



Effect of Mixed Corrosion Inhibitors in Cooling Water System

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Abstract

The effect of mixed corrosion inhibitors in cooling system was evaluated by using carbon steel specimens and weight loss analysis. The carbon steel specimens immersed in mixture of sodium phosphate (Na_2HPO_4) used as corrosion inhibitor and sodium gluconate ($\text{C}_6\text{H}_{11}\text{NaO}_7$) as a scale dispersant at different concentrations (20,40, 60, 80 ppm) and at different temperature (25,50,75 and 100) $^\circ\text{C}$ for (1-5) days. The corrosion inhibitors efficiency was calculated by using uninhibited and inhibited water to give 98.1%. The result of these investigations indicate that the corrosion rate decreases with the increase the corrosion inhibitors concentration at 80 ppm and at 100 $^\circ\text{C}$ for 5 days, (i.e, corrosion rate= 0.014gmd).

Keywords: corrosion in cooling tower, carbon steel corrosion, corrosion inhibitor of cooling tower.

1. Introduction

The term "corrosion" (in a cooling water system) is defined as the electrochemical deterioration of a metal that is in contact with cooling water. Corrosion occurs when an electric current flows from one part of the metal (anode) through the water (electrolyte) to another part of the metal (cathode). Corrosion takes place at the anode only. The cathode is the driving force of the corrosion action, as shown in the equation;

Metal \rightarrow Metal ions + electrons



This process degrades the metal, reduces its strength, thickness, and in some extreme cases, creates pits and then holes in the material. At some point in the corrosion process, the metal can no longer do its job as a system component. Corrosion, in general, and pitting corrosion, in particular, must be guarded against in order to ensure the long term integrity of the cooling system.[1]

In the corrosion of iron the reaction may proceed by a single step oxidation Fe into ferric ion :



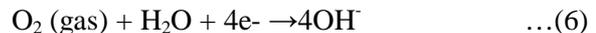
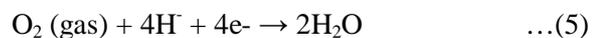
In practice, a two-step process occurs in which iron is first oxidized to ferrous ion depending on the anode potential,



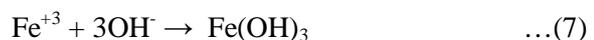
And then is oxidized into ferric ion



The reactions above take place at the anode and must be balanced by other reduction processes that occur at the cathode. For example:



The formation of OH^- at the cathode causes the pH here to be higher than in the bulk solution. Eventually, ion migration of OH^- occurs, towards the anode, which promotes the formation of ferric hydroxide



$\text{Fe}(\text{OH})_3$ appears in the form of reddish brown colloid. This ferric hydroxide may react further in the presence of ferrous ions to produce Fe_3O_4 [2].

The primary objectives of cooling water treatment are to maintain the operating efficiency of the cooling water system and to protect the equipment that contacts the cooling water. These objectives are accomplished by controlling or minimizing deposition, corrosion, and microbiological growth on the cooling water equipment.

The deposits that occur in cooling water systems are usually divided into two categories: scale and fouling. The presence of either type of deposit in the heat exchangers or in the film fill can interfere with heat transfer, thereby reducing the efficiency of operation. Deposits can also promote under-deposit corrosion.

Scale is formed from minerals, formerly dissolved in water, that were deposited from the water onto heat transfer surfaces or in-flow water lines. As water is evaporated in a cooling tower, the concentration of dissolved solids becomes greater until the solubility of a particular scale-causing mineral salt is exceeded. When this situation occurs in an untreated cooling water system, the scale will form on any surface in contact with the water, especially on heat transfer surfaces. The most common scaling minerals are calcium carbonate (CaCO_3), calcium phosphate (CaPO_4), calcium sulfate (CaSO_4), and silica, usually in that order. Formation of magnesium silicate scale is also possible under certain conditions. Most other salts, including silica, are more soluble in hot water than in cold water; however, most calcium and magnesium salts, including calcium phosphate and calcium carbonate, are more soluble in cold water than in hot water. This is called "reverse solubility." The water temperature will increase as recirculating water passes through the cooling system. As a result, calcium and magnesium scales may form anywhere in the system, but most likely on heated surfaces such as heat exchangers or surface condensers. Silica will form in areas having the lowest water temperature, such as in the cooling tower fill.

