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Cathodic Protection of Carbon Steel Pipes Affected by Microbial Corrosion in Different Soil Texture

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ABSTRACT

Key Words:
Cathdic protection, steel pipe, microbial corrosion, soil.

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Study had been done at Tikrit University/ College of Science/ Biology Department/ Environment Laboratory, from September/2014 to June/2015 .

This study was done on carbon steel pipes and those pipes with diameter 1.75 inch were cut in to 38 pieces with a length of 20cm with nearly the same weight (The carbon steel pipes and the donor Aluminum had been measured with a balance that is so accurate up to 3 decimal fractions).Soil samples were taken from three different regions which are: Altun Kopry/ Kirkuk (Soil 1, Loamy sand), Tikrit University (Soil 2, Sandy Loam) and Al- Siniya/ Baiji/ Tikrit (Soil 3, Sand) and these three samples were taken from depth 0-50 cm.

The results showed that the highest value of electric conductivity was (28.13 ms/cm) in dry soil 3, while the lowest value was (19.19 ms/cm) in wet soil 3 . As a mean, soil texture has a significant effect on electric conductivity, whereas the highest value of electric conductivity was (23.66 ms/cm) in soil 2, while the lowest value was (20.77 ms/cm) in soil1. The highest value of organic matter was (6.216 %) in dry soil 2, while the lowest value was (2.358 %) in wet soil 3. As a mean, soil texture has a significant effect on organic matter, whereas the highest value of organic matter was (5.706 %) in soil 2, while the lowest value was (2.720 %) in soil 3.

Cathodic protection has a significant effect on decreasing corrosion rate, whereas the corrosion of protected pipe was (1.462 %) while the corrosion of the pipe buried in the same circumstances but without protection was (11.267%).

The presence of *Pseudomonas aeruginosa* bacteria caused corrosion, microbiological analysis showed that biofilm are formed as microcolonies, which subsequently caused corrosion shows the role of *Pseudomonas aeruginosa* , *Enterobacter* sp. ,and *Staphylococcus aureus* bacteria these three types of bacteria oxidize the iron that means it is corrosive.

الحماية الكاثودية لأنابيب الفولاذ الكاربوني بتأثير التآكل المايكروبي المطمورة في ترب مختلفة النسجة

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الخلاصــة

الكلمات المفتاحية :
الحماية الكاثودية ، انابيب الفولاذ الكربوني ، التآكل المايكروبي ، التربة .

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أجريت هذه الدراسة في مختبر البيئة التابع لقسم علوم الحياة في كلية العلوم/جامعة تكريت للفترة، من ايلول 2014 لغاية حزيران 2015على أنابيب الكربون الصلب المستخدم في نقل المنتجات النفطية و المياه . قطعت تلك الأنابيب الى 38 قطعة بطول20سم وبقطر1.75انج و بوزن متساوي . تم أخذ عينات التربة من ثلاث مناطق مختلفة وهي: منطقة التون كوبري /كركوك ذات نسجة رملية مزيجية (التربة رقم 1)، تربة من موقع جامعة تكريت في تكريت ذات نسجة مزيجية رملية (التربة رقم2) و تربة من منطقة الصينية / بيجي ذات النسجة الرملية (تربة رقم 3) وكانت هذه العينات الثلاث مأخوذة من عمق0_50سم.

أظهرت النتائج أن أعلى قيمة للتوصيل الكهربائي كانت (28.13 مللي/ سم) في التربة الجافة رقم 3، في حين كانت أدنى قيمة (19.19 مللي/ سم) في التربة الرطبة رقم3. ان نسجة التربة كان لها تأثير كبير في التوصيل الكهربائي، في حين كانت أعلى قيمة للتوصيل الكهربائي(23.66 مللي سيمنز/ سم) في التربة2، في حين كانت أدنى قيمة (20.77 مللي سيمنز/ سم) في التربة1. أعلى قيمة للمادة

[1] This research is a part of M.Sc.D. thesis for the second Author.

العضوية بلغت (6.216%) في التربة الجافة رقم 2، بينما أقل قيمة بلغت (2.358%) في التربة الرطبة رقم 3. نسجة التربة لها تأثير معنوي في قيمة المادة العضوية حيث بلغت أعلى قيمة (5.706%) في التربة 2 بينما أقل قيمة بلغت (2.720%) في التربة 3.

الحماية الكاثودية لها تأثير معنوي على تقليل نسبة التآكل، حيث بلغ التآكل في انبوب الحماية الكاثودية (1,462 %) بينما بلغ التآكل في الانبوب المطمور بنفس الظروف ولكن من دون حماية (11,267 %). ان وجود الأنواع الثلاثة من بكتريا:

Pseudomonas aeruginosa ,*Enterobacte*r sp. ,and *Staphylococcus aureus*

قد سببت تآكل في الأنابيب و بشكل كبير ، إذ سببت هذه الأنواع تأكسد الحديد الموجود في الأنابيب.

