



CORROSION EVALUATION ON MILD STEEL IN DIFFERENT SELECTED MEDIA

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Abstract— Mild steel is a key materials used for construction work in the industry but its susceptibility to corrosion in humid air, acidic and other environments are the major obstacles that limit its usage in large scale. In this research work, an assessment of corrosion of locally produced mild steel in tetraoxosulphate (VI) acid (H_2SO_4), hydrochloric acid (HCl), underground soil and fresh water has been considered. The collected samples from Aladja, Warri, Delta State, Nigeria after chemical analysis were machined to the same sizes. Each of the samples was immersed in equal volumes of the selected media. The assessment of effect of corrosion on the mild steel samples used was carried out via weight loss at various exposure times which lasted for duration of 45 days. The results obtained indicated that tetraoxosulphate (VI) acid was most aggressive environment while fresh water the least. The average weight losses obtained are 5.02g (H_2SO_4), 0.19g (underground soil) and 0.144g (fresh water) with corresponding corrosion rate 0.06725 (mm/yr.), 0.0177(mm/yr.), 0.002793(mm/yr.) and 0.001996 (mm/yr.) respectively. The follow up statistical analysis output showed that loss in weight is significant for tetraoxosulphate (VI) acid when compared with other media. Thus, it can be concluded that of the four media examined, tetraoxosulphate (VI) acid is the most corrosive, followed by hydrochloric acid, underground soil and fresh water which shows a fairly low degree of corrosiveness. Therefore, facilities and equipment made of mild steel should not be used in an environment containing traces of acidic ions due to the hazardous effect it has on mild steel material.

Keywords—Mild steel, corrosion media, weight loss, corrosion rate, environment

I. INTRODUCTION

All over the globe, mild steel is a valuable material and generally use in most engineering applications for the production of some automobile components, structural shapes and sheets that are used in plants, Engineering facilities, pipelines, building bridges [1]. The usage of carbon steel material is noticeable in various facets of human life such as in manufacturing, oil and gas, construction, medical, textile, transport and aviation industries to mention a few. Despite the versatile usage of mild steel materials, the failure of parts and components of engineering materials produced from such materials in different industries environment by corrosion is one of the major problems facing mankind [2]. As a result of man activities in our ecosystem, the environment is increasing becoming corrosive thereby causing significant impact in the degradation of metals [3-5]. Most metals such carbon steels are prone to corrosion irrespective of their area of application be it power generation, paper industries, oil and gas etc.

Metals corrode because they are used in environment where they are chemically unstable. Apart from copper and the other precious metals such as gold, silver, platinum etc., which are found in nature in their free metallic state. Every other metal are processed from minerals or ores into metals which are inherently unstable in their environments hence, they tend to revert to their more stable state, a phenomenon termed as reversed extractive metallurgy [7-9]. Corrosion which has existed over the years and regarded as a gradual deterioration of materials, usually metals, by chemical reaction with its environment [10-13] is a menace to the existence of man and his environment [14-15]. Corrosion is said to be a destructive phenomenon of which its economics effects is detrimental to the appearance of metal and some cases can cause equipment failure [16]. Thus, the importance of corrosion effects calls for emphasis in knowing the kinetics of corrosion as to enable the prediction of service life of equipment. Corrosion studies might give insight into the chemistry and mechanism of



corrosion thereby indicating the environment control for which a particular material may be satisfactory [17].

II. MATERIALS AND METHODS

A. Materials Selection

The material used for the experimental study were locally produced mild steel premium steel and mines (formally Delta Steel) Aladja, Warri, Delta State. The element composition of the mild steel was conducted via Minipal 4 spectrometer, having a chemical composition as follow;

Table1. Composition of Mild Steel

Element	Percentage Composition (%)
C	0.14
Mn	0.48
P	0.017
Si	0.18
S	0.005
Cu	0.03
N	0.007
Cr	0.79
Fe	98.43

The collected samples were machined using a lathe and cutting machine into rectangular shape of dimension of 5mm by 3mm by 0.5mm thickness. The samples were then taken through grinding, polishing and etching preparation in order to eliminate the effect of surface impurity. The samples were finally rinsed in distilled water before drying.

B. Preparation of Test Media

The media in which the experiment was conducted consist of 2M tetraoxosulphate (VI) acid, 2M hydrochloric acid, fresh water and underground soil. Both acids were obtained from the industrial market, Warri, Delta State. Other media are readily available in the environment.

C. Shapes and Size of Samples

The samples used in this research work are rectangular in shape.