The principle factors responsible for scale formation are:

1. As alkalinity increases, calcium carbonate- the most common scale constituent in cooling systems - decreases in solubility and deposits.
2. The mechanism for scale formation is the in-situ crystallization of sparingly soluble salts as the result of elevated temperatures and/or low flow velocity. Most salts become more soluble as temperature increases, however,

some salts, such as calcium carbonate, become less soluble as temperature increases. Therefore they often cause deposits at higher temperatures.

3. High TDS water will have greater potential for scale formation. [4]

The water is used in cooling systems as a heat transfer medium and frequently also as the final point to reject heat into the atmosphere by evaporating inside cooling towers. Depending on the quality of available fresh water supply, waterside problems develop in cooling water systems from: Scaling, Corrosion, Dirt and dust accumulation and Biological growth.

Any of these problems or more usually a combination of them result in costly unscheduled downtime, reduced capacity, increased water usage, high operation and maintenance costs, expensive parts replacements, and acid cleaning operations which reduce the life of the cooling system. Selection of water treatment program for a specific system depends on:

1. System design, including system capacity, cooling tower type, basin depth, materials of construction, flow rates, heat transfer rates, temperature drop and associated accessories
2. Water, including makeup water composition / quality, availability of pre-treatment and assumed cycle of concentration
3. Contaminants, including process leaks and airborne debris
4. Wastewater discharge restrictions
5. Surrounding environment and air quality

The critical parameters for cooling water are: conductivity, total dissolved solids (TDS), hardness, pH, alkalinity and saturation index.

Conductivity is a measure of the ability of water to conduct electrical current and it indicates the amount of the dissolved solids (TDS) in water. Pure distilled water will have a very low conductivity (low minerals) and sea water will have a high conductivity (high minerals). Dissolved solids present no problem with respect to the cooling capacity of water, since the evaporation rate of seawater, which has 30,000ppm total dissolved solids, is only 1% less than that of distilled water. The problem with dissolved solids is that many of the chemical compounds and elements in the water will combine to form highly insoluble mineral deposits on the heat transfer surfaces generally referred to as "scale". The scale stubbornly

sticks to the surfaces, gradually builds up and begins to interfere with pipe drainage, heat transfer and water pressure.

pH: is a measure of how acidic/basic water is. The range goes from 0 - 14, with 7 being neutral. pHs of less than 7 indicate acidity, whereas a pH of greater than 7 indicates a base. pH is reported in "logarithmic units," like the Richter scale, which measures earthquakes.

In general, when pH points to acidic environment, the chances for corrosion increase and when pH points to alkaline environment, the chances for scale formation increase.

Alkalinity: The pH values above 7 signify alkalinity. At pH values less than 8.3, most of the alkalinity in the water is in the bicarbonate form, and scale formation is normally not a problem. However, when the pH rises above 8.3, the alkalinity converts from the bicarbonate to the carbonate and the scale will start to form.

Hardness: The amount of dissolved calcium and magnesium in water determines its "hardness." The total hardness is then broken down into two categories:

- a. The carbonate or temporary hardness
 - b. The non-carbonate or permanent hardness
- Hardness particularly the temporary hardness is the most common and is responsible for the deposition of calcium carbonate scale in pipes and equipment. Technically any bivalent metal ion such as iron, manganese or tin would constitute hardness, but calcium and magnesium are the two most prevalent forms.

Saturation Index: The saturation index of a water or Langlier Saturation Index (LSI) is a measure of the stability of the water with respect to scale formation. When LSI readings are positive they tend to be scale forming, and when they are negative they tend to be corrosive. Normally readings within 1.0 unit from zero are considered Table [5, 6].

