

DOI: <https://doi.org/10.5281/zenodo.10897163>

INFLUENCE OF SOLUTION ENVIRONMENT pH ON CORROSION OF CARBON STEEL IN GROUNDWATER

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ABSTRACT

In this article, the influence of solution pH environment on the corrosion of carbon steel in groundwater and favorable environmental conditions for protecting steel from corrosion are studied.

Key words: *groundwater, distilled water, corrosion, corrosion rate, carbon steel, pH of solution, flat corrosion.*

INTRODUCTION

Today, many industrial enterprises operating in our country uses groundwater in the water supply system of the workshop for the production. Due to the high carbonate hardness of groundwater (10-12 mg eq/l), salts are accumulated in carbon steel equipment in the water vaporization system, and rapid corrosion of equipment occurs under the influence of various aggressive ions and oxygen in the water. As the equipment becomes clogged and corroded, the steel pipes need to be cleaned and replaced with new ones. This, in turn, causes significant economic losses to enterprises due to the fact that the shops have been shut down for some time and replaced with new ones. Therefore, it is important to find a means of removing salt deposits (sediments) from the equipment, and to determine measures to protect steel products from corrosion.

LITERATURE ANALYSIS AND METHODOLOGY

Foreign scientists - R.Allan Freeze, John A.Cherry in their books called Groundwater gave very useful information about groundwater and various physical and chemical processes that take place in it. The selection and use of effective corrosion inhibitors in natural waters and corrosion inhibitors are described in the scientific works of scientists such as Umoren S.A, Li Y, Wang, Ambrish Singh, Monticelli C, Frignani A, Trabanelli, Sukhotin A.M, Kartasheva K.M. These scientific researches have a great theoretical and practical importance.

For carrying out the research, we used mass and comparing method. Groundwater with high hardness (10–12 mg eq / l) was used as the working solution. The pH of the water was determined using a universal ionomer. Steel.3 s was used to conduct corrosion studies. Corrosion studies were carried out on the basis of general specific methods of stationary (quiet) and natural aeration during the movement of the solution (in the presence of oxygen and in the absence of oxygen in the air).

RESULTS

Initially, the surface of 50x20x2 mm carbon steel (St.3) samples was cleaned to a glass gloss and degreased in acetone on special sandpaper abrasives, then the initial masses were weighed on a VLR-200 analytical balance, and the sides of the steel samples were measured by barbell.

Distilled water with different pH values was used as the control solution. Solutions based on groundwater were prepared and poured into beakers with a volume of 200 ml. Different values of pH in the working solutions (pH = 3:12) were obtained using hydrochloric acid and caustic soda solutions.

Carbon steel (St.3) samples with 3 net masses were then dropped into each solution and monitored for 110 days. The pH value was measured using a universal ionomer EV-74.

The results of the experiment are presented in Table 1.

The table shows that in comparison with distilled water, the samples of carbon steel (St.3) immersed in a natural aqueous solution corroded rapidly, and the samples were found to be subject to intensive corrosion erosion ($\rho = 0,25 \text{ g/m}^2 \text{ day}$).

Table 1

Corrosion of carbon steel (St.3) in distilled and groundwater ($t=20\pm 5^\circ\text{C}$; $\omega=0$ cycles; $\tau=110$ days in the presence of atmospheric oxygen)

№	Solution	Solution medium, pH	Sample mass		Lost mass, Δm	ρ , $\text{g/m}^2\text{day}$	Appearance of the sample surface
			Until the experience m_1	After the experience m_2			
1	H ₂ O (dist.)	7,0	15,0247	14,6150	0,409 7	0,04	A flat corrosion occurred on the surface of the steel sample
2	Ground water	7,0	11,5149	8,7190	2,795 9	0,25	There is a flat corrosion on the surface

In distilled water corrosion occurs more slowly than in groundwater, and the sample surface is much better preserved. The value of the corrosion rate is $0,05 \text{ g/m}^2\text{day}$.

