Journal of Engineering Research and Reports

Volume 26, Issue 6, Page 273-282, 2024; Article no.JERR.117126
ISSN: 2582-2926

The Inhibitive Action of *Ocimum gratissimum* leaf Extract on Mild Steel Corrosion using the Ultra Violet Light

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/jerr/2024/v26i61179

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/117126

Original Research Article

Received: 10/03/2004
Accepted: 13/05/2024
Published: 25/05/2024

ABSTRACT

This study investigated on the use of Ultra violet rays to determine its effect on mildsteel coated with *Ocimum gratissimum* leaf extract. It was an experimental research that was carried out using two media (the acid and the base), where the HCl served as the acidic medium while NaCl served as the basic medium respectively. Two containers containing 1200mg/l concentration of each corrodent, that is, 1200mg/l of HCl and NaCl respectively were used. Four well-polished coupons having mirror image were weighed and suspended over the corrodents HCl and NaCl respectively and placed in a dark cupboard over a UV light for one week. After one week two coupons were removed weighed, snapped and discarded. The remaining two were sprayed for another one week and kept under the UV light, they were blow dried and snapped for comparism. The results obtained showed that addition of *Ocimum gratissimum* leaf extract synergistically increased the efficiency of

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Cite as: *Ibeaja, A. C. E., & Ugorji, C. C. (2024). The Inhibitive Action of Ocimum gratissimum leaf Extract on Mild Steel Corrosion using the Ultra Violet Light. Journal of Engineering Research and Reports, 26(6), 273–282. https://doi.org/10.9734/jerr/2024/v26i61179*

the inhibitor and that the HCl corroded more than the NaCl. The result shows that there was a reduction in the weight of the coupons, indicating that the UV light had an effect on the coupons by reducing the corrosive effect. It is observed that the two coupons in the acidic medium (HCl) weighed 5.0403 before brushing and 4.7697 after brushing and after one week under the UV light, it was observed that they weighed 5.0938 and 4.6082 before and after brushing respectively. The same thing was done for the basic medium(NaCl) and the result showed the weight of the two coupons before brushing was 4.5647 and after brushing was 4.5073 respectively. After one week it was seen that the weight of the coupons before brushing was 4.8786 and after brushing was 4.7237 respectively. This shows that UV radiation also increased the inhibitor efficiency and that corrosion activation energy increased in presence of the inhibitor. There was a reduction in the weight of the coupons in both media. It is therefore recommended that a mechanism of adsorption is proposed to explain inhibition behaviour.

Keywords: Gravimetric technique; corrosion; UV radiation; inhibitor; leaf extract.

1. INTRODUCTION

“Corrosion is the slow, chemical reaction-induced degradation of materials (often metals) with their surroundings. Most metals naturally have a tendency to revert to their former states, which leads to corrosion. The production of iron oxides during rusting is a well-known instance of electrochemical corrosion. Usually, this kind of damage results in oxides or salts of the parent metal” [1].

“Many structural alloys erode just when exposed to airborne moisture, but exposure to specific chemicals can significantly accelerate the process. Corrosion can spread over a large region, corroding the surface more or less uniformly, or it might be confined locally, originating from a pit or fracture” [2]. “The process of corrosion requires four elements; an anode, a cathode, an electrolyte and a metallic path. Corrosion cannot be prevented because it’s a natural process but it can be controlled” [3].

The beneficial qualities of materials and buildings, such as strength, appearance, and gas and liquid permeability, are destroyed by corrosion.

"Materials other than metals, like ceramics and polymers, can also experience corrosion." Bethencourt and associates [4].

Therefore, techniques like chromate conversion and passivation that lower the activity of the exposed surface can improve a material's resistance to corrosion.

The basic reaction that occurs during the corrosion process is called an electrochemical reaction, in which an electron can move from one location on the metal surface to another by means of a solution that has the ability to conduct electricity [5]. “Most corrosion reactions are electrochemical in nature, at anodic sites on the surface of iron goes into solution as ferrous ion, this leads to anodic reaction. As oxidation occurs in atoms, they release electrons whose negative charge would quickly build up in metals and prevent further anodic reaction” [6].

“The part of a metal surface which becomes the corroding area is called the anode, the other part which acts as the other electrode of the battery is called cathode, which does not corrode. At the cathodic site the electrons react with some reducible components of the electrolyte and they are removed from the metal. The corroding piece of the metal is known as “mixed electrode” since both cathodic and anodic processes occur on its surface” [7].

