



## Comparison of water-line corrosion processes in natural and artificial seawater: The role of microbes



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### ABSTRACT

Large wire-beam electrodes constructed via the assembly of Q235 carbon steel cylinder electrodes have been utilized to investigate the processes of water-line corrosion in natural and artificial seawater, and different anode–cathode distribution characteristics were observed in these two kinds of media over time. In artificial seawater, sporadic cathodic sites away from the water line switched to anodes, and cathodes tended to concentrate on the water line for extended periods of time, which was in good agreement with the formation of differential aeration cells. Similar distribution characteristics were present at the initial stages in natural seawater, but the polarity was reversed on day 13. This reversal did not last for a long time, and the cylinders at the water line returned to acting as cathodes on day 17. The occurrence and fading of the polarity reversal in natural seawater appeared to be linked with the variation in pH at the gas/liquid interface, which was affected by the presence of microbes.

### 1. Introduction

Water-line corrosion (WLC) is a typical localized corrosion phenomenon believed to derive from the formation of differential aeration cells (DACs) [1]. The area above the water level is highly oxygenated and acts as a cathode while the part below is less oxygenated and behaves as an anode. The most serious corrosion therefore occurs just below the water line [1]. Despite the fact that WLC is a well-known phenomenon, it is quite difficult to obtain a full understanding of the processes and kinetics involved using conventional methods such as weight-loss measurements.

Thanks to the work of Tan et al. [2,3], more detailed information on the processes occurring in WLC was obtained using the wire-beam electrode (WBE) method. A WBE consisting of 100 mild steel wires with a diameter of 0.15 cm was partially immersed in NaCl solution with and without the addition of Na<sub>2</sub>CO<sub>3</sub>, and the potential and galvanic current distributions were monitored over time. Different corrosion patterns were observed in these two media. In pure NaCl solution, the anodic sites expanded to cover the majority of the electrode below the water line after five days, while wires at the water line behaved as cathodes and remained unattacked [2]. However, in NaCl solution containing Na<sub>2</sub>CO<sub>3</sub> severe corrosion was concentrated on wires at the water line after the initiation and propagation of WLC [2,3]. Unfortunately the authors did not offer any explanation for these differences.

Artificial seawater is frequently utilized in the laboratory to simulate marine corrosion, but different corrosion rates have been reported in synthetic media compared with those in natural seawater. This has been ascribed to differences in chemical composition and biological activity [4–6]. Apart from the corrosion rate, is the process by which WLC develops different in these two kinds of media? To the best of our knowledge, there has been no report comparing WLC in artificial and natural seawater. The presence of a wide variety of microorganisms is one of the prominent characteristics of natural seawater [7–9], and oxygen is vital for the metabolism of aerobic microorganisms. The metabolic assumption of oxygen by aerobes is believed to affect oxygen distribution, which might have an effect on DACs and WLC. It was therefore decided to investigate the development of WLC in natural and artificial seawater using the WBE method. Unlike the short WBEs (about 1.5 cm) utilized by Tan [2,3], large WBEs with a height of 36 cm were adopted in the present study; this large intercept was assumed to be beneficial for the development of DACs by oxygen transfer. As expected, natural and artificial seawater displayed different anode–cathode distribution characteristics over time.

### 2. Experimental

The natural seawater was acquired from Huiquan Bay, Qingdao, and two different artificial seawater media were prepared by the dissolution

