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Linear Polarization Study of the Corrosion of Iron in the Presence of *Thiobacillus ferrooxidans* Bacteria

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An electrochemical investigation was conducted to evaluate the corrosion behavior of iron in deionized water (DIW) and medium salt in the pH range of 1 to 4. The times of immersion of the electrode in solutions were changed in the range of 0 to 120 hours. Corrosion currents were determined using the linear polarization technique. Tafel slopes, b_a and b_c were also determined by Tafel polarization measurements. The effect of *Thiobacillus ferrooxidans* on the iron corrosion behavior was noticed in both solutions at pH=1. However, a significant difference between DIW and medium salt existed. While in DIW the corrosion increased continuously with time (after first 24 hours) in medium salt it started to increase after five hours, showing the loss of inhibition properties of a protective layer. The increase in current in the presence of bacteria at pH of 1 was noticed: from 205 nA to 320 nA, and from 175 nA to 400 nA, for DIW and medium salt, respectively.

Keywords: Linear polarization method, iron, *Thiobacillus ferrooxidans*, pure water, medium salt, inhibition effect.

1. INTRODUCTION

Microbiologically influenced corrosion, MIC is undoubtedly a phenomenon of great importance. The aerobic corrosion of iron induced by the sulfide and iron-oxidizing bacteria is of particular interest, both economically and scientifically. The way in which these bacteria influence aerobic corrosion of iron is, however, still a subject of some controversy. This may be due to distinctly different mechanisms associated with different types of bacteria or environmental conditions (concentration of ions, metal impurities, synthetic or natural solutions, pH, ionic strength, *etc.*).

Thiobacilli (*Thiobacillus ferrooxidans*) are best known as sulfur and iron oxidizers.This bacterium capable of obtaining energy from iron was first identified by Colmer and Hinckle in 1947

[1]. Reduced iron ions (Fe^{2+}) can be a source of energy for the *Thiobacillus ferrooxidans* bacterium. The capacity to oxidize iron and requirement for large quantities of ferrous ions make iron-oxidizing bacteria of particular interest in the study of MIC phenomena. The corrosion effect of *Thiobacillus ferrooxidans* most often appears in environments characterized by low pH. Examples of this type of corrosion are those involving acid drainage or acid soils.

Despite extensive bioleaching studies [2-8] conducted on minerals using *Thiobacillus ferrooxidans* bacteria, corrosion of metals (in particular iron) influenced by the presence of these bacteria has been investigated to a very limited degree [9-11]. In addition, there is a disagreement in a view of effect of *Thiobacillus ferrooxidans* on corrosion of ferrous metals [12].

For instance, W.K Choi observed the acceleration effect of *Thiobacillus ferrooxidans* on the corrosion of different steels (AISI types: 304, 316, and 416), immersed in nutrient 9K solution without added ferrous ions [13]. This effect was explained by the oxidation of elemental sulfur to sulfuric acid due to bacterial activity, since the highest corrosion rate was noticed for the sample with the highest sulfur content (416 SS, 0.32%S). Sulfuric acid has been identified as an important factor in the MIC of steel and concrete structures by other authors as well [12]. The prerequisite for this scenario is the existence of an iron sulfide (pyrite, FeS_2, for example) to form soluble ferric sulfate and sulfuric acid by the following chemical reaction:

$$FeS_2 + 15O_2 + 2H_2O \rightarrow 2Fe_2(SO_4)_3 + 2H_2SO_4 \qquad (1)$$

Tributsch *et al.* suggested that in this reaction pathway should be also involved an indirect electrochemical effect, expressed by the reaction [14]:

$$FeS_2 + 8H_2O - 15e \rightarrow Fe^{3+} + 2SO_4^{2-} + 16H^+ \qquad (2)$$

Another studied corrosion effect of *Thiobacillus ferrooxidans* bacterium is that influenced by its acceleration of the oxidation of ferrous to ferric ion in the presence of oxygen. For instance, in the study performed by B.J. Little and P.A. Wagner, the autotrophic iron-oxidizing bacteria were exposed to a stainless steel electrode both in the presence and absence of ferrous ions in solution and the resulting corrosion currents were measured [15]. Without added ferrous ions, these authors could not notice any corrosion of stainless steel as a result of bacterial activity. Also, it was shown that the specimen (carbon steel or nickel) immersed in the cell inoculated with iron-oxidizing bacteria becomes the anode of the galvanic couple, indicating that an oxidation reaction is controlling step in the overall corrosion process.

On the basis of the knowledge exposed above, which does not claim to include all possible mechanisms of bacterial corrosion of ferrous metals, electrochemical experiments with iron exposed to microbiologically activity were performed. A linear polarization method was applied to obtain the data about general corrosion of iron immersed in deionized water (DIW) and medium salt.

2. EXPERIMENTAL

2.1. Method

Electrochemical methods have been shown to be very useful for MIC studies in laboratory investigations and for monitoring purposes in field studies. One of the electrochemical techniques that has been applied to MIC studies is the "linear polarization method" or "linear resistance method." Applications of the linear polarization technique in MIC studies have been reported by several authors [11, 16-18].

As with all studies of corrosion phenomena more detailed and reliable information can be obtained when a number of different electrochemical techniques are combined. In this iron corrosion study, the combination of Tafel and linear polarizations is used. Tafel measurements were performed in order to determine the Tafel constant, b_a and b_c.

2.2. Material

Electrochemical experiments were conducted on specimens of an iron wire (analytical reagent, produced by the "Mallinckrodt Chemical Works"). Its chemical composition (wt.%) is as follows: Fe, 99.9; C, 0.010; Mn, 0.022; P, 0.0032; Si, 0.0028; and S, 0.0085. The wire was cut into 8 mm lengths, sealed in a plexi-glass, and put into a specially prepared holder.