“Hydrogen ions form as a protective layer on the surface of the cathode, preventing or slowing down further corrosion. This effect is known as cathodic polarization. Salt water environments are exposed to atmospheric oxygen following reactions involving the hydrogen ion on the surface of the cathode being reduced to hydrogen and oxygen lend to the formation of water” [8].

A Corrosion takes place with pure water provided that oxygen is present. In such cases oxygen combines with the hydrogen generated at the cathode removing it and permitting the reaction to go on.

“There are various types of corrosion which include Localized corrosion (Pitting corrosion) where the basic metal is eaten away and performed in places in the manner of holes, the rests of the surface being affected only slightly or not at all. This usually occurs in metals with passivation layers” [9-10].

"Inter granular corrosion usually occur from the outside within a grain structure of a metal. It is imperceptible or barely perceptible from outside since the corrosion proceeds at the grain boundaries. Stainless steel is an example" [9-10]

"Galvanic corrosionoccur when two different metals have physical contact with each other" [9-10]. It increases corrosion in crevices or cracks at contact surfaces.

"Corrosion Inhibitors is a chemical compound that is added to a liquid or gas which decreases the corrosion rate of a material a metal or alloy" [11] "The effectiveness of a corrosion inhibitor depends on fluid composition, quantity of water and flow regime. A common mechanism for inhibiting corrosion involves formation of a coating, often a passivation layer which prevents access of the corrosive substance of a metal They are also additives to the fluid that surrounds the metal. Permanent treatment such as chrome plating are not generally accepted inhibitors" [12].

"ULTRA-VIOLET (UV) is an electromagnetic radiation with wavelength shorter than that of visible light but longer than x-rays. UV is found in sunlight and is emitted by electric arcs and specialized light such as black lights. It can cause chemical reactions and may cause many substances to glow" [13]. UV rays are responsible for sunburn and also for the formation of vitamin D.

1.2 Statement of Problem

"Corrosion is a way of destroying materials, usually metals gradually through the chemical reaction process with the surrounding environment. This is caused by natural tendency for most metals to return to their original state. Rusting which is the formation of iron oxides, is a typical example of electrochemical corrosion. This damage results in the production of oxides or salts of the original metal" [1].

"Corrosion be extended across a wide area or can be concentrated locally from a pit or crack. It can more or less uniformly corrode the surface" [2].

"The four elements required for the process of corrosion include; an anode, a cathode, an electrolyte and a metallic path. Corrosion cannot be prevented because it's a natural process but it can be controlled" [3].

"Corrosion occurs in materials other than metals such as ceramics or polymers" [4]. A primary cause of corrosion is due to an effect known as galvanic corrosion. All metals have different natural electrical potentials. Metals are coupled together in a common environment which helps the steel corrode faster than normal.

Corrosion takes place with pure water provided that oxygen is present. In such cases oxygen combines with the hydrogen generated at the cathode removing it and permitting the reaction to go on.

"Hydrogen ions form as a protective layer on the surface of the cathode, preventing or slowing down further corrosion. This effect is known as cathodic polarization. Salt water environments are exposed to atmospheric oxygen following reactions involving the hydrogen ion on the surface of the cathode being reduced to hydrogen and oxygen lend to the formation of water" [8].

A corrosion inhibitor which is a chemical compound that is added to a liquid or gas which decreases the corrosion rate of a material usually a metal or alloy [11] can be used to prevent metal from rusting. One way to protect metal is by sacrificing a metal with a more active reduction potential through sacrificing coating. Developing a thick layer of corrosion in a process known as anodizing protects underlying metals from corrosion.

Other ways could include coating the metal with a thin layer of another metal by electrochemical means i.e. to electroplate, coating the metal surface with paint or ethanol provides a barrier between the metal surfaces and the moisture in the environment, thus removing the opportunity of oxygen and moisture to come in contact and to apply protective lubricants to metal to seal out moisture.

1.3 Aim

1. The aim of this study was to investigate the effectiveness of Ocimum gratissimum extract as a corrosion inhibitor in the presence of UV radiation.

1.4 Objective

- To determine the inhibitive effects of *Ocinum gratissimum* leaf extract on mild

steels in both salt(basic) and acidic environment under the ultraviolet light rays.

2. METHODOLOGY

2.1 Study Area

This research was conducted at Owerri, a metropolitan center in Nigeria's Imo State. Imo State is a State in the South-East geopolitical zone of Nigeria, bordered by Anambra State to the North for 84km, Abia State to the East for about 104km and Rivers State to the South and West for about 122km. The state lies within latitudes 4^{o} 45 N and 7^{o}15'N and longitude 6^{o} 50'E and 7^{o}25'E, with an area of around 5,100 sq km.

