The Evaluation of Brass and Low Carbon Steel Corrosion in Gabraun Water

*Abdussalam Abdallah Mohammed Gebril[1] , Ali Elzarog Ali[2]
[1]Materials and corrosion Engineering Department, Faculty of energy and Mining Engineering
Sebha University, Libya
[2]Chemical Engineering Department, Faculty of energy and Mining Engineering, Sebha University,
Libya
*Corresponding author: abd.gebril@sebhau.edu.ly

Abstract This work aimed to study the effect of Gabraun`s water on corrosion of brass and low carbon steel. The corrosion tests were carried out at room temperature. The test solution used was Gabraun water samples. From the results obtained, the weights of all the specimens after the immersion in Gabraun`s water were decreased. After the end of the experiments, the color of the Gabraun water samples that was used for the brass specimens was changed to dark blue color, but for the low carbon steel the color of the water did not change. During the corrosion tests period, the Gabraun water in the beakers was decreased about 50mL/week, this lack was substituted continuously by Gabraun water during the tests period. This addition of water, increased the concentration of the salts of the Gabraun water samples. This increment was played a role in the corrosion process. The average corrosion rate for the low carbon steel is less than yellow copper specimens. The Langelier Saturation Index (LSI) showed that the Gabraun water sample was not corrosive medium, also it showed all the Gabroun waters samples after testing all the specimens were not corrosive medium. The Pourbaix diagrams for both copper and iron in the water at 25°C showed both copper and iron are not corrode metals.
Keywords: Brass, Low Carbon Steel, Gabraun Water, Corrosion rate, Pourbaix diagrams, Langelier Saturation Index.

<div dir="rtl">

تقييم تآكل النحاس الأصفر و الصلب المنخفض الكربون في ماء قبرعون

*عبدالسلام عبدالله محمد جبريل1 و علي الزروق علي2

1قسم هندسة المواد و التآكل-كلية هندسة الطاقة و التعدين-جامعة سبها، ليبيا

2قسم الهندسة الكيميائية-كلية هندسة الطاقة و التعدين-جامعة سبها، ليبيا

*للمراسلة:abd.gebril@sebhau.edu.ly

الملخص هذا العمل يهدف لدراسة تأثير ماء قبرعون علي تآكل سبيكة النحاس الأصفر والصلب المنخفض الكربون. أجريت اختبارات التآكل في درجة حرارة الغرفة. تم استخدام عينات من ماء قبرعون كمحلول للاختبارات. النتاج المتحصل عليها، هي نقص أوزان العينات بعد الغمر في ماء قبرعون وأيضا بعد الانتهاء من التجارب اتضح بأن لون عينات ماء قبرعون المستخدمة لسبيكة النحاس الأصفر تغير إلى اللون الأزرق الداكن، أما بالنسبة لعينات ماء قبرعون المستخدمة للصلب المنخفض الكربون لم يتغير لونها. وفي خلال فترة الاختبارات لوحظ نقص في عينات ماء قبرعون في الأكواب بمعدل 50مل في الأسبوع وهذا النقص يتم تعويضه باستمرار بماء قبرعون وتبين ان هذه الإضافة من الماء تزيد في تركيز الأملاح وهذه الزيادة لعبة دور في عملية التآكل. متوسط معدل التآكل لعينات الصلب المنخفض الكربون اقل من عينات سبيكة النحاس الأصفر وأيضا دليل لانجليز المشبع (LSI) وضح إن عينات ماء قبرعون ليست أوساط أكالة وكذلك اتضح بأن العينات بعد الاختبارات ليست أوساط أكالة. نموذج بوربياكس الخاص بالنحاس وأيضا الخاص بالحديد في الماء عند درجة حرارة 25مo، بينا أن النحاس والحديد ليست معادن متآكلة في هذه الأوساط.

الكلمات المفتاحية: النحاس الأصفر، الصلب المنخفض الكربون، ماء قبرعون، معدل التآكل، نموذج بوربياكس، دليل لانجليز المشبع.

</div>

1- Introduction

Gabraun`s water is from Gabraun`s lake, this lake located in the middle of Libyan desert surrounded by a belt of palm trees and sand dunes towering height, the depth of this lake is about 7m and also it is characterized by its warm water start nearly from a depth of 1.5m. In addition, this lake has high Salinity[1].