In cooling water systems, two basic techniques are used to provide corrosion protection to the metals that the water contacts: use of chemical corrosion inhibitors, and raising the pH of the cooling water.

Most military cooling water systems contain components fabricated primarily of copper alloy and mild steel. Galvanized steel is present in galvanized cooling towers and stainless steel may be present in piping. As the cooling water pH is increased (ideally to within the range of 8.0 to 9.5.

Corrosion inhibitors are chemicals, which inhibit or reduce the corrosion rate of the steel or metallic surfaces. Corrosion is an electrochemical phenomenon, which occurs due to anodic and/or cathodic. Reactions. Generally, the anodic reaction is the metal ion oxidation, and the cathodic reaction is the hydrogen ion reduction. Therefore, the corrosion analysis and the corrosion inhibitors used to control the anodic reactions are classified as anodic corrosion inhibitor and the cathodic reactions are called as cathodic inhibitors. Anodic Inhibitors form a protective film coating on the anodic metal (where the metal is lost) and thus directly control corrosion by preventing the reaction that results in corrosion. Any unprotected areas will corrode at a much faster rate than the protected areas, a factor that could result in pitting or localized attack of the unprotected areas. Cathodic Inhibitors form a protective film coating of the cathodic metal (where metal is not lost) and thus indirectly prevent corrosion by interfering with the current flow required for the electrochemical reaction to proceed between the cathodic and anodic metals. The corrosion reaction rate is governed by the size and type of the cathode relative to the anode. Even when cathodic areas are not completely covered by the protective film, corrosion will occur, but usually more slowly and uniformly than when using anodic inhibitors alone. The occurrence of localized corrosion or pitting attack is greatly reduced. [6]

The criteria for the selection of corrosion inhibitors are shown in Table (1). The principal strategy for a cooling system corrosion protection program is to ensure protection of the metal in the heat exchanger (metal that is the thinnest metal in the system). The secondary goal is to provide protection from corrosion of the mild steel piping. When galvanized steel cooling towers are part of the cooling system, specialized corrosion inhibitors are the best control method. Galvanized steel is corroded at pH levels above 9.0 and below 6.0.

Effective corrosion control requires maintaining appropriate pH levels, plus adding maintenance dosages of chemical corrosion inhibitors. Chemical corrosion inhibitors form a protective film or barrier on the cooling system metal surfaces that have been cleaned prior to adding an initial high dosage of inhibitor. The initial high dosage of inhibitor passivates (protects) the metal. The appropriate dosage of corrosion inhibitor must be maintained

continuously in the cooling water to ensure continuing protection. The examples of various passivation and maintenance dosage levels of corrosion inhibitors are shown in Table (2) [7, 8] In order to prevent corrosion on galvanized steel cooling towers and associated pipes, formation of a non-porous surface layer of zinc carbonate is one of the effective methods. The formation of zinc carbonate layer is called passivation, which is accomplished by controlling pH during initial operation of the cooling tower. Control of the cooling water pH in the range of 7 to 8 for 45 to 60 days usually allows passivation of galvanized surfaces to occur. In addition to pH control, operation and moderate hardness levels of 100 to 300ppm as CaCO_3 and alkalinity levels of 100 to

300ppm as CaCO_3 will promote passivation. The chemical cleaning and passivation formulation apply when the water system pH is 7.5 to 8.5 and adjust pH as required. Formulation limitations may require adding separate components to keep things in solution. Other formulations may be used:

- *Orthophosphate or hexametaphosphate as (PO_4): 60 ppm
- * Polyacrylate (active): 20 ppm
- * Tolyltrizol (active): 10 ppm
- * Sodaum gluconate: 50 ppm
- * Pluronic L-61 (active)(non ionic surfactant with antifoam: 400 ppm
- * Phosphate scale inhibitor: 50 ppm . [9]

Table 1,
Criteria for Corrosion Inhibitor Selection.