2.3. Corrosion Measurements and Instruments

Polarization measurements were conducted potentiodynamically using an Princeton Applied Research (PAR) Model 283 potentiostat/galvanostat driven by the application software program (SoftCorr^{TM} III). Tafel polarization measurements were carried out at a sweep rate of 0.2 mV/s in the potential range of –250 mV to +250 mV in regard to the open circuit potential (OCP). Linear polarization measurements were conducted at a sweep rate of 0.166 mV/s in the potential range from –20 mV below the OPC to 20 mV above. Samples with an exposed surface area of 0.001 cm^2, determined using the optical microscope, were wet ground with 800-grit emery paper, alumina (0.3 μm), and washed in doubly distilled water prior to polarization. A saturated calomel electrode (SCE) was used as the reference electrode, and a platinum electrode was used as the counter electrode. All potentials were referred to the SCE.

2.4. Electrolytes

Deionized water (DIW) and medium salt solutions were used. The electrolytes were adjusted to desired pH values (1.0, 2.0, 3.0, or 4.0) with sulfuric acid and sodium hydroxide. Analytical grade salts were used for nutrient medium solution preparation (Table I). All solutions and glassware were autoclaved (20 minutes, t=125 ^{o}C).

Table I. Growth media for *T. forrooxidans* (g/L), pH=2.0.

$(NH_4)_2SO_4$	0.15	K_2HPO_4	0.15
KCl	0.15	$MgSO_4 \cdot 7H_2O$	3.36
$CaCl_2$	0.97	$Al_2(SO_4)_3 \cdot 18H_2O$	2.25
$MnSO_4$	0.12	$(NH_4)_6Mo_7 \cdot 4H_2O$ (From 1 g/L stock solution)	2.5 µL

2.5. Bacteria

The strain of *Thiobacillus ferrooxidans* used was ATCC 13598. Bacteria were maintained in 250 ml of this medium in 500 ml Erlenmeyer shaker flasks. To the flasks containing nutrient medium 10 ml of stock bacteria was added, and then 10 ml of ferrous sulfate stock (37.5 g/100 ml) was added as the energy source. The flasks were incubated at 25 ^{o}C and 250 rpm in a lab-line incubator shaker.

After five days of growing time, the bacteria were harvested according to the procedure given elsewhere [19]. The culture suspension was filtered through a 0.1 µm membrane filter and washed twice with acidified water (pH = 2.0) to remove the remaining iron salts. Finally, the bacteria were centrifuged at 4,000 rpm for 10 min and the growth media was decanted.

3. RESULTS

The final quantity of cells, determined using the optical method, was about 0.33 mg/ml total dry weight, or 1.9×10^8 cells/ml. Experiments were performed with a half milliliter of concentrated bacteria added to the electrolyte (175 ml). Parallel bacteria-free control experiments were conducted for the purpose of determining whether there were any surface changes due to bacterial activity, and aerobic conditions were maintained during the whole investigation. The same kind of experiments was also carried out in a deionized water (DIW).

3.1. General Polarization Behavior

Figure 1 shows a typical Tafel polarization curve obtained for iron recorded after 48 hours of immersion in medium salt containing bacteria at pH of 2.0. Similar curves were obtained in all investigated solutions at various pH values and conditioning times. These curves had in common that the Tafel slopes were changed in the range of 40 to 80 mV and 120 to 160 mV (or even more) for the anodic and cathodic process, respectively. Thus, the value of the B constant of 50 mV (assuming that $b_a = b_c = 100$ mV), in the Stern-Geary equation:

$$I_{corr} = (1 / 2.303R_p)(b_a b_c / b_a + b_c) = (1 / 2.303R_p)\ B \qquad (3)$$

that was used in a computer program for the calculation I_{corr} was closed to the experimentally determined values for b_a and b_c

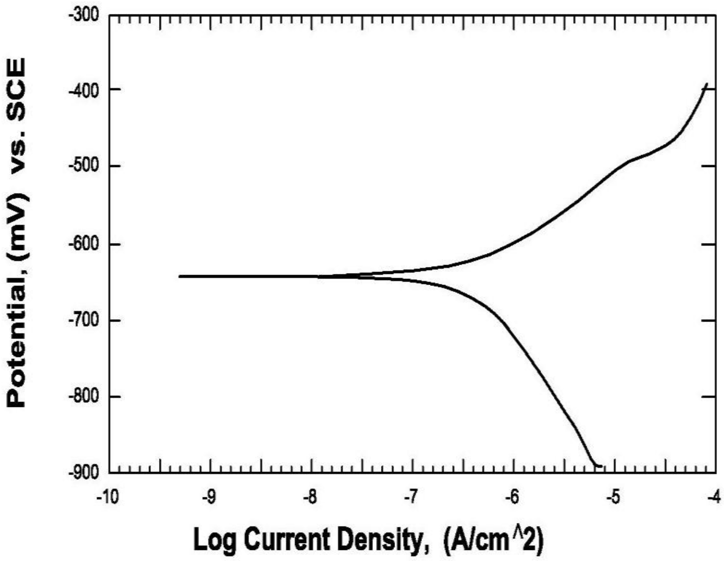

Figure 1. A typical experimental Tafel polarization curve for iron electrode recorded after 48 hours of immersion in medium salt containing bacteria at pH of 2.0

3.2. Corrosion Measurements in Deionized Water (DIW)

A set of linear polarization measurements was started with the experiments in deionized water (DIW). Simultaneously, these experiments provided relationships E_{corr} vs. Time. The effect of pH, in the range of 0 to 4, and conditioning (immersion or waiting) time, in the range of 0 to 48 hours were investigated. A typical linear polarization curve is shown in Figure 2.