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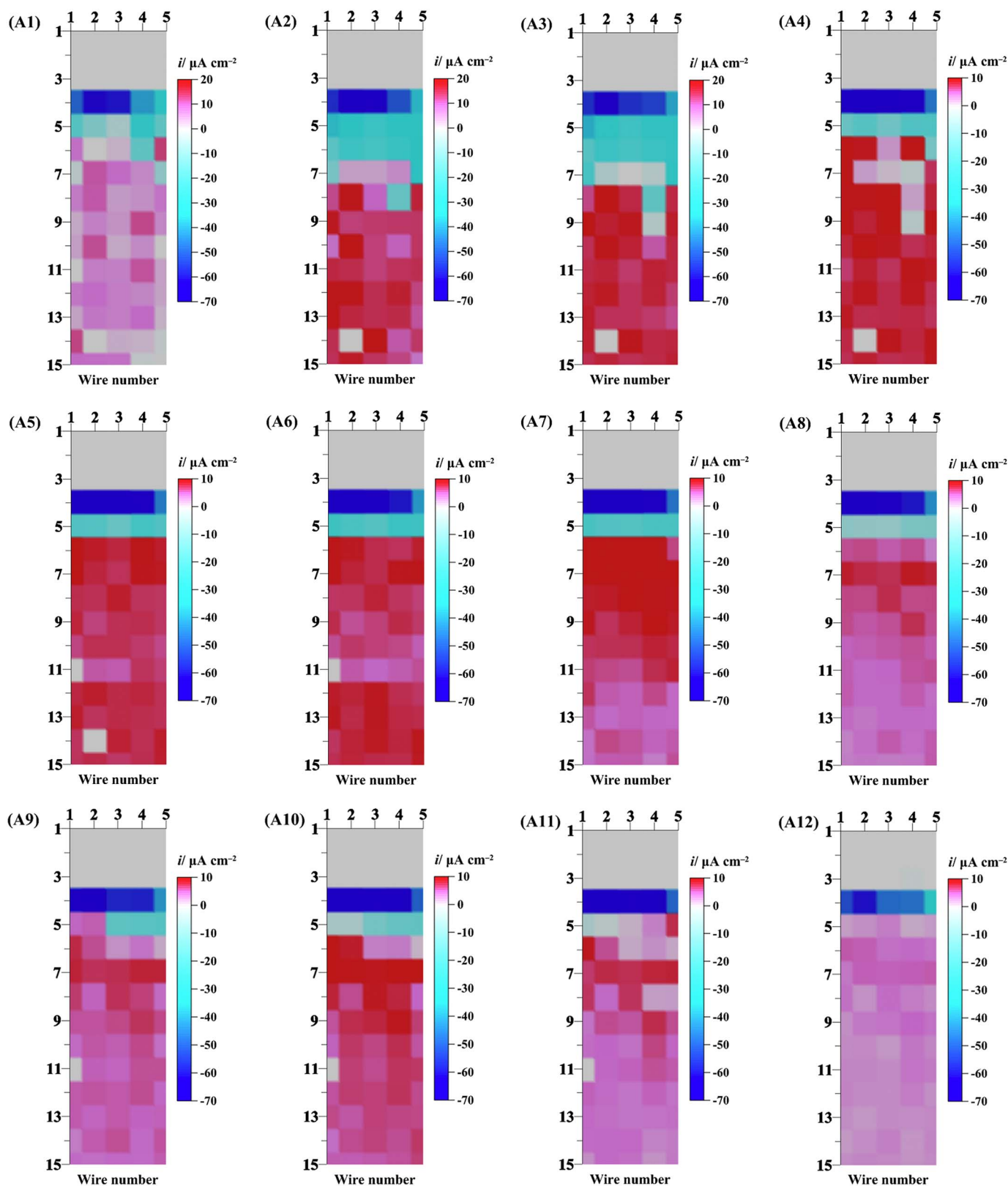


Fig. 1. Galvanic current recorded on the WBEs in artificial seawater 1# (A1 to A12), artificial seawater 2# (B1 to B12) and natural seawater (C1 to C12) at different times. (A, B, C)1 to (A, B, C)12 correspond to 5 h, 1, 3, 7, 11, 13, 15, 17, 21, 25, 31, and 40 days, respectively.

of reagents in distilled water. Artificial seawater 1# was 3.5% NaCl, and artificial seawater 2# consisted of NaCl,  $\text{CaCl}_2$ ,  $\text{NaHCO}_3$ ,  $\text{MgCl}_2$ ,  $\text{Na}_2\text{SO}_4$ ,  $\text{H}_3\text{BO}_3$ , and KBr [10,11].

The WBEs used in this work were constructed by assembling 75 cylinder electrodes ( $5 \times 15$ ). Cylinders (diameter: 1 cm, height: 1 cm)

were cut from a Q235 carbon steel sheet. Coupons were embedded in epoxy resin to leave only one end surface ( $0.785 \text{ cm}^2$ ) exposed to the aggressive electrolyte after the copper wires had been soldered. The cylinder electrodes were abraded, cleaned, and fixed into a polyamide plate with regularly arranged holes (diameter: 2.1 cm, interval: 2.5 cm).

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