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Study of Corrosion Control Using Epoxy Coating on Mild Steel in Different Environments

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Abstract

Mild steel is one of the major construction materials used for pipes. These pipes pass through different environments and corrode. Coating is one of the methods of corrosion control, and epoxy coating represents one of the most important engineered polymers that has drawn attention due to its wide applications, including structural materials and anti-corrosion coatings. This research, therefore, studies corrosion control using epoxy resin coats on mild steel in seawater and freshwater environments. The mild steel plate was cut into rectangular sizes of 30mm by 40mm of thickness 5mm. The samples surfaces were treated to get the surfaces clean and ready for coating. The cleaned mild steel samples were coated with the epoxy resin mixture using a drop-down method. The coated and uncoated mild steel samples were immersed in the different corrosion media for ninety days (90 days) At every fifteen days' interval, the corrosion rate due to weight loss was calculated. The weight of each sample was taken before and after each interval. Weight losses were recorded as a reduction in the weight of each sample before and after immersion periods. pH values of the media were recorded. The Protection efficiency of the epoxy coating on the mild steel at each immersion periods were also determined. The results of the experiment showed that the rate of corrosion for the various media varied increasingly in the seawater than in the freshwater. The epoxy resin coating on the mild steel plate was able to protect it up to an average rate of 92% in fresh water medium compared to 88.7% in seawater medium. The epoxy-resin coating on the mild steel plate improved its anti-corrosion performance in freshwater and seawater media. The epoxy resin coated mild steel plate offered better corrosion resistance in freshwater than in seawater.

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1. Introduction

Mild steel is one of the world's most inexpensive and beneficial metals. Mild steel is simply a class of steel with very low hardness invariably with low ultimate tensile strength and ductility (Ranganatha et al, 2012). Mild steel finds diverse use in several fields, beginning from building construction to kitchen utensils, aerospace and automobile (Majumdar, 2010). However ambient conditions of mild steel in an industrial environment are relatively more corrosive because of the presence of moisture and chemical pollutants in the air. Corrosion of mild steel in the presence of moisture is particularly severe when acidic gases or vapours are involved, such as oxides of nitrogen and sulfur or chlorine (Soares et al, 2009.). According to Tiwari et al (2011.), mild steel possesses reasonably good strength but exhibits poor resistance to corrosion. When mild steel comes in contact with alkalis and acidified media such as HCl and NaCl they are susceptible to corrosion degradation which imposes a major limitation on its usage in a severe atmospheric environment. The authors indicated that increasing the corrosion resistance of mild steel requires the formulation of a suitable conversion coating to provide an adherent and protective layer on the mild steel substrate. Panagopoulos et al.(2011), stated that the cost incurred due to the failure and repeated damage of mild steel in-service condition is a huge detriment to the integrity of steel usage in harsh conditions. The possibility of increasing the corrosion resistance and cost of mild steel has been on increasing paths since it is relatively cheap and possesses good weldability. According to Chinwko et al (2014), The application for which mild steel was developed generally did not involve corrosion resistance as a primary consideration. The corrosion resistance of metals and alloys is a basic property related to the ease with which these metals react in a given environment. With the increased utilization of this metal in manufacturing and construction firms, one of the major problems encountered is the control of corrosion rate when exposed to different corrosive environments. They ascertained that corrosion of most metals is inevitable while primarily associated with metallic materials, all material types are susceptible to degradation. Most metals in contact with water (and moisture in the air), acids, bases, salts, oils, oppressive metal polishes and other solid and liquid chemicals corrode as well as when exposed to gaseous materials like acid vapours, ammonia gas and sulphur containing gases. Chinwko et al (2014) however, recommended that Mild steel should be coated to achieve a useful service life and with minimum maintenance, preventive measures can be used to slow down the rate of corrosion of mild steel in different environments. Epoxy coatings represent the most important engineered polymers that have drawn attention due to their wide applications, including structural materials, tissue substitutes, (Mathiazhagan et al., 2011) anti-corrosion coatings (Ahmed et al., 2011) and flame retardant additives. (Edward, 2011) An epoxy coating is a coating compound consisting of two distinct elements: an epoxy resin and a polyamine hardener (also known as a catalyst). When mixed, the resin and hardener engage in a chemical reaction that creates cross-linking of the elements as it cures. When the epoxy coating is fully cured, the resulting product is a durable, rigid plastic coating with strong resistance to most chemicals and makes excellent anti-corrosion coatings. They are one of the principal materials used to control corrosion in the marine environment, (Bleile and Rogers 2001). Mild steel materials are subjected to seawater and freshwater conditions in numerous applications, for example, ships, pleasure boats, submarines, offshore platforms, subsea pipelines and telecommunications cables, wharves, seawater-cooled power, chemical plants, desalination plants and so on, (Pull et al, 2017). Some research has been done on the use of epoxy resin as a coating material. They include the work of Galliano and Landolt, 2002, who studied the effect of reinforcing epoxy coating with corrosion-inhibiting additives. They used both organic and inorganic-based materials. The results obtained showed that the corrosion-inhibiting additives significantly modified and improved the characteristics of epoxy coatings. Shi et al., 2009, also studied the effect of epoxy coatings containing nanoparticles on steel substrates immersed in saline solutions. The Steel corrosion resistance and microstructure of the coating matrix were found to improve significantly with the addition of nanomaterial. Since materials behave differently when exposed to a varied environment. It is very important to determine how epoxy resin coating can help protect against corrosion in a different environment. This research work, therefore, focuses on the study of corrosion control using epoxy resin coats on mild steel in two different environments (seawater and freshwater) to observe how efficiently the epoxy coating will perform.

