



## Comparative Analysis of Corrosion Rate of Low Carbon Steel in Acidic Environment

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**Abstract:** Low carbon steels (0.002-0.25%) account for a large proportion of the total output of steel. They are the most vital alloys used in petroleum and petrochemical industries since they account for over 98% of the construction materials. The wide application of low-carbon steel ranges from chemical, oil gas storage tanks and transportation pipelines are due to its moderate strength, good weld-ability and formability. However, the use of low carbon steel as construction material in industrial sectors has become a great challenge due to the effect of corrosion. This research work is focused on the comparative analysis of corrosion rate of low carbon steel in acidic environment. A low carbon steel of 0.145 weight percentage of carbon bought from a local market in Nigeria was used for this research work. The purchased low carbon steel sample was machined using lathe machine into cylindrical pieces of diameter of 25 mm and length of 60 mm and divided into four samples (Sample A, Sample B, Sample C, and Sample D). Four plastic bowls were filled with in traioxosulphate (vi) acid, hydrochloric acid, trioxosulphate (iv) acid, and ethanoic acid were used as acidic environment. The various steel samples were weighed with an analytical weighing balance before and after being immersed in the acidic environment in an interval of ten (10) days. The results obtained revealed that corrosion rate was comparatively high in the first twenty (20) days, and this was followed by continuous decrease in the corrosion rate of all the samples. However, the corrosion rate of the samples become partially uniform after thirty (30) days and the pattern remain the same for the remaining twenty (day 30-day 40) days and finally decreased gradually with subsequent increase in exposed acidic environment. More so, it was observed that samples soaked in the acidic solution of tetraoxosulphate (vi) acid shows a more aggressive corrosion rate as

**Keywords:** Corrosion Rate, Acidic Environment, Low Carbon Steel, Weight Loss, Tetraoxosullhate (vi) Acid

## INTRODUCTION

The wide application of low-carbon steel ranges from chemical, oil gas storage tanks and transportation pipelines are due to its strength, good weld-ability and formability (Afolabi, 2007). 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 (Oyejide *et al.*, 2017). Thus, the use of low carbon steel as construction material in industrial sectors has become a great challenge for corrosion engineers or scientists nowadays. Nevertheless, most industrial applications such as refining crude oil, acid pickling, industrial cleaning, acid descaling, oil-well acid in oil recovery and petrochemical processes use low carbon steel as their material. Steel material is susceptible to corrosion when used in chemical and sour crude oil environments such as sea water (Deyab, 2014; Oyejide *et al.*, 2017; Orhorhoro *et al.*, 2018; Okuma *et al.*, 2020). Degradation of materials produced from low carbon steel as a result of corrosion has come to be accepted worldwide as an unavoidable fact of life. For instance, 2241 major pipeline accidents were reported in the United Kingdom (UK) in the last 10 years and in the US alone the lost number on corrosion is approaching 350 million dollars per year (Trethewey and Roberge, 1995). In Nigeria, petroleum pipeline explosions occur regularly resulting in loss of lives and environmental pollution. There was a report of pipeline explosion in Idjerhe (Jesse), Ethiopie-West, Delta State, Nigeria, where hundreds of lives were lost (Trevor, 2005). A related incident in Adeje village near Warri, Delta State, where more than 250 Nigerians were fared died (Bodude, 2006).

Corrosion which has existed over the years and regarded as a gradual deterioration of materials, usually metals, by chemical reaction with its environment is a menace to the existence of man and his environment (Satapathy *et al.*, 2009; Orhorhoro *et al.*, 2017). 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 (Chinwko *et al.*, 2014). 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. A corrosion phenomenon is a natural process that results in considerable waste of industrial investment. This phenomenon can easily be found in different types of surfaces causing major economic losses in the industrial sector. Corrosion is an electrochemical process by which metallic surfaces react with their environment causing the metal to lose its material properties due to surface deterioration. Corrosion is a constant and continuous problem, often difficult to eliminate completely (Osarolube *et al.*, 2008). Prevention would be more practical and achievable than complete elimination. Corrosion processes develop fast after disruption of the protective barrier and are accompanied by a number of reactions that change the composition and properties of both the metal surface and the local environment. In contrast to general corrosion, attack by pitting sometimes occurs in some particular environmental conditions. These problems result from the presence of specific aggressive species such as chloride, sulphate or nitrate (Takasaki and Yamada, 2007). Each of these species alone can produce corrosion in alloy but with different levels of aggressiveness. For some corrosive resistance alloy such as copper, sulphate ions appear more aggressive than chloride ions and nitrate ions are more aggressive than sulphate ions (Duthil *et al.*, 1996). El Wanees *et al.* (2010) in their study about pitting corrosion in the presence of  $\text{Cl}^-$  as aggressive ions and  $\text{CrO}_4^{2-}$ ,  $\text{HPO}_4^{2-}$ ,  $\text{NO}_2^-$ ,  $\text{WO}_4^{2-}$  and  $\text{MoO}_4^{2-}$  as inhibiting anions, found that the limiting corrosion currents increase with an increase in the  $\text{Cl}^-$  ion concentration and decrease with an increase in the pH and inhibiting ions concentration for reinforcing steel (carbon steel) in concrete. The injection of the inhibiting anions in solution causes re-passivation of pre-formed pits through competition with  $\text{Cl}^-$  ions for adsorption sites on metal oxide surface. In a study by Takasaki and Yamada (2007) about the effects of temperature and aggressive anions on the corrosion of carbon steel in potable water it was concluded that the corrosion rate increased in proportion to the concentration of aggressive anions and with increasing temperature.

