

Selection Of Best Water Quality With Sodium Polyphosphate Inhibitor To Control The Corrosion Of Carbon Steel Sheet

Shahad Falih Hassan, Ali khalid

Abstract: Many trials have been done around the world to control the corrosion rate especially by adding inhibitors, and in this work, we used Sodium Polyphosphate Inhibitor with different types of water (Filtered water, Soft water, demineralized water) and different dosage of inhibitor, the results shows that best water quality with inhibitor is the demineralized water to reduce the corrosion rate in carbon steel sheet

Index Terms: Corrosion inhibitor, Sodium Polyphosphate, Filtered water, Soft water, demineralized water, carbon steel sheet.

1. INTRODUCTION

Corrosion is the loss of metal through electrochemical reaction with its surrounding environment. There are different types of corrosion, but the most common is often characterized as general, pitting and galvanic corrosion.

1. General attack: exists when the metal surface is uniformly corroded.
2. Pitting attack: exists when the corrosion happens only in small area from the metal. The metal may perforate by pitting in short time. Dissolved oxygen is the main source for pitting attack.
3. Galvanic attack: this type of corrosion can occur when two different metals are in contact. The more active metal corrodes rapidly. Common examples in water systems are steel & brass, aluminum & steel, Zinc & steel and zinc & brass. If galvanic attack occurs, the metal named first will corrode.

Corrosion rates are most commonly tested using metal coupons. Mild steel and copper coupons are frequently used since these represent the metals that are most vulnerable to corrosion in the system. An acceptable cooling water treatment program should be able to reduce corrosion rates to the following average levels reported as mils/yr(1):

Rating	Rate (Mils/yr)
Poor	>5
Fair	3.5 – 5.0
Good	2.0 – 3.5
Excellent	0.0 – 2.0

Inhibitors for corrosion control

The use of corrosion inhibitor is one of the very important methods of minimizing corrosion of metals. When these

chemical substances are present in the corrosion system at a suitable concentration, it will decrease the corrosion rate without changing the concentration of any corrosive agents significantly—ISO1999 (2). The National Association of Corrosion Engineers (NACE) defines corrosion inhibitors in the following way: A substance which retards corrosion when added to an environment in small concentrations (3). Corrosion inhibitors are either organic or inorganic chemicals, or more commonly, formulations thereof that are added, either in a form of a liquid or vapor, in small amounts in order to delay or decrease the corrosion process of the surface to be protected, parts per million, to a corrosive environment. It is common to use corrosion inhibitors as a practical, economical and simple alternative due to that equipment constructed with materials resistant to corrosion is very expensive. These inhibitors can be identified according to their purpose of use: corrosion inhibitor or scale and deposition inhibitors. Corrosion inhibitors are added to many systems including cleaning pads, cooling systems, various refinery units, pipelines and different chemical operations. Inhibitors can be injected into a completely aqueous re-circulating system in a cooling system, to reduce the corrosion rate in that system.

Two processes are involved in the action of these inhibitors on the metal surface. The first step involves the transport of the inhibitor to the metal surface followed by the second step involving chemical interaction between the inhibitor and the metal surface (4). A corrosion inhibitor may act in a number of ways: it may restrict the rate of the anodic process or the cathodic process by simply blocking active sites on the metal surface. Alternatively, it may act by increasing the potential of the metal surface so that the metal enters the passivation region where a natural oxide film forms. A further mode of action of some inhibitors is that the inhibiting compound contributes to the formation of a thin layer on the surface which stifles the corrosion commonly by limiting the rate of cathodic process (5).

Corrosion inhibitors are not universally applicable, a fact supported in some degree by the large number of compounds used and also by the fact that an inhibitor effective in one system may not be effective in another (6).

1. Inhibitors classified by their chemical functionality:

- a- Inorganic inhibitors
- b- Organic inhibitors

2- Inhibitors that affect the electrochemical reactions of the corroding system:

- a- Anodic inhibitors
- b- Cathodic inhibitors

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c- Mixed inhibitors

3- Inhibitors which affect the metal surface (surface effect):

a- Adsorption inhibitors.

b- Film- forming inhibitors

4- Inhibitors also classified as:

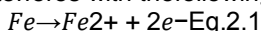
a- Safe or dangerous

b- Toxic or eco-friendly

In practical applications, the concept of safe and dangerous inhibitors is important. Cathodic inhibitors are safe in the sense that if they are present at insufficient concentration, they simply fail to protect completely and do not stimulate corrosion on unprotected areas. In contrast, anodic inhibitors are dangerous because they function by causing the formation of a protective oxide layer on the metal surface and if the inhibitor concentration is too low, pores and defects can arise in the oxide layer and thus, accelerated localized corrosion can take place (7). In addition, if by inadequate initial additions or subsequent poor maintenance the supply of inhibitor fails locally, corrosion is stimulated on the depleted areas because they become anodes in active/passive cells supported by large cathodic currents collected by the passive area. Numerous inorganic compounds have been reported as effective corrosion inhibitors for metals in different media, but the toxic nature of many of them limits their application. Recently, inhibitors are classified according to their effect on the environment to green or toxic inhibitors. Furthermore, due to the issues of toxicity of substances like chromate inhibitors, there is an increasing interest in exploration and utilization of green inhibitors. Green inhibitors like natural products from plant extracts and substances from other renewable sources presumably possess biocompatibility due to their biological origin. (8), (9)