Basically Corrosion is the result of chemical or electrochemical interaction between a metal and environments. In the broad sense, corrosion may be defined as "the destructive attack of a metal by chemical, electrochemical, or metallurgical interaction between the environment and the metal [2, 3]. It is a chemical reaction that involves oxidation and reduction. The corrosion of metals can also occur in freshwater, seawater, salt solutions, and alkaline or basic medium. The most familiar corrosion of this type is the rusting of iron when exposed to a moist atmosphere or water [4].

$$4Fe+6H_2O+3O_2 \rightarrow 4Fe(OH) \ldots\ldots(1)$$
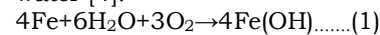
As shown in the equation (1), iron combination with water and oxygen, yielding ferric hydroxide, an insoluble red-brown substance [4].

Brass is mainly an alloy that consists of copper with zinc added and had good atmospheric corrosion resistance. Brasses can have varying amounts of zinc or other elements added. Brass can range in color from red to yellow depending on the amount of zinc added to the alloy [5, 6, 7].

Memon Samina *et al* :[8] studied the corrosion of iron, copper and brass alloy in different medium *i.e.* HNO_3, H_3PO_4, H_2SO_4, HCl, CH_3COOH. The study reveals that the corrosion rate increases in the order, iron > copper > brass and for the medium the corrosion follows the order HNO_3 > H_3PO_4 > H_2SO_4 > HCl > CH_3COOH.

W.H. Rahmanto *et al* :[9] investigated Copper and iron metal wire corrosion in artificial seawater in three corrosion systems. In the (i) closed bath, (ii) opened or air exposed bath, and (iii) aerated bath. Results show that air oxygen give a strong effect on the corrosion of copper and iron metal.

Howaida M. *et al* :[10] studied the rate of copper corrosion in the presence of phosphoric. The rate of corrosion is measured in the presence and in the absence of benzoic acid, p-toluic acid, phthalic acid and salicylic acid. In the presence of these acids, the rate of corrosion decrease.

Jamal Abdulnasser *et al* :[11] studied The inhibition effect of the addition of organic compounds containing a sulphur group such as Diethyl sulphide (DES) on the corrosion of copper in nitric acid, results obtained revealed that the organic compound is a good inhibitor.

E.E. Foad El-Sherbini *et al*:[12] studied the dissolution of copper in hydrochloric acid medium and the effect of potassium chromate and sodium molybdate on the corrosion process. The corrosion rate was retarded in presence of sodium molybdate.

A Pourbaix diagram for the copper/water system is shown in Fig. (1) [13]. Copper (E = 0.337 V) is nobler than iron (E_{Fe}=−0.444V), however, it is more stable in water (SHE) than iron. Copper is not passive in acid electrolytes. It would also corrode under strongly alkaline conditions in higher oxidizing potentials [13].
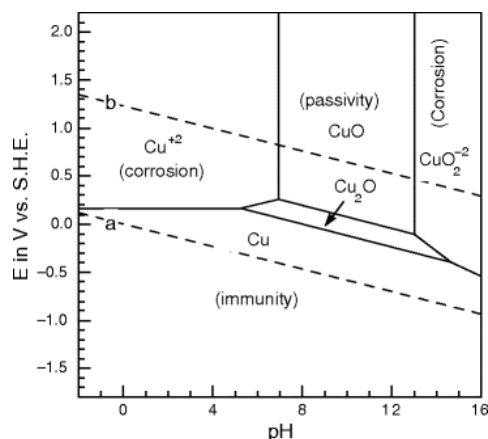

Figure (1) Pourbaix diagram for the copper–water system at 25°C[13]

Dezincification occurs when zinc leaches out of the alloy, leaving behind a copper-rich shell with little mechanical strength. Dezincification can be avoided in most cases by maintaining the zinc content below 15% [14].

Jamal Choucri *et al* [15] had found that the dezincification of CuZn36Pb2As and traditional alloys only affected the β' phase, while on CuZn21Si3P dealloying produced zinc and silicon leaching from both α and κ phases.

