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EVALUATION OF ANNUAL CORROSION TESTS FOR AGGRESSIVE WATER

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ABSTRACT

Internal corrosion has a significant effect on the useful life of pipes, the hydraulic conditions of a distribution system and the quality of the water transported. All water is corrosive under some conditions, and the level of this corrosion depends on the physical and chemical properties of the water and properties of the pipe material. Galvanic treatment is an innovation for protecting against corrosion, and this method is also suitable for removal of water stone too. This method consists of the electrogalvanic principle, which is generated by the flowing of water between a zinc anode and the cupro-alloy cover of a column. This article presents experimental corrosion tests at water resource Pernek (This water resource-well marked as HL-1 is close to the Pernek of village), where the device is operating based on this principle.

1. INTRODUCTION

Corrosion of water significantly affects the useful life of pipes, the hydraulic conditions in a distribution network and the quality of the water transported. All water is corrosive to some extent; the degree of the corrosion depends on the physical and chemical properties of the material properties of the pipe.

The undesirable effects of corrosion are always reflected in financial losses, whether due to deterioration in the water's quality or hydraulic flow conditions, the increased water losses, the number of failures and reducing useful life of pipe. The closure of a pipe that is being repaired can increase pressure on other parts of the system and cause other disturbances to corrosible old pipes.

Corrosion has a significant impact on the reliability of a water supply system, which also affects the public's opinion about the

system's operator. A reliable, uninterrupted supply of water is often an essential requirement for consumers, especially major customers, and may be an important factor in the further development of a region [1, 2].

2. DETERMINING THE CORROSIVE EFFECTS OF WATER

The corrosive effects of water can be identified on the basis of chemical water analyses, using the solid CaCO_3 test (the Heyer test), various calculation relationships and tables or corrosion tests.

Determining the corrosive effects of water has its advantages and disadvantages. The advantage is that the results of the chemical analyses are available within a relatively short period of time, and

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- Corrosive declines.

the analyses can be carried out on a regular basis. This allows for the continual monitoring of the quality of the water and its changes along with a comparison of the parameter values. The disadvantage according to various writers is that the calculations of potential water corrosion only take into account the corrosive effects of water due to aggressive CO_2 . Despite the fact that the concentration of dissolved oxygen can be the dominant factor and that the flow velocity has a significant effect on the corrosion process, these calculations do not take these parameters into consideration.

Since calculations of the calcium-carbonate balance do not include other effects influencing the balance (the complex effect of some organic and inorganic substances, the effect of chemicals such as magnesium inhibiting CaCO_3 crystallization, the presence of extraneous substances, dissolved chlorine concentrations, etc.), the results do not always correspond to practical experience. [5, 6].

A corrosion test is another method for determining the corrosive effect of water. The test methodology is included in the Slovak Technical Standard STN 75 7151 "Requirements for Quality of Water in Piping Systems", and is based on measuring the difference in the weight loss of a sample material on the 30th and 60th days after its exposure to flowing water. Weight loss is a measure of corrosion rates, which indicate the difference in measured thickness in comparison to the original thickness of the pipe material. Based on the corrosion rate ($\mu\text{m}/\text{year} = 10^{-6}\text{m}/\text{year}$) between the 30th and 60th days, the water is evaluated and categorized according to the level of the corrosive effect. STN 75 7151 defines the three levels of the corrosive effects of water (table 1):

Tab. 1 *Water categories according to the level of the corrosive effect.*

Corrosive effect	Corrosion velocity ($\mu\text{m}/\text{year} = 10^{-6}\text{m}/\text{year}$)	Category
I.	under 50	mildly corrosive
II.	from 50 to 150	moderately corrosive
III.	over 150	strongly corrosive

No corrosion protection measures are needed for the first level of the corrosive effect. The measures for the second level of the corrosive effect are applied based on the results of a technical-economic analysis that takes into account the required service life of the pipes. The third level requires implementation of corrosion protection measures.

The corrosion test is relatively difficult and time consuming. In the event you also want to identify the type of corrosion, i.e., whether the pipe corrosion is uniform (general) or non-uniform (point) or what types of corrosion sediments are present, the test could last up to one year. The advantage of the test is the effect of water on a sample material is the same as the effect on a pipe. The effect of the dissolved oxygen can be present – whether it is the

dominant corrosive factor or has a positive role regarding metal passivation by forming a protective layer that separates water from the pipe's surface [3, 4].

3. CORROSION TESTS AT WATER RESOURCE

The Department of Sanitary and Environmental Engineering, Faculty of Civil Engineering, in cooperation with BVS, a.s. (Bratislava Water Company), is currently performing corrosion tests at the Pernek water resource, which contains corrosive water. This water resource is currently used for supplying the municipalities of Jablonové and Pernek in Slovakia. The corrosion tests have been running since April 2010.

Two 1.5 m-long test units (columns) are placed in the HL-1 well. Both columns contain 6 stands with test samples. Each stand includes 5 samples separated by a non-conductive strip. The test samples are made of steel sheets: class 11, thickness of 1mm and a size of 42 x 42 mm. Water is pumped into the testing columns from the well using one Grundfos pump. The pipes are divided into two directions, and the water flows separately into each column. The test devices are placed parallel to each other. After passing through the columns, the water flows back into the well.