INTRODUCTION:

One general definition of corrosion is the degradation of a material through environmental interaction (Mohitpour *et al.,* 2003). This definition encompasses all materials, both naturally occurring and man-made and includes plastics, ceramics, and metals. This research focuses on the corrosion of metals, with emphasis on corrosion of carbon steels used in underground pipelines.

A significant amount of energy is put into a metal when it is extracted from its ores, placing it in a high-energy state. These ores are typically oxides of the metal such as hematite (Fe_2O_3) for steel or bauxite ($Al_2O_3.H_2O$) for aluminum. One principle of thermodynamics is that a material always seeks the lowest energy state. In other words, most metals are thermodynamically unstable and will tend to seek a lower energy state, which is an oxide or some other compound. The process by which metals convert to the lower-energy oxides is called corrosion (Peabody, 2001).

The change from the metallic to the combined form occurs by an “anodic” reaction:

$M \rightarrow M^{(n+)} + (n)e^{-}$ …….. (1)

A common example is:

$Fe \rightarrow Fe^{++} + 2e^{-}$ …….. (2)

This reaction produces free electrons, which pass within the metal to another site on the metal surface (the cathode), where it is consumed by the cathodic reaction. In acid solutions the cathodic reaction is:

$2H^{+} + 2e^{-} \rightarrow H_2$ …….. (3)

In neutral solutions the cathodic reaction involves the consumption of oxygen dissolved in the solution:

$O_2 + 2H_2O + 4e^{-} \rightarrow 4OH^{-}$…….. (4)

$2Fe + O_2 + 2H_2O \rightarrow 2Fe(OH)_2$ ....(5)

$4Fe(OH)_2 + O_2 \rightarrow 2H_2O + 2Fe_2O_3.H_2O$ ....(6)

(brown rust)

The oxidation reaction is commonly called the anodic reaction and the reduction reaction is called the cathodic reaction (Bardal, 2003; Nimmo and Hinds, 2003). Both electrochemical reactions are necessary for corrosion to occur. The oxidation reaction causes the actual metal loss but the reduction reaction must be present to consume the electrons liberated by the oxidation reaction, maintaining charge neutrality. Otherwise, a large negative charge would rapidly develop between the metal and the electrolyte and the corrosion process would cease (Peabody, 2001).

Carbon steel has been widely employed as a construction material for pipe work in the oil and gas production such as down hole tubular, flow lines and transmission pipelines (Rozenfeld, 1981).At Al-Dura refinery the pipes used for water transmission in cooling towers are also made of low carbon steel.

Carbon steel pipes has been used in this research experiments. Because of corrosion, these pipelines must be regularly inspected, maintained, and sometimes replaced. For example, U.S.A. is spending nearly 6 billion dollar because of losses in pipe industries. In addition, other losses such as loss of products which results accidents and fires (Wadullah, 2009).

Cathodic protection is the electrical solution which dissolve the corrosion problems. This system is widely used on buried metallic pipelines and cables. It protects pipeline structures and metal work from corrosion, making the metal surface to be protected by a cathode element in a path of electric current, encouraging corrosion to form elsewhere in the circuit in a less critical or cheaper material (Salama *et al*., 1993 ; Rajani, 2004). Cathodic protection can be provided through the use of impressed current or sacrificial anodes. The principle of cathodic protection is that an external anode is connected to the metal to be protected; anodes transmit protective current from the power supply to the metal and the electrochemical potential of the structure becomes more negative, eventually reaching a value that provides cathodic protection (Davies, 1981).

In practical applications, the structures most commonly provided with protection are constructed of iron or steel (including stainless steel) and the electrolytes are most often soil and water. Other metals commonly provided with cathodic protection include, lead sheathed cables, copper and aluminum piping, galvanized steel, and cast iron (Bushman, 1988).

Microbiologically influenced corrosion (MIC) refers to corrosion that is influenced by the presence and activities of microorganisms and/or their metabolites (the products produced through their metabolism). Bacteria, fungi, and other microorganisms (such as the protozoa) can play a major part in soil corrosion (Bradford,2001). Dramatic rapid corrosion failures have been observed in soil as a result of microbial action, and it is becoming increasingly apparent that most metallic alloys are susceptible to some form of MIC(Roberge, 2000).

AIMS OF THE STUDY:

1.Evaluate the percentage of corrosion in a matter of time.
2.Diagnosing the microorganisms that caused the corrosion.
3. Prevention of pipes from corrosion by cathodic protection to avoid damage by corrosion with the aim of increasing the component’s service life expectancy, that will protect the environment from leaching of the pipes and reduce the cost of corrosion.