Corrosion Inhibitor	Metal			pH Range (ideal)
	Steel	Copper	Aluminum	
Cathodic Inhibitor				
Polyphosphate	Excellent	Attacks	Attacks	6.5-8.5
Zinc salts	Excellent	None	None	6.5-8.5
Polysilicate	Excellent	Excellent	Excellent	7.5-10.0
Molybdate	Good	Fair	Fair	7.5-10.0
Anodic Inhibitor				
Orthophosphate	Good	Attacks	Attacks	6.5-8.5
Orthosilicate	Good	Good	Good	7.5-10.0

Table 2,
Guide lines for Passivation Film Formation and Subsequent Maintenance.

Corrosion inhibitor	Dosage (ppm)		Film formation Time (days)
	Initial	Maintenance	
Cathodic inhibitor			
Polyphosphate	40-60 as po_4	10-20 as po_4	5-6
Zinc salts	10-20 as zn	3-5 as zn	5-6
Polysilicate	40-60 as SiO_2	10-20 as SiO_2	10-12
Molybdate	40-60 as Mo	5-20 as Mo	10-12
Anodic inhibitor			
Orthoophosohate	40-60 as po_4	15-20 as po_4	5-6
Orthosilicate	40-60 as SiO_2	10-15 as SiO_2	10-12
Copper Corrosion inhibitor			
Tolyltrizole	10-20 as TTA	1-2 as TTA	5-6

In general, other types of corrosion inhibitors are: Mixed inhibitor: is composed of two or three types of inhibitor and majority of the proprietary corrosion inhibitor formula falls into this category.

Adsorption inhibitor: Protective absorbed film is formed over the entire metal surface if adsorption inhibitor is used. The film helps to protect electrochemical reactions between metal and aqueous ions. Some of the organic compounds are suitable to act as adsorption inhibitors [10].

2. Experimental Procedure

A lab rotary test was used in this investigation, the hot plate and stirrer (Jenway 1000) were used and a 500 ml of beaker capacity was filled with mixture of corrosion inhibitors and specimen immersed for (1-5) days. The carbon steel specimen materials used in this investigation has the chemical composition which done in the Al doura refinery by spectrometer Ultima 2000 as shown in Table (3):

The surface of rectangular carbon steel alloy specimens which has the dimensions (10 x 3 x

0.2cm), (9 x 2 x 0.25 cm) were abraded by using emery paper of different grade numbers (220, 320, 400, 600), after abrasion the surfaces were cleaned with running tap water, followed by acetone rinse for 5 minutes and were dried in discator. Different concentration of corrosion inhibitor were prepared, (20, 40, 60 and 80 ppm) mixture of $Na_2 HPO_4$ and $C_6 H_{11} NaO_7$.

After specimen's preparations, weighing the specimen and record W_1 , the specimen was clamped and immersed in a mixture of corrosion inhibitors at 20 ppm concentration, (i.e. The ratio = $\frac{Na_2 HPO_4}{C_6 H_{11} NaO_7} = \frac{10}{10}$) using hot plate stirrer at medium velocity and at temperature 25°C, after 1 day the immersion specimen, was removed and cleaned by washing it with running tap water and brushing it with bristle brush. Then the specimens were immersed in benzene for 5 minutes to ensure removal of corrosion products from metal surface. The specimens were immersed in ethanol were dried in discator, then weights represented as W_2 . the procedure by using (40, 60 and 80 ppm) concentration and immersion for 2, 3 and 5 days at (50,75 and 100°C) temperature as shown in Fig.(1) and Fig.(2)

**Table 3,
The chemical Composition for Carbon Steel**

Fe	Si	Mn	Cr	Ni	Mo	Cu	Co	Al	C	S	HB	Total Elements %
74.2	2.2	9.0	2.2	2.7	3.5	1.1	2.5	1.3	1.2	0.1	300	100



Fig.1. Carbon Steel Specimen Immersed In Mixture of Sodium Phosphate And Sodium Gluconate.



Fig. 2. Carbon Steel Specimen Immersed in Mixture of Corrosion Inhibitor on Hot Plate and Stirrer at Medium Velocity .

