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Comparison of the corrosion ratio of carbon steel pipes buried in sandy soil due to cathodic protection and sandy soils with added ratios of Na_2SO_4 Salt

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ABSTRACT

The purpose of this study was to compare the corrosion ratio of carbon steel pipes buried in sandy soil of cathodic protection and sandy soils with an added ratio of sodium sulphur Na_2S_{O4} for two periods of half a year and one year from September 2016 to September 2017, as well as comparison soils, i.e., burying in untreated sandy soils. This aim was conducted to determine which of these methods are the most effective in inhibition the corrosion, The results Show that the: pipelines protected by cathodic protection during the half year and one year periods were 1.143% and 1.748%, respectively, compared with the control soil pipelines which recorded 13.441% and 26.069% for the half and one year periods. As for the pipelines buried in soils with certain added ratios 73% of sodium sulphate, the soils were less efficient in corrosion prevention and the results were 7.131% and 18.312% for the two periods of half-year and one-year. Thus, the treatment of sand soils with cathodic protection has proven corrosion of carbon steel pipes. In addition, the causes of corrosion in carbon steel pipes and soil germination tests were also studied to detect the types of corrosive bacteria. The following species of bacteria, such as Pseudomonas, Proteus and Enterobacter, were observed in different conditions of pH.

1. Introduction

defined corrosion by (1) as: the destructive attack of a metal by chemical or electrochemical reaction with its environment. The word corrosion comes from the Latin word *corrodere* which means "necrosis into parts" (2,3). Corrosion processes in soil are very complex phenomena; therefore, the corrosion behavior of metals and alloys in other environments should not be extrapolated because of its performance in soil. In general, soil is considered a highly corrosive environment and often requires the use of inhibitors for metals and general engineering alloys (4). The concept of rust applies to the corrosion of iron or ferro alloys with the formation of corrosion products consisting largely of hydrothermal oxides. Thus, the non-ferrous metals erode but do not rust. Corrosion can affect the safety of operating equipment by causing failure in operation, for example, pressure vessels, boilers, and metal containers for nuclear power reactors (1,5). Corrosion usually begins on the material surface and occurs due to the automatic direction of the material to return to its stable thermodynamic state or to one of the shapes originally found. Metals are usually susceptible to corrosion because most of it is naturally sourced (6). The cathodic protection principle is that the outer anode is linked to the metal that is to be protected. Anodes send the protective current from the source of energy to the metal, and the electrochemical potential and ability of the framework become more negative and finally reach the value of cathodic protection (7). The ideal design of the cathodic protection system provides the required degree of protection at the lowest total annual cost and during the life expectancy of the protected framework (1). The inhibitioing corrosion with cathodic protection is not new; this technology has existed for more than 189 years. Sulphate ions were also found to accelerate the process of active decomposition of iron, and the thin layers formed in sulphate solutions are the result of saturated solutions of iron salts, more probably ferrous sulphate hydroxide. This means that iron dissolves in sulphate solutions at high rate, creating an over-saturated solution that allows the deposition of a non-protective layer (8). The corrosion of carbon steel in neutral environments is of practical importance; therefore, we find many studies that take this into account.