2. Materials and Method

The material used for this research work was mild steel and was purchased from the steel market, Owode Onirin, Mile 12, Lagos State, Nigeria. The chemical analysis as shown below was carried out at Yongxn Steel Industry along Benin Sapele road Benin city, Edo State, Nigeria, using a hand-held spectrometer laser.

Table 1: Chemical Composition of the Mild Steel

metal	Percentage composition
Carbon (C)	0.04
Copper (Cu)	0.2
Iron (Fe)	98.0
Manganese (Mn)	1.03 AISI Allowable
Silicon (Si)	0.280
Phosphorus (P)	0.04
Sulphur (S)	0.050

2.1 Corrosion Media Environment

The seawater was collected from Oniru Beach Victoria Island, Lagos state, Nigeria and the freshwater was obtained from a bole hole in the University of Benin, Benin City, Edo state, Nigeria. Both chemical compositions were carried out at the physical chemistry Department Laboratory of the University of Benin as shown in Table 2 below:

Table 2: Chemical Compositions of Seawater and Freshwater

PARAMETERS	SEAWATER	FRESH WATER
PH at 27.05^{O}C	5.91	7.31
SALINITY in Chloride form (Mg/L)	314	108
DISSOLVE OXYGEN(Mg/L) at 28.03^{O}C	32.7	16.8
SODIUM (Mg/L)	83.20	0.1
POTASSIUM (Mg/L)	48	12

2.2 Sample Preparation and Procedure

The mild steel plate was cut into rectangular sizes of 30mm by 40mm of thickness 5mm. A hole was drilled in the steel sample to ease handling during the coating and curing processes. The sample's surfaces were treated by abrading them on silicon carbide paper and then on an emery cloth, they were rinsed in distilled water and then in ethanol for degreasing and were dried at room temperature to get them ready for coating. The pictures of the steel samples before treatment are shown in Figure 1.

Figure 1. Samples before Treatment.

2.3 Preparation of Epoxy Coating Mixture

The epoxy resin (EPOCHEM 105) and the hardener (EPOCHEM 205) used in this research work were purchased from Epoxy Oilserve Limited, Ikeja Lagos, Nigeria. The resin is a fast-drying type of epoxy, a blend of polymeric epoxy resin Bisphenol A diglycidyl ether (DGEBA). The hardener is based on aliphatic amines (polyaminoamide) and it can cure at room temperature.

The coating mixture was made by mixing epoxy resin and polyaminoamine hardener in a weight ratio of 2:1. The contents were blended to ensure proper mixing.