Materials & Methods:

This study had been done at Tikrit University College of Science/ Biology Department/ Environment
Laboratory, from September/2014 to June/2015 .

Soil samples were taken from three different regions which are: Altun Kopry/ Kirkuk (Soil 1, Loamy sand), Tikrit University (Soil 2, Sandy Loam) and Al- Siniya/ Baiji/ Tikrit (Soil 3, Sand) and these three samples were taken from depth 0-50 cm.

All soils were air-dried, then crushed to pass through a 2-mm sieve, soil texture was determined by the hydrometer method for silt and clay, then each type of soil were placed in 6

Plastic containers with another 6 containers for each one for replication:
1. Dry soil 1 with pH ≅5, ≅7, ≅9
2. Dry soil 2 with pH ≅5, ≅7, ≅9
3. Dry soil 3 with pH ≅5, ≅7, ≅9
4. Wet soil 1 with pH ≅5, ≅7, ≅9
5. Wet soil 2 with pH ≅5, ≅7, ≅9
6. Wet soil 3 with pH ≅5, ≅7, ≅9

In addition to that, there are two containers occupied by (soil1) with 50% humidity and pH≅ 7 for cathodic protection experiment.

Pipes Specimen Preparation

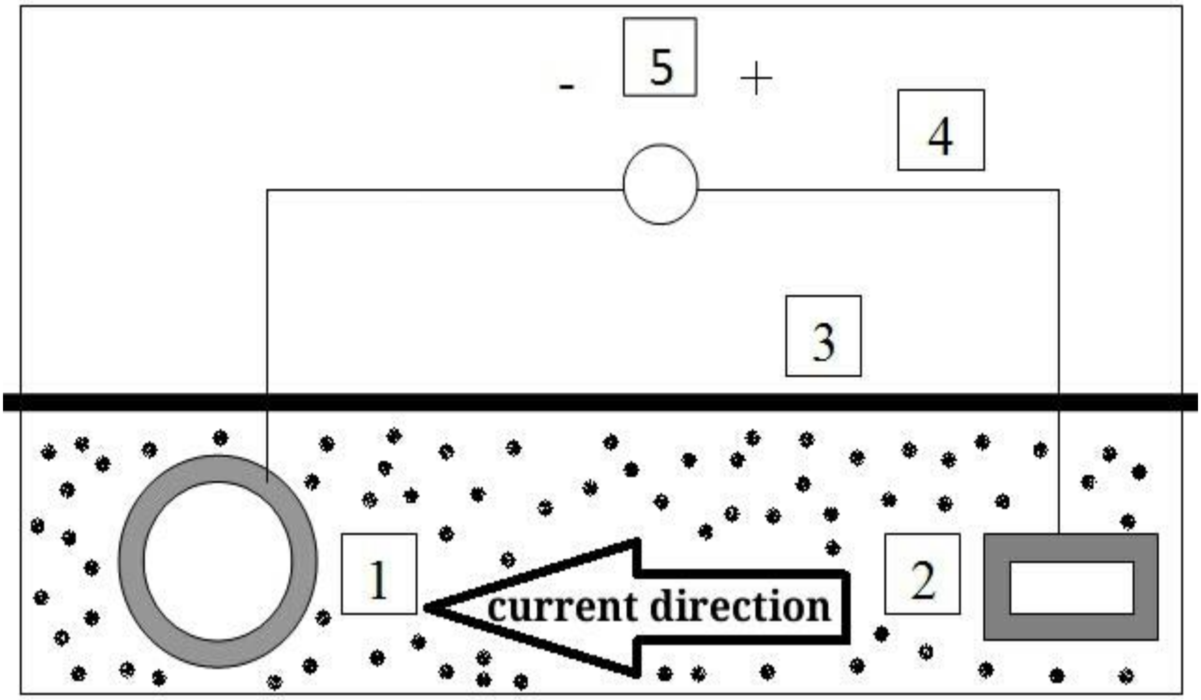
The study was done on carbon steel pipes and those pipes with diameter 1.75 inch were cut in to 38 pieces with a length of 20cm with nearly the same weight (The carbon steel pipes and the donor Aluminum had been measured with a balance that is so accurate up to 3 decimal fractions).

The pipes were cleaned perfectly by scrub to remove any effect of corrosion that could be present and the pipes had been dried by white tissues, after that- the pipes- were buried in the containers mentioned previously on a depth of 7cm.

Plastic burial chamber

Plastic containers were taken with dimensions of 32cm length, 24cm width and 14cm height, 8kg of soil placed in each container, The surface of the soil settlement, it has been added 50% of water from the soil weight to become 50% of field capacity, the pH and the humidity of each container were measured every week and corrected accordingly by adding HCl, NaOH and water.

