialisation of SA's large metropolitan areas, global climate change effects and improved mapping techniques, this chart has become outdated. The present study focused on the development of a new corrosion map for SA, with the emphasis placed on the provision of more detail concerning the atmospheric corrosivity of the Greater Johannesburg Metropolitan Area (GJMA) – SA's economic heartland.

In the study, historical published and unpublished corrosion data for South Africa were assimilated and analysed. The atmospheric corrosivity of the GJMA was also measured using ASTM G116 wire-on-bolt and ISO 9226:1992 open aluminium, zinc and copper wire helix devices, including ISO 9226:2012 flat mild steel and hot-dip galvanised steel coupons. Coated mild steel specimens were also exposed to determine the corrosive effects of the GJMA's atmosphere on organic materials. The morphologies and chemical compositions of the mild steel corrosion products, using SEM-EDS, FTIR and Raman spectroscopy, as well as pH and water-soluble salt measurement techniques were furthermore investigated, along with correlations between the measured corrosion data, and general meteorological and pollution parameters for the GJMA area.

The study showed that the corrosivity of SA's coastal environments decreases rapidly within the first 150 m from the ocean and that for most inland locations, very *low* (C1) to potentially *high* (C4) corrosive conditions may be expected, as per the ISO 9223

rating scheme. High correlations were also found between the first-year corrosion rates of mild steel, hot-dip galvanised steel, zinc, aluminium and copper. Moreover, it was confirmed that the corrosivity of the GJMA is influenced by precipitation, humidity, PM_{10} and $PM_{2.5}$ particulate matter, as well as SO_2, NO_2, NO, CO and O_3 levels in the atmosphere, including wind direction and daily temperatures (maximum and minimum). Other factors found to affect the corrosivity of the GJMA's atmosphere are: elevations above sea and ground level; the presence of vegetation and large water bodies; topography; shielding and shading effects; the occurrence of an El Niño or La Nina event; and acid rain.

Moreover, it was established that the GJMA is most corrosive during spring and summer and that at least 90% of the area can be rated Upper-C2 (*low* to *medium*) corrosive. The results furthermore revealed high correlations between the ISO 9223 (1992 and 2012) corrosion monitoring devices and that wire-on-bolt (CLIMAT) units are better indicators of the impact of atmospheric pollutants on the 12- month corrosion rate of hot-dip galvanised steel than uncoated steel. A strong linear correlation was also found regarding the average corrosion rate of mild steel with every 20 mg/m^2 rise in the concentration of water-soluble salts in the corrosion product.

The East Rand of the GJMA rated most corrosive, with corrosion trouble spots identified at Aeroport, Bonaero Park, Brakpan, Chloorkop, Dalpark, Dunnottar, and Nigel. The Kagiso-Randfontein area was the only other area, outside the East Rand, that rated more corrosive. Extrapolations of the long-term corrosion rates of mild steel and hot-dip galvanised steel in the GJMA were additionally made based on logarithmic regressions of the 6-, 12-, 18- and 24-month corrosion data. Finally, geoprocessed (metal specific) corrosion maps were developed for the GJMA, subsequently incorporated into several corrosion maps for SA (also metal specific), to provide better clarity regarding SA's inland areas.

Keywords: Corrosion, atmosphere, South Africa, Greater Johannesburg, inland Metropolitan, wire-on-bolt, CLIMAT, ISO 9223, mapping, pollution, mild steel, hot-dip galvanised steel, aluminium, zinc, copper, coatings