The efficiency of mixture corrosion inhibitors and scales dispersant (sodium phosphate and sodium gluconate) were calculated, by using make up water (raw water) without corrosion inhibitor then calculated the corrosion rate for (1,2,3 and 5) days with corrosion inhibitor as shown in Fig. (3), and analyze make up water and an inhibited water chemically.

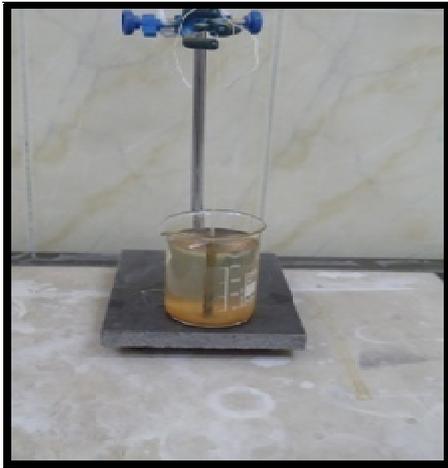
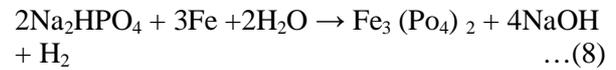


Fig . 3. Carbon Steel Specimen Immersed in Makeup Water.

3. Results and Discussion

3.1. Sodium phosphate effect

The effect of corrosion inhibitor of sodium phosphate indicates that the film of iron phosphate ($\text{Fe}_2(\text{PO}_4)_2$) produced to protect the surface of the specimen to passivate them and prevent the corrosion. as shown in the eq.



The results indicate that when the specimen immersed in the mixture of corrosion inhibitor for 5 days at a concentration of 30-40 ppm, this gave low value of corrosion rate than the immersion for 1 day. The relation was linear, this mean that the corrosion rate decrease with increasing the concentration and the time, as shown in Table (4) and Fig. (4).

Table 4,
Corrosion Rate of Carbon Steel in Mixture of Sodium Phosphate And Sodium Gluconate at Different Concentration and 25 °C Temperature .

Test no.	Time /day	Conc. in ppm	Weight/w1 in gram	Weight/w2 in gram	Δw	Surface area (cm) ²	*C.R. in gmd
1	1	20	47.1500	47.1516	0.0016	0.00652	0.24
2	1	40	47.1500	47.1514	0.0014	0.00652	0.21
3	1	60	47.1400	47.1412	0.0012	0.00652	0.18
4	1	80	47.1400	47.1411	0.0011	0.00652	0.16
5	2	20	47.1500	47.152	0.002	0.00652	0.15
6	2	40	47.1500	47.1519	0.0019	0.00652	0.14
7	2	60	47.2999	47.301	0.0011	0.00415	0.13
8	2	80	47.2999	47.3008	0.0009	0.00415	0.10
9	3	20	47.1500	47.1519	0.0019	0.00652	0.097
10	3	40	47.1400	47.1418	0.0018	0.00652	0.092
11	3	60	47.1400	47.1411	0.0011	0.00415	0.088
12	3	80	47.2999	47.3007	0.0008	0.00415	0.064
13	5	20	47.1423	47.1439	0.0016	0.00652	0.049
14	5	40	47.1400	47.1411	0.0011	0.00652	0.033
15	5	60	47.3300	47.3305	0.0005	0.00415	0.024
16	5	80	47.3300	47.3303	0.0003	0.00415	0.018

