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Comparative Corrosion Behaviour of Mild and Carbon Steel in Fresh and Salt Water Environments of the Niger Delta, Nigeria.

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ABSTRACT
This study investigates the comparative corrosion behavior of mild steel and carbon steel in fresh water and salt water environments of the Niger Delta. The experiment was conducted using weight loss measurements, visual inspection, and corrosion rate calculations, to evaluate material degradation over a defined exposure period of 4320 days. Prepared mild and carbon steel coupons were immersed in fresh and salt water bodies. The results revealed that the average corrosion rate of mild steel are 0.258mm/yr and 0.425mm/yr and that of carbon steel are 0.192mm/yr and 0.325mm/yr in fresh water and salt water environments respectively. Both steels experienced higher corrosion rates in salt water than in fresh water due to the presence of chloride ions and increased ionic conductivity. Mild steel exhibited greater susceptibility to corrosion compared to carbon steel in both environments. The findings indicate that environmental salinity significantly influenced corrosion severity, while carbon steel possesses relatively better corrosion resistance because of its higher carbon content and micro-structural characteristics. The study recommends the application of protective coatings, cathodic protection systems, and corrosion inhibitors for steel structures operating within the Niger Delta environments.

Keywords: corrosion, mild steel, carbon steel, salt water, fresh water

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I. INTRODUCTION

Corrosion of metallic materials remains a major challenge in industrial and marine environments, particularly in the Niger Delta region of Nigeria where oil exploration, transportation pipelines, marine operations, and industrial activities are dominant (Amadi & Erewari, 2026).

In the Niger Delta region of Nigeria, corrosion has become increasingly significant because of the combined effects of high humidity, saline coastal waters, industrial pollutants, and microbial activities associated with petroleum exploration and transportation (Groysman, 2017).

Corrosion occurs as a result of the physicochemical interaction of metals with their environment. It is an electrochemical reaction between a material usually metal and its environment that results in the deterioration of the metal and its property (Naja'atu Auwal Usman, 2019). It is a process that reverses a refined metal to its original ore. It weakens the strength of metal and has the potential to impair the function of the metal, environment or the technical system of which the metal forms a part (Revie & Uhlig, 2008). Corrosion is a major engineering problem affecting pipelines, storage tanks, offshore structures, ship hulls, and industrial equipment (Amadi & Wami, 2009).

Steel is widely used in construction, marine applications, pipelines, and industrial systems due to its strength, availability, and cost-effectiveness. However, its susceptibility to corrosion, particularly in aqueous environments, poses durability and safety concerns (Jassim & Hussain, 2017; Zheng et al., 2015). Steel materials are widely used in engineering applications because of their strength, affordability, and ease of fabrication. Among the most commonly used steels are mild steel and carbon steel. Mild steel contains a relatively low percentage of carbon, typically between 0.05% and 0.25%, while carbon steel contains higher carbon content, improving hardness and strength (Koc et al., 2015). Despite their usefulness, both materials are vulnerable to corrosion under aggressive environmental conditions (Oguike, 2014; Orozco-Cruz et al., 2017).

Fresh water and salt water environments exhibit different corrosion behaviors due to variations in dissolved oxygen, ionic concentration, pH, and conductivity (Lawson, 2011). Salt water, particularly seawater, contains high concentrations of chloride ions which accelerate electrochemical corrosion processes (Song et al., 2017). The Niger Delta region contains numerous rivers, creeks, and coastal waters that expose engineering structures to both fresh and saline conditions.

Understanding the comparative corrosion behaviour of mild steel and carbon steel in these environments is important for selecting suitable materials for industrial applications. It is the purpose of this study to evaluate and compare the corrosion performance of mild steel and carbon steel in fresh water and salt water environments of the Niger Delta region of Nigeria in order to generate corrosion data that may serve as a guide to engineers and other professional bodies in materials selection.

II. MATERIAL AND METHODS

2.1 **Materials**

The materials used for this study include mild steel coupons, carbon steel coupons, fresh water samples, Salt water samples, Digital weighing balance, emery papers, measuring cylinder, beakers, plastic containers, vernier caliper, desiccators, oven, ruler, iron sponge, ethanol, acetone, distilled water, detergent, polypropylene ropes.

