



## Corrosion control of Buried Low Carbon Steel Structure by Using Alteration Medias method

Amel S. Merzah\*

Mohammed H. Hafiz\*\*

Sarah k. Mohammed\*\*\*

\*, \*\*\* Technical college- Baghdad

\*\* Department of Petroleum Technology / University of Technology

\*Email: [amelmerza@yahoo.com](mailto:amelmerza@yahoo.com)

\*\*Email: [Drmhh1962@gmail.com](mailto:Drmhh1962@gmail.com)

\*\*\*Email: [Sarah\\_materials@yahoo.com](mailto:Sarah_materials@yahoo.com)

(Received 1 September 2013; accepted 15 April 2014)

### Abstract

The aim of the present work is to control of metal buried corrosion by alteration the media method. This method depended on the characteristics of each media. The corrosion rates in different media (soil, sand, porcelanite stone and gravel) for specimens of low carbon steel were measured by two methods weight loss method and polarization method, weight loss measured by buried specimens in these medias separately for 90 days. The polarization method includes preparing of specimen and salt solutions have electrical resistivity equivalent electrical resistivity of these media. The corrosion rate of two method results in (soil > sand > porcelanite stone > gravel). The lower corrosion rate happened in gravel media because of characteristics of high electrical resistivity and lower porosity for gravel while the higher corrosion rate occurred in the soil.

**Keywords:** Low carbon steel, corrosion rate, medias, electrical resistivity, soil, sand, porcelanite media, gravel.

### 1. Introduction

The study of soil as a corrosive medium is important taking into account the large amount of buried structures. The deterioration of that kind of structures could represent economic, safety, and environmental problems through the years. Soil as defined is an aggregate of minerals, organic matter, water, and gases (mostly air). It is formed by the combined weathering action of wind and water, and also organic decay [1]. Then the corrosion process of buried metal structure is extremely variable and can range from rapid to negligible [2]. The corrosiveness of the soil can be defined as the capacity of producing and developing the corrosion phenomenon. Soil is defined as an electrolyte and can be studied by electrochemical methods [3]. The factors effects of corrosive in soil included:

- Electrical resistivity
- Porosity
- Dissolved salts including depolarizes or inhibitors
- Moisture
- pH.

Each of these variables may affect the anodic and cathodic polarization characteristics of a metal in a soil [4]. Soil electrical resistivity is an important parameter in underground corrosion. In general, the lower the resistivity, the higher the corrosion rate as shown in (Table 1).

**Table1,**  
**Corrosivity rating based on soil resistivity [1].**

| Soil resistivity<br>$\Omega \cdot \text{cm}$ | Corrosion rating         |
|--|--------------------------|
| >20,000                                      | Essentially noncorrosive |
| 10,000-20,000                                | Mildly corrosive         |
| 5000-10,000                                  | Moderately corrosive     |
| 3000-5000                                    | Corrosive                |
| 1000-3000                                    | High corrosive           |
| <1000  | Extremely corrosive      |

Ions from dissolved salts and minerals must migrate through the electrolyte in a soil to supply the metal surface with the electron donors or acceptors necessary for the corrosion reaction to proceed. Soil resistivity is a measure of the concentration of these ions and how easily they move through the soil environment [6]. Metals buried in low resistivity soils will generally be anodic, whereas metals buried in adjacent high resistivity soils will generally be cathode. While the completely free of water has an extremely high resistivity. For example, sandy soils that easily drain water away are typically noncorrosive; clayey soils that hold water have low resistivity and are typically corrosive.

Alteration soil one method of corrosion control soil high in organic acids can be made less corrosive by surrounding the metal structure with limestone chips. A layer of chalk ( $\text{CaCO}_3$ ) surrounding buried pipes has been used in some soil formations likely to produce microbiologically influenced corrosion [4]. The resistivity indicates the probable corrosivity of the soil decreases with increasing water contents ions, thus nonporous soils. Exhibit relatively high value of resistance, since the water content is small; these include nearly all of the igneous and metamorphic rocks such as granite, plus much sedimentary rock such as dense limestone or sandstone. The resistivity of bedrock can vary considerably depending upon the type of bedrock and extent of weathering and fracturing. The resistivity of the sand and gravel deposits generally high and uniform, while many bedrock formations have high but erratic resistivity or in the other word Clay soils and shale layers generally have low resistivity values resulting from their inherent moisture and mineral content. Very dry sand, gravel or rock has a very high resistance. As empty pore space fills the water,

resistivity decreases. Materials that lack pore space such as massive limestone, granite, and basalt have high resistivity. All other factors being constant, the degree to which crack and fissure are present controls the resistivity of rock [2]. In (Table 2) typical resistivity values minerals and soils are given.