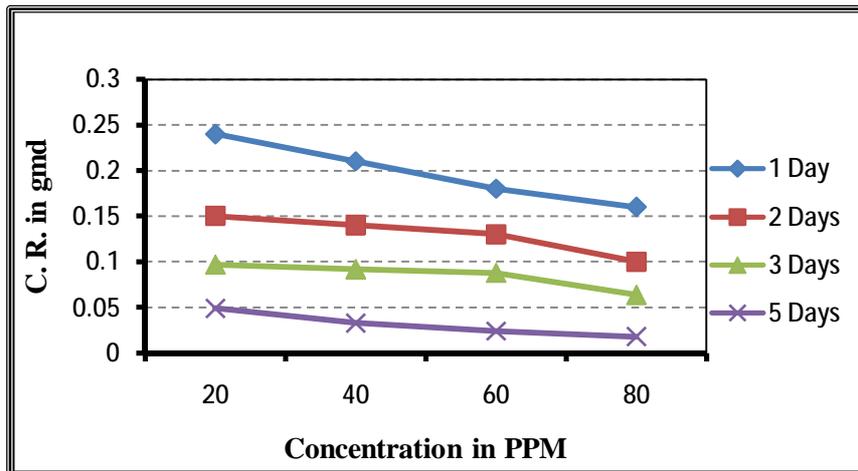
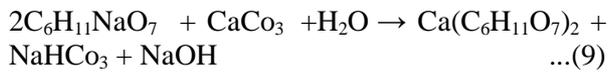


Fig. 4. Effect of Concentration of Mixture Inhibitor on Corrosion Rate.

3.2. Sodium glocunate effect

The effect of sodium glocunate as scale dispersant indicates that the total dissolved solids (T.D.S.) will be decreased from 3000 ppm and to 300 ppm then minimize the electrochemical reaction under the deposit and tubes failed. Their effect as sequestering agent forming water solution complexes with calcium in alkaline media and with iron in near neutral solutions is shown in the equation:



The concentration at 30-40 ppm of sodium glocunate indicates that the corrosion rate

decreases for 5 days of immersion as shown in Table (4) and Fig.(4) .

3.3. Time effect

The corrosion rate decreases with increasing time at constant concentration according to the equation of corrosion rate. Time and longer protective layer of mixture will prevent and decrease the corrosion rate as shown in Fig.(5).

$$Corrosion\ rate = \frac{\Delta\omega\ (Gram)}{Surface\ area^2\ (cm) \times time\ (day)} \quad [11] .$$

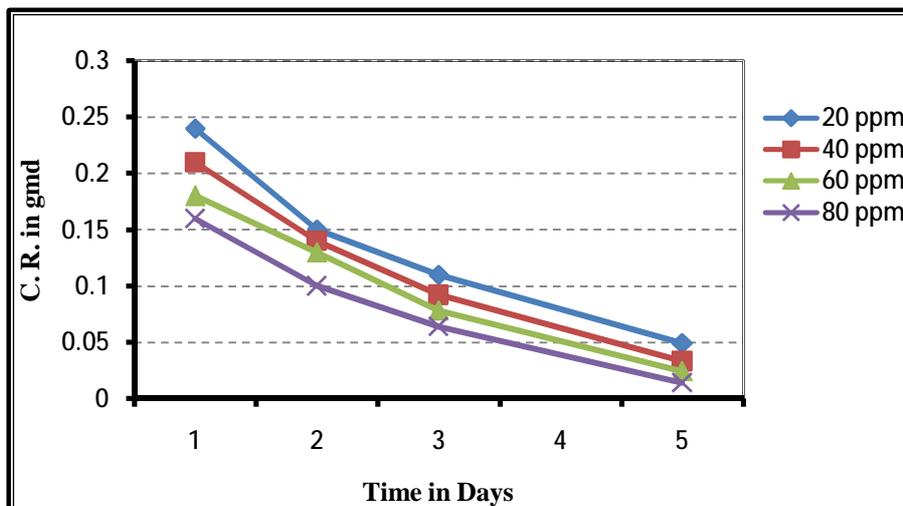


Fig. 5. Effect of Time on Corrosion Rate with Different Conc. of Mixture Inhibitor.

3.4. Temperature effect

The corrosion rate increased at temp. (25,50 and 75) °C for 1and 2 days because temp. increasing caused low passivity of corrosion

inhibitors at 100 °C, the temp. effect will be less on the corrosion rate at 3 and 5 days because of the passivation film that will reduce heat transfer on the metal surface as shown in Table(5) and fig.(6).