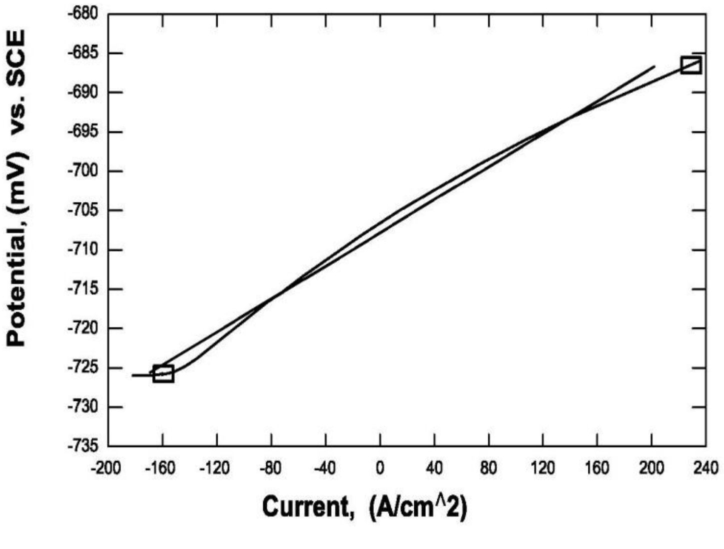

Figure 2. A typical experimental linear polarization curve for iron electrode recorded after 1 hour of immersion in DIW at pH of 2.0

Variations of polarization resistance, R_p, (kOhms-cm^2) of iron with immersion time in the investigated pH range are presented in Figure 3. R_p values for iron in DIW at pH of 4 show a sharp decrease (starting from nearly 400 kOhms-cm^2) between 24 and 72 hours, reaching a stationary value (slightly below 100 kOhms-cm^2) after 96 hours. R_p values for iron in DIW at pH of 2 and 3 display a similar trend in that they change with immersion time within the narrow range of R_p (80 kOhms-cm^2), reaching a stationary value around 100 kOhms-cm^2. At the lowest pH value of 1, these times and resistances become less pronounced, and, a stationary value of R_p have been already reached after 24 hours. This is in agreement with findings reported in other works. For instance, it was shown by Frangini that R_p for iron in the 0.5 M sulfuric acid solution decreased from approx. 48 to 26 Ohms-cm^2 within one hour [20].

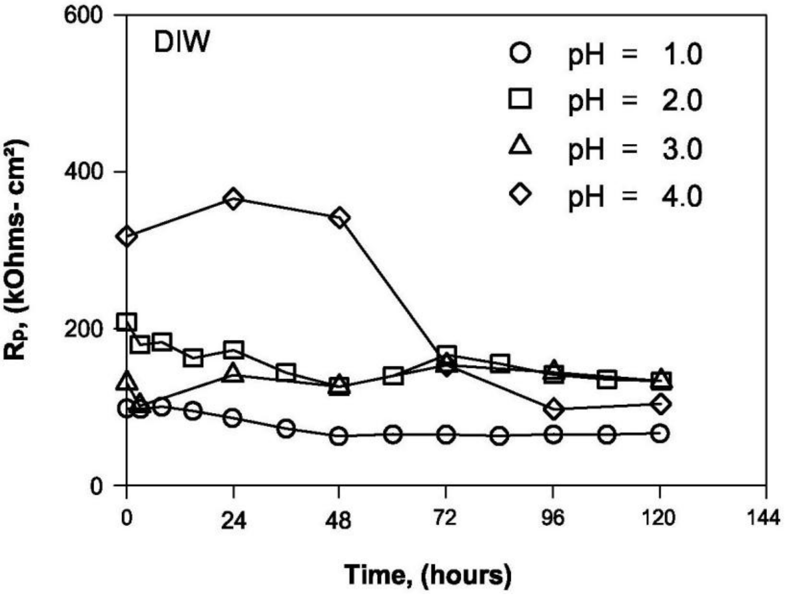

Figure 3. pH and conditioning time effects on polarization resistance, R_p, for iron in DIW

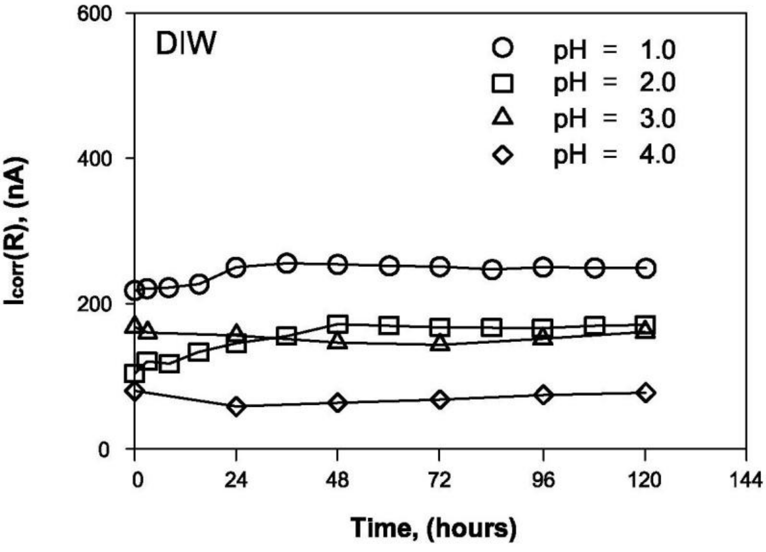

Figure 4. pH and conditioning time effects on corrosion current, I_{corr} (R), for iron in DIW

The following graph (Figure 4) illustrates changes of corrosion current with time. As it could be expected, the corrosion rate of iron in DIW at pH=1 is significantly higher than those at higher pH values. The current increases with time noticeably at pH=1, reaching a maximum after 24 hours. On the other hand, at higher pHs, the corrosion current of iron stays more or less constant after 48 hours. The relationships E_{corr} vs. Time are presented in Figure 5. They reveal that the stationary condition is more difficult to attain in solution at pH of 3 and 4 due to potential fluctuations.