Cathodic Protection and basic theory of it. It is an electrical method to reduce the corrosion of structures exposed to electrolytic environments such as soils and water (9). Cathodic protection is a way to reduce corrosion by reducing the difference of voltages between the anode and cathode (10). This means that the corrosion of the structures will stop completely when the open circuit voltages of the cathode sites are polarized for the open-circuit voltage of the anode areas (9). Cathodic protection is basically appropriate when the surfaces to be protected are buried or submerged. The external surfaces of the buried metal structures as well as the surfaces of the structures facing water such as the substrates of the bearings and the inner surfaces of the tanks containing electrolytes such as water are applications where the use of cathodic protection is technically appropriate and practical and is widely used in the protection of such structures (11). The applicability of cathodic protection is limited in certain proportions to the internal surfaces of small diameter pipes as well as to other areas where the flow of ions through the electrolyte is restricted by electrolyte resistance (12). Cathodic Protection (CP) is a technique used to reduce the corrosion rate of the metal surface by making it The cathode electrode in an electrochemical cell (9). The cathodic protection principle consists of connecting an external anode to the metal to be protected with a flow of a direct electric current (DC) where all surface areas become cathodic and thus do not rust (13). Anodic and cathodic areas exist on the pipe surface. In anodic areas, the current flows from the pipe to the surrounding electrolyte which is soil or water, and the pipe is corroded. In the cathodic areas, the current flows from the electrolyte to the pipe surface and reduces the rate of corrosion. In light of the above, it is clear that the rate of corrosion can be reduced if each part of the exposed metal on the surface of the pipe collects the current by applying the current (DC) on all the surfaces of the pipeline. This direct current will reverse the pipeline voltage in an effective (negative) direction, resulting in a decrease in the metal corrosion rate (14). When the rate and amount of the flowing current is adjusted appropriately, it will overcome the emptied corrosion current through the anode areas that are present on the pipeline, and a net current flow will occur on the outer pipe surface at these points. The entire surface will then become cathode and the corrosion rate will decrease (15). The early failure of bridge structures is due to corrosion and the failure of the operating equipment resulting from corrosion can have the same disastrous consequences (14). When all these factors are taken into account, it becomes clear why the problem of corrosion should be taken into account during the early stages of any project design, and why it is necessary to monitor the cohesion of structures and bridges as well as mechanisms and equipment consistently to prevent early failures (16).

2. Material and Methods of Work

2.1 Methods of soil preparation

Soil samples were obtained from the Tel Kseiba area of Hamreen region in Salah Al-Deen governorate. This study had been done at College of pure Science/ Biology Department/ Environment Laboratory. The soil was dried in air and then sifted through a sieve of 2 mesh mm. The soil texture was determined by means of a fluid scale method for silt and mud, and then 10 kg of soil was placed in 3 plastic containers with 3 containers for replication. The total number was 12 plastic containers.

Table (1): Chemical and physical properties of soil used in this study

Unit	Estimation	Material
(%)	97	Sand
(%)	2	Silt
(%)	1	Mud
(%)	2.3935	Organic material
(ms/cm)	2.2	Electrical conductivity
	7.84	pH
(ppm)	135	Chlorides
(%)	2.4122	Gypsum
(ppm)	27	Sulphurs
(meq/L)		Dissolved ions
	4	sodium
	1	potassium
	7.8005	magnesium
	4.5177	calcium
	1.736	Total nitrogen
(ppm)		Heavy metal
	1.01	iron
	0.001	copper
	0.02	manganese
	Nil	chrome

2.2 Preparation of pipe samples

The study was conducted on carbon steel pipes. These pipes, which were 2 inches in diameter, were cut into 12 pieces with a length of 15 cm and with approximately the same weight. As for the aluminum granter pipes, four pieces were taken with a diameter of 1.85 inches and a length of 15 cm. The carbon steel pipes and donor aluminum were measured with a precise balance to 3 decimal fractions. The pipes were finely tuned with mono-silicon carbide sheets (17). It was then cleaned with a plastic brush and tap water to remove any corrosive effect that could be present and then dried with paper tissues and dessicated using a 110 ° C oven for 10 minutes (18). The pipes were buried horizontally in the containers mentioned above with a depth of 7 cm. The tests were carried out to determine the components of the carbon steel pipe at the Ministry of Industry and Minerals - the General Company for Examination and

Engineering Qualification-the Laboratory and Engineering Testing Department- Mineral Laboratory (Spectroscopy) for Carbon Steel of low alloying, and the laboratory is certified by the Iraqi Accreditation System under the No. TI 006. The results were as follows:

Table (2): Chemical compounds for carbon steel pipes

Material	Estimation (%)
Fe	98.817
C	0.078
Si	0.208
Mn	0.416
P	0.018
S	0.004
Cr	0.136
Mo	0.033
Ni	0.09
Al	0.019
Cu	0.136

2.3 Preparing of plastic burial chamber

The plastic containers were taken in dimensions 34 cm long, 20 cm wide and 14 cm high, with 10 kg of soil in each container.