Carbon steel is classified according to the percentage of carbon. They are referred to low carbon steels, medium carbon steels, and high carbon steels [7].

Subir Paul et al.[16] have concluded that all three corrosive ions SO_4^{2-}, S^{2-}, and Cl^- have a strong effect on increasing the corrosion rate of carbon steel.

Uzorh *et al* :[17] Evaluated the corrosion of two grades of plain carbon steels, DIN 35-2 (Ribbed rod) and DIN 37-2 (plain rod) in three environments: Salt solution, Tap water and Moist soil. The results obtained show that the moist soil having the highest corrosive ability, followed by tap water and then 3% by weight of sodium chloride salt solution. Moreover, the rib rod samples essentially corroded more than the plain rod samples in these various environments.

Tadeusz Hryniewicz et al:[18] studied the corrosion behavior of C45 carbon steel. Two different medium, based on sodium chloride as the corrosive agent, were applied for the electrochemical studies, with one of them imitating the synthetic seawater environment. The results showed that the corrosion resistance increases almost 3 times in case of 3% NaCl solution, and 1.6 times for 0.03% NaCl solution.

Ismaeel Andijani *et al* :[19] evaluated the corrosion behavior of carbon steel in deaerated 1.0 M NaCl solutions and artificial seawater at pH ranges of 3 to 8.5 and temperatures up to 80°C under static conditions. The results revealed that the polarization resistance of carbon steel in deaerated solutions is generally high. With increasing pH, the polarization resistance increases, and is highest at 25°C and lowest at 80°C.

Sanusi Kazeem Oladele *et al* :[20] investigated the corrosion effect of mild steel in orange juice. This research proved that mild steels are corrosive in fruit juice environments.

Ismail *et al* :[21] studied the corrosion behaviour of AISI 1040 steel in artificial seawater and different sulphate (SO_4^{2-}) to chloride (Cl^-) ratio. It was concluded that the corrosion rate of carbon steel in NaCl as compared to the corrosion rate in different sulphate and chloride content in with and without oxygen content. The corrosion rates are higher in solutions with oxygen content in all solutions.

Mohammadreza Tavakkolizadeh *et al* :[22] studied the galvanic corrosion of carbon and steel in aggressive environments. It was concluded that the galvanic corrosion rate in the deicing salt solution was slightly higher than that in seawater (15% on average).

Gebril and N. Ali [23] studied The effect of Gabraun water, Distilled water & Different Volumes of their mixture on the corrosion rate of

carbon steel and concluded that Gabraun water sample is not corrosive media.

Gebril [24] study the effect of Gabraun`s water on corrosion of low carbon steel compared with the water from Zweala, Ubari and Sebha and concluded that Gabraun water sample is not a corrosive medium (scale formation can occur), while the other types of water samples are a corrosive medium.

Figure (2) illustrates the potential pH diagram (Pourbaix diagram) for iron exposed to water. The various regions indicate the compounds which are stable under those conditions. For example, at potential more positive than -0.6 and pH values below about 9, ferrous ion(Fe^{+2}) is the stable substance [4]. This indicates that iron will be corroded under these conditions, yielding Fe^{+2} as can be seen in equation (2) [4]

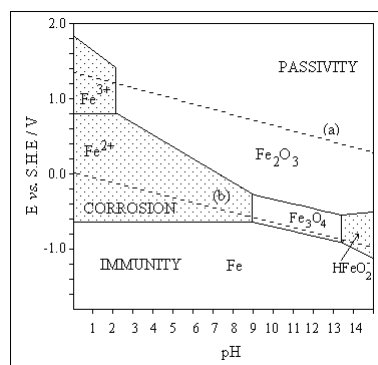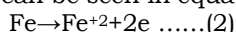$Fe \rightarrow Fe^{+2} + 2e$ ......(2)

Figure (2) Simplified potential-pH diagram (Pourbaix diagram) for the Fe-H$_2$O system [4].

[4]. The large region in figure (2) labeled **Fe** indicates that iron will not corrode under these conditions of potential and pH.

2- Experimental work

2.1. Materials

The materials used in this work were Brass (yellow copper), and low carbon steel. Carbon steel.

