IJAAR PUBLISHING®

Engineering Research Journal | ISSN: 2782-8212
Vol. 6, Issue 1 (2026) | www.ijaar.org/erj

CORROSION EFFECT ON MILD STEEL COUPON IN SALT WATER MEDIUM

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Abstract:

This study was carried out to investigate the corrosion effect of mild steel coupon in salt water medium. Corrosion is the chemical reaction between a metal by chemical or electrochemical reactions with its environment. Mild steel coupons in cuboid shape were constructed with dimensions 3.7cm x 2.6cm x 0.2cm. Salt medium was formed with $50cm^3$ of distilled water and 10g, 20g and 30g of sodium chloride respectively. The three coupons were dipped into the three concentrations of sodium chloride solutions, before dipping into the solutions the coupons were weighed to know the initial weights of the coupons. Samples were collected every 7 days for five weeks which is 35 days cure. After seven days the coupons were removed and sand papered and reweighed to obtain final weights of the coupons to enable the weight loss to be calculated by removing the final weighs from initial weights. The corrosion rate was also calculated using the appropriate equation. The P^H of the solutions containing coupons, temperatures of the solutions, final weights of coupons, weight loss of coupons and corrosion rates of the coupons in different concentrations of the medium were also obtained. It was concluded that the P^H decreased with increased in time, the temperatures increased with increased in time, final weights decreased with increased in time, weights loss increased with increased in time and corrosion rates increased with increased in time.

Keywords – corrosion, mild steel, coupon, salt water, weight loss

https://doi.org/10.46654/6wbygq64

1.0 Introduction

Corrosion is the chemical reaction between a metal by chemical or electrochemical reactions with its environment. Alloy steel was used in large amounts in marine application because it offers excellent mechanical properties and lower cost. The study of mild steel corrosion phenomena in seawater has become a great challenge for corrosion engineers or scientists nowadays Prifiharni, et al (2018), Salam, et al (2007) and Jeffrey and Melchers, (2009).

Sea water covers more than 70% of the Earth's surface and is considered the most abundant natural electrolyte. Most metallic materials exposed to sea water are destroyed, due to corrosion. For many engineering materials, sea water is considered the most corrosive of all naturally occurring electrolytes. The most significant parameters that determine seawater corrosively are the content of dissolved oxygen, temperature, flow rate, salinity and pH. Other factors that determine corrosively are biological activity (bio-deposits), and the environmental zone of exposure Prifiharni, et al (2018). In Indonesia, due to wide spread use of mild steel, zinc, and galvanized iron, it was considered desirable to study the corrosion behavior of these materials in the marine. Because of excellent mechanical properties and relatively low prices. However, mild steel has very low corrosion resistance for most environments and it leads to rust formation and consequent loss of some mechanical properties, Rincón *et al.*, (2009). Coatings are the most commonly used method to protect steel from the aggressiveness of the marine environment where it is widely used. The basic concept is not electrochemical in nature but simply to isolate the steel component or construction from the environment. In coating applications, zinc primer is widely used due to their high corrosion protection performance. Hot-dip galvanization is a cost effective process that has many advantages over other coatings, in terms of mode of application and extended protection Shibli, *et al* (2007).

2.Materials and Methods

2.1 Materials

Sodium Chloride (NaCl), mild steel rod, conical flask, wooden test tube holder, retort stand, clamp, boss head, electronic weighing balance, sample bottles, water, corrosion meter, acetone, distilled water, sand paper (smooth sand rough), pH meter, thermometer and cylinder.



Figure 1: Materials for the Experiment

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Figure 2: Weight of mild Steel Coupon

2.2 Method

The metal coupon (mild steel) was purchased from Mile Three Market, Building Materials Layout, and the sodium chloride was purchased at Choba market both in Obio Akpor Local Government Area of Rivers State.

Preparation of Metal Rod for Experiment

The mild steel plate was cut 3.7cm long, 2.6cm wide and 0.2cm high into three pieces of equal lengths, widths, heights and sizes.

Preparation of Sodium Chloride (NaCl) Solution

10g of NaCl (50ml of water) will be formed each for the first five sets of the 5cm mild steel rods, 20g of NaCl (50ml of water) will be formed each for the second five sets of the 5cm mild steel rods and 30g of NaCl (50ml of water) will be formed each for the third five sets of the 5cm mild steel rods The test solutions will be prepared in different containers to carry out the corrosion experiment.