The state has several natural resources which includes crude oil, natural gas, lead, Calcium Carbonate and zinc. Profitable flora including iroko, rubber tree and oil palm are also found in the state.

There are several institutions of higher learning including both State and Federal government run institutions such as Federal University of Technology, Owerri, Alvan Ikoku College of Education, Federal Polytechnic, Nekede, Imo State University, Owerri and an Airport called Sam Mbakwe International Cargo Airport.

2.2 Research Design

The experimental research design was used for this research. Two containers containing the highest concentration of each corrodent i.e. 1200mg/l of HCl and NaCl respectively were used. Four well-polished coupons having mirror image were weighed and suspended over the corrodents HCl and NaCl respectively and placed in a dark cupboard over a UV light.

2.3 Sampling Technique

The purposive sampling technique was used. Four well-polished coupons having mirror image were weighed and suspended over the corrodents HCl and NaCl respectively and placed in a dark cupboard over a UV light.

2.4 Variables

2.4.1 Preparation of specimen (Ultra Violet Experiment)

The mild steel was bought from the department of Material and Metallurgical Engineering in Federal University of Technology Owerri. The surface of the coupons was cleaned using smooth and rough emery paper from grit size 220 and above. The samples were neatly wiped with cotton wool, ethanol and dried with acetone and stored in a desiccator. Accurate weight of each coupon was taken and recorded as initial weight. The coupons were labeled to avoid mix up. Two containers containing 1200mg/l concentration of each corrodent i.e. 1200mg/l of HCl and NaCl respectively were used.

Four well-polished coupons having mirror image were weighed and suspended over the corrodents HCl and NaCl respectively and placed in a dark cupboard over a UV light for one week.

After one week two coupons were removed weighed, snapped, discarded and the remaining two were sprayed for another one week and kept under the UV light, they were blow-dried and snapped for comparism. It was discovered that the HCl corroded more than the NaCl.

2.4.2 Preparation of the extract

The ethanol was added to the sample and leaf for 2days (48hrs). After 48hrs, the sample was squeezed using a sieve cloth and the chaff discarded. The volume of the inhibitor solution was measured out with a measuring cylinder.

2.4.3 Preparation of acid and salt

The acid used was Hydrochloric Acid and the salt was Sodium Chloride. The acid was prepared using the measuring cylinder (1000mg/dm^3) prior to that; the molar solution of HCl was gotten. 1dm^3 of the molar solution will contain 58.5g of HCl. Now, to get the volume of HCl that contains 58.5g.

$$Volume = \frac{Mass}{Density}$$

Where 3.14g is the weight of active sample

$$3.14g \longrightarrow 400ml$$

Amount in 1000ml

$$= \frac{3.14\ x\ 1000ml}{400ml} = 7.85g$$

Stock concentration = $7850mg/l$

2.4.4 For the salt

29.25g of salt was added to 1000ml of distilled water until the desired quantity was gotten.

For the various concentrations used for dipping, the dilution formula was used i.e. $C_1V_1 = C_2V_2$

For 200 concentration = 7850 x ? = 200 x 200

$$= \frac{200\ x\ 200}{7850} = 5.1ml$$

For 400 concentration = $\frac{400\ x\ 200}{7850} = 10.2ml$

For 800 concentration = $\frac{800\ x\ 200}{7850} = 20.4ml$

For 1200 concentration $\frac{1200\ x\ 200}{7850} = 30.6ml$

2.4.5 Materials

The materials used for this study include: Beakers, measuring cylinder (1000mg/dm^3), thread, glass hooks used to suspend the coupons, emery paper (Smooth and Rough), funnel, sample bottles, sample (Scent leaf), Sample Extract, weighing balance for weighing, generator to ensure steady power during weighing, metal coupons (The Specimen),sieve cloth, grinder and bench,cotton wool,syringes, masking tape, stirrier, spray pump and dryer.

2.4.6 Reagents

The reagents used include: NaCl, HCl, Acetone, Ethanol, Distilled and non -distilled water.

2.4.7 Sample

3cm x3cm mild steel coupons.

3.RESULTS AND DISCUSSION

3.1 Weight loss

Table 1 shows the weight of the coupons before and after the use of UV light in the acidic medium (HCl). The result shows that there was a reduction in the weight of the coupons, indicating that the UV light had had an effect on the coupons by reducing the corrosive effect.