## 2. Experimental Work

Corrosion rate was measured for specimen of low carbon steel in four different media (soil, sand, porcelainite stone and gravel). (Table 3) shows the chemical composition of the low carbon steel. The specimen prepared for corrosion and microstructure test included grinding, polishing, etching and examination processes. (Fig. 1) shows the microstructure of low carbon steel before it was buried in different media.

Methods of measuring the corrosion rate:

1. Weight loss: In these method specimens was buried in (soil, sand, porcelainite stone and gravel) separately for 90days. The corrosion rate (CR), was calculated using the following formula:

$$\text{CR} = \Delta W / AT \quad \dots(1)$$

CR: Corrosion rate in mdd.

$\Delta W$ : weight loss in milligrams.

A: Exposed surface area in  $\text{cm}^2$ .

T: time exposure in days.

The conversion of corrosion rate in units milepenetration per years (mpy) by following relationship [7]:

$$\text{C.R (mpy)} = (1.44/\text{S.G})\text{C.R (mdd)} \quad \dots(2)$$

Where:

mpy: corrosion rate unit (mils penetration per year)

S.G: specific density of metal (for steel = 7.9  $\text{mg}/\text{cm}^3$ ).

2. Electrochemical techniques called polarization method this method is carried and consisting with an instrument of an electrochemical cell. The electrochemical cell contain three electrodes immersed in the solution ,working electrode (WE) which represents the studied sample ,reference electrode (calomel) and an auxiliary (platinum) electrode, the cell is connected to a device ,which allows the changing in current range and measuring the output potential as a function of current ,at which the input and output data are controlled by computer program .the applied current is a linear function potential.

The corrosion of metal in soil depends upon its resistivity. Electrochemical polarization methods are used for measuring corrosion rate using three solutions of resistivity of (20, 10000, 20000)  $\Omega\cdot\text{cm}$ , (20 $\Omega\cdot\text{cm}$ ) for soil measurement by use device (soil box resistivity and DET5/4D Megger Digital Earth Tester) shown in (Fig. 2), (10000 $\Omega\cdot\text{cm}$ ) for sand and porcelanite, and 20000 for gravel [2],

Table (4) represents the equivalent values of the resistivity of this media depending on the standard value with varying the concentration of NaCl as shown in (Table 4). The electrical conductivity of the solution was measured using digital electrical conductivity meter model (DDS-307) which is shown in (Fig. 3).

**Table 2,**  
**Electrical resistivity of various minerals and soil [2].**

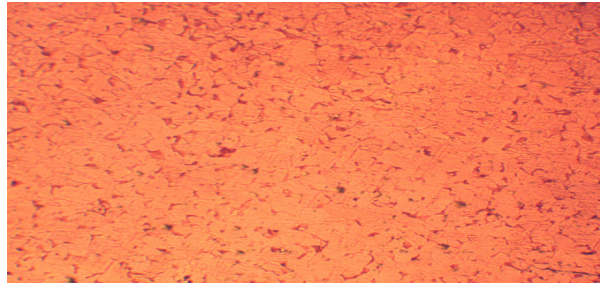
| Minerals and Soil               | Resistivity , $\Omega\cdot\text{cm}$ |
|---------------------------------|--------------------------------------|
| <b>Minerals</b>                 |                                      |
| Pyrite                          | 0.1                                  |
| Magnetite                       | 0.6-1.0                              |
| Graphite                        | 0.03                                 |
| Rock Salt(impure)               | 3000-500 000                         |
| Serpentine                      | 20 000                               |
| <b>Igneoue Rock</b>             |                                      |
| Granite                         | 500 000-100 000                      |
| Diorite                         | 1 000 000                            |
| Gabbro                          | 10 000 000-1 400 000 000             |
| Diabase                         | 310 000                              |
| <b>Metamorphic Rocks</b>        |                                      |
| Garnet gneiss                   | 20 000 000                           |
| Mica chist                      | 130 000                              |
| Biotite gneiss                  | 100 000 000 -600 000 000             |
| Slate                           | 64 000 -6 500 000                    |
| <b>Sedimentary Rock</b>         |                                      |
| Chattanooga Shale               | 2000-130 000                         |
| Michingan Shale                 | 200 000                              |
| Calumet and hecla conglomerates | 200 000-1 300 000                    |
| Muschelkalk sandstone           | 7000                                 |
| Ferruginous sandstone           | 18 000                               |
| Muschelkalk limestone           | 18 000                               |
| Marl                            | 7000                                 |
| Glacial till                    | 50 000                               |
| <b>Type of Soil</b>             |                                      |
| sand                            | 10 000- 500 000                      |
| oil sand                        | 400 – 22 000                         |
| Gravel                          | 20 000 – 400 000                     |
| Loam                            | 3000- 20 000                         |
| Clay                            | 500 -2000                            |
| Silt                            | 1000 -2000                           |