The chemical compositions for the material of Brass (yellow copper) and low carbon steel that was used in the experiments are shown in Table(1) and Table (2) respectively.

Table 1. Chemical composition by wt% of Brass (yellow copper) specimens before tests

Cu%	Zn%	Pb%	Si%	Ni%	Sn%	Fe%	Nb%	P%	Pt%	Au%	As%	Co%	others
57.8	37.6	2.03	1.41	0.254	0.233	0.207	0.0957	0.0688	0.0276	0.0269	0.0252	0.0153	balance

Table 2. Chemical composition by wt% of low carbon steel specimens

Wt% C	wt% Si	Wt% Mn	Wt % S	wt%P	Wt% Fe
0.153	0.046	0.424	0.048	0.012	Balance

Eight (8) specimens used in this work were cut from metal rods with square cross-sectional areas and with dimensions of 10mm long, 10mm width and 10mm thickness as shown in figure (3).

Four (4) specimens, from low carbon steel and Four (4) specimens, from Brass (yellow copper).

All the surfaces of the specimens were cleaned well and polished with 800 and1200 grit emery papers to remove oxides and contaminants.
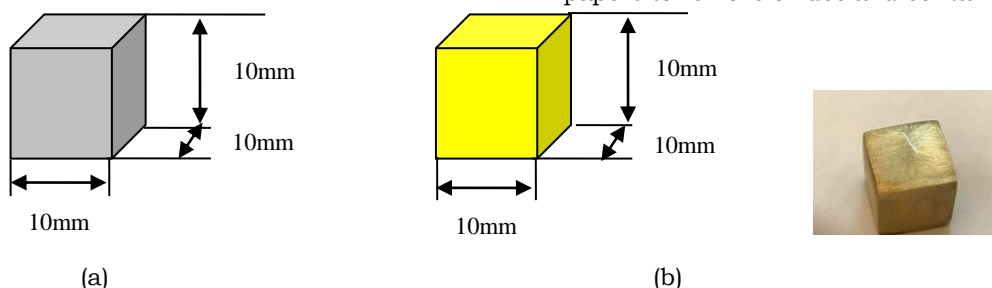

(a)

(b)

Figure (3) The dimension of al specimens (a) for low carbon steel & (b) for brass (yellow copper)

2.2. Corrosion tests

Gabraun water was used as a test solution in this work, and a number of 500 ml beakers were used and filled by this type of water and then all the specimens were completely immersed in the filled beakers. Each specimen was put in one beaker. All the specimens were

cleaned and weighed before and after the corrosion tests. All the tests were carried out at room temperature. The corrosion test period was 55 days for all the specimens. The chemical analysis of the used Gabraun water is shown in Table (3) was done in faculty of science sebha university.

Table 3. show the analysis of Gabraun's water before and after tests

Parameter	Gabraun water before immersion	Gabraun water after immersion Carbon steel	Gabraun water after immersion Yellow copper
Ph	9.41	11.41	11.26
Conductivity (µS/cm)	137800	233400	163900
Salinity (ppt)	790	141	960
TDS (mg/L)	67540	114340	80330
Total Alkalinity(mg/L)	314	422	401
Hardness Ca++ (mg/L)	335.1	412.3	395.4

In order to predict the tendencies of Gabraun water to precipitate or dissolve calcium carbonate, the Langelier Saturation Index (LSI) was designed to measure calcite formation and used as a measure of corrosion. Also, this index indicates the driving force for scale formation and growth in terms of pH as a master of a variable.

In order to calculate the LSI, it is necessary to know the alkalinity (mg/L, as $CaCO_3$, or calcite), the calcium hardness (mg/L Ca^{+2} as calcium carbonate), the total dissolved solids (TDS) (mg/L TDS), the actual pH, and the temperature of water (ᵒC) [25].

LSI is defined as the following equation [25]:

LSI = pH - pHs ....(2)

Where:

pH is the measured water pH.

pHs is the pH at saturation in calcite or calcium carbonate and is defined as [25]:

pHs=(9.3+A+B)-(C+D)................(3)

$A=\{log_{10}[TDS]-1\}/10$

$B=-13.12 \times log_{10}(^oC+273)+(34.55)$

$C=log_{10}[Ca^{2+}$ as $CaCO_3]-[0.4]$

$D=log_{10}[alkalinity$ as $CaCO_3]$

The LSI indicates three situations [25]:

If LSI is negative: No potential to scale, the water will dissolve $CaCO_3$.