Table 3 shows the weight of the coupons before and after the use of UV light in the acidic medium (HCl) after a week. The result shows that there was a reduction in the weight of the coupons, indicating that the UV light had had an effect on the coupons by reducing the corrosive effect.

Table 4 shows the weight of the coupons before and after the use of UV light in the alkaline medium (NaCl) after a week. The result shows that there was a reduction in the weight of the coupons, indicating that the UV light had had an effect on the coupons by reducing the corrosive effect.

Table 1. The weight of the coupons before and after the use of UV light

Before brushing	After brushing
5.0403	4.7697

Table 2. The weight of the coupons before and after the use of UV light in the alkaline medium (NaCl). The result shows that there was a reduction in the weight of the coupons, indicating that the uv light had had an effect on the coupons by reducing the corrosive effect

Before brushing	After brushing
4.5647	4.5073

Table 3. The weight of the coupons before and after the use of UV light in the acidic medium (HCl)

Before brushing	After brushing
5.0938	4.6082

Table 4. The weight of the coupons before and after the use of UV light in the alkaline medium

Before brushing	After brushing
4.8786	4.7237

3.2 The Pictorial Effects of the Two Media (HCl and NaCl) on the Mild Steel under UV Light

Fig. 1 and 2 shows the effect of UV on NaCl before and after cleaning respectively. The result shows that the UV had an effect on the mild steel by reducing the corrosion.

Fig. 3 and 4 shows the effect of UV on HCl before cleaning and after cleaning respectively. The result shows that the UV had an effect on the coupons by reducing the corrosion.

Fig. 6 and 7 shows the effect of UV on HCl before cleaning and after cleaning respectively. The result shows that the UV had an effect on the coupons by reducing the corrosion.