**Table 3,**  
**The chemical composition of the specimen.**

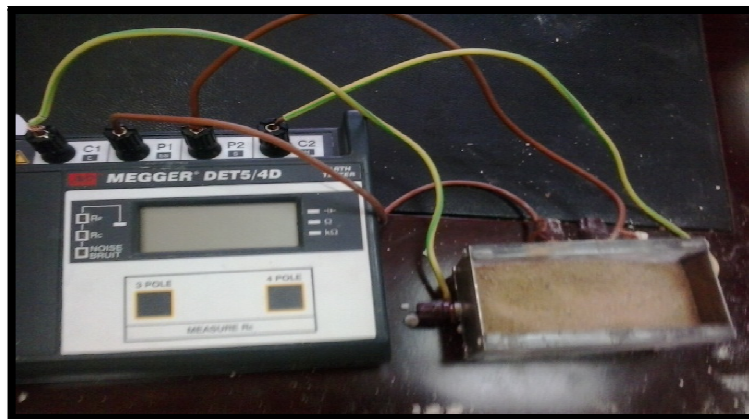
| Alloy %   | C    | Si   | Mn  | Fe    |
|-----------|------|------|-----|-------|
| Component | 0.16 | 0.15 | 0.7 | Reme. |

**Table 4,**  
**Equivalence of resistivity by NaCl concentration.**

| NaCl content g\L | Concentration % | Resistivity $\Omega\cdot\text{cm}$ | Conductivity ( $\mu\Omega/\text{cm}$ ) |
|------------------|-----------------|------------------------------------|--|
| .30              | 3               | 20                                 | 50 000                                 |
| 0.04             | 0.004           | 10000                              | 100                                    |
| 0.0187           | 0.00187         | 20000                              | 50                                     |