Length=5mm=50cm

Breath=3mm=30cm

Thickness = 0.5mm=5cm

Area of flat Sides = $2(L \times B) = 2(50 \times 30) = 3000\text{cm}^2$

Area of Edges = $2(\text{Length} \times \text{Thickness}) + 2(\text{Length} \times \text{Thickness})$
 $= 2(50 \times 5) + 2(30 \times 5) = 500 + 300 = 800\text{cm}^2$

Therefore,

Total Area = Area of flat sides+ Area of edges = $3000 + 800 = 3800\text{cm}^2$

D. Determination of Corrosion Rate

Twenty (20) samples of properly machined mild steel to shape and dimension were used for the weight loss and corrosion rate experiment and analysis. The initial weight of each samples was measured with a weighing balance and recorded (all samples have equal weight). Each of the samples was immersed in each of the media for initial period of 5 days and the investigation was continue for a period 10 days intervals and this lasted for a duration of 45 days. Equation (1) was used to determined the weight loss [17].

$$C_R = \frac{K \times \Delta W}{A \times T \times \rho} \quad (1)$$

where,

C_R = Penetration (Corrosion) rate in (mm/wk.)

ΔW = Weight loss in gram

A = Exposed Surface area of sample = $3.8 \times 10^2\text{cm}^2$

ρ = Density of mild steel (g/cm^3) = 7.86 g/cm^3

T = Time of exposure in hours

K = Constant for unit conversion = 8.76×10^4

Also, to provide minimum uncertainty in the corrosion rate, this method implicitly assumes that [17];

- i. The corrosion rate does not vary with exposure time
- ii. The area does not change as mass is lost to corrosion
- iii. The projected and actual surface areas are the same
- iv. The penetration rate is uniform over the entire surface
- v. The weight is unaffected by corrosion product removal, and even assuming that the above criteria are fulfilled, errors can still be propagated because of the uncertainty in the measurement of time, mass and dimension.

III. EXPERIMENT AND RESULT

The weight loss and the corrosion rate of the different mild steel samples were calculated and tabulated as shown in Table 2-Table

Table 2. Weight Loss of Sample in 2M H₂SO₄

Days	Initial Weight(g)	Final Weight(g)	Weight Loss(g)	Corrosion Rate (mm/yr)
5	78.50	70.90	7.60	0.1856
15	70.90	64.70	6.20	0.0758
25	64.70	60.10	4.60	0.3748
35	60.10	56.30	3.80	0.0232
45	56.30	53.40	2.90	0.0142

Table 3. Weight Loss of Sample in 2M HCL

Days	Initial Weight(g)	Final Weight(g)	Weight Loss (g)	Corrosion Rate (mm/yr)
5	78.50	76.33	2.30	0.0538
15	76.33	74.73	1.60	0.0196
25	74.73	73.63	1.10	0.0090
35	73.63	72.93	0.70	0.0043
45	72.93	72.53	0.40	0.0020

Table 4. Weight Loss of Sample in Water (H₂O)

Days	Initial Weight(g)	Final Weight(g)	Weight Loss(g)	Corrosion Rate (mm/yr)
5	78.51	78.27	0.24	0.00587
15	78.27	78.09	0.18	0.00210
25	78.09	77.96	0.13	0.00106
35	77.96	77.86	0.10	0.00061
45	77.86	77.79	0.07	0.00034

Table 5. Weight loss of sample in Underground Soil

Days	Initial Weight(g)	Final Weight(g)	Weight Loss (g)	Corrosion Rate (mm/yr)
5	78.51	78.27	0.24	0.00587
15	78.27	78.09	0.18	0.00210
25	78.09	77.96	0.13	0.00106
35	77.96	77.86	0.10	0.00061
45	77.86	77.79	0.07	0.00034

From the result analyzed, the average weight loss are 5.02g (H₂SO₄), 1.20g (HCL), 0.144g (fresh water) and 0.19g (underground soil) with corresponding corrosion rate of values 0.06725, 0.0177, 0.001996 and 0.002793 (mm/yr). The sample in Tetraoxosulphate (VI) acid shows a more severe level of corrosion rate when compared to the other media and this was due to the aggressiveness of the sulphate (SO₄²⁻) ion in the solution. Also the sample in hydrochloric acid experienced what is considered in Engineer literature as chloride aggressiveness. The presence of halide ions breakdown any passive films available and sometimes prevent passive films from forming on the mild steel. The specimen on the underground soil and fresh water experience a fairly the same gradual decrease in weight loss as time of the exposure increases. However sample exposed to tetraoxosulphate (VI) acid environment show a sharp increase in corrosion rate, this might be attributed to high oxidizing nature of the corrodent.