Cathodic Protection Chamber



Current will flow from the anode bed to the cathode

Item No.	details
1	Cathode (carbon steel pipe)
2	Anode bed (aluminum)
3	Soil surface
4	Connection wire
5	DC source
dots	Soil electrolyte

After the expiry of the period, the pipes were taken off and the following steps had been done:

1. Clean samples with hard plastic brush under running tap water (use acetone for greasy samples).
2. Use Clark's solution (antimony trioxide, Sb_2O_3 of the strength 20 g L-1) and tin chloride ($SnCl_2 . 2H_2O$) of the strength 60 g L-1) dissolved in concentrated hydrochloric acid, HCl).

3. Quickly rinse the sample in running tap water.
4. Dip and rinse the sample in ethanol.
5. Dry the sample with hairdryer.
6. Allow the sample to cool down (~15-45 min).
7.Weigh and record the weight of the sample.
8. Repeat steps 2-7 until three constant weight losses are obtained.
9. Calculate the weight loss (Chozi, 2007).

Isolation of iron oxidizing bacteria from soil samples:

1.Weight 10g of soil and transfer it to flask contain 90 ml of distilled water, shake well (about 10 min), the concentration will be 1/10.
2.Transfer 10 ml from this flask to another flask which contain 90 ml of distilled water_ using sterile pipette, shake for 30 sec, the concentration will be 1/100.
3.Continue transferring until having concentration of 1/1000, 1/10000, 1/100000 and 1/1000000, shake well in every step.
4.Transfer 1 ml from concentration of 1/100000 and 1/1000000 using pipette in to Petri dishes and make 3 replications for each one.
5.Put 15 ml of nutrient agar (its temperature should be 45°C) in the 3 Petri dishes that contain 1 ml of soil solution, repeat that for macConkey and blood agar.
6.Gently move the dishes on the table 5 times clockwise and 5 times reverse the clockwise, tow times forward and 2 times backward for the distribution of microorganisms uniformly.
7.Incubate the dishes in the incubator upside down at 37°C.
8.Examine the microorganisms after 7_10 days.
9.Make pure cultures from isolated bacteria.
10.Diagnose that pure culture of the bacteria (I used Vitek to diagnose the bacteria).
11.Prepare a media to find which type of bacteria is iron-oxidizing bacteria, the medium is prepared by combining three separately sterilized solutions: (solution A)FeSO4.7H20 (33.4 g/liter) at 300 ml adjusted to pH2.5 with 6 M H2SO4, stirred until almost colorless, filter sterilized, and brought to ambient temperature
before use; (solution B) basal salts [6.0 g of (NH4)2SO4 per liter, 0.2 g of KCl per liter, 1.0 g of MgSO4-7H2O per liter, 0.02 g of Ca(NO3)2 per liter] at 550 ml adjusted to pH 3.0 and autoclaved at 121 °C for 15 min in a 1-liter flask; (solution C) Purified Agar(7.0 g) added to 150 ml of distilled water, soaked for 15 min, and autoclaved at 121°C for 15 min in a 1-liter flask. Solutions B and C were removed
from the autoclave and allowed to cool for 5 min at ambient temperature, and solution B was added to C with gentle mixing. Solution A was added to this combination and mixed well. The mixture then was poured into petri dishes to about one-half the depth of the bottom dish.
12.Cultures were streaked on the media and incubated at 28 °C and examined daily for dark brown colonies surrounded by yellow-orange colour (Colmer, *et al*., 1950; Leathen, *et al*., 1956; Silverman and Lundgren, 1959; Kinsel, 1960; Manning, 1973; Tuovinen and Kelly, 1973).

Results & Discussion:

Table (1) showed the effect of different burying period , soil texture, pH and humidity, the highest value of electric conductivity was (62.7 ms/cm) in dry soil 1 with pH≅ 5 after 9 months burying, while the lowest value was (2.02 ms/cm) in dry soil 3 with pH≅ 7 after 3 months burying, because the increase of H+ as a result of HCl adding after 9 months which caused increasing the electric conductivity.

On the other hand the results showed that the highest value of electric conductivity was (28.13 ms/cm) in dry soil 3, while the lowest value was (19.19 ms/cm) in wet soil 3, this result occur maybe because the ions in wet soil have been washed and that decreases the electric conductivity and that agree with (Hanlon, 2012).

As a mean, soil texture has a significant effect on electric conductivity, whereas the highest value of electric conductivity was (23.66 ms/cm) in soil 3, while the lowest value was (20.77 ms/cm) in soil 1, that's not agree with Robert, *et al.* (2009) which showed that the soft soils have high conductivity, the EC correlates strongly to soil particle size and texture.