The ISB-ION SCALEBUSTER device, which has mainly been used in Slovakia for service water treatment, is mounted on one of these units. In addition to testing the performance of the device, the suitability of the methodology used is also evaluated, since such a methodology for corrosive tests has not yet been used for evaluating the device's efficiency [7, 8].

The loss of material due to corrosion, corrosion velocities, the amount of sediments and the water flow rate in the testing units is evaluated for both columns. Presently now one-year measurements, two half-year measurements and six 60-day measurements have been completed and evaluated. The results are listed in table 2. The two uppermost stands with samples are used in the 60-day measurements. These stands are replaced by new ones immediately after they are taken out. For the half-yearly examinations third test stands were used and for the one-year measurement, fourth test stands were used with the samples, which were also replaced with new stands.

To determine if some measurement is not loaded by a serious error (whether a minimum or maximum error) and thus avoid the potential misrepresentation of the results of the average corrosion loss of the test, the measured values of the corrosion losses (g/sample , respectively g/m^2) tested the extreme deviations. The Dixon and Grubbs test was used. The 210 test values were evaluated, and 10 of them were unsuitable. In the case of standard equipment 4 values in the area of the maximum and the device with the Scalebuster 6 values have been excluded.

Tab. 2 Corrosion rates attained during the period monitored.

days	corrosion velocities v_t ($\mu\text{m}\cdot\text{year}^{-1} = 10^{-6}\text{m}\cdot\text{year}^{-1}$)					
	Standard test			ISB-ION SCALEBUSTER		
	range	average	%	range	average	%
30 – 60	83.24 – 218.34	131.39	100.0	73.71 – 221.57	146.66	100.0
30 – 180	48.31 – 87.92	71.40	54.3	55.68 – 72.83	63.06	43.0
30 – 365	59.85 – 67.27	63.55	48.4	54.96 – 62.64	57.96	39.5

The previously completed and evaluated 60-day measurements indicate that the corrosive effect of the water is in the second and third categories.

Chart 1 shows the changes in the corrosive properties of the water during the period monitored. The corrosive rates considerably increased, especially in the second 60-day trial, which was probably due to a significant rise in the groundwater level caused by a long-lasting heavy rainfall.

A comparison of the values of the corrosive velocities obtained from the one-year and half-year measurements is shown in charts 2 and 3.

Chart 1 Corrosion velocities obtained in the first to sixth 60-day cycles.

Chart 2 Comparison of the corrosion velocities obtained in the individual trials between the 30th and 60th days of the cycle, the 30th and 180th days of the cycle, and the 30th and 365th days of the cycle with the standard equipment.

The charts indicate that the corrosion rates in the longer half-year trial were considerably lower than those in the short standardized 30-day and 60-day trials. The rates are slightly above the lower limit of the second level of the water's corrosive effect.

The amount of the sediment is also evaluated for each test sample. Chart 4 shows the corrosion losses and the amount of sediment measured during the five 60-day trials. When comparing the amount

Chart 3 Comparison of the corrosion velocities obtained in the individual trials between the 30th and 60th days of the cycle, the 30th and 180th days of the cycle, and the 30th and 365th days of the cycle with the equipment with the Scalebuster.

Chart 4 Comparison of the amount of sediments and corrosion declines obtained using standard equipment during the 30-day and 60-day trials.

of sediment [g/sample] and corrosion losses [g/sample], it can be stated that the corrosion losses and thus the corrosion also increased with the amount of the sediments. The correlation between the sediments and corrosion losses can be more precisely assessed after further tests.

4. CONCLUSION

The results obtained from the one-year monitoring of the water aggressiveness at the Pernek water resource show a decrease in the corrosion velocities during the longer-term trials (30-day up to 365-day trials) in comparison with the standard tests (30-day up to 60-day trials). With the standardized tests made using standard equipment the corrosion velocities ranged from 83 to 218 $\mu\text{m}\cdot\text{year}^{-1}$, which correspond to the second and third levels of the corrosive effects. Anticorrosion protective agents should seriously be considered, the longer-term corrosion tests showed that the corrosion velocities significantly decreased and were between the 1st and 2nd levels of the corrosive effect. The average corrosion velocity during the half-year measurements attained only 54.3% of the corrosion velocity determined according to the standard; during the one-year measurements, the corrosion velocity decreased to 48.4%.

In the equipment with the Scalebuster higher corrosion losses and velocities were recorded in the second, fourth and fifth 30-60 day trials than when using standard equipment. During the short-term trials (the 30-day up to 60-day trials) the corrosion rates were in a range from 74 to 223 $\mu\text{m}\cdot\text{year}^{-1}$ (corresponds to the second and third levels of the corrosive effect). The corrosion rates significantly decreased during the long-term trials as well as in the standard equipment, (in the half-year trials they obtained only 43% and in the one-year trials they obtained only 39.5% from the value specified in the standard for short-term trials (30-day up to 60-day trials). The second level of corrosive effects can be assigned to the water (to its lower half) according to the results of the one-year trials.

On the basis of these results it can be asserted that short-term trials (30-day up to 60-day trials) can overestimate the aggressiveness of water. In the event that the water in the standard test shows stronger aggressive effects, it is suitable to perform long-term trials so that these effects can be checked and confirmed or modified.

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