Subsequent experiments studied the corrosion process of carbon steel (St.3) samples at different values of pH (Table 2).

The table shows that the mass loss of carbon steel (St.3) samples in pH less than 7 in natural aqueous solution in relation to distilled water has large values, the high corrosion rate is almost the same at different values of pH (except pH = 8).) were determined in experiments. That is, a change in the pH values has a significant effect on the corrosion process of steel in natural water, and the corrosion rate is partially reduced.

In the aqueous solution of groundwater, a sharp decrease in the rate of corrosion was observed with increasing pH of the solution medium. A sharp decrease in the corrosion rate at pH = 8 (0.0005 g/m² day) was detected.

The results of the experiments were proved to be correct by comparing the surface of the carbon steel (St.3) samples before the test and after removing the working surface from the working solutions and cleaning the sample surface from corrosion products by special methods (Figures 1.1).

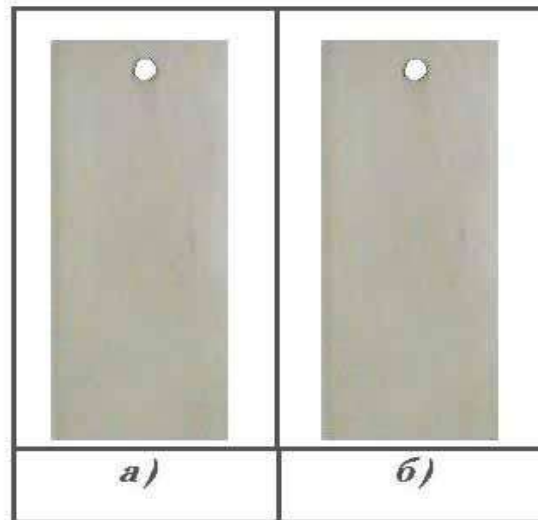


Figure 1.1 The surface condition of the carbon steel (St.3) samples before the experiment: a- distilled water; b-groundwater.

Figure 1.2 Diagram of corrosion rates of carbon steel (St.3).

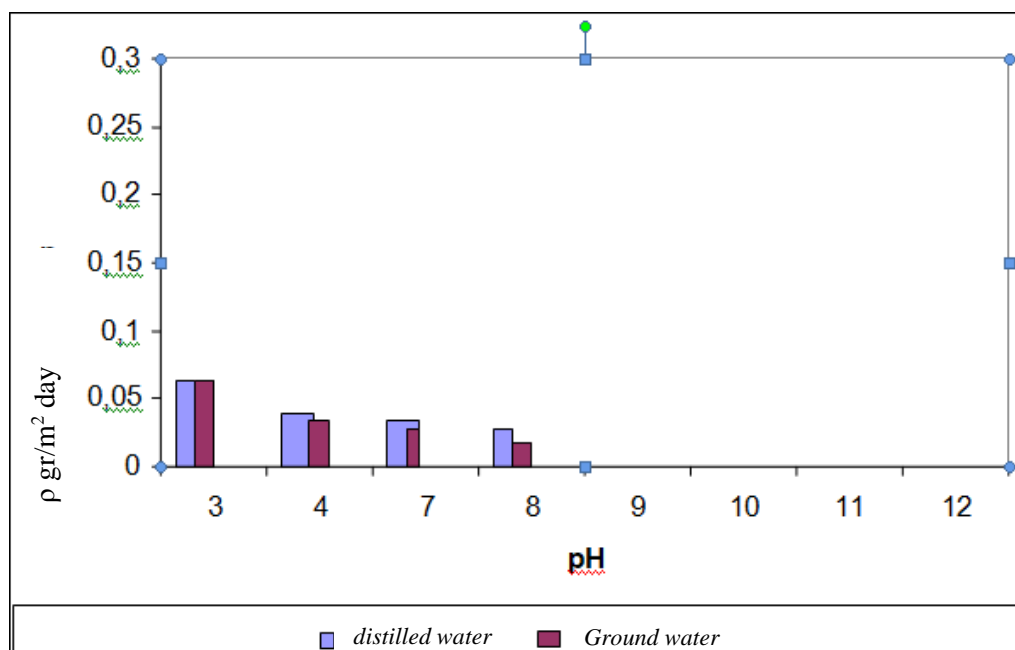


Table 2

Influence of solution pH on the corrosion of carbon steel St.3 ($t=20\pm 5^{\circ}\text{C}$; $\omega=0$ round/min; $\tau=110$ days in the presence of atmospheric oxygen)