Furthermore, as shown in Fig. 1 and Fig. 2, the corrosion rate of all the samples of mild steel used in different media increases steadily for the first fifteen (15) days with the peak on day fifteen (15). This was however followed by continuous decrease in the corrosion rate of all the samples used. Nevertheless, the corrosion rate of the samples become moderately uniform after the forty (40) days and the pattern remain the same for the remaining five (5) days. The decreased in the corrosion rate of all the samples between the period of 15th day and 40th day can be ascribed to the aggressiveness of the chemical reactivity, transport properties of the corrosion medium, pH of the corrosion medium, concentration of the corrosion species, and the metallurgy of the alloy sample [5, 18-21].

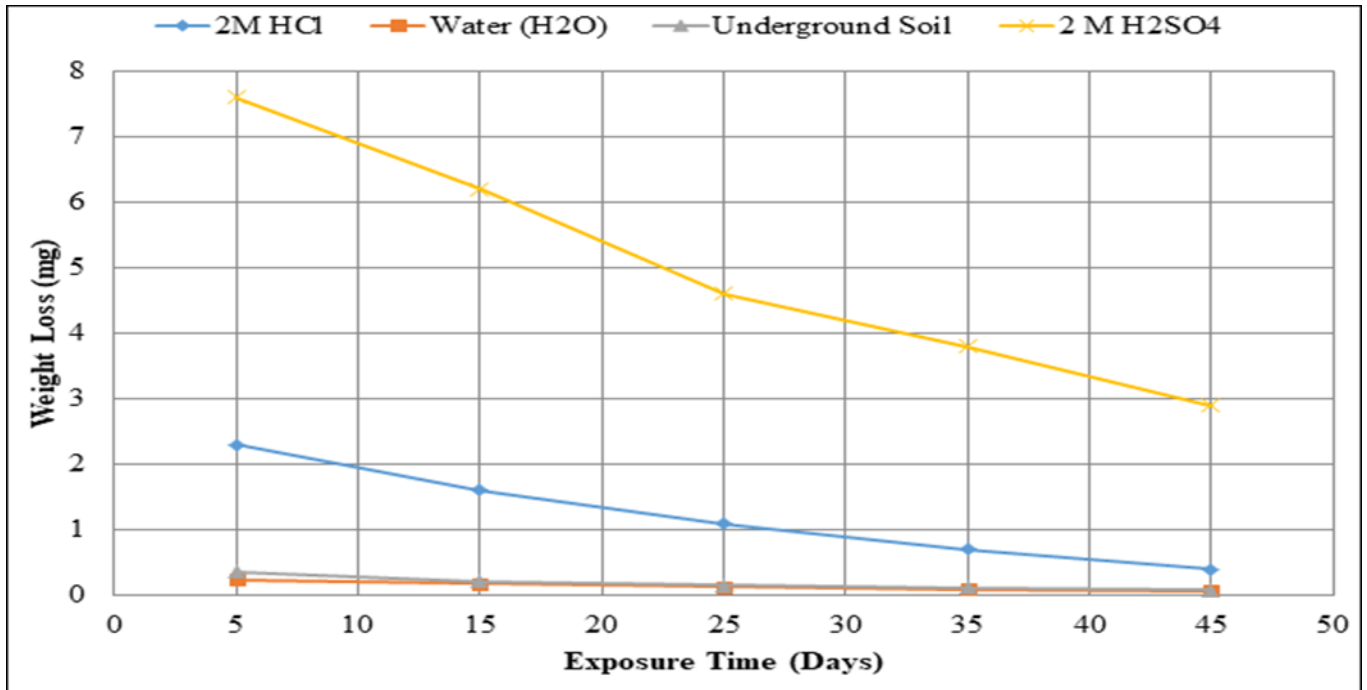


Fig. 1 Graph of Weight Loss against Exposure Time

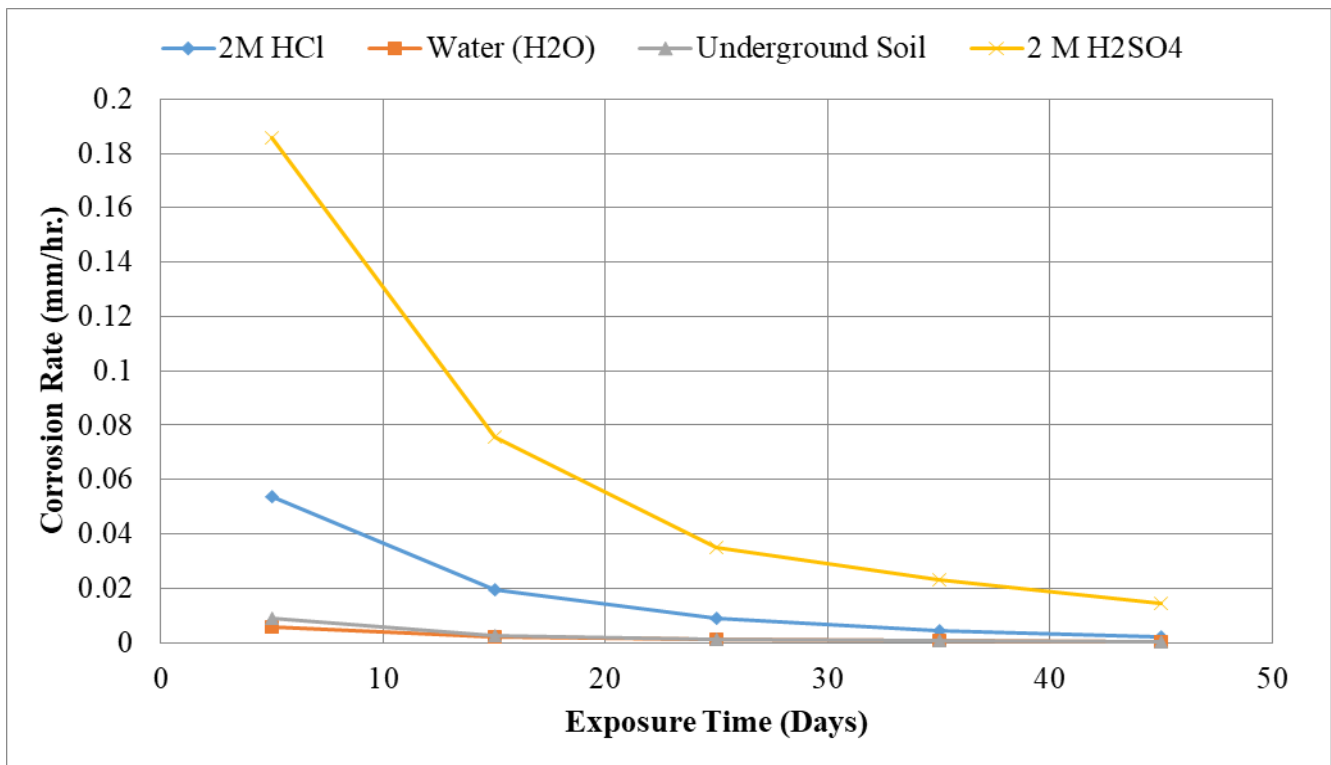


Fig. 2 Graph of Corrosion Rate against Exposure Time



Besides, it was observation that;

- Corrosion proceeded faster rate when ions are present.
- In the presence of an acid, corrosion was detrimental in a short period of time.
- Corrosion was quicker in acidic environment than other environment
- The rate of corrosion rate was proportional to the time of exposure.
- Underground soil and fresh water shows a fairly slight change in corrosion rate, hence it can be concluded that the rate of corrosion of mild steel was faster in tetraoxosulphate (VI) acid (H_2SO_4), followed by hydrochloric acid (HCl), underground Soil and fresh water respectively.

IV. RECOMMENDATION

The following is recommended;

- i. Mild steel should not be used in an environment with traces of acidic contents.
- ii. Mild steel tends to be suitable in fresh water and underground soil environment but should be coated to achieve a useful service life and with minimum maintenance, preventive measure like the use of inhibitors can also be used in order to slow down the rate of corrosion of mild steel in different environment.

V. CONCLUSION

From the foregoing, it was concluded that mild carbon steel samples experienced fast corrosion rate at the early stage of exposure period to the different media used in this research work. However, as exposure time prolongs, there was a continuous decreased in corrosion rate. Besides, among the media used in this research work, tetraoxosulphate (VI) acid showed more aggressiveness in terms of corrosion and weight loss when compared to hydrochloric acid, underground soil and fresh water environment. Therefore, for the purpose of corrosion control, a proper measure should be put in place if mild steel must be should in acidic and underground environment that might contains traces of ions that can easily react to produce acidic medium.

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