If LSI is positive: Scale can form and $CaCO_3$ precipitation may occur.

If LSI is close to zero: Borderline scale potential.

2.3. Corrosion rate calculations

The corrosion rate was calculated by using the following relation[26]:

$$Corrosion\ rate = \frac{W \times 365}{\rho \times A \times T} ....(4)$$

Where:

W = weight loss (g)

365 = number of days per year (day/year)

A = the area of the specimen exposed to the solution (cm^2)

ρ = the metal density (7.8 g/cm^3)

T = exposure time of the specimens (55 days)

3- Results and discussion

Table (4) The results of the corrosion test for brass (yellow copper) specimens

No pecime	Weight before mmersion (g)	Weight after mmersion (g)	Weight loss (W) (g)	Area(Cm²)	Corrosion rate cm/year
1	8.3232	8.2755	0.0477	1	0.0405
2	8.2347	8.1950	0.0397	1	0.0337
3	8.1876	8.1442	0.0434	1	0.0369
4	8.3402	8.3034	0.0368	1	0.0313

Table 5. Chemical composition by wt% of Brass (yellow copper) specimens after tests

Cu %	Zn %	Si%	Al%	Cl%	Pb %	Ca %	K%	S%	P%	Ni%	Fe%	Sn%	Nb%	Pt%	Others
50.5	32.2	9.02	1.93	1.62	1.2	1.09	0.791	0.317	0.286	0.268	0.260	0.195	0.068	0.0361	Balance

Figure (4) The yellow copper specimen after testing

According to the corrosion tests results of the brass (yellow copper) mentioned above in Table (4), visual observations, the amount of the sulfate which is 25mg/liter and the amount of chlorides which is 0.8mg/liter in Gabraun water, it was seen that from the first two weeks of the immersion, the color of the water was changed to light blue color and became darker blue gradually until the end of the experiments, this color was attributed to the copper sulfate ($CuSO_4(H2O)$) produced from the corrosion reaction. Also, it was found that after two weeks

from the immersion, the amount of Gabraun water in the beakers was decreased about 50ml from each beaker. This resulted from the vaporization of the water, which was the result of the raise of the room temperature that was more than 25oC, this is because of the weather change in the Sebha region which was hot that time and the temperature was ranged from 25oC to 43oC.

The vaporization of the water during that time caused precipitation of salts around and at the base of the beakers. This lack of water in the beakers was substituted continuously by Gabraun water during the test period.

These salts (for example chlorine and others) and the addition of water, increased the concentration of the salts of the Gabraun water samples. This increment was played a role in the corrosion process, this what was happen in all the experiments.

According to the surfaces of the specimens, it was observed that the surface that was faced to the base of the beaker was not smooth as before the start of the experiments, it was rough, this is shown in figure (4).

Referring to the Table 1 and 5, it is shown that the percentage of Zinc and Cu has different values, it can be seen that the percentage of Zinc (Zn) before the immersion is 37.6 mass% and after the immersion is 32.2 mass%, also the percentage of copper (Cu) before the immersion is 57.8 mass% and after the immersion is 50.5

mass%. These results indicate that Zinc leaches out of the alloy or is removed from the alloy, leaving behind a porous copper-rich structure with little mechanical strength, this means that Dezincification is occurred [14, 15]. The higher the concentration of zinc in the brass, the more it can be affected by zinc leaching out of the alloy. Why Dezincification occurs Copper-zinc alloys containing more than 15% zinc are susceptible to dezincification[14, 15]. Zinc is a highly reactive metal, as seen in its galvanic series ranking. This reactivity stems from the fact that zinc has a very weak atomic bond relative to other metals. Simply, zinc atoms are easily given up to solutions with certain aggressive characteristics. During dezincification, the more active zinc is selectively removed from the brass, leaving behind a weak deposit of the porous, more noble copper-rich metal. Conditions favoring dezincification are contacted with slightly acid or alkaline water [14, 15]. According to this result, Dezincification is another parameter that played a role in the weight loss of the specimens and corrosion rate. Despite the LSI results and Pourbaix diagram show that the Gabraun water before and after the immersion is not corrosive media.

