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Case study

Critical analysis of laboratory measurements and monitoring system of water-pipe network corrosion-case study.

Agata Jazdzewska[a,*], Kazimierz Darowicki[a], Juliusz Orlikowski[a], Stefan Krakowiak[a], Krzysztof Zakowski[a], Maciej Gruszka[b], Jacek Banas[c]

[a] Department of Electrochemistry, Corrosion and Materials Engineering, Gdansk University of Technology, Narutowicza 11/12, 80-952 Gdansk, Poland
[b] MPWIK S.A.(Municipal Waterworks in Cracow), Senatorska 1, 30-106 Krakow, Poland
[c] AGH University of Science and Technology, Reymonta 23, 30-059 Krakow, Poland

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ABSTRACT

Case study of corrosion failure of urban water supply system caused by environmental factors was presented. Nowadays corrosion monitoring of water distribution systems is an object of major concern. There is possibility of application broad range of techniques like gravimetric and electrochemical. Both kinds of techniques can be applied in laboratory and field conditions. In many cases researches limit the case analysis to measurements in laboratory conditions. Presented work contain critical analysis of results obtained in laboratory and field conditions based on corrosion monitoring of three pipelines systems failure in Krakow.
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1. Introduction

Carbon steel is still one of the most common and popular construction material, despite the high development of materials. Carbon steel, the most widely used as engineering material, is counted for approximately 94% of the annual steel production in United States. Relatively limited corrosion resistance of carbon steel do not change the fact that it is used in large tonnages in marine applications, pipelines, mining, chemical processing, nuclear power and fossil fuel power plants, transportation, petroleum production and refining, construction and metal-processing equipment [9,12,1,2].

The economic cost due to corrosion can hardly be overestimated. As calculated by the National Association of Corrosion Engineers, in the USA alone, the total cost involved in 2012 amount to above $1 trillion, no less than 6.2% of GDP [7,15].

Corrosion of water distribution systems is a widespread issue that can cause unwanted changes in water quality and failures of the water distribution systems. These considerations suggest that a complete monitoring program and water treatments controlling and guaranteeing the water quality are necessary [3].

Krakow is large city in Southern Poland. The beginning of the water-pipe network of Krakow is dated to 15 February 1901. With regard to over 100-year exploitation of water-pipe network, it is characterized by essential age differentiation. In the city pipelines from the first decades of the distribution system operating period still exists, of the age over 50 years. Krakow is divided into separate water-pipe zones of supplying fed from independent sources which are 4 top water intakes supplied from: the Raba River, the Rudawa River, the Dlubnia River and the Sanka River and one underground intake placed in

* Corresponding author.
E-mail address: agata.jazdzewska@pg.gda.pl (A. Jazdzewska).

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Mistrzejowice. Presented case study comply with corrosion of three water distribution systems from sources named as Bielany, Rudawa and Dlubnia and its water average production is counted for 17.9; 37.7 and 28.5 m^3/d respectively [19]. Total length of steel pipeline is equal to over 600 km. In recent years number of corrosion related problems with pipeline significantly increased and was source of some leakage, outages in water supply and discoloration events. The presence of large number of failures forces creation of corrosion rate monitoring system.

Monitoring program can be realized by controlled laboratory studies or field survey or combination of both. Laboratory studies are mostly in the form of electrochemical impedance spectroscopy and Tafel polarization. Overall corrosion rates can be estimated by means of fitting, typically using the Butler–Volmer equation or its variants [6,10,11,18]. The complexity of predicting responses of corrosion processes and metal release to long- and short-term variations of drinking water properties and flow conditions, it is mostly critical to monitor these responses in real time [8,14,17].

The purpose of this study was to examine the effects of water corrosivity of various rivers using a combination of controlled laboratory studies and a field survey.

2. Experimental

The electrochemical experiments were performed at room temperature, using Ag/AgCl and Pt-mesh as reference and auxiliary electrodes, respectively. The exposed surface of the working electrode in the solution was circular in shape with an area of 1 cm^2. The working electrode was a cylindrical disc cut from a specimen of S236JR having the chemical composition determined in polish norm no. PN 10020. The working electrode was first prepared using 400–2500 grade abrasive paper, and following this procedure, it was rinsed with distilled water and degreased with acetone.

The EIS measurements were performed using a Reference 600, Gamry Potentiostat/Galvanostat/ZRA supplied by M/S Gamry Instruments (USA). Before EIS measurement, each sample was immersed in the corrosion cell and allowed to stabilize for 2 h. The EIS studies were performed by imposing a sinusoidal voltage of 10 mV amplitude as the open circuit potential of the working electrode. The frequency was varied between 100 kHz and 18 mHz.

The corrosion monitoring system consists of industrial computers performing measurements together with a data transfer system, data control and conditioning systems, a multiplexer-enabling sensor control and sensors placed inside the water pipeline [13].

The monitoring system was managed digitally. The digital system includes a data conditioning module and a sequential control module for measurements from individual sensors. The data conditioning system is also directly connected with a measuring computer.

Corrosion processes are monitored automatically, the corrosion rate was measured on the basis of linear polarisation resistance (LPR) measurements. This measurement technique allows for determining the corrosion rate directly during tests [16].

3. Results and discussion

Impedance, Tafel polarization and monitoring system results of carbon steel exposed to three different waters from Bielany, Dlubnia and Rudawa river are presented. Monitoring system includes the results from 90 days of exposition. Impedance and Tafel polarization measurements were performed in laboratory conditions on water samples collected in 5th day of monitoring system. Obtained impedance spectra are presented on Fig. 1.

The acquired impedance spectra demonstrate a flattened circular shape. In order to obtain more qualitative information of inhibition mechanism the impedance data were analyzed with the use of the electrical equivalent circuit.

The equivalent circuit (Fig. 2) consists the resistor, representing the solution between working and the reference electrodes R_s, in series to a parallel combination of the resistor, R_{ct}, playing the role of the charge transfer (corrosion) resistance and constant phase element CPE. Its impedance, Q is used instead of capacitor due to presence of depressed semicircles in the spectra, and O as a finite-length Warburg diffusion impedance [4].

The value of charge transfer resistance is of high importance and decides about the dynamic of the corrosion process. Values of R_{ct} obtained from impedance spectra are presented in Table 1. Values of ba and bc Tafel coefficient were obtained by analysis of Tafel slopes in manner taking to account diffusion control. Corrosion rate were calculated using Stern–Geary equation. Tafel polarization curves are presented in Fig. 3.

Table 1 presents values of corrosion current obtained from extrapolation of Tafel curves and by application of Stern–Geary equation. The difference between both obtained results is a consequence of electrolyte resistance contribution which is not differentiated by Tafel polarization. Larger value of electrolyte resistance contribute to more significant error. As a results corrosion current obtained from Stern–Geary equation is more accurate and was used for further corrosion rate calculations.

Corrosion rates (Fig. 4) of steel obtained from monitoring systems in the first 5 days shown similar values for all three rivers, moreover Bielany river in some period of time is described by the highest corrosion rate. After 10 days metal exposed in Bielany river is representing decreasing tendency in the same becoming the smallest value of corrosion rate. Samples exposed to Dlubnia and Rudawa rivers after 30 days of measurement keeps similar corrosion speeds until the end of presented results of monitoring system.

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