Electric conductivity of cathodic protection soil is nearly the same because it was with neutral pH, so there is no H+

Table (1) the effect of different burying period , soil texture, pH and humidity on the electric conductivity

soil	humidity	PH	time			means of PH	means of humidity	means of soil
			after 3 months	after 6 months	after 9 months			
soil 1	dry	5	18.8 ef	16.7 f	62.7 a	32.72 E	22.25 B	20.77 B
		7	2.1 g	2.2 g	2.48 g	2.26 I		
		9	14.2 f	36.7 c	44.4 b	31.77 E		
	wet	5	17.0 f	22.5 e	36.1 c	25.20 F	19.28 C	
		7	2.3 g	3.1 g	2.53 g	2.64 I		
		9	30.1 d	41.4 b	18.53ef	30.01 E		
mean effect of time in soil 1			14.08 b	20.43b	27.79a			
cathodic protection			2.5 a	2.62 a	2.38 a			
soil 2	**dry**	5	26.5 e	31.5 d	54.5 a	37.50CD	20.04 C	21.40 B
		7	2.2 h	2.6 h	2.18 h	2.33 I		
		9	11.8 g	13.1f g	36.0 c	20.3 G		
	wet	5	36.3 c	43.8 b	38.8 c	39.63 B	22.76 B	
		7	2.4 h	2.6 h	2.07 h	2.36 I		
		9	26.7 e	35.2 cd	17.01 f	26.30 F		
mean effect of time in soil 2			17.65 b	21.47 ab	25.09 a			
soil 3	**dry**	5	37.2 c	43.3 b	59.1 a	46.53 A	28.13 A	23.66 A
		7	2.02 g	2.2 g	2.32 g	2.18 I		
		9	20.1 e	29.2 d	57.7 a	35.67 D		
	wet	5	31.9 d	40.4 bc	39.4 bc	37.23CD	19.19 C	
		7	2.8 g	3.4 g	3.46 g	3.22 I		
		9	13.8 f	16.4 f	21.2 e	17.13 H		
mean effect of time in soil 3			17.97 b	22.48 b	30.50 a			
general mean effect of time			16.57 b	21.46 b	27.79 a			

*The same small letters in rows means no significant differences between them at 0.05%.
*The same capital letters in columns means no significant differences between them at 0.05%.

Table (2) showed the effect of different burying period , soil texture, pH and humidity on the organic matter ratio, the highest value of organic matter was (10.563 %) in wet soil 2 with pH≅ 5 after 9 months burying, while the lowest value was (0.296 %) in dry soil 2 with pH≅ 7 after 6 months burying, the burying period play an important role in the accumulation of organic matter in soil because the decay of microorganisms were increased the organic matter because of the increment of acidity or alkalinity of the soil, these results agree with (Primavesi, 1984).

On the other hand, the mean effect of humidity showed that the highest value of organic matter was (6.216 %) in dry soil 2, while the lowest value was (2.358 %) in wet soil 3, this results agree with (Al-Marsoumi, *et al*., 2006) who showed that soil content of gypsum has negative effect on increasing the degradation of organic matter in soil.

Table (2) the effect of different burying period , soil texture, pH and humidity on the organic matter ratio

soil	humidity	PH	time			means of pH	Means of humidity	means of soil
			after 3 months	after 6 months	after 9 months			
soil 1	dry	5	2.811 cd	0.662 f	5.723 a	3.07 D	2.87 B	2.897 B
		7	2.041 de	1.449 ef	3.520 bc	2.34 D		
		9	3.728 bc	2.001 de	3.838 bc	3.180 D		
	wet	5	2.963 cd	1.079 ef	4.809 ab	2.95 D	2.92 B	
		7	3.26 cd	2.368 de	3.176 cd	2.93 D		
		9	2.667 cd	2.172 de	3.845 bc	2.89 D		
mean effect of time in soil 1			2.912 b	1.622 b	4.152 a			
cathodic protection			3.169 c	4.842 b	12.904 a			
soil 2	dry	5	6.338 c	1.229 fg	3.732 e	3.766CD	6.216 A	5.706 A
		7	9.702 ab	0.296 g	8.612 b	6.203 B		
		9	5.692 cd	0.977 fg	9.682 ab	8.678 A		
	wet	5	4.308 de	1.084 fg	10.563 a	5.318 BC	5.196 A	
		7	3.817 e	1.911 f	10.545 a	5.424 BC		
		9	6.609 c	2.006 f	5.925 c	4.847BCD		
mean effect of time in soil 2			6.78 a	1.250 b	8.180 ab			
soil 3	dry	5	3.091 cd	0.946 f	7.011 a	3.683CD	3.082 B	2.720 B
		7	2.039 de	2.089 de	3.133 cd	2.420 D		
		9	2.951 cd	1.953 de	4.522 b	3.142 D		
	wet	5	2.340 de	1.937 de	4.529 b	2.935 D	2.358 B	
		7	1.986 de	1.420 ef	2.577cde	1.994 D		
		9	1.817 de	0.838 f	3.784 bc	2.146 D		
mean effect of time in soil 3			2.371 b	1.531 b	4.259 a			
general mean effect of time			3.787 b	1.468 c	5.530 a			

*The same small letters in rows means no significant differences between them at 0.05%.
*The same capital letters in columns means no significant differences between them at 0.05%.