**Fig.1.** the microstructure of surface of low carbon steel specimen before it was buried in different media (200X).



**Fig. 2.** Devices connected and the experiment of electrical resistivity measurement.



**Fig.3.** Digital electrical conductivity meter.

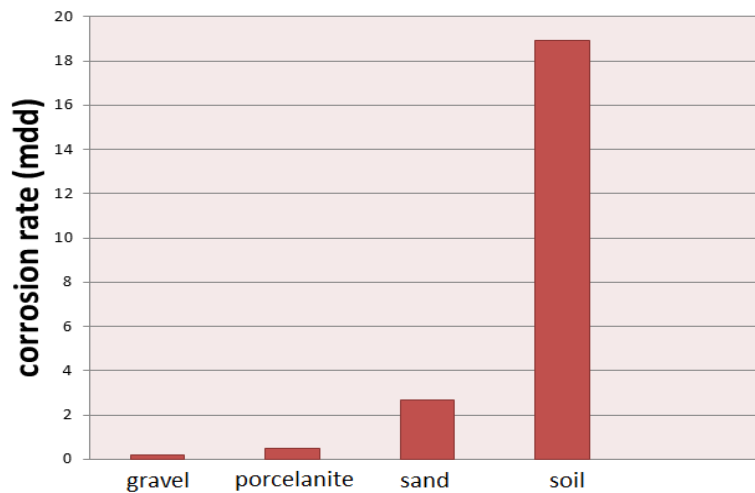


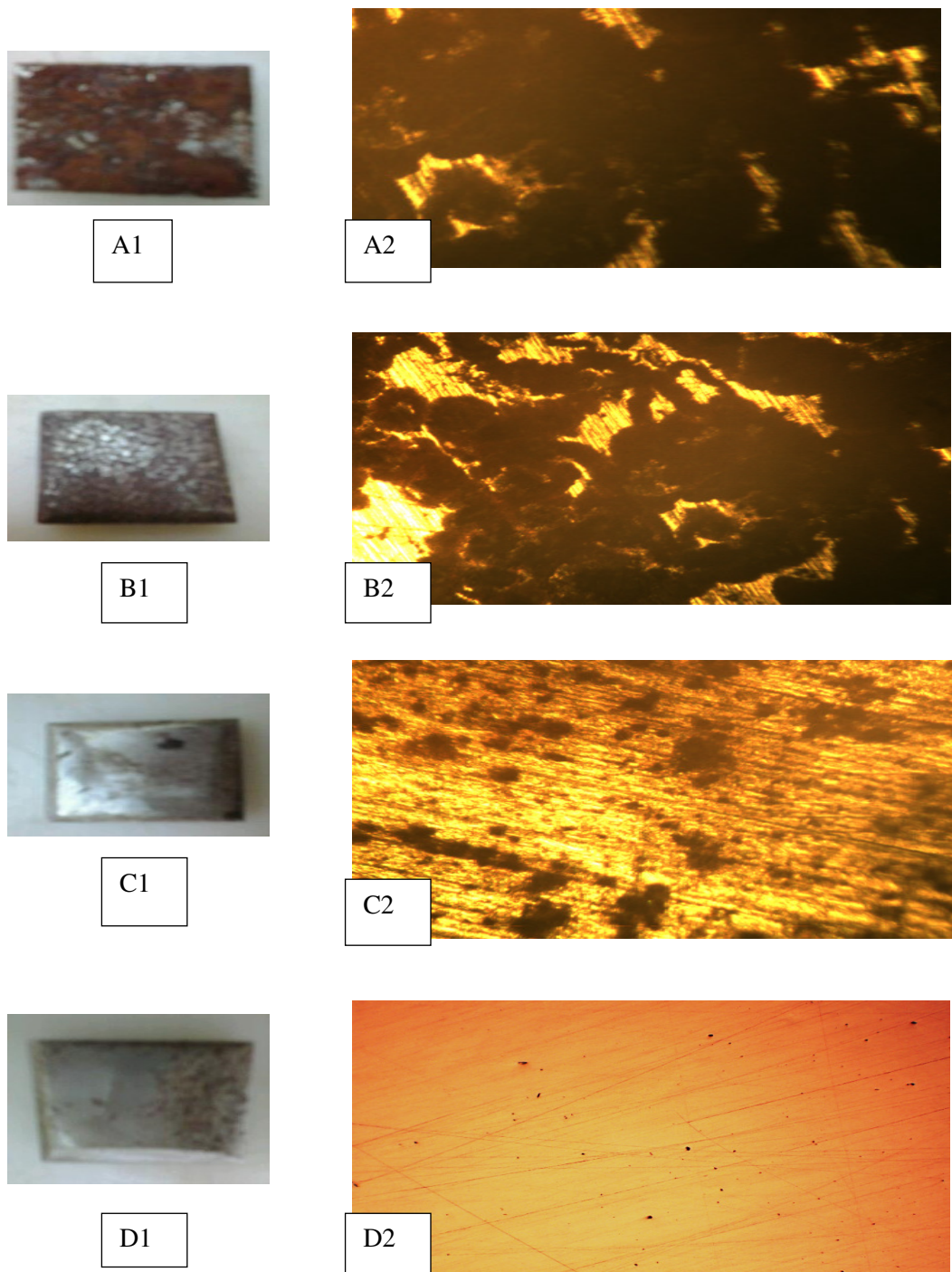
Fig.4. Shows corrosion rates of low carbon steel in different media the buried for 90 days.