2.4 Coating of the Mild Steel Samples

The cleaned mild steel substrates were dipped into the final coating mixture one time and then gradually withdrawn with the help of the rope tied through the hole of the sample. They were then kept at room temperature for one week to allow full curing. This led to the formation of uniform coating with an average thickness of 40µm measured on a micrometer screw gauge as shown in Figure 4 below:

2.4 Weight Loss and Corrosion Rate Determination

Before the immersion, all specimens were cleaned and weighed (initial weight) using a digital weighing balance. (Model OHAUS PIONEER- PA213) After the immersion, a sample was taken out of each of the containing media at each of the six time periods, that is, 15, 30, 45, 60, 75 and 90 days respectively, cleaned in phosphoric acid or citric acid to loosen the corrosion products, rinsed in distilled water and dried at room temperature and then weighed again (final weight). Weight losses were calculated as a reduction in weight of each specimen before and after immersion times and the corrosion rate calculated using the formula obtained from (Chinwko et al, 2014), is as follows:

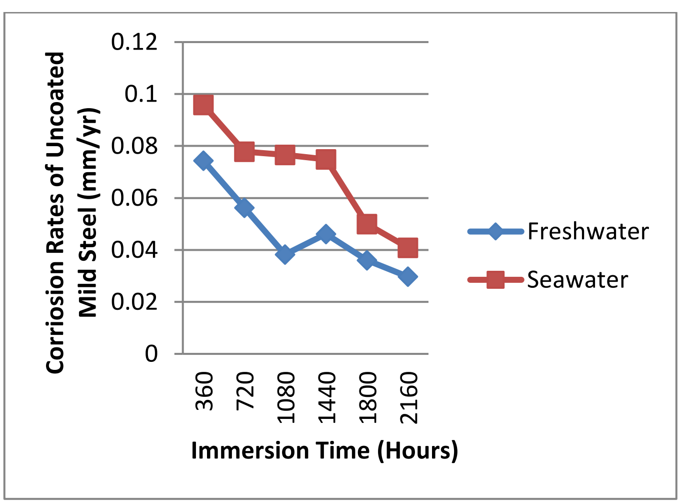
$$C_R = \frac{k\Delta W}{A\rho T} \quad (1)$$

PH values of the media were recorded at each interval. The protection efficiency of the epoxy coating on the mild steel at each immersion periods were also determined using this formula obtained from (Ziad, 2018) as given below:

$$\%IE = \frac{C_R^0 - C_R^0}{C_R^0} \times 100 \quad (2)$$

3. Results and Discussion

3.1. Corrosion Rate Result for Seawater and Freshwater Environment



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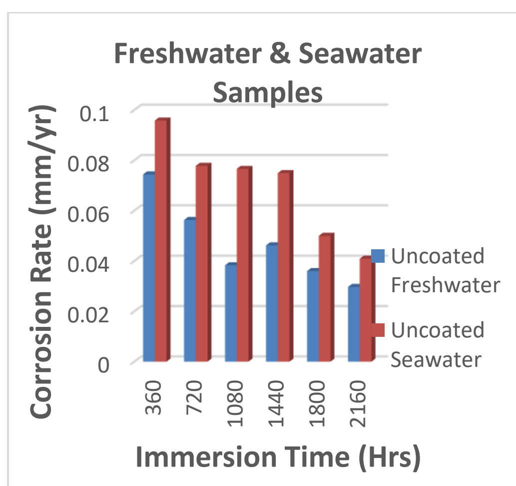

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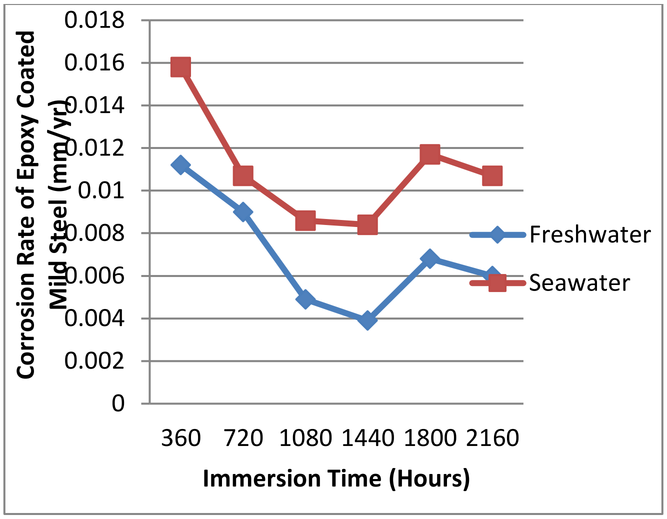