2.4 Cathodic protection chamber

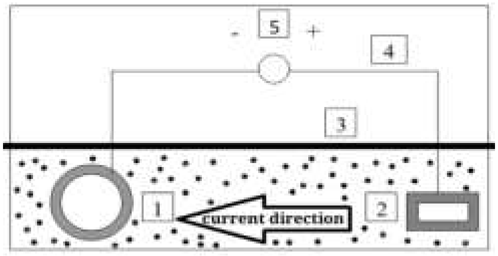

Figure (7)

1	Cathode (Carbon Steel Pipes)
2	Anode basin (aluminum)
3	Soil surface
4	Power cord
5	Direct current source
Dots	Soil electrolyte

2.5 Preparing the remaining containers

73% of Na_2SO_4 produced by the Spanish company Scharlau was added after a 99.8% purity test and a molecular weight of 142.04 g /gmol for four basins to complete the basic sulphur content in the soil, which amounted to 27% according to the tests conducted in the laboratories of the Department of Chemical Engineering at the College of Engineering-University of Tikrit to become 100%. For cathodic protection containers, 50% of the water was added to the soil weight to become 50% of the field capacity according to the weight ratio. pH and humidity were measured per container weekly and corrected accordingly.

After the period, the pipes were removed and the following was conducted:

1) Cleaning the samples using a solid plastic brush under tap water. Clark solution (antimony trioxide, Sb_2O_3 with 20 g L-1) and tin chloride ($SnCl_2$ $2H_2O$ with 60 g L-1) dissolved in hydrochloric acid HCl were used (19,20).

2) The sample was dipped and rinsed into ethanol (17).

3) The sample was dried with a hairdryer.

4) Allowing the sample to cool for about (15-45 minutes).

5) The sample was then weighed and the weight recorded.

6) Repeating steps 2 to 7 until three constant losses in weight are obtained.

7) Finally, weight loss is counted (21).

2.6 Isolating iron oxidizing bacteria from soil samples

Tools and Materials:

1. Soil sample dried in the air.
2. Distilled water and sterilized laboratory glass.
3. Sterilized pipettes.
4. Medium for bacterial growth: nutrient agar, mackonci agar and blood agar.
5. Petri dishes.

Work Steps

1. Weighting 10 g of soil and transferring it to a flask container which contains 90 ml of distilled water, then shaking it well (about 10minutes), so the concentration becomes 1/10 .
2. Transferring 10 ml of this flask container to another containment flask container which contains 90 ml of distilled water using a sterile pipette, shaking it for 30 seconds,and the concentration will become 1/100.
3. Continuing to dilute until the concentrations we obtained become 1/1000, 1/ 10000, 1/ 100,000, and 1/1000000, shaking it in every step.
4. 1ml of the concentrations 1/100 and 1/1000 were transferred using a pipette to the petri dishes, and 3 replicates were used for each concentration.
5. Placing 15 ml of nutrient agar at 45 ° C in 3 dishes containing 1 ml of soil solution, repeating it for macConkey agar and blood agar.
6. The dishes were moved on the table 5 times clockwise and 5 times counterclockwise, two times forward and two times backward to distribute the microorganisms uniformly.
7. Placing the dishes in the incubator upside down
8. The microorganisms were examined after 7-10 days.
9. Diagnosing of bacteria using the *Vitek* device to diagnose bacteria. (22,23)