From the results in the Table (4), it can be seen that the weights after the immersion of the specimens are less than the weights before the immersion of the specimens, this indicates that there are corrosion and corrosion rate for the specimens.

Table (6). The results of the corrosion test for low carbon steel specimens

No Specimen	Weight before immersion (g)	Weight after immersion (g)	Weight loss (W) (g)	Area(Cm²)	Corrosion rate cm/year
1	7.4745	7.4683	0.0062	1	0.0052
2	7.5534	7.5424	0.0110	1	0.0093
3	7.5491	7.5383	0.0108	1	0.0091
4	7.6092	7.6032	0.0060	1	0.0051

Figure (5) The low carbon steel specimen after testing

According to the results of the corrosion tests of the low carbon steel specimens, the color of the water was not changed during the test period, but the color of the specimens was changed a little bit, this was due to the increase of the concentration of the water salts that assist the metal to be corroded and the presence of the two corrosive ions SO_4^{2-} and Cl^- which have a strong effect on increasing the corrosion rate of

carbon steel, this was approved by Subir Paul et al.[16].

According to the surfaces of the specimens, it was observed that the surface of the tested specimens that were faced to the base of the beaker was not smooth as before the start of the experiments, it was rough as shown in figure (5).

From the visual observations of the water, it was seen that some white salts precipitated at the base and around the wall of the beaker.

From the results in the Table (6), it can be seen that the weights after the immersion of the specimens are less than the weights before the immersion of the specimens, this indicates that there are corrosion and corrosion rate for the specimens.

The results mentioned above were expected to be the result of the oxidation reaction proceeds as rapidly as oxygen reaches the metal surface. The following chemical reaction equations can be clarifying the resulted rust[26].

$$Fe \rightarrow F e^{+2} + 2e^- \quad ....(5)$$

$$2H^+ + \frac{1}{2} O_2 \rightarrow H_2O + 2e^- \quad ....(6)$$
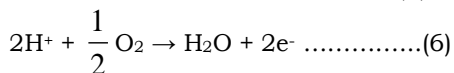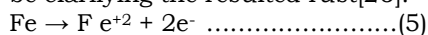
From the above equations, ferrous hydroxide can be obtained $Fe(OH)_2$.

$$Fe + H_2O + \frac{1}{2} O_2 \rightarrow Fe(OH)_2 \quad ....(7)$$
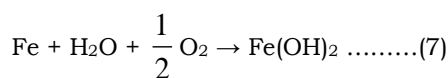
At the outer surface of the oxide film, access to dissolved oxygen converts ferrous oxide to hydrous ferric oxide or ferric hydroxide, in accord with the following equation

$$Fe(OH)_2 + \frac{1}{2} H_2O + \frac{1}{4} O_2 \rightarrow Fe(OH)_3 ....(8)$$
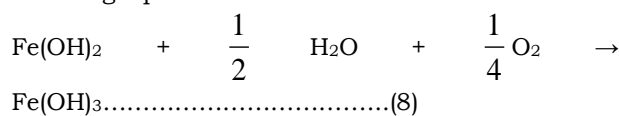
Hydrous ferric oxide $(Fe(OH)_3)$

From the images that were taken for all the tested specimens, small spots were seen on the surfaces, these spots were assumed to be pits.

As can be seen from the Table (7) shown below the lowest average corrosion rate is for the carbon steel specimens.

Table (7) The average corrosion rate

Type of the specimens	Average corrosion rate (cm/year)
Yellow copper (Brass)	0.0356
Carbon steel	0.00719

Table (8) Results of The Langelier Saturation Index (LSI)

Gabraun water before the test the specimens	Gabraun water after testing carbon steel specimens	Gabraun water after testing brass (yellow copper) specimens
2.355	4.551	4.377

As can be seen from Table (8) the highest Langelier Saturation Index (LSI) is for the gabraun water after testing carbon steel specimens, while the lowest Langelier Saturation Index (LSI) is for the gabraun water before the test the specimens.