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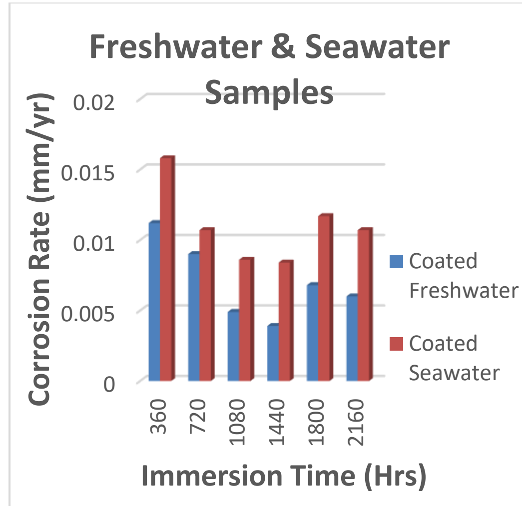

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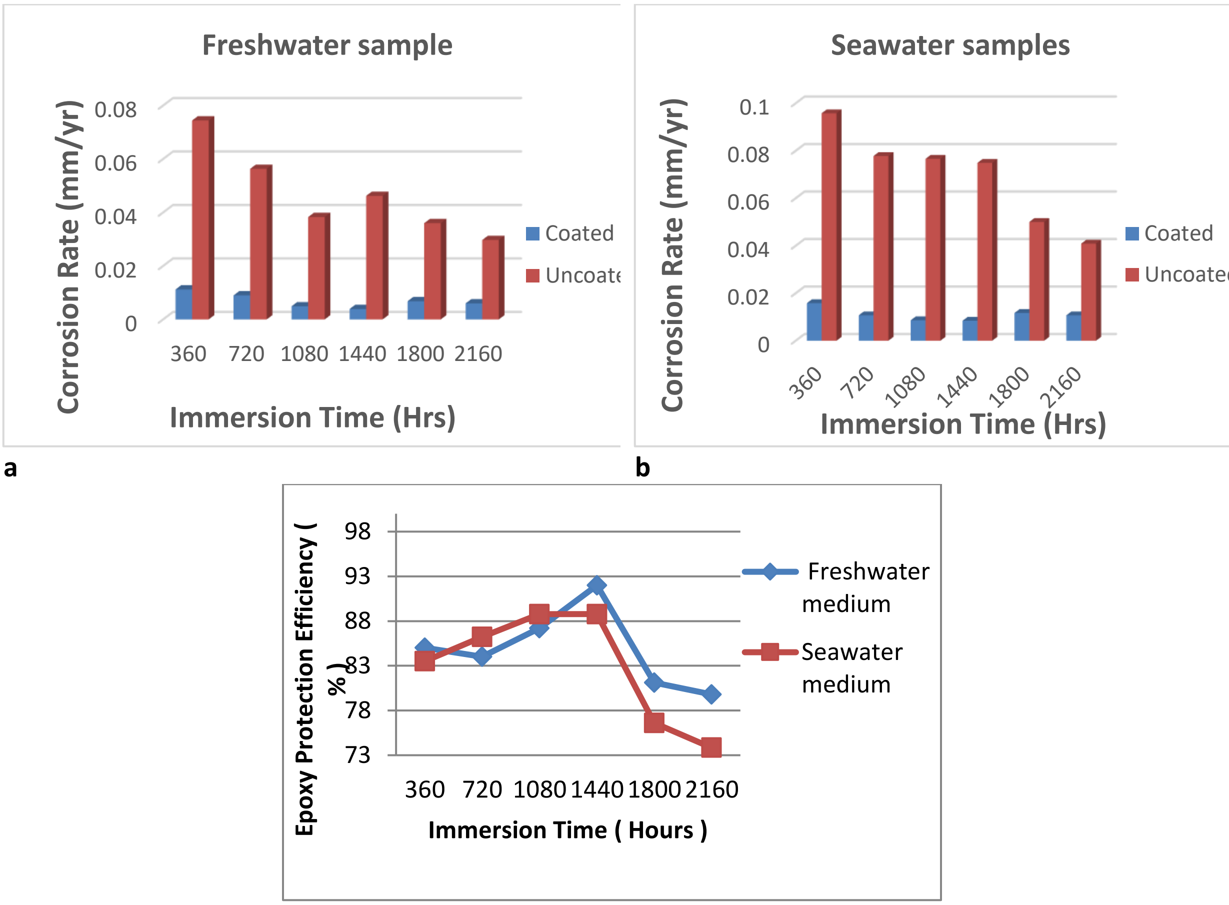
Figure 2a&b. Corrosion Rate of Uncoated Mild Steel in Seawater and Freshwater
2a&b. Corrosion Rate of Epoxy Coated Mild Steel in Seawater and Freshwater