Preparation of Metal Specimen

The cubiod mild steel specimens were mechanically cut into dimension of lengths = 3.7cm, width = 2.6cm and height = 0.2cm. Prior to all, the mild steel rods were mechanically polished with smooth sand paper to sufficiently remove any mill scale on the sample of the mild steel coupons. The specimen outer surface area was washed thoroughly with distilled water, degreased with absolute ethanol, dipped into acetone to avoid corrosion and dried in air. The dried specimens were stored in desiccators before use.

Experimental procedure

The mild steel coupons of length 3.7cm, width 2.6cm and heights 0.2cm were cut into three sets. Fifty-centimeter cube ($50cm^3$) from 10g of NaCl (50ml of water) of sodium chloride solution was prepared into a set and the mild steel coupon was dipped into the container. Then the next fifty centimeter cube ($50cm^3$) from 20g of NaCl (50ml of water) of sodium chloride solution was prepared into a set and the mild steel was dipped the container and finally, fifty centimeter cube ($50cm^3$) from 30g of NaCl (50ml of water) of sodium chloride solution was prepared into a set and the mild steel coupon was dipped into the container. The

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mild steel coupons were weighed to know the weights before suspending them into the different concentrations of sodium chloride solution in the beakers, for 7days with the help of retort stand, clamp, string and test tube holders in the beakers. After, 7days the coupons were removed from the three different concentrations of sodium chlorides brushed with both rough and smooth sand papers and passed through the procedures stated above and reweighed to obtain the new weight to enable the loss in weight and corrosion rate to be calculated. The tests for the weight loss, corrosion rate, pH, and temperature in sodium chloride solution. The process was continued for five weeks.



Figure 3: Experimental Set up of Corrosion Rate of Mild Steel Coupons in NaCl Solutions

Cleaning of corrosion coupon were as follows:

a) The coupons were cleaned by firstly dipping coupon in distilled water for 5 minutes.

b) Followed by washing all the coupons in ordinary fresh water with a soft brush.

c) After which, the coupons were soaked in Acetone for 5 min.

d) Then allowed to dry in sun, followed by obtaining the initial weight (W1) of the individual coupons using a digital weighing balance.

e) The sizes of the coupons measured to ascertain the area of the coupons

f) The weighed coupons were thereafter put back inside the solutions.

2. After every 7days (168 hours) of immersion, each of the coupons were brought out and thoroughly cleaned by same procedure as above and weighed again. Final weight is (W2).

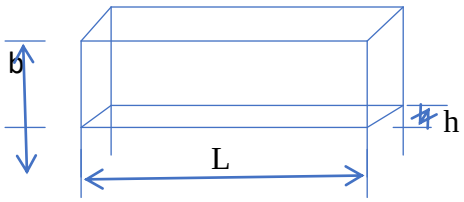
3. The weight loss (W_f) in milligram and the corrosion rate was calculated using the formula below:

Test for the pH and temperatures of the mediums

The pH meter and thermometer were inserted into the three mediums on weekly basis to ascertain the pH and the temperatures of the mediums.

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Shape and Size of Specimens



Anyanwum et al (2014)

The weight loss is obtained using the equation (1) below

$$W_f = \Delta W = W_2 - W_1 \quad (1)$$

Anyanwum et al (2014)

The shape of the mild steel rod is cuboid, (Anyanwum et al, 2014) therefore, the surface area of a cubiod,

Surface area of coupon = $bl + bl\,bh + bh + hl + hl = 2bl + 2bh + 2hl = 2(bl + bh + hl)$

$$SA_{coupon} = 2(bl + bh + hl) \quad (2)$$

Anyanwum et al (2014)

$$SA_{coupon} = 21.76cm^2$$

The density of the coupons can be calculated using equation (3) below

$$Density_{coupons} = \frac{Mass_{coupons}}{Volume_{coupons}} \quad (3)$$

The volume of the coupons can calculated using the formula of cuboid as in (4)

$$Volume_{coupons} = lbh \quad (4)$$

Volume of coupon = $1.924cm^3$

Determination of Corrosion Rate

The corrosion rate is calculated using equation (5) below.

$$\text{Corrosion rate in } (mmpy) = \frac{87.6\ x\ Weig\,ht\ Loss}{Area\ x\ Time\ x\ Density} \quad (5)$$

Anyanwum et al (2014)

The most common method for estimating a corrosion rate from mass loss is to weight the corroding sample before and after exposure and divide by the total exposed area and the total exposure time making sure that appropriate conversion constants are used to get the rate in the required units. The method in mm/wk can be represented by the following equation (Freeman, 2020).