2.2 **Methods**

2.2.1 ***Water Sample Collection***

Fresh water samples were collected from a bore-hole while salt water samples were obtained from a natural salt water body. Both samples were collected within Port Harcourt environments.
Fresh water and salt water were each collected with a-10 litre plastic container as outlined in (Amadi et al., 2010).

2.2.2 ***Preparation of Corrosion Coupons***

The mild and carbon steel Coupons used for the study was obtained from a corrosion monitoring and control company in Port Harcourt, Nigeria. A sheet of mild and carbon steel was cold-cut into smaller sheets of length 50mm, width 25mm, and 1mm thickness. The cold-cut technique was used to maintain the integrity of the steel and hence avoid the probable effects of heat-affected zone on corrosion. A hole of approximately the same diameter was drilled at the top of each coupon midway along the width for passage of a polypropylene rope. The coupons were thoroughly surface - finished with emery paper, sterilized by dipping in absolute ethanol and degreased by washing in acetone. The coupons were then dried in an oven at a temperature of 80^0C for 20 minutes, and were cooled in a dessicator. A total of twenty (24) corrosion coupons (12 each of mild and carbon steel) were prepared and used for the study. The initial weight of the coupons were taken using a digital balance and recorded. The method used in preparing the corrosion coupons is consistent with the literature (Amadi et al., 2026; Afolabi, 2007).

2.2.3 **Experimental Procedure**

Six (6) pieces of mild steel and carbon steel coupons each were immersed separately in containers containing fresh water and salt water respectively and suspended in the water samples with the help of a polypropylene rope. The coupons were retrieved at intervals of 720 hours (30 days) from both water samples. The retrieved coupons were washed with distilled water, cleaned, dried and reweighed. The process was repeated every 720 hours for a total period of 4,320 hours (180 days).The corrosion rate was determined using the weight loss method according to the equation (Rajesh et al., 2014; Amadi et al., 2026):