Also referring to the results of the Langelier Saturation Index (LSI), showed that the Gabraun water sample was not corrosive media, also it showed all the Gabroun waters samples after testing all the specimens were not corrosive media. In addition, it is known that the potential (E) at 25°C for copper is = 0.337V and for iron is = -0.444V and from Table 3, the Ph of Gabrraun water before immersion is = 9.41, the Ph of Gabraun water after immersion low Carbon steel is = 11.41 and the Ph of Gabraun water after immersion Yellow copper is = 11.26. So from these results, the Pourbaix diagrams of copper and iron showed that copper and iron are in a passive region (are not corroded), while the results obtained were opposite to what it was expected, this is because the weights of all the specimens were decreased, this means that the corrosion rate exists. This is due to the increment of the concentration of the Gabraun water salts during the vaporization and the addition of the Gabraun water during the test period up to the original level, also increased the concentration of the salts. The increment of the concentration of the salts was played a role in the corrosion rate of all the specimens.

Referring to Table 3. that shows the analysis of all the samples of Gabraun's water before and after the immersion of the specimens, it was found that TDS of Gabraun water sample before the immersion is less than that after the Immersion. This means that the concentration of the salts of Gabraun water samples increases after the immersion (at the end of the experiments) which was affected on the corrosion and corrosion rate.

4- Conclusions

1. The colors of the Gabraun water used for brass (yellow copper) specimens corrosion tests were changed to dark blue color, this is due to the reaction between the copper (Cu) and sulfate (SO_4), produced copper sulfate ($CuSO_4$).

2. The color of the Gabraun water used for carbon steel specimens corrosion tests was not changed but the color of the specimens was changed a little bit.

3. The average corrosion rate of the low carbon steel specimens is less than the brass (yellow copper) specimens.

4. Small spots were seen on the surfaces, these spots were assumed to be pits.

5. After two weeks from the immersion of the specimens, the amount of water decreased about 50ml from each beaker, this resulted from the raise of the room temperature between 25°C to 43°C, this lack was substituted continuously during the test period.

6. The precipitations of salts around and at the base of the beakers were caused by the rise of the temperature that causes the vaporization of the water during test period time, and these salts and addition of the Gabraun water increased the concentration of the Gabraun salts.

7. Dezincification was played a role for decreasing the weight of the brass specimens

8. LSI and Pourbaix diagrams show Gabraou water is not corrosive media.

9. Dezincification is another parameter that played a role in the weight loss of the specimens and corrosion rate

References

[1]- www.startimes.com/?t=25903838 *(translated to English language on 27/3/2015)*

[2]- Sidney H. Avner. Introduction to physical metallurgy copyright@ 1974,1964 by Mcgraw-Hill, Inc. ISBN 0-07-002499-5.

[3]- Herbert H. Uhlig. Corrosion and corrosion control. Second Edition. Cpyright©1963, 1971, by John Wiley & Sons, Inc. ISBN 0-471-89563-6.

[4]- N. D. Green. Corrosion-related chemistry and electrochemistry. Chapter 3, Basic corrosion course, NACE, Copyright 1970. USA

[5]- W. Qafsaoui, G. Mankowski, P. Leterrible and F. Dabosi, Proc. Inf. Symp. on Control of Copper and Copper *alloys* Oxidation, July 6-8, 1992, Rotten, France MetaNurgie, (1992).

[6]- Sidney H. Avner "Introduction to physical Metallurgy" New York city community college city University of new York,1987.

[7]- Rakesh Dogra; Arvind Sharma "Advances in materials science "Beant college of Engineering and technology Gurdaspur (Punjab)1999.

[8]- Memon Samina, Abdulkarim and A.Venkatachalam. Corrosion Study of Iron and Copper Metals and Brass Alloy in Different Medium" Department of Post Graduate Studies and Research in Chemistry Bhavan's College, Andheri (W), Mumbai 400058, India Received 30 October 2010; Revised 4 March 2011; Accepted 12 April 2011 E-Journal of Chemistry2011, **8(S1),** S344-S348

[9]- W. H. Rahmanto, Gunawan, and Rahmad Nuryanto. Corrosion rate of Copper and Iron in sea water based on resistance measurement. Electrochemical and Energetics Division of physical chemistry Laboratory. 2001

[10]- Howaida M. EL-Kashlan. Kinetics of Corrosion of Copper Metal in Presence of Benzoic Acid. Asian Journal of Chemistry; Vol. 23, No. 12 (2011), 5235-5246.