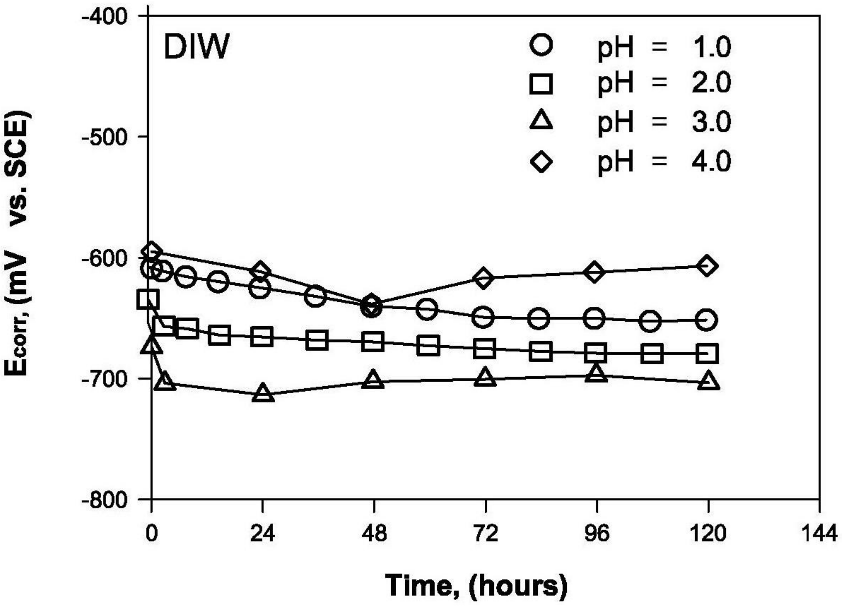

Figure 5. pH and conditioning time effects on corrosion potential, $E_{corr.}$, for iron in DIW

3.3. Measurements in DIW Containing Thiobacillus ferrooxidans Bacteria

Variations of polarization resistance, R_p, of iron immersed in deionized water containing *Thiobacillus ferrooxidans* bacteria with time at different pHs are given in Figure 6. These curves show somewhat different trend compared to those given in Figure 3. First of all, at pH of 1 and 2, a stationary condition could not be achieved at all. Second, a stationary condition at pH of 1 is attained in significantly longer time, *i.e.*, after 72 hours of immersion.

Figure 7 illustrates changes of corrosion current with time for this biotic system. The most important changes at pH of 1 and 2 are the initial decrease in current within the first 6 – 10 hours of immersion and the subsequent increase in current up to 72 hours. After this initial period, the current reaches a relatively stable value. This is the main difference compared to the abiotic system (Figure 4). For instance, the corrosion current in the presence of *Thiobacillus ferrooxidans* bacteria after 72 hours and at pH of 1 is significantly higher than that in DIW (320 nA vs. 210 nA). The initial increase of the iron dissolution rate can be attributed to the bacterial activity, *i.e.*, acceleration of the oxidation reaction: $Fe^{2+} \rightarrow Fe^{3+} + e$.

The relationships E_{corr} vs. Time for iron in DIW containing bacteria are presented in Figure 8. The general trend of these curves is similar to that noticed in Figure 5. Here again, the corrosion potentials at pHs of 3 and 4 are moved significantly (approx. 200 mV) to more negative direction. Clearly, when iron is immersed in the DIW, independently on the presence of bacteria, a quite different electrochemical behavior appears at lower pH range (up to 2) and higher pH range (between 3 and 4).

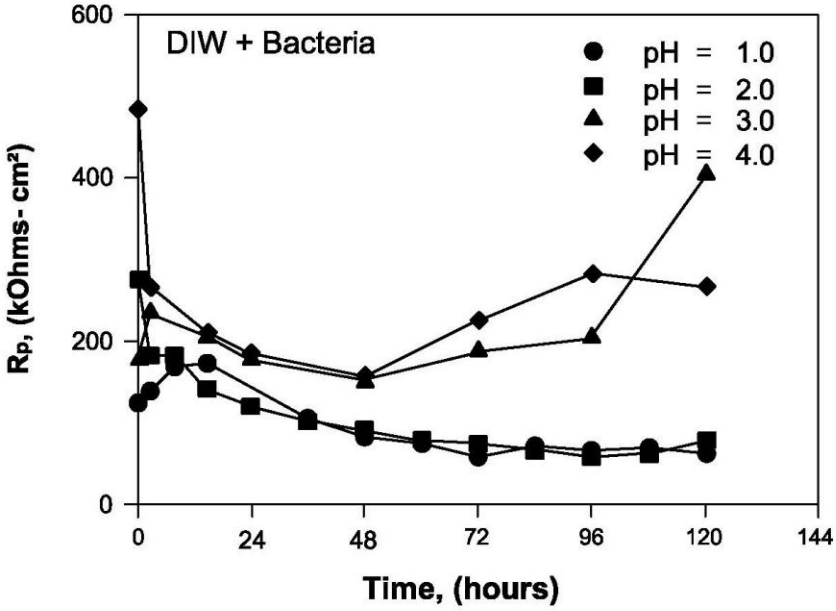

Figure 6. pH and conditioning time effects on polarization resistance, R_p, for iron in DIW containing *Thiobacillus ferrooxidans* bacteria

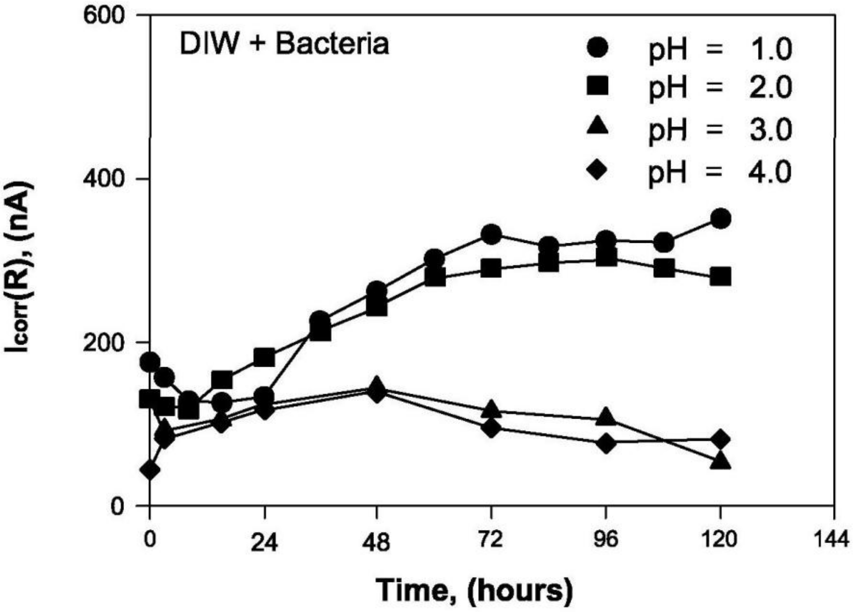

Figure 7. pH and conditioning time effects on corrosion current, I_{corr} (R), for iron in DIW containing *Thiobacillus ferrooxidans* bacteria