Furthermore, [El-Naggar \(2006\)](#) who studied the aggressive anions  $\text{Cl}^-$ ,  $\text{NO}_3^-$  and  $\text{SO}_4^{2-}$  on the corrosion and passivation behaviour of carbon steel in 0.50 M sodium bicarbonate solutions, found that the presence of these aggressive anions stimulates the anodic dissolution rate in both the active and pre-passive potential regions. Pitting corrosion was only observed in the presence of  $\text{Cl}^-$  anions, while the presence of  $\text{NO}_3^-$  and  $\text{SO}_4^{2-}$  anions was only facilitated by the oxygen in the water without themselves participating in the cathodic process. The effect of  $\text{SO}_4^{2-}$  anion exerts an indirect effect on increasing the cathodic reaction and influence the anodic reaction ([El-Naggar, 2006](#)). He found that increasing the concentration of  $\text{Cl}^-$  ion in the range from 0.002 to 0.100 M in 0.50 M  $\text{NaHCO}_3$  solutions shows a very low anodic passivating current followed by pitting potential (Epitting). Increasing the  $\text{Cl}^-$  ion concentrations from 0.003 to 0.040 M reduce the oxygen evolution on passive electrode and cause the current density increase abruptly and developing pitting corrosion at Epitting. Increasing the concentrations of  $\text{Cl}^-$  ion to 0.04 M, Ebreak coincide with Epitting thus,  $\text{Cl}^-$  ions concentration is considered as the limiting concentration.

## MATERIAL AND METHOD

A low carbon steel of 0.145 weight percentage of carbon bought from a local market in Nigeria was used for this research work. In this research work, several equipment such as lathe machine, power saw, weighing balance were used. A power saw was used to cut the low carbon steel into the required sizes. An analytical weighing machine was used to determine the weight of the steel samples.

### *A. Determination of the Chemical Composition of Low Carbon Steel*

The chemical composition of the low carbon steel samples used for this investigation was determined in the laboratory and results tabulated as showed in [Table-1](#).

### *B. Preparation of Low Carbon Steel*

The purchased low carbon steel sample was machined using lathe machine into cylindrical pieces of diameter of 25 mm and length of 60 mm. The cylindrical pieces of machined low carbon steel samples were divided into the following groups:

- i. Sample A: Five (5) pieces immersed and soaked in traioxosulphate (vi) acid
- ii. Sample B: Five (5) pieces immersed and soaked in hydrochloric acid
- iii. Sample C: Five (5) pieces immersed and soaked in trioxosulphate (iv) acid
- iv. Sample D: Five (5) pieces immersed and soaked in ethanoic acid

### *C. Determination of Weight Loss and Corrosion Rate*

The prepared low carbon steel samples and the acidic solution corrosion environment were used for the experiment to determine the corrosion rate of the low carbon steel, which was performed at room temperature. Four plastic bowls were filled with in traioxosulphate (vi) acid, hydrochloric acid, trioxosulphate (iv) acid, and ethanoic acid were used as acidic environment. The various steel samples were weighed with an analytical weighing balance and recorded as ( $W_i$ ) before being immersed into their respective labeled plastic bowls. After ten (10) days intervals, each of the steel samples were retrieved, properly cleaned and allowed to dry for about ten (10) minute. They were then placed on a weighing balance to record their weights ( $W_f$ ). This procedure was repeated at ten (10) day intervals for a period of fifty (50) days. Equation (1) was used to calculate the weight loss.

$$W_L = W_i - W_f \quad (1)$$

where,

$W_L$  = Weight loss

$W_i$  = Initial weight

$W_F$  = Final weight

Equation (2) was used to calculate the corrosion rate of low carbon steel.