Table 5,
Corrosion Rate of Carbon Steel in Mixture of Sodium Phosphate and Sodium Gluconate at 80 ppm Concentration and at Different Temperature.

Test no.	Time /day	Temp. in °C	Weight/w1 in gram	Weight/w2 in gram	Δw	Surface area (cm) ²	*C.R. in gmd
1	1	25	47.1500	47.1511	0.0011	0.00652	0.16
2	1	50	47.1498	47.1415	0.0017	0.00652	0.27
3	1	75	47.1432	47.1445	0.0022	0.00652	0.34
4	1	100	47.1400	47.1414	0.0014	0.00652	0.23
5	2	25	47.2999	47.3008	0.0009	0.00415	0.10
6	2	50	47.2998	47.3014	0.0016	0.00415	0.20
7	2	75	47.1500	47.1539	0.0039	0.00652	0.30
8	2	100	47.1500	47.1515	0.0015	0.00652	0.20
9	3	25	47.2999	47.3007	0.0008	0.00415	0.064
10	3	50	47.1400	47.1417	0.0017	0.00652	0.09
11	3	75	47.1400	47.1429	0.0029	0.00652	0.15
12	3	100	47.3300	47.3312	0.0012	0.00415	0.12
13	5	25	47.3300	47.3303	0.0003	0.00415	0.018
14	5	50	47.1500	47.1506	0.0006	0.00652	0.02
15	5	75	47.1400	47.1409	0.0009	0.00652	0.028
16	5	100	47.2999	47.3002	0.000029	0.00415	0.014

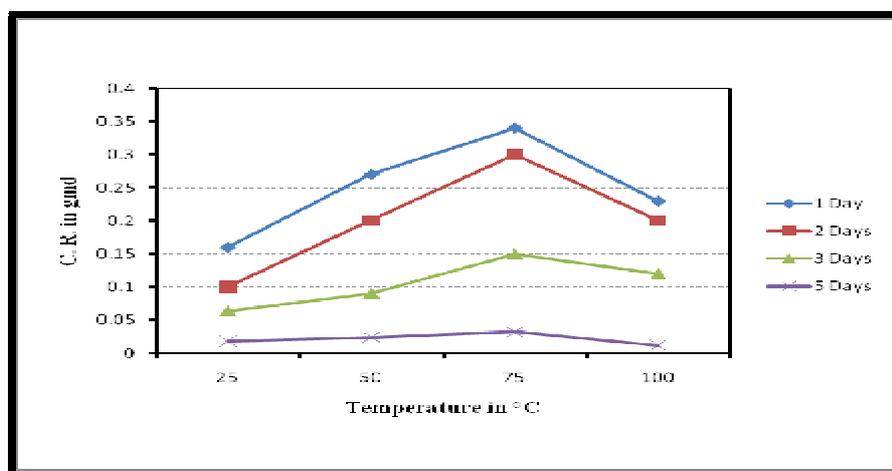


Fig. 6. Effect of Temp. on Corrosion Rate at Different Times and at 80 ppm of Mixture Corrosion Inhibitors Concentration.

3.5. Mixture efficiency

The efficiency of mixture of sodium phosphate and sodium gluconate were (83.3, 87.5, 93.8 and 98.1%) at 80 ppm concentration, and at 1,2,3,5 days respectively, the corrosion rate of makeup water (raw water) were calculated for 1, 2, 3 and 5 days to compare the efficiency of the mixture by applying the equation of the efficiency, where the efficiency increases with time as shown in the Table (6) and Table (7).