Anodic (Passivating) Inhibitors

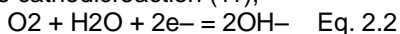
As the name implies, an anodic inhibitor is a substance that interferes with the following anodic process:



For example, this is caused by a large anodic shift of the corrosion potential (forcing the metallic surface into the passivation range) by assisting the natural passivation tendencies of metal surfaces, or by formation of an insoluble salt film layer. Anodic inhibitors are usually used in near-neutral solutions where sparingly soluble corrosion products, such as oxides, hydroxides, or salts, are formed. They form, or facilitate the formation of passivating films that inhibit the anodic metal dissolution reaction and that is why they are often called passivating inhibitors (10).

Cathodic Inhibitors (Precipitation)

During the corrosion process, the cathodic corrosion inhibitors limit the rate of the cathodic reaction of the metal. These inhibitors are generally metal ions that precipitate selectively on cathodic sites. Cathodic inhibitors in cooling systems produce adherent compact deposits on metal surfaces that suppress the cathodic reaction (11),



By reducing the available area for the cathodic reaction, i.e. creating a barrier to oxygen diffusion and preventing transfer of electrons from the metal. The inhibitor reacts with the hydroxyl ion to precipitate insoluble compounds on the cathode sites. As shown in fig 2.3, the presence of a cathodic inhibitor causes a shift in the corrosion potential and the corrosion rate to E'_{corr} and i'_{corr} respectively. The corrosion rate is reduced,

while the corrosion potential shifts towards lower (more negative) values.

The most widely used inhibitors of this type are metal cations, polyphosphates, silicates and borates (12).

Mixtures of Inhibitors

In modern practice, inhibitors are rarely used in the form of single compounds. It is more usual for formulation made up from two or more inhibitors to be employed. This is because individual inhibitors are effective with only limited number of metals and the protection of multi-metal system requires the presence of more than one inhibitor. Also, chemicals with different characteristics (e.g. anodic and cathodic inhibition) supplement their deficiency with each other, so the efficacy of the mixed inhibitor increases. Hence, dosage concentration can be significantly reduced, thus, lowering the operating cost and environmental impacts caused by chemicals (13).

Experimental Work

We made many laboratory trials to select the best water quality to control the corrosion which can happen in carbon steel by using Sodium Polyphosphate inhibitor and in three types of water as explained in the table below:

Spec.	Filtered water	Soft water	Dematerialized water
Water treatment	Ultra-Filtration membrane	Reverse Osmosis membrane	Mixed bed ion exchange resin
Conductivity (us/cm)	860	75	0.1
Total dissolved solid (PPM)	421	33	>0.05
Hardness (PPM)	220	17	0
PH	7.84	8.2	6.8
Chloride (PPM)	52	15	0
Chlorine (PPM)	0.8	0	0
Turbidity (NTU)	0.1	0	0

Trail No. 1:

We took three carbon steel sheets then we weight each one from them after that we put one of them in filtered water and another one in soft water and the third one in mixed water (filtered and soft), and we added 25 ppm from Sodium Polyphosphate inhibitor to each one and after 8 days we took them out and we weight them again to calculate the corrosion rate (Photo C).

Trail No. 2:

We took three carbon steel sheets then we weight each one from them and we used just soft water, the first sample was without adding Sodium Polyphosphate inhibitor, the second one was with adding 50 ppm from Sodium Polyphosphate inhibitor, the third one was with adding 75 ppm from Sodium Polyphosphate inhibitor and after 8 days we took them out and we took the weight again to calculate the corrosion rate (Photo D).

Trail No. 3:

We took one carbon steel sheet and we took the weight for it then we used just demineralized water, and we add 75 ppm from Sodium Polyphosphate inhibitor and after 8 days we took it out and we took the weight again to calculate the corrosion rate (Photo D). During the trials we checked the phosphate level by using (DR900) showed in (photo A), also we took the weight of carbon steel pieces by using ENTRIS2202-1S balance (photo B).



Photo (A) DR900



Photo (B) ENTRIS2202-1S balance



Photo (C) 50ppm from inhibitor with three types of water.