$$C_R = \frac{87.6W_L}{DAT} \quad (2)$$

where,

$C_R$  = Corrosion Rate (mm/y)

$W$  = Weight loss (mg)

$D$  = Density of Low Carbon Steel = 7.85g/cm<sup>3</sup>

$A$  = Area of medium carbon steel samples used (cm<sup>2</sup>)

$T$  = Exposure time in acidic environment (days)

## RESULTS AND DISCUSSION

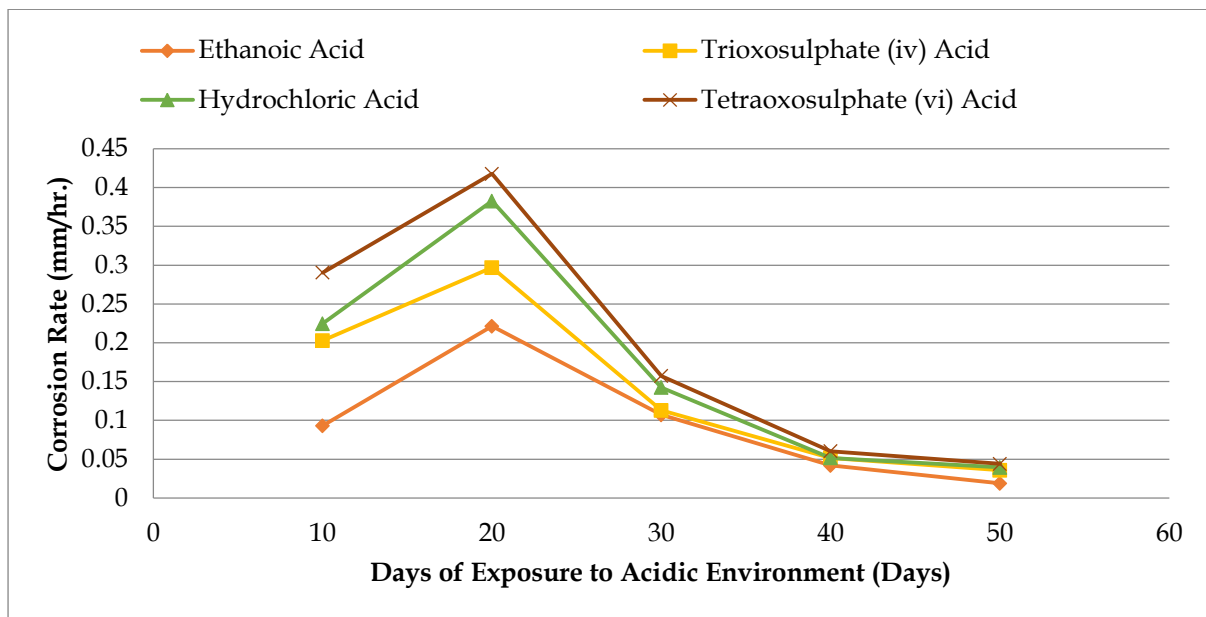
Table-1 shows the chemical composition of percentage weight of low carbon steel. The results obtained shown that low carbon steel comprises predominantly of iron, carbon, silicon, manganese, sulphur, titanium, chromium, nickel, copper, vanadium, tungsten, etc.

Table-1 Chemical composition of the Low Carbon Steel Sample (wt. %)

Element Present	Percentage Weight (%)
Carbon (C)	0.360
Silicon (Si)	0.490
Manganese (Mn)	0.850
Phosphorous (P)	0.025
Sulphur (S)	0.127
Titanium (Ti)	0.000
Copper (Cu)	0.530
Nickel (Ni)	0.240
Chromium (Cr)	0.070
Molybdenum (Mo)	0.004
Vanadium (V)	0.001
Aluminium (Al)	0.023
Tungsten (W)	0.005
Niobium (Nb)	0.000
Nitrogen (N)	0.005
Iron	97.171

Fig. 1 shows the plot of corrosion rate of low carbon steel in exposed in tetraoxosulphate (VI) acid (Sample A), hydrochloric acid (Sample B), trioxosulphate (IV) acid (Sample C), and ethanoic acid (Sample D). Corrosion rate was comparatively high in the first twenty (20) days, and this was followed

by continuous decrease in the corrosion rate of all the samples. However, the corrosion rate of the samples become partially uniform after thirty (30) days and the pattern remain the same for the remaining twenty (day 30-day 40) days and finally decreased gradually with subsequent increase in exposed acidic environment. The reason for this may have been as a result of the stagnant corrosion acidic media used in this research work as reported by [Oyejide et al., \(2017\)](#). More so, the decreased in the corrosion rate of all the samples between the period of 20<sup>th</sup> day to 40<sup>th</sup> 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 as reported by [Lee et al., \(2004\)](#); [Pruthviraj and Prakash, 2013](#); [Orhorhoro et al., 2016](#).