As a mean, soil texture has a significant effect on organic matter, whereas the highest value of organic matter was (5.706 %) in soil 2, while the lowest value was (2.720 %) in soil 3, because soil organic matter tends to increase as the clay content increases. This increase depends on two mechanisms. First, the bonds between the surface of clay particles and organic matter retard the decomposition process. Second, soils with higher clay content increase the potential for aggregate formation, macro aggregates physically protect organic matter molecules from further mineralization caused by microbial attack ,the results agree with (Rice, 2002).

The highest value of organic matter in cathodic protection soil was (12.904 %) after 9 months burying while the lowest value was (3.169 %) after 3 months burying because the electromagnetic media caused by cathodic protection decay the microorganisms that consume the organic matter, this agree with (Bill and Gareth, 2003), they showed that the prevention of microbial corrosion can be achieved by cathodic protection.

Plate (1) *Pseudomonas aeruginosa* on iron oxidizing bacteria media.

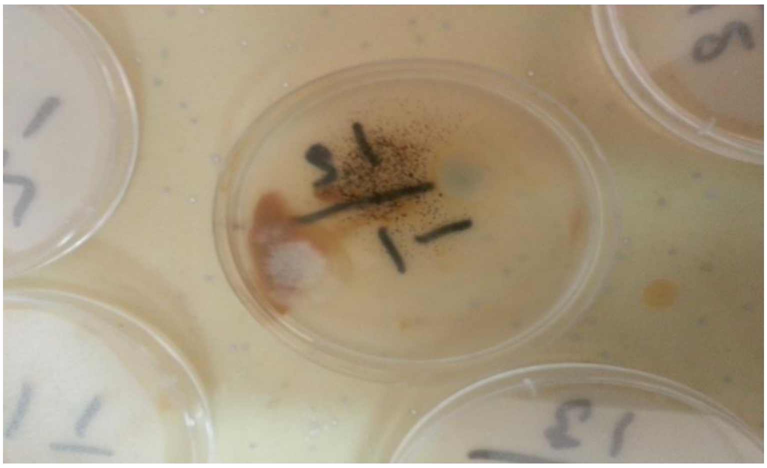


Plate (2) *Enterobacter cloacae* on iron oxidizing bacteria media.

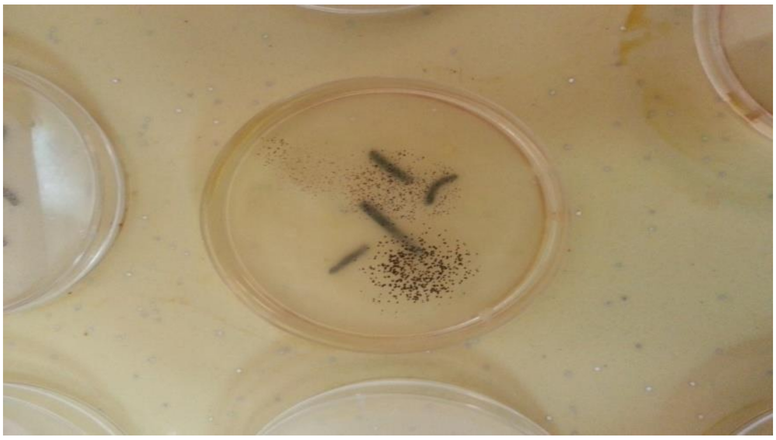


Plate (3) *Staphylococcus aureus* on iron oxidizing bacteria media.

