Analysis of corrosion rates on wreckage steel: A model exercise in the North Sea

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The bottom of our North Sea is studded with ship- and other historic wrecks ranging from 18th century till present times. 228 identified have been identified and 62 are still anonymous. Not surprisingly most date from the first and Second World War. These wrecks tell a story and it is important that these memories are protected. In 2013, Belgium ratified the UNESCO Convention on the Protection of Underwater Cultural Heritage and at present twelve wrecks are protected in Belgian waters. All wrecks of more than 100 years old obtain this special status automatically. However, protecting wrecks should also entail conservation for future generations. Without protection, corrosion wins and these wrecks, together with their story, will disappear. A key element enabling the selection of most appropriate preservation method is the knowledge of the actual corrosion rate.

The most appropriate model able of predict corrosion rates over a period of more than 100 years is the multiphase model of Melchers (2008). It is completely empirical and makes a distinction between the aerobic and the anaerobic phase of the corrosion process. For immersion times, the model is complex and involves a combination of aerobic and anaerobic (microbiological) corrosion processes; however, after a set and calculable time point t_s (15 years for the North Sea), the corrosion loss becomes a linear function of time:

Total corrosion loss = $c_s + (t-t_0)*r_s$

with c_s = intercept of the linear anaerobic corrosion function on the corrosion loss axis, t = time (in years), t_0 = the time period between sinking and coating failure (in years), and r_s = the apparent anaerobic corrosion rate; c_s and r_s can be inferred from actual corrosion measurements.

The Melchers model was adopted to long term North Sea conditions by changing 2 parameters being the average seawater temperature and the dissolved inorganic nitrogen (DIN) concentration. An average seawater temperature of 12.5°C was calculated based on data obtained from the Flemish Marine Institute. The anaerobic corrosion rate (r_s) is 0.053mm/year at 12.5°C without taking into account the influence of the N concentration. Melchers (2013) also provides a correction factor Rp based on the Dissolved Inorganic Nitrogen (DIN) in the sea water (set between 0.3mgN/L (OSPAR, 2017) and 1.4mgN/L (Janssen, 1993).

Rp = ratio between corrosion loss with and without the influence of microbiological activity as a function of dissolved inorganic nitrogen (DIN).

In order to subsequently validate the North Sea adaptation of the Melchers model, thickness measurements were performed on four wrecks in the Belgian part of the North Sea: the cargo ships Garden City (sunk in 1969) and Birkenfels (1966), the German WW I submarine U11 (1914) and the French destoyer Bourrasque (1941). The wrecks were chosen based on the ease of access (at 30 meters below the sea surface), and on the availability of the original construction plate thickness (data which are either lost or hidden in enclosed military archives).

Underwater plate thickness measurements were performed using a Cygnus M2-Dive with the S2C single Crystal Probe.

A preliminary analysis shows that the Melcher's anaerobic corrosion rate of 0.054mm/year (12.5°C) is overrated. A more realistic North Sea value is most probably somewhere in the neighborhood of 0.025mm/year. Moreover, MIC appears not to be involved, which corresponds with XRD and DNA analysis on historic submerged steel artefacts.

References

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