**Fig. 1** Effect of Corrosion Rate of Low Carbon Steel in Acidic Media

Besides, it was observed that samples soaked in the acidic solution of tetraoxosulphate (VI) acid shows a more aggressive corrosion rate as compared to the other acidic media used in this research work. This can be attributed to the corrosive nature of the sulphate ( $S04^{2-}$ ) ion present in the tetraoxosulphate (VI) acid solution as reported by [Okuma et al., \(2020\)](#). Also, there was chloride aggressiveness in all the samples soaked in the hydrochloric acid (HCl) solution and this was as a result of the presence of halide ions that enhances breakdown of any passive films available and thus, prevent passive films from forming on the low carbon steel.

[Fig.2](#) shows the plot of weight loss of low carbon steel against time of exposure in acidic environment. It was observed that the samples loss in weight was increasing with exposure time with increased in tetraoxosulphate (vi) acid, followed by hydrochloric acid, trioxosulphate (vi) acid, and ethanoic acid.

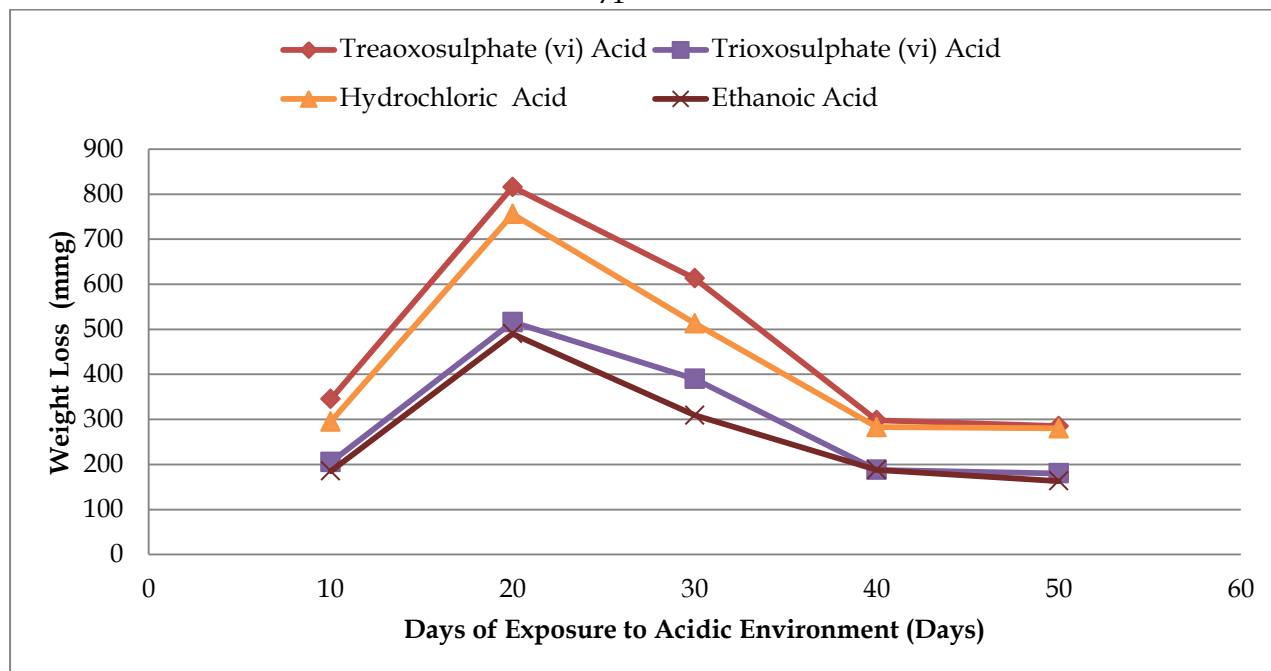


Fig. 2 Effect of Weight Loss of Low Carbon Steel in Acidic Media

## CONCLUSION

Corrosion which has existed over the years and regarded as a gradual deterioration of materials, usually metals, by chemical reaction with its environment is a menace to the existence of man and his environment. 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. This research work that focused on comparative analysis of corrosion rate of low carbon steel in acidic environment was successfully carried out. The outcome of the research revealed that acidic environment enhances corrosion rate with tetraoxosulphate (vi) acid environment appeared more aggressive as compared to other acidic environment used in this research work.

## CONFLICT OF INTEREST

We hereby state that no conflict of interest will arise in any form in publication of this research work.

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