$$C_R = \frac{k\Delta W}{AxTx\ \rho} \quad (6)$$

Where

$k =$ constant of unit conversion = 8.76×10^4

$\Delta W =$ Weight loss in gram

$A =$ Exposed Surface Area of Coupons $= 21.76 cm^2$

$T =$ Time of exposure in hour

$\rho =$ Density of Mild Steel coupons in g/cm^3

To provide minimum uncertainty in the corrosion rate, this method implicitly assumes:

The corrosion rate does not vary with exposure time

The area does not change as mass is lost to corrosion

The projected and actual surface areas are the same

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The penetration rate is uniform over the entire surface
The weight is unaffected by corrosion product removal
Even assuming that the above criteria are fulfilled, errors can still be propagated because of the uncertainty in the measurement of time, mass, and dimensions (Freeman, 1988).

3. Results and Discussion

P^H of the Sodium Chloride Mediums with Time

Table 1: pH of Different Concentration of Sodium Chloride with Respect to time

pH/Time	10g NaCl	20g NaCl	30g NaCl
7	6.9	6.5	5.3
14	6.4	6	5
21	6	5.8	4.8
28	5.7	5.3	4.6
35	5.2	5	4.5

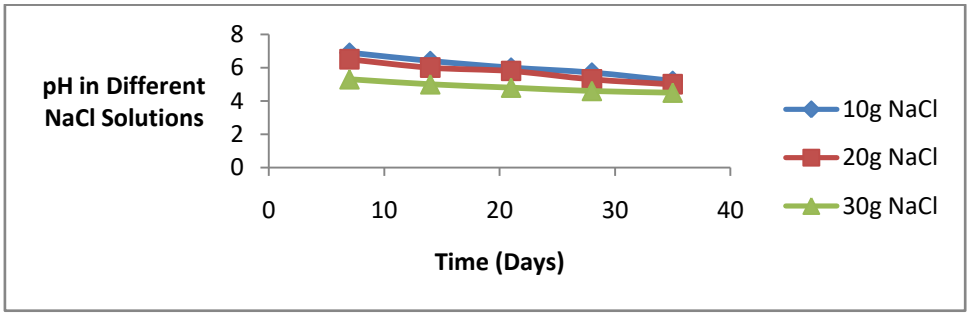


Figure 1: Graph of pH in Different Sodium Chloride Concentration against Time (Days)

Figure1: Depicts the relationship between pH of different concentrations of sodium chloride solution with time in days. It shows that as time increases, the pH in different concentration of sodium chloride solution decreases, the decrease was rapid in the three concentrations of sodium chloride solution. The decrease may be attributed to the concentrations of iron (iii) chloride and time. The decreases were in increasing order of 10g NaCl > 20g NaCl > 30g NaCl.

Temperatures of the Sodium Chloride Mediums with Time

Table 2: Temperature of Different Concentration of Sodium Chloride with Respect to time

Temp/Time	10g NaCl	20g NaCl	30g NaCl
7	25.1	25.3	25.6
14	25.3	25.7	25.9
21	25.5	25.9	26
28	25.9	26.1	26.4
35	26	26.4	26.8

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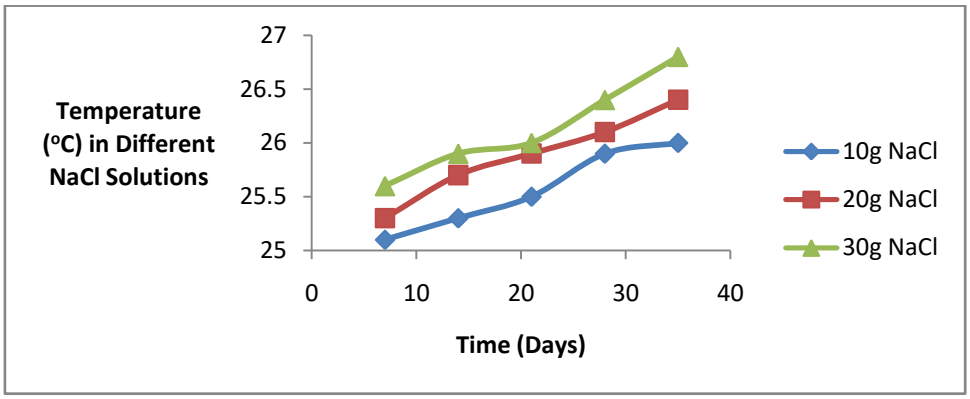


Figure 2: Graph of Temperature in Different Sodium Chloride Concentration against Time (Days)

Figure 2 shows the relationship between temperatures of different concentrations of sodium chloride solution with time in days. It shows that as time increases, the temperatures in different concentration of sodium chloride solution increases, the increases were rapid in the three concentrations of sodium chloride solution. The increase may be attributed to the concentrations of iron (iii) chloride released and time. The increases were in increasing order of 30g NaCl > 20g NaCl > 10g NaCl.