Table (3) Types of bacteria which dominant in soil (1) with different pH and humidity degrees

humidity	pH	dilution	media	Proteus	Pseudo.	Enter.	Staph.	E.coli
Dry	5	1	N-agar	-	-	+	+	-
			B-agar	-	-	-	+	-
			M-agar	-	-	-	-	-
		2	N-agar	+	-	-	+	-
			B-agar	-	+	-	+	-
			M-agar	-	-	-	-	-
	pH	dilution	media	Proteus	Pseudo.	Enter.	Staph.	E.coli
	7	1	N-agar	-	-	-	+	-
			B-agar	-	-	-	+	-
			M-agar	-	-	-	-	-
		2	N-agar	-	-	+	-	-
			B-agar	-	-	+	+	-
			M-agar	-	-	+	-	-
	pH	dilution	media	Proteus	Pseudo.	Enter.	Staph.	E.coli
	9	1	N-agar	-	-	-	+	-
			B-agar	-	-	-	+	-
			M-agar	-	-	-	-	-
		2	N-agar	-	-	+	-	-
			B-agar	-	-	+	+	-
			M-agar	-	-	-	-	-
humidity	pH	dilution	media	Proteus	Pseudo.	Enter.	Staph.	E.coli
wet	5	1	N-agar	-	-	-	+	-
			B-agar	-	-	-	+	-
			M-agar	-	-	-	-	-
		2	N-agar	+	-	-	+	-
			B-agar	-	-	-	+	-
			M-agar	-	-	-	-	-
	pH	dilution	media	Proteus	Pseudo.	Enter.	Staph.	E.coli
	7	1	N-agar	+	-	-	-	-
			B-agar	+	-	-	-	-
			M-agar	-	-	-	-	-
		2	N-agar	-	-	+	-	-
			B-agar	+	+	+	-	-
			M-agar	-	-	-	-	+
	pH	dilution	media	Proteus	Pseudo.	Enter.	Staph.	E.coli
	9	1	N-agar	-	-	-	+	-
			B-agar	-	-	-	+	-
			M-agar	-	-	-	-	-
		2	N-agar	-	-	+	+	+
			B-agar	-	-	-	+	+
			M-agar	-	-	-	-	+

There are about a dozen of bacteria known to cause microbiologically influenced corrosion of carbon steel, stainless steel, copper alloy and aluminum alloy, these bacteria can be broadly classified as aerobic requires oxygen to be active or anaerobic oxygen is toxic to the bacteria (Schwermer, *et al*., 2008; Weisman and Lohse, 2007). The study of Zuheir (2012) showed that the presence of *Pseudomonas aeruginosa* bacteria caused corrosion, microbiological analysis showed that biofilm are formed as microcolonies, which subsequently caused corrosion shows the role of *Pseudomonas aeruginosa* bacteria in acceleration corrosion on aluminum alloy.

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Reza, *et al*., (2013) showed that *Enterobacte*r sp. have measurable effect on carbon steel corrosion, whereas the corrosion rates in biotic cases show an increase in comparison with the abiotic environment. Kurissery, *et al*. (2005) used *Staphylococcus aureus*as a bacteria that cause microbial influenced corrosion then he found which metal is antibacterial metal. All of these studies are agree with my study because as I showed in the pictures above that these three types of bacteria oxidize the iron that means it is corrosive. These findings may strongly suggest that iron oxidizing bacteria are indeed very corrosive and thus must be taken care of when they exist in a system.

Table (4)Types of bacteria which dominant in soil (2) with different pH and humidity degrees

humidity	pH	dilution	media	Proteus	Pseudo.	Enter.	Staph.	E.coli
Dry	5	1	N-agar	-	-	+	-	-
			B-agar	-	+	+	-	-
			M-agar	-	+	-	-	-
		2	N-agar	-	-	+	-	-
			B-agar	-	-	+	-	+
			M-agar	-	-	-	-	+
	pH	dilution	media	Proteus	Pseudo.	Enter.	Staph.	E.coli
	7	1	N-agar	-	-	+	-	-
			B-agar	-	-	+	-	-
			M-agar	-	-	-	-	-
		2	N-agar	-	-	+	-	-
			B-agar	-	-	+	-	-
			M-agar	-	-	+	-	-
	pH	dilution	media	Proteus	Pseudo.	Enter.	Staph.	E.coli
	9	1	N-agar	+	-	-	-	-
			B-agar	+	+	-	-	-
			M-agar	+	+	-	-	+
		2	N-agar	-	+	+	-	-
			B-agar	-	+	+	-	-
			M-agar	-	+	+	-	-
humidity	pH	dilution	media	Proteus	Pseudo.	Enter.	Staph.	E.coli
wet	5	1	N-agar	-	+	-	+	-
			B-agar	-	+	-	+	-
			M-agar	-	-	-	-	-
		2	N-agar	-	+	-	-	-
			B-agar	-	+	-	-	-
			M-agar	-	+	-	-	-
	pH	dilution	media	Proteus	Pseudo.	Enter.	Staph.	E.coli
	7	1	N-agar	+	-	+	-	-
			B-agar	+	-	-	-	-
			M-agar	+	-	-	-	+
		2	N-agar	+	-	+	-	+
			B-agar	+	-	-	-	+
			M-agar	-	-	-	-	+
	pH	dilution	media	Proteus	Pseudo.	Enter.	Staph.	E.coli
	9	1	N-agar	-	+	+	-	-
			B-agar	-	+	-	-	-
			M-agar	-	+	-	-	-
		2	N-agar	-	+	+	-	+
			B-agar	-	+	-	-	-
			M-agar	-	+	-	-	-