[11]- Jamal Abdulnasser, V. Rethinagiri and J. Abdulhakeem. Investigation of the inhibition of copper corrosion in nitric acid solutions by organic sulphide compound" Pelagia Research Library Advances in Applied Science Research, 2012, 3 (3):1749-1756 Trichy, India.

[12]- E. E. Foad El-Sherbini, Mustafa M. H. Khalil, Eman H. Ismail, and Soha S.Tobar. The Corrosion of Copper Metal in HCl Solutions and the Effect of Molybdate and Chromate" 16th International Conference on Aerospace Sciences & Aviation Technology. 2015, Military Technical College, Kobry Elkobbah, Cairo, Egypt.

[13]- www.researchgate.net/figure/pourbaix-diagram-of-copper (viewed on 2/12/2019)

[14]- https://www.nace.org/resources/general-resources/corrosion-basics/group-2/dezincification (viewed on 8/2/2020)

[15]- Jamal Choucri, Fedrica Zanotto, Vincenzo Grassi, Andrea Balbo, Mohamed Ebn Touhami, Ilyass Mansouri and Cecilia Monticelli. Corrosion Behavior of Different Brass alloys for Drinking Water Distribution system. Metals 2019, 9(6), 649. https://doi.org/10.3390/met9060649

[16]- Subir Paul, Anjan Pattanayak, and Sujit K. Guchhait. Corrosion Behavior of Carbon Steel in Synthetically Produced Oil Field Seawater" Department of Metallurgical and Material Engineering, Jadavpur University, Kolkata 700032, India Published 17 December 2014 Academic Editor: Chi Tat Kwok.

[17]- 1Engr Dr A. C Uzorh "Corrosion Properties of Plain Carbon Steels. The International Journal Of Engineering And Science (IJES) Volume 2, Pages 18-24, 2013.): 2319 – 180514. Nigeria.

[18]- Tadeusz Hryniewicz, Krzysztof Rokosz. Corrosion Behaviour of C45 Carbon Steel After Mechanical Surface Finishing" Technical University of Koszalin, Raclawicka 15-17, 75-620 Koszalin, METAL 2004.

[19]- Ismaeel Andijani and S. Turgoose. Studied on Corrosion of carbon steel in Deaerated Saline Solutions in Presence of Scale Inhibitor. Presented at the WSTA IV Gulf Conference, Bahrain, 13-18 February, 1999.

[20]- Sanusi Kazeem Oladele, Hussein Kehinde Okoro. Investigation of corrosion effect of mild steel on orange juice" African Journal of Biotechnology Vol. 10(16), pp. 3152-3156, 18 April, 2011 Academic Journals South Africa.

[21]- A. Ismail, N. H. Adan. Effect of Oxygen Concentration on Corrosion Rate of Carbon Steel in Seawater"American Journal of Engineering Research (AJER) Volume-03, Issue-01, pp-64-67 UniversitiTun Hussein Onn Malaysia (UTHM) Batu Pahat, Johor.

[22]- Mohammadreza Tavakkolizadeh, Hamid Saadatmanesh" Galvanic corrosion of carbon steel in Aggressive Environments" Journal of Composites for Construction /August 2001, P(200-2100).

[23]- A. A. M. Gebril and N. A. I. Ali. The effect of Gabraun water, Distilled water & Different Volumes of their mixture on corrosion rate of carbon steel. Journal of Sebha University (pure and applied sciences) vol. 16, No. 1, 2016.

[24]- A. A. M. Gebril. The effect of Gabraun`s water on corrosion of low carbon steel compared with other types of water in south of Libya. Journal of Sebha University (pure and applied sciences). Vol. 15, No. 1, 2015

[25]- Corrosion Doctors, corrosion by water.(As viewed on 26/11/2019). http://www.corrosiondoctor.org/corrosion-by-water.htm

[26]- Bernard W. Lifka and Frank L. McGeary. (1970) Corrosion Testing. Nace Basic Corrosion Course. NACE. USA.