№	Solution	Solution medium pH	Sample mass		Lost mass, Δm	ρ , $\text{g/m}^2\cdot\text{day}$	Surface appearance of carbon steel (St.3) samples
			Until the experience m_1	After the experience m_2			
1	2	3	4	5	6	7	8
1	H ₂ O (dist.)	3,0	14,200	14,000	0,200	0,021	Partially corroded
2	Groundwater	3,0	11,600	10,000	1,600	0,173	Corroded, the edges were eroded.
3	H ₂ O (dist.)	4,0	15,300	15,100	0,200	0,02	Partially corroded
4	Groundwater	4,0	13,300	11,680	1,620	0,172	Corroded, the edges were eroded.
5	H ₂ O (dist.)	7,0	15,02470	14,8247	0,200	0,019	Partially corroded
6	Groundwater	7,0	13,200	11,600	1,600	0,16	Corroded, the edges were eroded.
7	H ₂ O (dist.)	8,0	14,100	13,000	0.100	0,008	Partially corroded
8	Groundwater	8,0	12,900	12,280	0,620	0,005	Less corroded
9	H ₂ O (dist.)	9,0	16,100	15,900	0,200	0,016	Partially corroded
10	Groundwater	9,0	9,600	8,960	0,640	0,005	less corroded, eroded,
11	H ₂ O (dist.)	10,0	14,000	13,900	0,100	0,013	Partially corroded
12	Groundwater	10,0	13,600	12,88	0,720	0,059	Partially corroded, eroded, no stains on the surface
13	H ₂ O (dist.)	11,0	16,300	16,100	0,200	0,001	No corrosion
14	Groundwater	11,0	13,200	12,300	0,900	0,034	Intensively corroded, eroded and carved
15	H ₂ O (dist.)	12,0	12,700	12,520	0,180	0,004	Partially corroded
16	Groundwater	12,0	15,900	15,800	0,980	0,028	Intensively corroded, eroded and carved

DISCUSSION

The pH of a solution is an important factor in the corrosion resistance of materials because hydrogen ions can interact and modify the surface and therefore alter the corrosion resistance of a material. Perfectly pure metals with a uniform surface are also

susceptible to corrosion. Since the nature of the electrolyte is one of the factors that determine the potential of the metal, the influence of the medium on the course of the corrosion process can be very strong. The corrosion rate depends on the concentration and chemical nature of the salts. This influence is different.

For typical steel/iron/cast iron, when the pH is less than about 4, protective oxide films tend to dissolve and corrosion rates increase. When the pH is between about 4 and 10, soil corrosion is independent of pH. When the pH is greater than 10, the metal becomes passive and corrosion rates decrease with increasing pH. In neutral media and oxidant solutions, an increase in the carbon content in the metal has practically no significant effect on the corrosion rate, which occurs in most cases with oxygen depolarization, in which the access of oxygen to the metal surface plays a decisive role. In addition, insoluble corrosion products with protective properties are formed on the metal surface. However, electrolytic iron (0.01% C) and Armco iron (0.02-0.03% C) still have increased resistance compared to conventional carbon steel. All common iron-based materials of construction, such as mild steels, low alloy steels and wrought iron, corrode at almost the same rate in natural aqueous environments when fully immersed. Wrought iron has a slightly higher resistance than mild steel when tested in seawater in Gosport (Scotland), the weight loss of wrought iron specimens after immersion for 1 year was 15% less than that of conventional mild steel. As discussed above in relation to the effect of pH, the rate of corrosion of iron or steel in natural waters is controlled by the diffusion of oxygen to the metal surface. From this it follows that whether it is Bessemer or open-hearth steel, wrought iron or cast iron, all of them in their corrosive properties in natural (but not in sea) water differ little or not at all from one another. The same is true for corrosion in various soils due to the fact that the factors that determine the rate of soil corrosion are the same as those at full immersion in water. Therefore, for these environments, as a rule, the least expensive steel should be used.