$$\mathrm{CR} = \frac{8.76\,x\,10^4 \times \mathrm{W}}{DAT} \qquad (1)$$

$where$

$CR = Corrosion\ rate\ \left(\frac{mm}{yr}\right)$

$W = Weight\ loss\ (mg)$

$D = Density\ of\ steel\ \left(\frac{g}{cm^3}\right)$

$A = Surface\ area\ of\ coupon\ (cm^2)$

$T = Expose\ time\ (hours)$

III. RESULTS AND DISCUSSION

3.1 *Weight Loss Analysis*

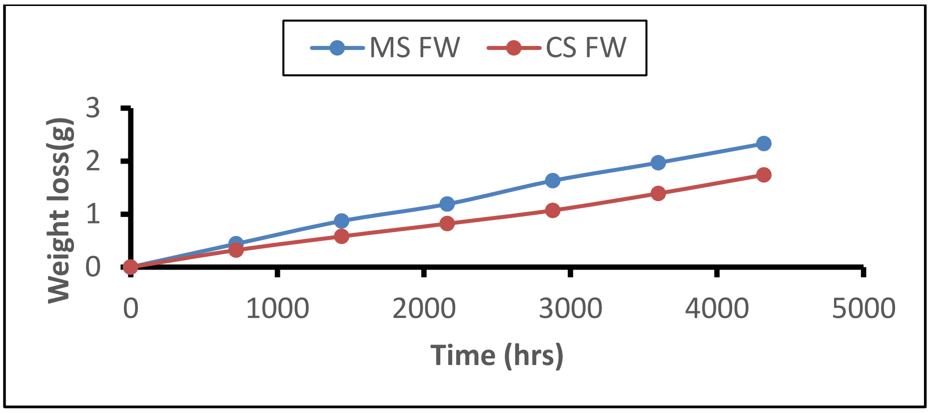

Figure 1: Weight loss of mild and carbon steel against time in Fresh water

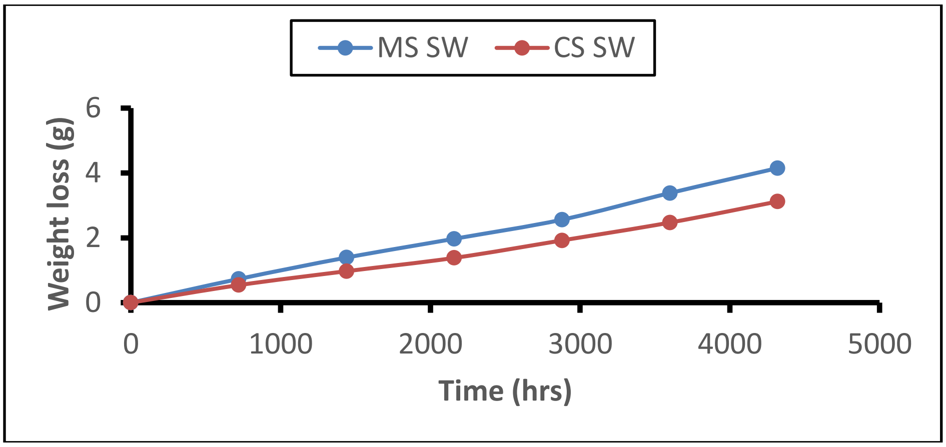

Figure 2: Weight loss of mild and carbon steel against time in Salt water

Figures 1 and 2 showed the weight-loss analysis of mild steel and carbon steel in fresh and salt water samples. The experimental results showed progressive weight loss for both mild steel and carbon steel in the two environments throughout the exposure period. The results further indicate that mild steel experienced greater weight loss than carbon steel under similar conditions. The highest weight loss occurred in mild steel immersed in salt water. The higher corrosion rate observed in salt water may be due to high ionic concentration (Na^+ and Cl^- ions), increased electrical conductivity, and enhanced electrochemical reactions (Zheng et al., 2015; Orozco-Cruz, 2017; Hasan, 2010). For example, chloride ions play a key role in breaking down protective oxide layers, thereby promoting localized corrosion such as pitting (Sun et al., 2012). However, the lower corrosion rate observed in fresh water may be due to lower conductivity, and reduced electrochemical activity (Salam, 2007). In addition, it was revealed that mild steel was prone to uniform corrosion due to its lower carbon content and simpler microstructure, while carbon steel had slightly improved resistance in some cases due to micro-structural variations, though still susceptible in salt water. Surface observation showed that salt water samples had heavy rusting and pitting, whereas, fresh water samples exhibited lighter rust formation. It was further observed that mild steel surfaces were more uniformly corroded, while carbon steel showed localized attack in some areas. These observations are consistent with literature (Jeffrey and Melchers, 2009; Jin et al., 2014).