3. Results and Discussion

Table (1) shows cathodic treatment of pipes , sample weight before and after treatment and burying for half a year and one year. The rate of corrosion in cathodic protection after half a year of treatment was 1.272% and after one year was 1.870%. As for the change in the weights of the pipes before and after treatment, the mean weight after six months was 459.114 g and after one year was 456.338 g while the rate of sample weights before treatment was 465.035 g. These results were consistent with (19), who showed a reduction in corrosion rates for cathodic steel-treated steel pipes and for 3, 6 and 9 months of burying, as well as with (24) who demonstrated that microbial corrosion prevention can be achieved by cathodic protection. These results indicate that the main cause of corrosion is bacteria, and when treated with cathodic protection, microbial corrosion stopped; and corrosion rate was relatively low.

Table (1) Results of cathodic protection treatment

Sample No.	Sample weight Before treatment/gm	Sample weight after half a year/gm	Corrosion rate%	Sample weight after one year/gm	Corrosion rate%	Total corrosion Average %
1	466.811	460.222	1.412	458.312	1.821	1.616
2	478.883	473.001	1.229	470.014	1.853	1.541
3	472.271	466.201	1.286	463.122	1.938	1.612
4	442.178	437.033	1.164	433.905	1.871	1.517
Avarage	465.035	459.114	1.272	456.338	1.870	1.571

Table (2) shows the amount of corrosion in the buried pipes in the soils with added Na_2SO_4. The corrosion rate for half a year of burying was 7.131%, and for one year 18.312%. On the other hand, the average pipe weights recorded the following changes: 468.966 g 435,638 g and 383,265 g before burying and after burying for half a year and one year respectively.

Table (2): Results of Na_2SO_4 Sodium Sulphate Addition

Sample No.	**Sample weight Before treatment/gm**	**Sample weight after half a year/gm**	**Corrosion rate%**	**Sample weight After one year/gm**	**Corrosion rate %**	**Total corrosion Average%**
1	436.112	400.122	8.253	350.155	19.71	13.981
2	485.682	450.221	7.302	400.331	17.574	12.438
3	467.881	437.193	6.559	381.923	18.372	12.465
4	486.191	455.017	6.412	400.653	17.594	12.003
Avarage	468.966	435.638	7.131	383.265	18.312	12.721

The pH of these containers was continuously measured and the rates were between 4.2-2.7. This is consistent with both (19), who showed high rates of corrosion in acid soils with pH 5 or less, and (25) who confirmed that the rate of rust increased over time with Na_2SO_4 concentrations. As for (26) their results showed an increase in rust formation with concentrations of Na_2SO_4.

Table (3) shows corrosion rates and burying times for pipe samples buried in sandy soils without any addition for half a year and one year.

Table (3): Control soils without any addition

Sample No.	Sample weight Before treatment/gm	Sample weight After half a year/gm	Corrosion rate %	Sample weight After one year/gm	Corrosion rate%	Total corrosion Average %
1	449.333	389.218	13.379	330.251	26.502	19.940
2	459.505	401.328	13.687	343.421	25.263	19.475
3	469.772	425.122	12.996	350.188	25.456	19.226
4	469.118	400.172	13.705	342.199	27.055	20.38
المعدل	461.932	403.96	13.441	341.514	26.069	19.755

Corrosion rates were very high at 13.441% for the period of half year and 26.069% for one year. Also note the amount of corrosion of the weight of the pipes through the rates of weight before the burying and after the burying, and the two time periods of half a year and one year ago, before the burying 461.932 g, and after the burying 403.96 g 341.514 g for the periods of half a year and one year, respectively. This group was counted as a control group to compare the rest of the samples with it.

There are about twelve genera of known bacteria that cause microbial corrosion affected by carbon steel, stainless steel, copper alloys and aluminum alloys. These bacterial strains can be classified as aerobic and anaerobic according to their need for oxygen (27). (28) in a study showed that the presence of *Pseudomonas aeruginosa* bacteria caused corrosion. Microbiological analysis showed that the biofilms formed in the form of precise colonies, which later resulted in corrosion. This shows the role of *Pseudomonas aeruginosa* bacteria in accelerating corrosion in aluminum alloys.