As mentioned above, in neutral media, corrosion occurs mainly with oxygen depolarization. The degree of influence of neutral salt solutions on the corrosion rate depends on the properties of the formed corrosion products. Sparingly soluble compounds shield the metal surface, as a result of which the corrosion rate decreases. Iron carbonates slow down the corrosion of iron.

In high-temperature aqueous media on iron and its alloys, a characteristic two-layer oxide film is formed, consisting in deoxygenated solutions, of magnetite Fe_3O_4 . The outer layer consists of loosely packed crystals 1 μm in diameter, the inner protective layer consists of close-packed crystallites 0.05-2 μm in diameter, which are firmly bonded to the metal substrate. However, in solutions with very high or very low

pH values, the protective magnetite layer dissolves or loses, as a result of which the corrosion rate increases. The effect of dissolved oxygen is more complex.

Oxygen dissolved in the medium can have a double effect on the metal corrosion process. If oxygen plays the role of a depolarizer, as, for example, during corrosion in neutral and alkaline media, then it enhances the destruction process, and in pure distilled water (in the absence of depassivators) oxygen, especially at elevated temperatures, can lead to the formation of an oxide film on the metal surface and thereby inhibit corrosion processes. The effect of oxygen concentration in water on the corrosion rate is complex. At first, with an increase in the oxygen concentration to about 12 ml / L, the corrosion rate of low-carbon steel in distilled water increases, and with a further increase in the concentration, it sharply decreases. In the presence of dissolved salts in water (for example, groundwater), the oxygen concentration corresponding to the maximum corrosion rate shifts towards higher values, and decreases in alkaline solutions. The decrease in the rate of corrosion of iron at high oxygen concentrations is explained by the fact that there is more oxygen at the cathode than is necessary for the assimilation of electrons. Excess oxygen, being adsorbed at the cathode sites, leads to the formation of an adsorption layer or a layer of oxides that act as a diffusion barrier. Water and aqueous solutions of salts and acids also increase the rate of development of fatigue cracks in iron-based alloys.

The external environment affects the nature of the resulting corrosion products. If they are difficult to dissolve and reliably shield the metal, completely covering its surface, then the corrosion rate will become practically insignificant. Iron in alkaline solutions also corrodes slowly because OH ions in the solution help to strengthen the protective film of iron hydroxide. But even in those cases when no insoluble products are formed, the influence of the external environment on corrosion is very great.

CONCLUSION

The results of research on the corrosion process of carbon steel in natural water revealed the following:

1. In groundwater, carbon steel samples corrode rapidly at all values of pH less than 7 ($\text{pH} = 3\div 5$).
2. Carbon steel samples in groundwater are subjected to a uniform corrosion and the samples do not become unusable as a result of corrosion.
3. The process of corrosion of carbon steel in groundwater is very dangerous at low values of pH, there are cases of abrasion and abrasion of the edges of the samples. When the pH value is 6-7.5, a flat corrosion occurs on the surface of the samples.
4. To protect carbon steel in groundwater from corrosion, it is advisable to keep the pH of the solution medium at 7.5-8 and use sodium benzoate as an inhibitor.

By in large, the corrosion rate of carbon steel decreases with increasing pH value toward the alkaline end while increases with increasing AC current density. When the solution pH becomes alkaline, say passivation occurs on carbon steel surfaces, with an enlarging passive region as pH increases.

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