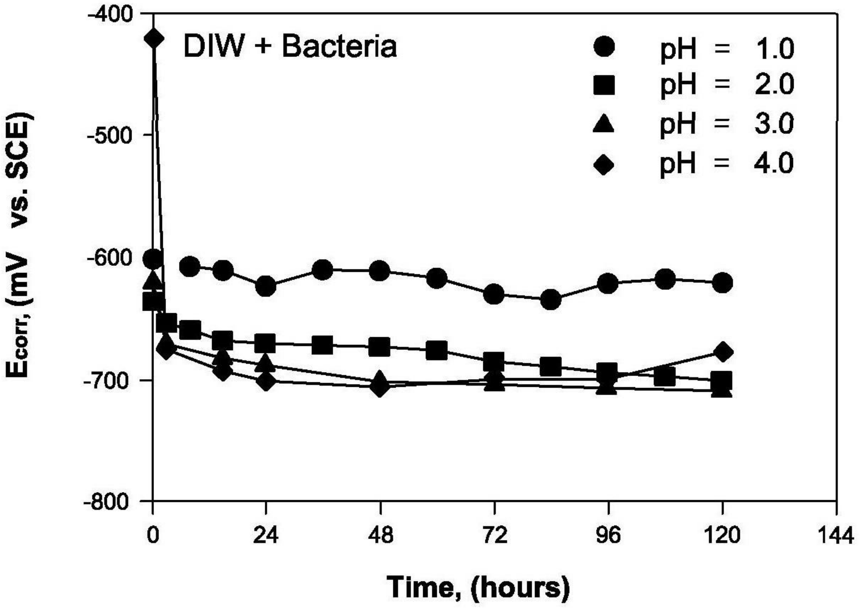

Figure 8. pH and conditioning time effects on corrosion potential, $E_{corr.}$, for iron in DIW containing *Thiobacillus ferrooxidans* bacteria

3.4 Measurements in Medium Salt

Variations of polarization resistance, R_p, with time for iron immersed in medium salt are presented in Figure 9.

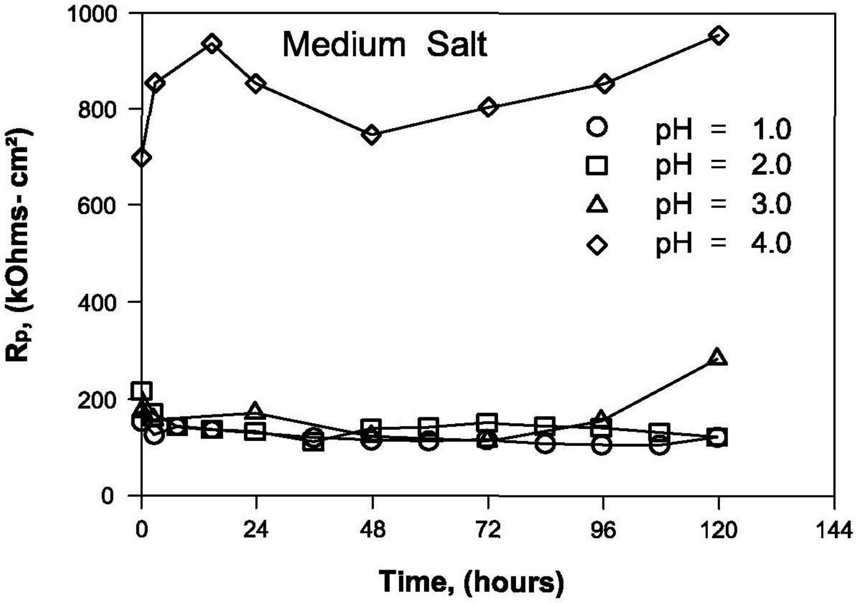

Figure 9. pH and conditioning time effects on polarization resistance, R_p, for iron in medium salt

Rp - Time curves for iron at pH values of 1, 2, and 3 display a similar trend. Resistances are almost constant during the whole time of immersion (120 hours). Also, compared to the pure DIW

(Figure 3), corresponding resistances at pH values of 1, 2 and 4 are slightly lower. The presence of different ions in medium salt (components are given in Table 2) may cause the decrease in resistance of the electrolyte. On the other hand, fluctuations in R_p at pH of 4 are more pronounced, what was quite different than in the pure DIW.

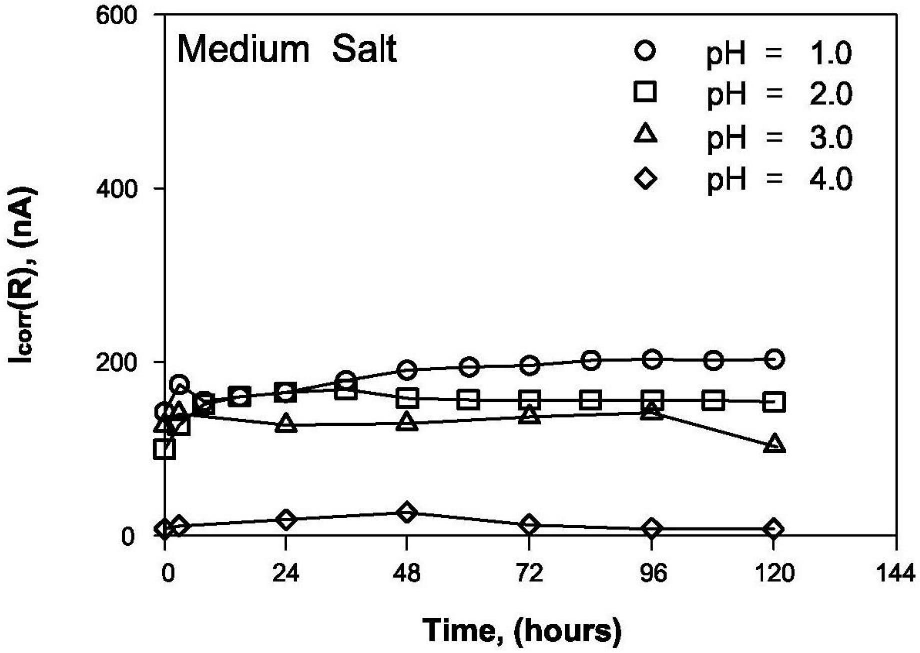

Figure 10. pH and conditioning time effects on corrosion current, I_{corr} (R), for iron in medium salt