Final Weight of mild steel coupons with time

Table 3: Final Weight of Different Concentration of Sodium Chloride with Respect to time

Final Weight/Time	10g NaCl	20g NaCl	30g NaCl
7	13.54	13.49	13.42
14	13.50	13.45	13.33
21	13.48	13.33	13.21
28	13.28	13.18	13.13
35	13.23	13.13	12.93

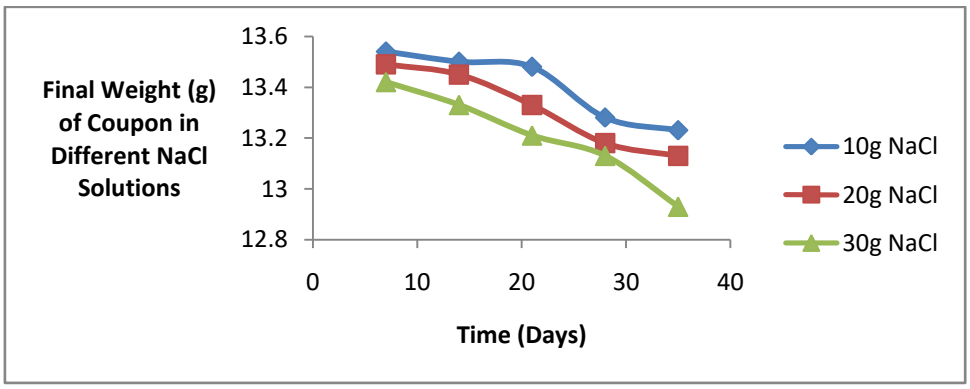


Figure 3: Graph of Final Weight of Coupons in Different Sodium Chloride Concentration against Time (Days)

Figure 3: Illustrates the relationship between final weights of coupons in different concentrations of sodium chloride solution with time in days. It shows that as time increases, the final weights in different concentration of sodium chloride solution decreases, the decreases were rapid in the three concentrations of sodium chloride solution. The decrease

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may be attributed to the concentrations of iron (iii) chloride released and time. The decreases were in increasing order of 10g NaCl > 20g NaCl > 30g NaCl.

Weight Loss of mild steel coupons with time

Table 4: Weight Loss of Coupons in Different Concentration of Sodium Chloride with Respect to time

Weight Loss/Time	10g NaCl	20g NaCl	30g NaCl
7	2.39	2.44	2.51
14	2.43	2.48	2.60
21	2.45	2.60	2.72
28	2.65	2.75	2.80
35	2.70	2.80	3.00

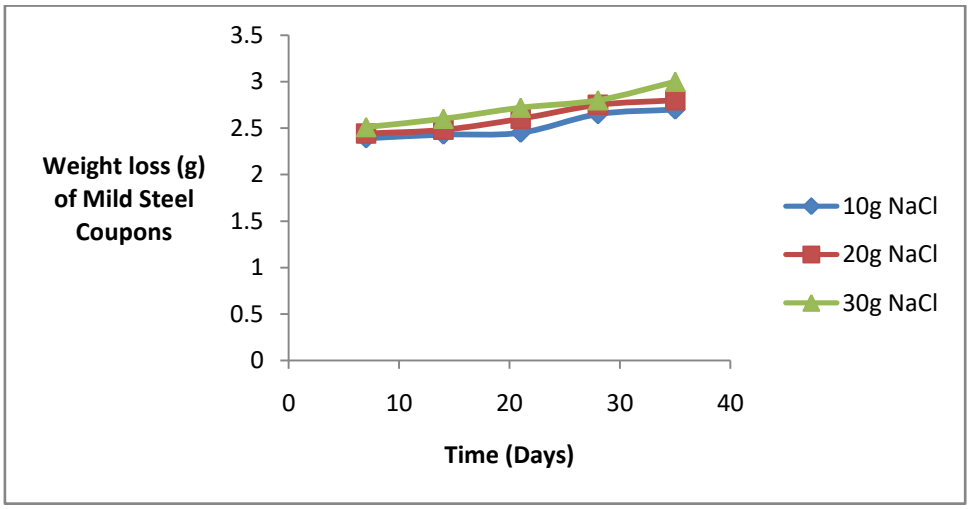


Figure 4: Graph of Weight Loss of Coupons in Different Sodium Chloride Concentration against Time (Days)