Table (4) : Types of dominant bacteria in sandy soil used in experiments with different degrees of pH

pH	Dilution	medium	*Proteus*	*Pseudo.*	*Enter.*	*Staph.*	*E.coli*
5	1	N-agar	+	+	+	-	-
		B-agar	+	-	-	-	-
		M-agar	-	-	-	-	-
	2	N-agar	+	-	+	-	-
		B-agar	+	-	-	-	-
		M-agar	+	-	-	-	-
PH	Dilution	Medium	*Proteus*	*Pseudo.*	*Enter.*	*Staph.*	*E.coli*
7	1	N-agar	+	-	+	-	-
		B-agar	+	-	+	-	-
		M-agar	+	-	-	-	+
	2	N-agar	-	-	+	-	-
		B-agar	-	-	-	+	+
		M-agar	+	-	-	-	-
PH	Dilution	medium	*Proteus*	*Pseudo.*	*Enter.*	*Staph.*	*E.coli*
9	1	N-agar	+	-	+	-	-
		B-agar	+	-	+	+	-
		M-agar	+	-	+	-	-
	2	N-agar	-	-	+	-	-
		B-agar	-	-	+	-	-
		M-agar	-	-	+	-	-

Table (5) Type of dominant bacteria in soil used in cathodic protection with neutral pH

pH	Dilution	Medium	*Proteus*	*Pseudo.*	*Enter.*	*Staph.*	*E.coli*
7	1	N-agar	+	+	+	-	-
		B-agar	+	+	+	-	-
		M-agar	-	+	+	-	-
	2	N-agar	-	-	+	-	+
		B-agar	-	-	+	+	+
		M-agar	-	-	-	-	-

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مقارنة نسبة التآكل لانابيب الكاربون الفولاذية المطمورة في ترب رملية من الحماية الكاثودية وترب رملية مضافة لها نسب من ملح Na_2So_4

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الملخص

هدف هذه الدراسة هو المقارنة بين نسبة التآكل الحاصلة في انابيب الكاربون الفولاذية المطمورة في ترب رملية للحماية الكاثودية وترب رملية مضافة لها نسبة من كبريتات الصوديوم Na_2SO_4 لفترتين زمنيتين نصف سنة وسنة كاملة فضلا عن ترب المقارنة وهي الطمر في ترب رملية غير معاملة. وذلك لمحاولة تحديد أي من هذه الطرق هي الاكثر فاعلية في إيقاف التآكل او تقليله وكانت النتائج كالتالي:

الانابيب المحمية بواسطة الحماية الكاثودية وخلال الفترتين نصف السنة والسنة الكاملة 1.143 % و 1.748 % على التوالي مقارنة مع انابيب ترب السيطرة والتي سجلت 13.441 % و26.069 % وللفترتين نصف السنة وسنة واحدة. اما الانابيب المطمورة في ترب مضافة لها كبريتات الصوديوم Na_2SO_4 بنسب معينة فقد كانت اقل كفاءة في منع التآكل وسجلت النتائج التالية 7.131 % و 18.312 % للفترتين الزمنيتين نصف السنة والسنة الواحدة. وبذلك فقد اثبتت طريقة معاملة الترب الرملية بالحماية الكاثودية تقليل ومنع تآكل انابيب الكاربون الفولاذية. كذلك تمت دراسة أسباب التآكل الحاصل في انابيب الفولاذ الكاربوني واجراء فحوصات زرعية للتربة للكشف عن أنواع البكتريا المسببة للتآكل، وقد لوحظ وجود الأنواع التالية من البكتريا مثل Pseudomonas و Proteus و Enterobacte ، في ظروف مختلفة من الآس الهيدروجيني.