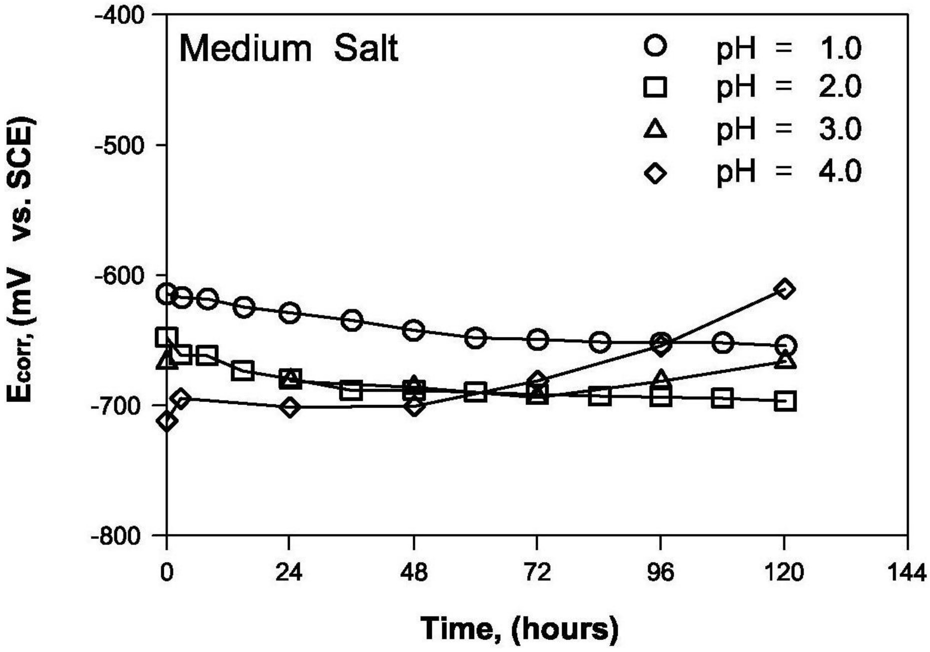

Figure 11. pH and conditioning time effects on corrosion potential, $E_{corr.}$, for iron in medium salt

Figure 10 shows changes of corrosion current with time for iron immersed in medium salt. No increase in corrosion current after 48 hours of immersion can be seen only for iron exposed to the medium. A similar behavior was already observed for iron in DIW.

At last, for this system, relationships E_{corr} vs. Time are given in Figure 11. As can be seen, corrosion potential just kept linear relationship with value of pH in definite time and after 60 hours, the result was thoroughly changed.

3.5. Measurements in Medium Salt Containing Thiobacillus ferrooxidans Bacteria

Figure 12 shows variations of polarization resistance, R_p, with time for iron immersed in medium salt containing *Thiobacillus ferrooxidans* bacteria. When pH was 3, the curve measured was very fluctuating, which was entirely distanct with the situations when pH was 1 2 as well as the instance in Figure 9.

Figure 13 illustrates changes of corrosion current with time for iron immersed in medium salt containing bacteria. As it can be seen, the corrosion rate of iron at pH = 1 decreases slightly with time (up to 5 hours), and, then, sharply increases. A similar initial decrease in corrosion current of iron in the presence *Thiobacillus ferrooxidans* bacteria was noticed in DIW (Figure 7). A possible explanation could be the inhibition action of this type of bacteria in these systems due to the formation of Fe^{3+}-compounds. Yet, Figures 7 and 12 reveal significant difference between DIW and medium salt solutions at pH = 1. While in the DIW the inhibition effect of *Thiobacillus ferrooxidans* bacteria is present during the period (24 hours), in the medium salt it disappears after 5 – 6 hours. This can be explained by the dissolution of the formed insoluble Fe^{3+}-compounds due to activities of various aggressive anions present in the solution (Table I.).

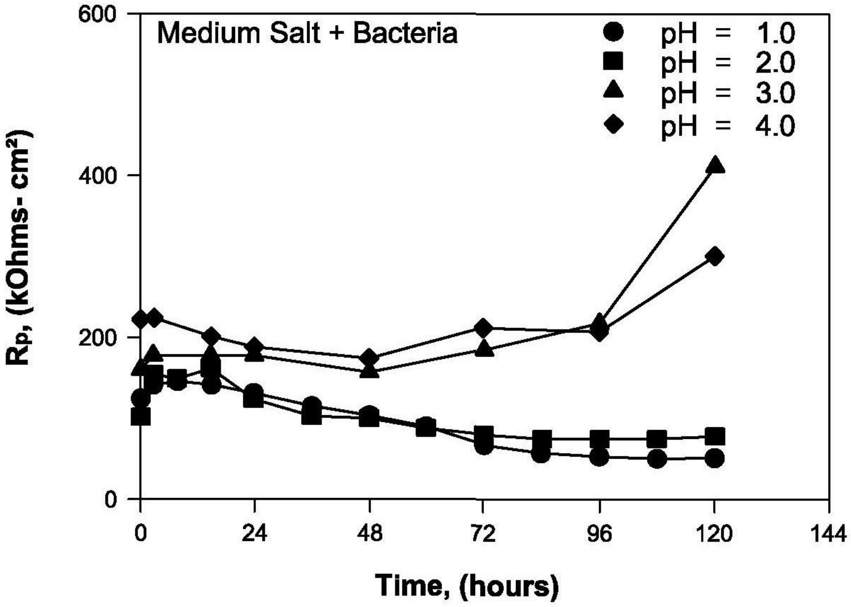

Figure 12. pH and conditioning time effects on polarization resistance, R_p, for iron in medium salt containing *Thiobacillus ferrooxidans* bacteria

Finally, Figure 14 shows curves E_{corr} vs. Time. As can be seen, corrosion potential also moves to a more negative direction as the pH increases. The differential ($\partial E_{corr}/\partial pH$) determined after 48 hours is somewhat lower, *i.e.*, around 45 mV, than that determined in a pure medium salt, *i.e.*, 60 mV.