Table 5,  
Corrosion rates (mdd) and (mpy) for low carbon steel specimen at different medias.

| Media             | Corrosion rate (mdd) | Corrosion rate (mpy) |
|-------------------|----------------------|----------------------|
| Soil              | 18.93628             | 3.4516               |
| Sand              | 2.6717933            | 0.4870               |
| Porcelanite stone | 0.516                | 0.094055             |
| Gravel            | 0.2231               | 0.040666             |

Table 6,  
The corrosion rate of specimen of low carbon steel by polarization method.

| Resistivity ( $\Omega \cdot \text{cm}$ ) | Corrosion potential $E_{\text{corr}}$ (mV) | Corrosion current density $i_{\text{corr}}$ ( $\mu\text{A}/\text{cm}^2$ ) | Corrosion rate (mpy) |
|--|--|---|----------------------|
| 20                                       | -450.1                                     | 199.21  | 83.592               |
| 10000                                    | -330.9                                     | 14.38   | 6.03413              |
| 20000                                    | -268                                       | 13.16   | 5.522                |



**Fig. 5. (A<sub>1</sub>, A<sub>2</sub>), (B<sub>1</sub>, B<sub>2</sub>), (C<sub>1</sub>, C<sub>2</sub>) and (D<sub>1</sub>, D<sub>2</sub>) photographs and the microstructure of the surface specimens buried in soil, sand, porcelainite and gravel respectively (200X).**

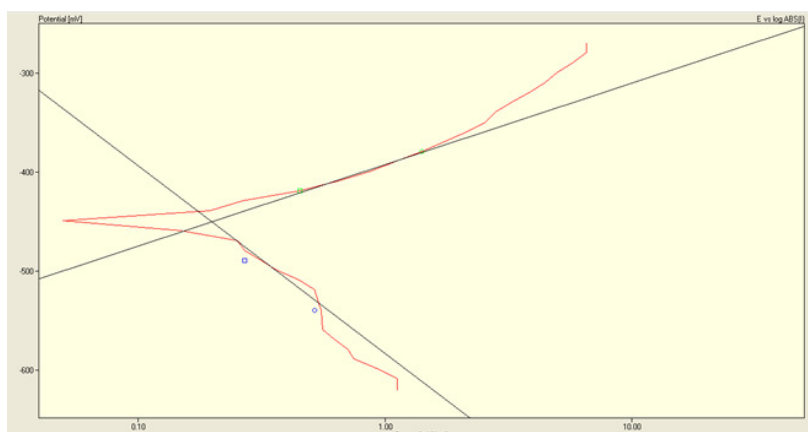


Fig. 6. Polarization curve of specimen of low carbon test in solution with electrical resistivity (20  $\Omega$ . cm).

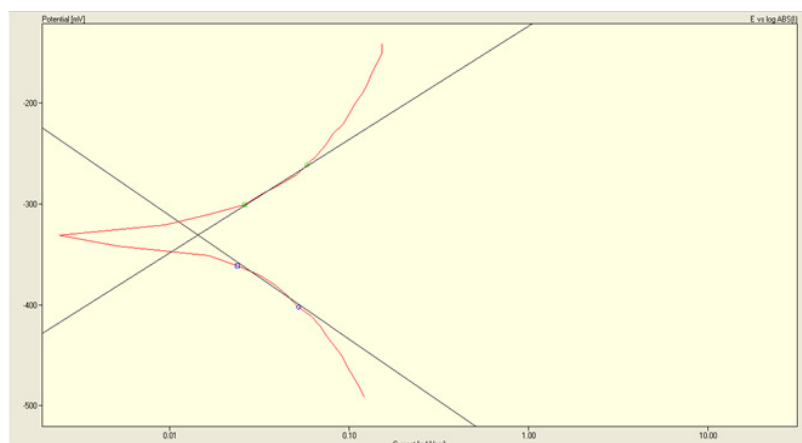


Fig.7. Polarization curve for specimen of low carbon steel in solution with electrical resistivity (10000  $\Omega$ . cm).