Figures 2a and b show the corrosion rate of uncoated mild steel in seawater and freshwater. Both samples displayed an initial increase in corrosion rate at the 360th hour and then the corrosion rate began to decrease gradually. The decrease in the corrosion rate could be a result of the formation of a corrosion product that acts as a passive film. (Unueroh and Onyekpe 2014 and Priyotomo et al 2017) The passive film was however not fully bonded to the steel resulting in a further increase in the rate of corrosion in the 1800th hour. The corrosion rate of the uncoated samples in seawater shown it was also found to be greater than that of samples in freshwater. The corrosion rate of samples in the seawater on the 15th day was 0.0988mm/yr. while in freshwater, it was 0.0774mm/yr. On the 90th day, the uncoated samples in seawater increased to 0.0409mm/yr., while samples in freshwater were 0.029mm/yr. According to Ferry et al, 2013, one possible reason why samples in seawater corroded faster could be a result of the availability of dissolved oxygen at the metal-water interface. The corrosion rate of the epoxy resin-coated steel samples in seawater and freshwater shown in Figures 2b and c, decreased gradually. The samples exposed to seawater medium decreased from 0.0158mm/yr on the 15th day (360hrs) to 0.0107mm/yr on the 90th day (2160hrs). The samples exposed to seawater medium also decreased gradually from 0.0112mm/yr on the 15th day (360hrs) to 0.0060mm/yr on the 90th day (2160hrs). The corrosion rate of samples immersed in seawater was also found to have the highest corrosion rate when compared to that of samples exposed to fresh water. The reason for this could be a result of the aggressive chloride ion present in seawater trying to destroy the epoxy resin coating thus preventing the ability of the epoxy coating to work efficiently. This also explains why the corrosion rate of the uncoated samples in seawater was also found to be greater than that of samples in freshwater.

3.2. Protection Efficiency of Epoxy Resin Coating



c

Figure 3a. Corrosion rate of coated and uncoated steel in seawater. 3b. Corrosion rate of coated and uncoated steel in seawater. 3c. Protection Efficiency of Epoxy Resin in Freshwater and Seawater Media

Figure 3c shows the protection efficiency of epoxy resin coating on mild steel in seawater and freshwater against immersion time. The corrosion rate was found to decrease with the formation of a coating barrier layer between the metal surface and the environment studied. In the freshwater medium, the optimum coating efficiency was found to be 92%, while in the seawater medium, it was 82% on the 60th day (1440). After the 60th day, the epoxy resin coating could no longer efficiently protect the samples from corroding.

4. Conclusion

Epoxy resin coating was found to generally reduce corrosion in both seawater and freshwater environment. The optimum protection efficiency was found to be 92% for freshwater samples and 82% for seawater samples at the 60th day. The corrosion rate of samples in seawater was found to be greater than those in freshwater. Therefore, from this research work, Epoxy resin coating performed better in Fresh water environment.

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