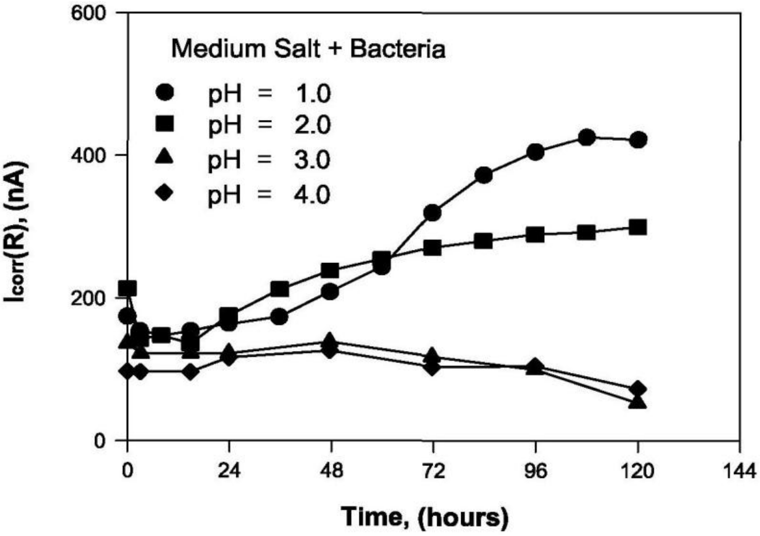

Figure 13. pH and conditioning time effects on corrosion current, I_{corr} (R), for iron in medium salt containing *Thiobacillus ferrooxidans* bacteria

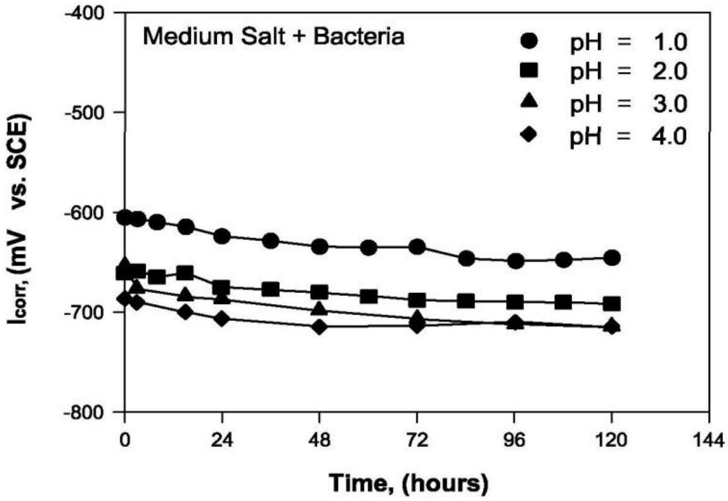

Figure 14. pH and conditioning time effects on corrosion potential, $E_{corr.}$, for iron in medium salt containing *Thiobacillus ferrooxidans* bacteria

4. DISCUSSION

4.1. General Considerations

The Stern-Geary equation, used in this study, is only applicable if both corrosion processes are controlled by charge transfer, *i.e.*, no limiting currents are involved. The Tafel polarization curves like that presented in Fig. 1 were obtained in all experiments. Thus, the linear polarization method, as a non-destructive technique, could be applied. However, practical use of the Stern-Geary equation is tied to a number of difficulties. Some of them will be considered below, especially in the light of microbiologically influenced corrosion.

First of all, there is no linear part of the polarization curve in the vicinity of η=0, when $b_a \neq b_c$. In this case, making a linear approximation is equal to drawing a tangent to the curve at η=0. Therefore, to obtain the proper $d\eta/di$, current should be measured for η<3 mV. However, most commercially used instruments do not satisfy this condition (fluctuations of E_{cor}, electrical noise, etc). In the case of iron, the problem is more expressed. This metal slowly attains the steady-state polarization conditions, especially at higher pH values.

Another problem deals with the need to have Tafel slopes, b_a and b_c for the Stern-Geary equation. The b_a and b_c values obtained by means of Tafel polarization measurements (as it was done in this study) are not necessary in agreement to the Tafel slopes that are operative at the surface at the corrosion potential. The reason is the following; in order to determine b_a experimentally, it is usually necessary to polarize the iron surface anodically for a rather long time (*e.g.*, approx. 20 min, at v = 0.2 mV/s and the final potential is 250 mV vs. the OCP) or with a high electrical charge. This might change the surface properties to a considerable extent. At higher current densities, due to the fast removal of metal atoms from the surface and the slow adsorption of inhibiting species, the surface is virtually free of adsorbed species. The slope of the anodic polarization curve after “cleaning” of the surface is different, and changes from experiment to experiment depending on what was the highest current density. Hence, the real b_a value obtained by the electrochemical dissolution reaction mechanism can be quite different.

When the bacteria are added to the system describe above, the situation becomes quite different. First, the rather large polarizations needed in the Tafel experiments cause not only changes of the electrochemical conditions but also may be deleterious to bacteria in the biofilm [21]. At any scan rate, the large applied potentials often used in the Tafel polarization measurements may disturb the organisms in the biofilm. Second, the proper scan rates are of great importance in MIC studies. Tafel polarization curves in this study were obtained at slow scan rate, v=0.2 mV/s. There is a general agreement that slow scan rates provide maximum stability of the metal surface, but increase the chance for changes in the environment or in biofilms at the potentials furthest from the corrosion potentials [21]. This could be the reason for the absence of significant bacterial effect on the iron corrosion in electrolytes investigated here. Finally, the biological films formed at metal surfaces immersed in natural aqueous electrolytes cause an uncompensated IR drop through the biofilm. This has a significant effect on the shape of polarization curve.