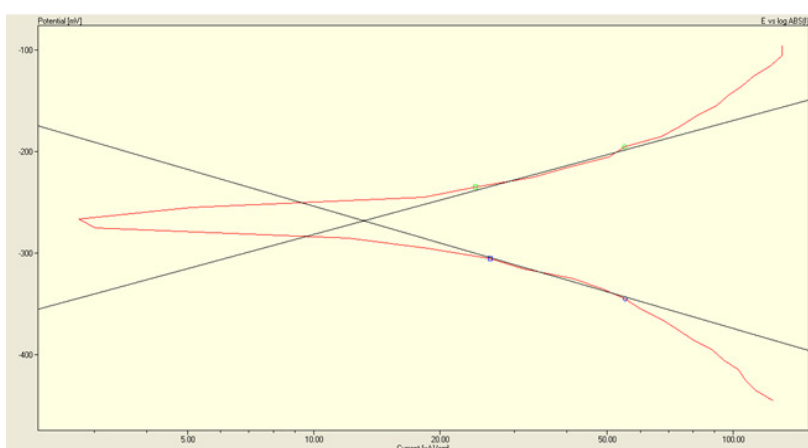
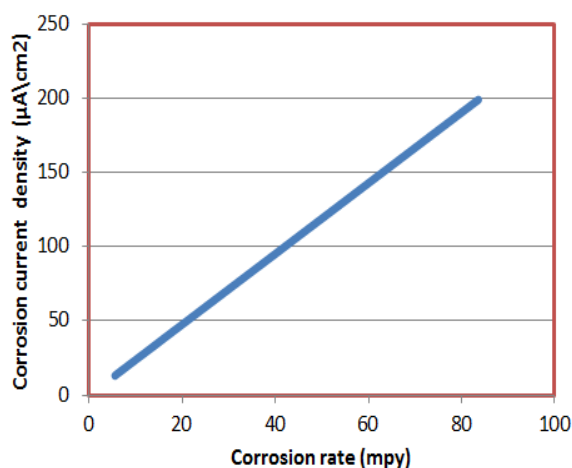


Fig.8. Polarization curve for specimen of low carbon steel in solution with electrical resistivity (20000  $\Omega$ . cm).



**Fig.9. The relationship between corrosion rate and current density.**

### 3. Results and Discussion

( Fig .4 ) and (Table 5) represents the corrosion rate of low carbon steel specimens in different media (soil ,sand ,porcelanite stone and gravel) calculated by weight loss (first method) , specimens buried in this media for 90 days. Note that the corrosion rates in (soil> sand >porcelanite stone> gravel), are the highest corrosion rates occurring in the soil and the less the corrosion rate occur in gravel because the highest electrical resistivity.

(Fig.5) shows the photographs and the microstructure of the surface of low carbon steel specimens after buried in different media. So the corrosion on surface of specimen buried in soil and sand can be observed, the corrosion product seen here is rust, surface color was dark orange to brown. Those areas that are dark in color contain significant sediment on the surface as shown in (Fig. 5) at (A 1, A2) and (B1, B2).The corrosion product on surface of specimen buried in porcelanite stone and gravel show very low , surface color ranging light orange to dark orange, and the rust is not uniform as shown in Figure (5) at (C1,C2)and (D1,D2).

Calculation of corrosion rates by the second method (polarization method) using three solutions with different electrical resistivity (20,10000,20000) Ω.cm representing the electrical resistivity of (soil, sand and porcelanite stone ,gravel) respectively. The solution resistances are very low as would be the case with a specimen

having a high corrosion rate ,the effect of the solution resistance may be a significant portion of the corrosion current reading , where corrosion rate can by determined be the following relationship [8]:

$$\text{Corrosion rate (mpy)} = 0.13 \cdot i_{\text{Corr}} \cdot e/D \quad \dots(3)$$

Where :

$i_{\text{corr}}$ : Corrosion current density  $\mu\text{A}/\text{cm}^2$

$e$  :Equivalent weight (for steel= 25.5)

$D$  :Density of metal(for steel = 7.9 gm/cm<sup>3</sup>)

The polarization gave us values corrosion potential ( $E_{\text{corr}}$ ) y-axis and corrosion current density ( $i_{\text{corr}}$ ) x-axis as shows in (Table 6) and (Fig. (6), (7), (8)). The result higher corrosion current density ( $i_{\text{corr}}$ ) at low electrical resistivity values (20Ω.cm) this indicates the high corrosion rate , while lower corrosion current density ( $i_{\text{corr}}$ ) in high electrical resistivity solution (20000Ω.cm) indicates the lower corrosion rate. Results show a propotional relationship of corrosion rate with current density, but inversily proportional with resistivity, this is due to the reduction of water content, the density increases (soil,sand,porcelanite and gravel) which reflects at the values of resistivities.In (Fig. 9) shows relationship between corrosion rate and corrosion current density .