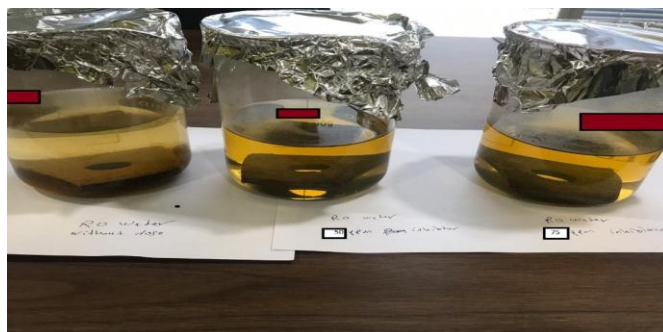


Photo (D) 0 PPM & 50 PPM & 75 PPM of inhibitor with soft water

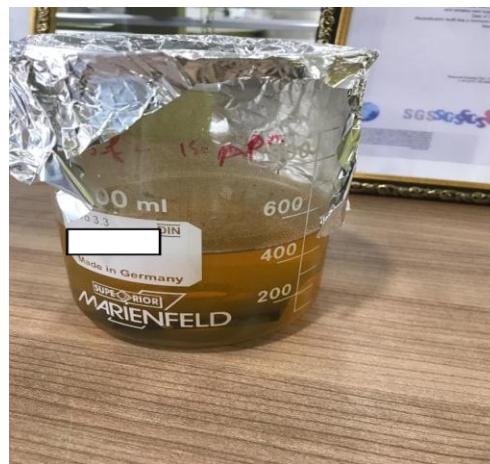


Photo (F) 75 PPM of inhibitor with dimi. water

RESULTS AND CONCLUSIONS

Trail No. 1: adding 25ppm inhibitor

Filtered water cup:

Weight of carbon steel sheet before experiment =24.79g

Weight of carbon steel sheet after experiment =24.69g

difference between the weights =0.1g

area of sheet =0.0012m²

corrosion rate = difference between the weights/ (area of sheet *time)

$$= 0.1 \text{ g} / (0.0012 \text{ m}^2 * 192 \text{ hr}) = 0.434\text{g/m}^2.\text{hr}$$

Soft water cup:

weight of carbon steel sheet before experiment =22.72g

weight of carbon steel sheet after experiment =22.68g

difference between the weights =0.04g

area of sheet =0.001125m²

corrosion rate = difference between the weights/ (area of sheet *time)

$$= 0.04 \text{ g} / (0.001125 \text{ m}^2 * 192 \text{ hr}) =$$

0.1851g/m².hr

Mixed water cup:

weight of carbon steel sheet before experiment =22.26g

weight of carbon steel sheet after experiment =22.14g

difference between the weights =0.12g

area of sheet =0.00108m²

corrosion rate = difference between the weights/ (area of sheet *time)

$$= 0.12 \text{ g} / (0.00108 \text{ m}^2 * 192 \text{ hr}) =$$

0.5787g/m².hr

Trail No. 2:

Soft water without inhibitor:

weight of carbon steel sheet before experiment =192.45g

weight of carbon steel sheet after experiment =192.34g

difference between the weights =0.11g

area of sheet =0.004365m²

corrosion rate = difference between the weights/ (area of sheet *time)

$$= 0.11 \text{ g} / (0.004365 \text{ m}^2 * 192 \text{ hr}) =$$

0.1312g/m².hr

Soft water with 50ppm inhibitor:

weight of carbon steel sheet before experiment =189.62g

weight of carbon steel sheet after experiment =189.52g

difference between the weights =0.1g

area of sheet =0.00433m²

corrosion rate = difference between the weights/ (area of sheet *time)

$$= 0.1 \text{ g} / (0.00433 \text{ m}^2 * 192 \text{ hr}) = 0.12 \text{ g/m}^2 \cdot \text{hr}$$

Soft water with 75ppm inhibitor:

weight of carbon steel sheet before experiment =184.58g

weight of carbon steel sheet after experiment =184.5g

difference between the weights =0.08g

area of sheet =0.004256m²

corrosion rate = difference between the weights/ (area of sheet *time)

$$= 0.08 \text{ g} / (0.004256 \text{ m}^2 * 192 \text{ hr}) =$$

0.097g/m².hr

Trail No. 3:

Demineralized water with 75 ppm inhibitor

weight of carbon steel sheet before experiment =189.5g

weight of carbon steel sheet after experiment =189.46g

difference between the weights =0.04g

area of sheet =0.00433m²

corrosion rate = difference between the weights/ (area of sheet *time)

$$= 0.04 \text{ g} / (0.00433 \text{ m}^2 * 192 \text{ hr}) =$$

0.0481g/m².hr

From the above results we conclude that demineralized water with the inhibitor is the best water quality to choose, and the mixed of soft and filtered water is the worst quality of water to choose. Also we was checking phosphate concentration along the period of experiment by DR900 and the result of demineralized water was better from other kinds of water in the inhibitor consumption side because after 8 days from the starting of experiments the level of phosphate was 25.7ppm, while in soft water the level of phosphate was 1.89ppm when we used 50ppm of inhibitor, and 2.22ppm when we used 75ppm of inhibitor, and in mixed water it was 0.1ppm.

RECOMMENDATIONS

- 1- Increase the dosage of the inhibitor to notice the corrosion rate.
- 2- Make the experiments with longer time than 8 days.
- 3- Try to maintain the phosphate level in the water by adding the inhibitor regularly and checking phosphate level and notice the results.

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