Table (5)Types of bacteria which dominant in soil (3) with different pH and humidity degrees

humidity	pH	dilution	media	Proteus	Pseudo.	Enter.	Staph.	E.coli
Dry	5	1	N-agar	+	+	+	-	-
			B-agar	+	-	-	-	-
			M-agar	-	-	-	-	-
		2	N-agar	+	-	+	-	-
			B-agar	+	-	-	-	-
			M-agar	+	-	-	-	-
	pH	dilution	media	Proteus	Pseudo.	Enter.	Staph.	E.coli
	7	1	N-agar	+	-	+	-	-
			B-agar	+	-	+	-	-
			M-agar	+	-	-	-	+
		2	N-agar	-	-	+	-	-
			B-agar	-	-	-	+	+
			M-agar	+	-	-	-	-
	pH	dilution	media	Proteus	Pseudo.	Enter.	Staph.	E.coli
	9	1	N-agar	+	-	+	-	-
			B-agar	+	-	+	+	-
			M-agar	+	-	+	-	-
		2	N-agar	-	-	+	-	-
			B-agar	-	-	+	-	-
			M-agar	-	-	+	-	-
humidity	pH	dilution	media	Proteus	Pseudo.	Enter.	Staph.	E.coli
wet	5	1	N-agar	-	-	+	-	-
			B-agar	-	-	-	+	-
			M-agar	-	-	-	-	-
		2	N-agar	-	-	+	-	-
			B-agar	-	-	-	+	-
			M-agar	-	-	-	-	-
	pH	dilution	media	Proteus	Pseudo.	Enter.	Staph.	E.coli
	7	1	N-agar	-	+	+	-	+
			B-agar	-	+	+	+	+
			M-agar	-	+	+	-	+
		2	N-agar	-	-	-	+	+
			B-agar	-	-	-	+	+
			M-agar	-	-	-	-	+
	pH	dilution	media	Proteus	Pseudo.	Enter.	Staph.	E.coli
	9	1	N-agar	-	-	-	+	-
			B-agar	-	-	-	+	-
			M-agar	-	-	-	-	-
		2	N-agar	-	-	-	+	-
			B-agar	-	-	-	+	-
			M-agar	-	-	-	-	-

Table (6) Types of bacteria which dominant in cathodic protection soil with different pH and humidity degrees

humidity	pH	dilution	media	Proteus	Pseudo.	Enter.	Staph.	E.coli
wet	7	1	N-agar	+	+	+	-	-
			B-agar	+	+	+	-	-
			M-agar	-	+	+	-	-
		2	N-agar	-	-	+	-	+
			B-agar	-	-	+	+	+
			M-agar	-	-	-	-	+

As a mean, table (7) showed that the highest value of corrosion was (13.637 %) in soil 2, while the lowest value was (9.483 %) in soil 3 because the order of soil corrosiveness is clay > loam > sand, this results agree with (Oguzie, 2004).

Cathodic protection really worked and the pipe protected very well, whereas the corrosion of protected pipe was 1.462 % while the corrosion of the pipe buried in the same circumstances but without protection was 11.267 %.

Table (7) the percentage of corrosion in the pipes that are buried in different soil texture with different pH and humidity

Soil type	humidity	pH	Estimation (%)	means
Loamy sand	Dry soil	≅ 7	1.426	11.481 B
Loamy sand	Dry soil	≅5	16.576	
Loamy sand	Dry soil	≅9	7.002	
Loamy sand	50% humidity	≅ 7	11.267	
Loamy sand	50% humidity	≅5	21.442	
Loamy sand	50% humidity	≅9	11.176	
Sandy Loam	Dry soil	≅ 7	2.794	13.637 A
Sandy Loam	Dry soil	≅ 5	17.853	
Sandy Loam	Dry soil	≅ 9	7.813	
Sandy Loam	50% humidity	≅ 7	15.871	
Sandy Loam	50% humidity	≅ 5	21.383	
Sandy Loam	50% humidity	≅ 9	16.112	
sand	Dry soil	≅ 7	2.672	9.483 C
sand	Dry soil	≅ 5	10.472	
sand	Dry soil	≅ 9	5.965	
sand	50% humidity	≅7	11.668	
sand	50% humidity	≅5	13.892	
sand	50% humidity	≅ 9	12.230	
Loamy sand	**50% humidity**	**≅7 for cathodic protection**	**1.462**	

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