All these problems led a number of authors to propose procedures for estimating corrosion rates with good reliability from low-polarization measurements. A recent use of mathematical, graphical and computer methods has led to the conclusion that the assumption of linearity is sufficient for the technique to be valid in many practical corrosion systems. The presence of biofilms in any MIC scenario changes the situation in that way that introduce the additional electrochemical reactions and adsorption phenomena. This can cause non-linear polarization behavior. Despite these obstacles, the linear polarization method performed at a sufficiently slow polarization scan rate is useful for MIC systems undergoing uniform corrosion.

4.2. Corrosion Rate Behavior

The electrochemical nature of iron corrosion in acidic solutions is well established. The charge balance during oxidation of iron to Fe^{2+}:

$$Fe \rightarrow Fe^{2+} + 2e \qquad (4)$$

is maintained by the following reduction reactions:

- the hydrogen evolution reaction:

$$H^+ + e \rightarrow 1/2H_2 \qquad (5)$$

- the reduction of oxygen:

$$O_2 + 4H^+ + 4e \rightarrow 2H_2O \qquad (6)$$

- the reduction of an oxidant in solution or at the metal surface:

$$Ox + ne \rightarrow Red. \qquad (7)$$

The rates for these reactions are functions of the iron surface and electrolyte composition. Once Fe^{2+} is present in solution, the formation of a number of corrosion products follows. In deriving a mechanistic understanding of iron corrosion, it is important to keep in a mind that iron is initially oxidized to ferrous ion, that the intermediate corrosion products include both Fe^{2+} and Fe^{3+}, and that the final corrosion products include only Fe^{3+}-compounds.

When bacteria are involved in the system described above, corrosion phenomena become more complicated. The microbial involvement may be manifested in a variety of ways. In the case of iron-oxidizing bacteria, (*Thiobacillus ferrooxidans*), bacterial effect on the iron corrosion is manifested via the increasing of the Fe^{2+} oxidation rate (Reaction 4) and oxidation of Fe^{2+} cations to less soluble forms:

$$Fe^{2+} \rightarrow Fe^{3+} + e \qquad (8)$$

As it was shown, the effect of reactions (4) and (8) due to bacterial activity is more pronounced at pH=1. This could be attributed to the Reaction (4) that at lower pH could be occurred in addition to the indirect iron dissolution. Indirect iron dissolution occurs via the suggested mechanisms that involve the OH^- ions [22]:

$$FeOH^{+} + H^{+} \rightarrow Fe^{2+} + H_2O \qquad (9)$$

The formation of $FeOH^{+}$ ion is the rate-determining step. According to Bala, below pH=0.2 the anodic process rate is determined only by the Reaction (4), *i.e.*, OH^{-} ions do not take part [23].

Table II summarizes some characteristic parameters obtained in both electrolytes (DIW and medium salt). It also reveals differences in corrosion activities of bacteria in terms of the type of electrolyte. The corrosion rate of iron in inoculated medium salt was initially high (at time 0) but declined up to 5 hours later; thereafter it rose slightly (Figure 13), almost linearly, with immersion time. The rising in current after 5 hours occur as a consequence of the destroying of a protective layer by the aggressive anions present in this electrolyte, (*e.g.*, chloride ions). In addition, iron-oxidizing bacteria are able to accumulate chlorides and manganese ions, forming acidic ferric chloride and manganic chloride, which are highly corrosive [24].

Table II. Corrosion Currents for Iron in Different Electrolytes (pH=1)

	Pure DIW	**Inoculated DIW**	**Medium Salt**	**Inoculated Medium Salt**
t = 0 h	205 nA	180 nA	150 nA	175 nA
t = 5h	210 nA	160 nA	175 nA	150 nA
t = 24 h	220 nA	120 nA	170 nA	150 nA
t = 96 h	220 nA	320 nA	400 nA	400 nA

On the other hand, microbiological inhibition of corrosion in natural environments occurs through the following three simultaneous ways of action [24]:

- Neutralizing the action of corrosive substances present in the environment.
- Inducing a decrease in the medium corrosiveness.
- Forming protective films or stabilizing a pre-existing protective film on a metal.

Under the experimental conditions performed in this work (synthetic solutions and pure bacterial culture), the third way is of importance for inhibition of iron corrosion in DIW and medium salt (Table II).

The results presented in this study were obtained by using the linear polarization method. It allowed a good insight into general MIC phenomena on iron in the presence of *Thiobacillus ferrooxidans* bacteria in investigated solutions: DIW and medium salt. However, the bacterial activity can affect the anodic-half reaction, the cathodic half-reaction, or both. In the case of *Thiobacillus ferrooxidans*, shifts in the anodic half-reaction should be expected as the significant effect on the corrosion process. For instance, it was shown that the presence of iron oxidizing bacteria on carbon steel or stainless steel in aerated environments can produce a similar increase in corrosion current as ferrous ion is oxidized to the ferric state; a noble shift. Obviously, the other electrochemical techniques should be used in further studies of MIC on iron.

5. CONCLUSIONS

The following conclusions from this study can be drawn:

1. Linear polarization measurements suggest that some degree of inhibition of corrosion of iron by *Thiobacillus ferrooxidans* bacteria appears at pH=1 in both deionized water (DIW) and medium salt during the initial period of dissolution (up to 24 hours). After that, a sufficient increase in corrosion occurs in both deionized water (DIW) and medium salt.
2. In the presence of bacteria, initially dissolved ferrous ions quickly turn into ferric ions increasing the iron dissolution rate. The increase of this reaction is much more pronounced in DIW.
3. The inhibition (retardation) of corrosion occurs as a result of bacterial activity. A large amount of ferric ions transforms in some of Fe^{3+}-compounds. $Fe(OH)_3$ is the most often present protective layer on the iron surface.
4. At higher pH values, the amount of ferrous ions formed by a spontaneous ion dissolution is negligible which causes the absence of any bacterial effect on the iron corrosion.
5. The experimental technique applied to obtain these results may be used as a tool for research of microbiologically influenced corrosion in various environments and conditions. A special caution, however, must be paid to the selection of appropriate electrochemical experimental conditions which differ significantly from those applied for pure metal/electrolyte systems.

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