Figure 4 indicates the relationship between weights loss of coupons in different concentrations of sodium chloride solution with time in days. It shows that as time increases, the weights loss in different concentration of sodium chloride solution increases, the increases were rapid in the three concentrations of sodium chloride solution. The increases may be attributed to the concentrations of sodium chloride and time. The increases were in increasing order of 30g NaCl > 20g NaCl > 10g NaCl.

The corrosion rate of mild steel coupons with time.

Table 5: Corrosion Rate of Coupons in Different Concentration of Sodium Chloride with Respect to time

Corrosion Rates/Time	10g NaCl	20g NaCl	30g NaCl
7	0.84	0.85	0.88
14	0.85	0.87	0.91
21	0.86	0.91	0.95
28	0.93	0.96	0.98
35	0.95	0.98	1.05

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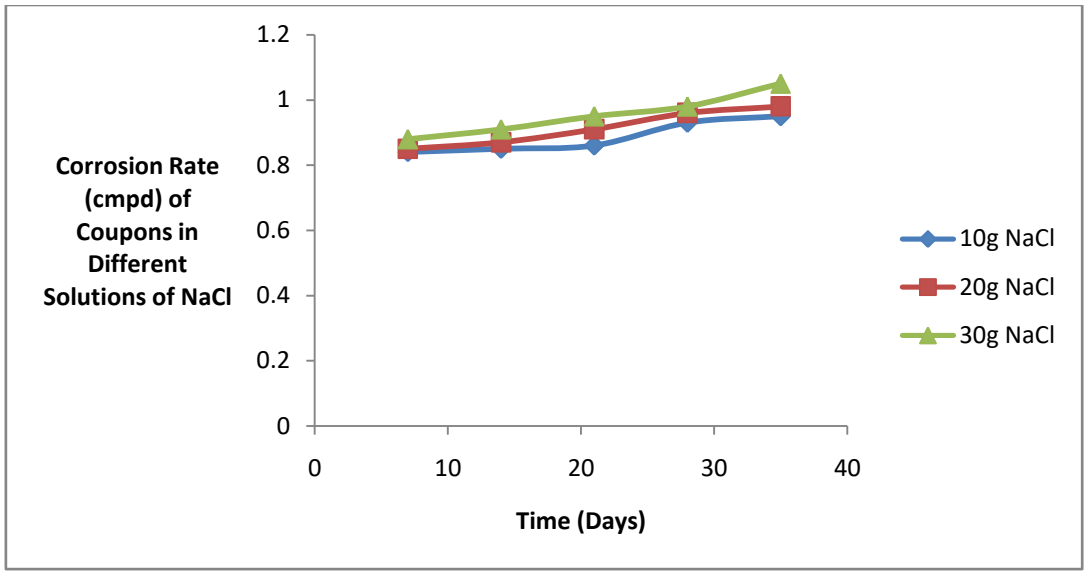


Figure 5: Graph of Corrosion Rates of Coupons in Different Sodium Chloride Concentration against Time (Days)

Figure 5: Depicts the relationship between corrosion rates of coupons in different concentrations of sodium chloride solutions with time in days. It shows that as time increases, the corrosion rates in different concentration of sodium chloride solution increases, the increases were rapid in the three concentrations of sodium chloride solution. The increases may be attributed to the concentrations of sodium chloride and time. The increases were in increasing order of 30g NaCl > 20g NaCl > 10g NaCl.

4. CONCLUSION

The most significant parameters that determine seawater corrosively are the content of dissolved oxygen, temperature, flow rate, salinity and pH. The factors that determine corrosively are biological activity (bio-deposits), and the environmental zone of exposure. Based on major findings and discussions the following conclusion were made. The P^H of different concentrations of sodium chloride solutions decreases with respect to increase in time.Temperatures of different concentrations of sodium chloride solutions increase with respect to increase in time.The mild steel coupons final weights decrease in different concentrations of sodium chloride solutions with respect to increase in time.The mild steel coupons weights loss increases in different concentrations of sodium chloride solutions with respect to increase in time. The mild steel coupons corrosion rate increases in different concentrations of sodium chloride solutions with respect to increase in time.

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