Show presenceis a difference in the rate of corrosion between two methods corrosion rate higher in polarization method than weight loss the reason , The corrosion behavior of iron and steel buried in the soil approximates , in some respects, the behavior of the iron and steel on total immersion in water [4]. When soil resistivity value (> 20,000Ω.cm) essentially noncorrosive [1], This point different corrosion between soil and water, very pure or very soft waters are often excellent solvents for metallic ions. If these waters are very pure or very soft waters are often excellent solvents for metallic ions [9].

Rates corrosion in media depended on the characteristics of the media buried metal structure , Many factors affected of corrosion rate, important factor affected electrical resistivity and porosity . Lower corrosion rate in media with high electrical resistivity and less porosity (more dense ) .Than gravel of these four media is best media protect from corrosion .

#### 4. Conclusions

1. Corrosion rates of structure metal buried in media depend on the characteristics of this media (electrical resistivity, porosity, hydraulic permeability which describes how pores are interconnected, etc.).
2. Electrical resistivity of media is important factor effect on corrosion rate for metal buried in it.
3. Select best media for buried metal structure with low corrosion rate. Sand, porcelaine stone and gravel have best corrosion resistance compared to soil.
4. Gravel is the best media with higher corrosion resistance.

#### 5. Reference

- [1] Roberge P.R, "Handbook of Corrosion Engineering", McGraw-Hill, USA 2000.
- [2] Robert Baboian, "Corrosion Test and Standards: Application and Interpretation", Second Edition, ASTM Stock Number: MN120-20nd, 2005.
- [3] Córdoba V. C., Mejía M. A., Echeverría F., Morales M. and Calderón J. A. , "Corrosion mitigation of buried structures by soils modification", Chilean Journal of Engineering, vol. 19, No.3, pp486-497, 2011.
- [4] Winston R. R., Herbert U. H., "Corrosion and Corrosion Control", Fourth Edition, USA, 2006.
- [5] M. Romanoff, "Underground Corrosion," NBS 579, NTIS PB 168,350, National Bureau of Standards, April 1957.
- [6] 6. "Standard Method for Field Measurement of Soil Resistivity Using the Wenner Four-Electrode Method," G 57, Annual Book of ASTM Standards, American Society for Testing and Materials, 1995.
- [7] Naser Korde, "Cathodic Protection of Steel Pipelines Using Solar Energy", MSc Thesis, Department of Production Engineering and Metallurgy, University of Technology, 2012.
- [8] Formerly EFM, Engineering Field Handbook, Engineering Field Manual Notice NB-21, 1979.
- [9] ASM Handbook, "Corrosion Fundamentals, Testing, and Protection", Vol .13A, ASM, 2003.

## حماية التآكل للفولاذ الكربوني المدفون بوساطة تغير الوسط

امل صالح مرزّه\*

محمد هليل حافظ \*\*

ساره كريم محمد\*\*\*

\* \*\*\*/ الكليه التقنيه- بغداد

\*\*قسم تكنولوجيا النفط / الجامعة التكنولوجية

\*البريد الالكتروني: [amelmerza@yahoo.com](mailto:amelmerza@yahoo.com)\*\*البريد الالكتروني: [Drmhh1962@gmail.com](mailto:Drmhh1962@gmail.com)\*\*\*البريد الالكتروني: [Sarah\\_materials@yahoo.com](mailto:Sarah_materials@yahoo.com)

### الخلاصة

الهدف من هذا العمل هو السيطرة على تآكل المعدن المدفون بطريقة استبدال أوساط، وهذه الطريقة تعتمد على خصائص كل وسط . حيث حسبت معدلات التآكل لعينات من فولاذ منخفض الكربون في اوساط مختلفة واختيار افضل وسط حامي من التآكل والأوساط تشمل (التربة، الرمل، صخر البورسلينات والحصى) . حسبت معدلات التآكل بطريقتين طريقة فقدان الوزن وطريقة الاستقطاب، قيس فقدان الوزن بـ ٩٠ يوماً) وطريقة الاستقطاب تضمنت تحضير محاليل ملحية تملك مقاومات كهربائية مكافئة للأوساط المستخدمه وحساب معدلات التآكل في هذه المحاليل. اظهرت نتائج معدلات التآكل على نحو التالي (التربة < الرمل < صخر البورسلينات < الحصى). اقل معدلات تآكل حصلت للعينات المدفونة في الحصى بسبب خصائص هذا الوسط من مقاومة كهربائية عالية ومسامية قليلة واقل معدلات تآكل حدثت للعينات المدفونة في التربة.