3.2 Corrosion Rate Analysis

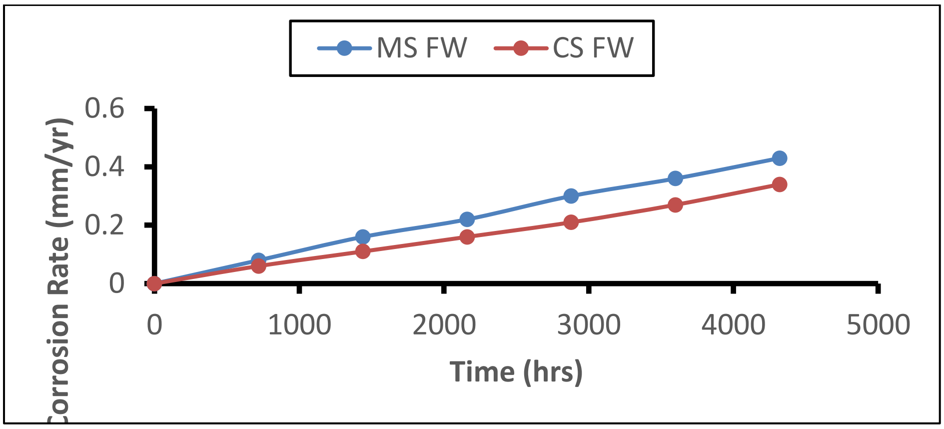

Figure 3: Corrosion rate of mild and carbon steel against time in Fresh water

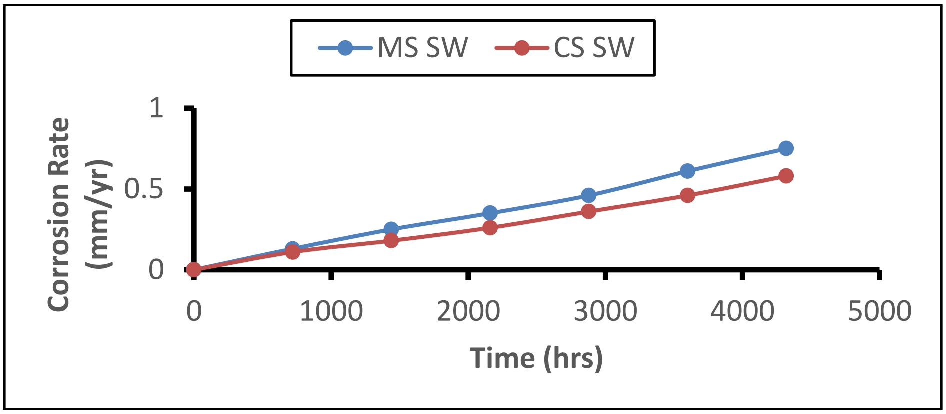

Figure 4: Corrosion rate of mild and carbon steel against time in Salt water

Figures 3 and 4 show the corrosion rate of mild steel and carbon steel in fresh and salt water environments. The calculated corrosion rates revealed that salt water accelerated corrosion significantly compared to fresh water. This corroborates the earlier work done by researchers (Wu et al., 2017; Zheng et al., 2015; Rajesh et al., 2014). The higher corrosion rates in salt water are attributed to the abundance of chloride ions which enhanced electrochemical reactions and destroyed passive oxide films on the metal surfaces (Song et al., 2017; Naja'atu Auwal Usman 2019).

The graphs show that environment plays a more dominant role than material type, although material composition still matters. The Niger Delta environment presents severe corrosion challenges because of high humidity, saline coastal atmosphere, industrial pollutants, acid rain from gas flaring, microbial activities in swampy regions, among other factors (Onwugbuta & John, 2020; Amadi & Ukoha-Onuoha, 2026).These conditions undoubtedly contributed to frequent failures of pipelines, storage facilities, and marine infrastructure in the region (Grolleau et al., 2016; Onwugbuta & John, 2020).

Generally, the results demonstrate a clear influence of environmental conditions on corrosion behavior. Salt water significantly increased corrosion rates for both mild steel and carbon steel. This is consistent with previous studies, which attribute increased corrosion to the presence of chloride ions that disrupt protective oxide films and enhance electrochemical reactions (Amadi & Wami, 2023; Refait et al., 2018; Sun et al., 2012; Ibrahim et al., 2009).

Mild steel exhibited higher corrosion rates than carbon steel in both environments. This can be attributed to its lower carbon content and simpler microstructure, which provides less resistance to electrochemical attack (Clover et al., 2005; Zou et al., 2011; Jassim & Hussain, 2017). Carbon steel, while still susceptible, showed slightly improved resistance due to its structural composition.

The difference between fresh water and salt water environments highlights the importance of ionic conductivity in corrosion processes. Fresh water, with lower ion concentration, resulted in reduced corrosion rates. These findings align with established corrosion theories (Alo & Ibitoye, 2015; Orozco-Cruz et al, 2017;

Zou et al., 2011). Surface observations further supported quantitative data, with salt water samples showing extensive rust formation and localized pitting, particularly in mild steel samples.

IV. CONCLUSION

This study investigated the comparative corrosion behavior of mild steel and carbon steel in fresh water and salt water environments of the Niger Delta, Nigeria. The results demonstrated that corrosion was more severe in salt water than in fresh water due to increased salinity and chloride ion concentration. Mild steel showed greater susceptibility to corrosion compared to carbon steel in both environments. The findings confirm that environmental conditions significantly influence the durability of steel materials used in industrial and marine applications. Carbon steel exhibited relatively better corrosion resistance and may therefore be more suitable for certain engineering applications in aggressive environments. The findings emphasize the need for careful material selection and corrosion protection strategies in environments exposed to saline conditions.

V. RECOMMENDATIONS

To minimize corrosion-related failures in the Niger Delta region, industries should adopt effective corrosion control measures such as protective coatings, cathodic protection, corrosion inhibitors, and regular maintenance programs. Material selection for engineering applications must consider exposure conditions, especially in marine or coastal environments.

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