Efficiency =

$$\frac{\text{Uninhibited water} - \text{inhibited water}}{\text{Uninhibited water}} \times 100\%$$

[12]

When carbon steel is immersed in raw water, the anodic reaction is:



The cathodic reaction is:



**Table 6,
The Corrosion Rate of Makeup Water.**

Time/day	W1(gram)	W2(gram)	Δw	Surface area cm^2	C. R. (gmd)
1	47.1423	47.1486	0.0063	0.00652	0.96
2	47.1414	47.1558	0.0144	0.00652	1.1
3	47.3200	47.3402	0.0202	0.00415	1.5
5	47.1435	47.2184	0.0749	0.00652	2.3

**Table 7,
Efficiency of Mixture of Sodium Phosphate and Sodium Glucuronate at 80 ppm.**

Time (day)	C.R.(uninhibited water)	C.R.(inhibited water)	Efficiency%
1	0.96	0.16	83.3
2	1.1	0.15	87.5
3	1.5	0.092	93.8
5	2.3	0.042	98.1

Then after 5 days the uniform corrosion will occur while the protective layer of $\text{Fe}_3(\text{PO}_4)_2$ formed on the surface of carbon steel specimen as shown in Fig.(7) and Fig.(8) respectively, The

chemical analysis of cooling water (inhibited water) were obtained from Al-doura refinery explain the values of alkalinity and pH increased because of mixture effect as shown in Table (8).

**Table 8,
Chemical analysis for make up(raw water) and cooling tower water.**

Water Parameter	Make up water	Cooling water
Alkalinity as ppm	144	374
Total Hardness as ppm	250	544
T.D.S as ppm	397	1370
pH	7.4	8.27
Conductivity in mmhoms	663	1712
Sodium phosphate as ppm	-	80
Sodium gluconate as ppm	-	80



Fig. 7. Uniform Corrosion on Carbon Steel Specimen.



Fig. 8. Protective Layer on Carbon Steel Specimen.

4. Conclusion

From experimental results using corrosion inhibitor mixture (sodium phosphate as corrosion inhibitor and sodium gluconate as scale dispersant) in cooling tower at 20,40,60 and 80 ppm concentration, one concludes that at 80 ppm concentration of mixture and at temp. above 75 °C and for 5 days is more efficiently in cooling tower treatment to form a passive film and decrease the corrosion rate.

5. Recommendation

Some recommendations are suggested to improve the future work. Because of microbiological growth in cooling tower such as algae, fungi and bacteria, then:

- 1- The treatment with biocides by adding to sample of cooling water :
 - a. Oxidizing Biocides such as (Chlorine, Bromine, Chlorine Dioxide, Ozone, Silver Peroxide, etc)
 - b. Non-oxidizing Biocides : Organic chemical compounds .
 - c. Biocidal dispersants : Surfactant.
- 2- Study the effect of the microbiological growth in cooling tower and measure the corrosion rate of carbon steel with effect of microbiological growth.
- 3- Calculate the corrosion rate of carbon steel immersed in corrosion inhibitor, scale dispersant and biocidal dispersant mixing .

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تأثير خليط مثبتات التآكل في منظومة خزان التبريد

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الخلاصة

تم تقييم تأثير خليط مثبتات التآكل في منظومة التبريد باستعمال معدن كربون ستيل وطريقة فقدان الوزن . غمرت نماذج الكربون ستيل في خليط من فوسفات الصوديوم Na_2HPO_4 كمثبط تآكل و كلوكنيت الصوديوم $\text{C}_6\text{H}_{11}\text{NaO}_7$ كمثبتات تكلسات وبتراكيز مختلفة (٢٠,٤٠,٦٠,٨٠) جزء بالمليون وعند درجة حرارة مختلفة (٢٥,٥٠,٧٥,١٠٠) م° و لمدة (١-٥) أيام . تم حساب كفاءة المثبطات باستخدام ماء بدون إضافات ومع الإضافات وكانت كفاءة الخليط 98.1% عند تركيز ٨٠ جزء بالمليون. نتائج البحث تبين أن معدل التآكل يقل مع زيادة تركيز خليط مثبت التآكل عند تركيز ٨٠ جزء بالمليون ودرجة حرارة ١٠٠م° ولمدة ٥ أيام، أي إن معدل التآكل = ٠.٠١٤ غم/م^٢. يوم .