Fig. 1. Shows the effect of UV on NaCl before cleaning

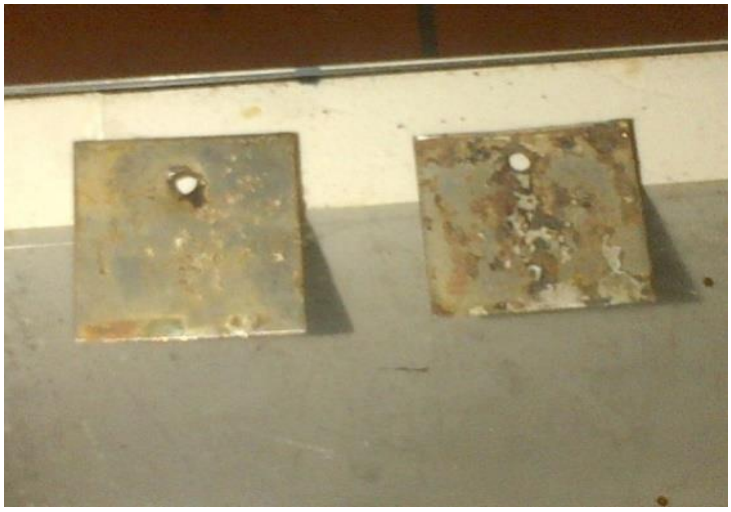

Fig. 2. Shows the effect of UV on NaCl after cleaning

Fig. 3. Shows the effect of UV on HCl before cleaning

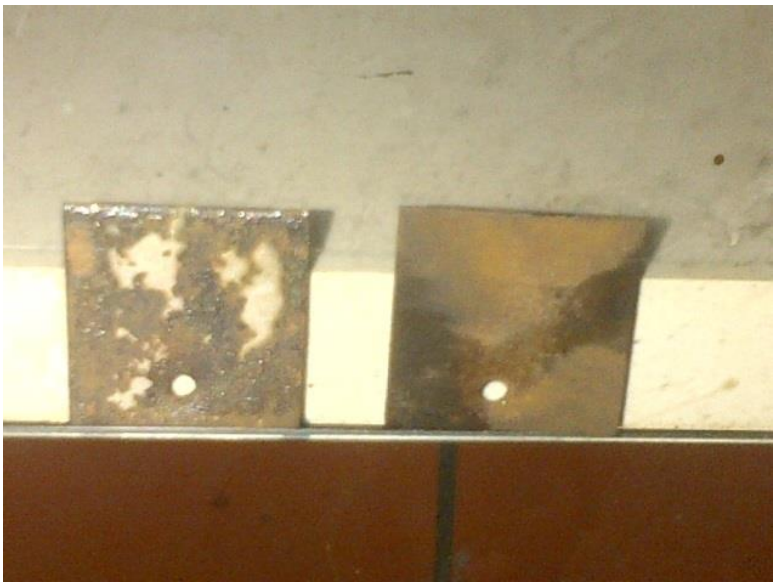

Fig. 4. Shows the effect of UV on HCl after cleaning all for the first week

Fig. 5. Shows the effect of UV on NaCl after one week before cleaning

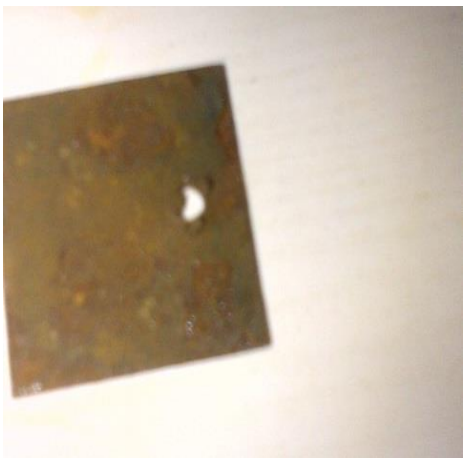

Fig. 6. Shows the effect of UV on NaCl after one week after cleaning

Fig. 7. shows the effect of UV on HCl after one week before cleaning

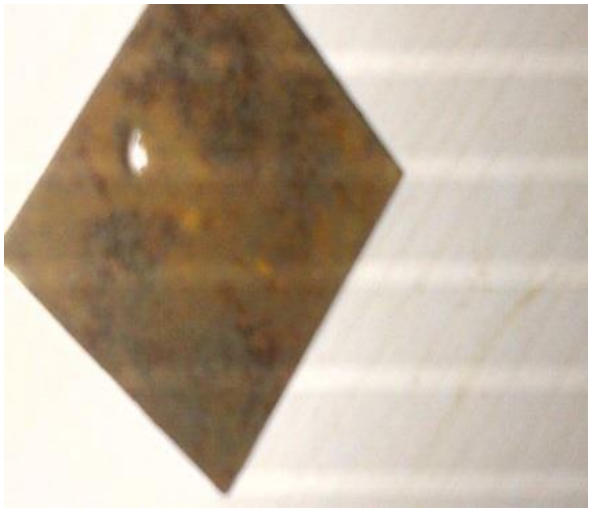

Fig. 8. shows the effect of UV on HCl after one week after cleaning

3.3 Mechanism of Action of Corrosion Inhibitors

A common mechanism for inhibiting corrosion involves formation of a coating, often a passivation layer, which prevents access of the corrosive substance to the metal. Generally, the mechanism of the inhibitor can be noticed in either of these ways- the inhibitor is chemically adsorbed (chemisorption) on the surface of the metal and forms a protective thin film with inhibitor effect or by combination between inhibitor ions and metallic surface, the inhibitor leads a formation of a film by oxide protection of the base metal and finally the inhibitor reacts with a potential corrosive component present in aqueous media and the product is a complex [14]. This can be seen in Fig. 1-8 representing the corroded and treated coupons dipped in the acidic and alkaline(salt) media respectively. The results showed that the inhibitor had a positive effect on the coupons after a period of time. It helped prevent further corrosion of the mildsteels.

The mechanism of action of corrosion inhibitors can be seen in the electrochemical mechanism and physical-chemical mechanism. The electrochemical mechanism is based on the electrochemical process occurring on the metal surface to explain the role of corrosion inhibitors. The corrosion of metals is mostly the result of galvanic reaction on the metal surface, which is also the most important factor causing erosion

and corrosion. The galvanic reaction includes anode reaction and cathode reaction. If the corrosion inhibitor can inhibit either or both of the anode and cathode reactions, the galvanic cell reaction will slow down and the corrosion rate of the metal will slow down. We call corrosion inhibitors that can inhibit anodic reactions as anode-inhibited corrosion inhibitors; corrosion inhibitors that can inhibit cathodic reactions are called cathodic-inhibited corrosion inhibitors; and corrosion inhibitors that can inhibit both anodic and cathodic reactions The agent is called a mixed corrosion inhibitor. The physical- chemical mechanism is based on the physical and chemical changes that occur on the metal surface to illustrate the role of corrosion inhibitors. The two mechanisms deal with problems in different ways but they are not contradictory.

Cathodic corrosion inhibitors mainly achieve corrosion inhibition through the following effects: (1) Increase the overpotential of the cathode reaction which is a process by which anionic corrosion inhibitors inhibit the hydrogen ion discharge reaction by increasing the over potential of hydrogen ion discharge [15]. This can be seen from the results presented in Fig. 1-8 showing the alkaline corrosion inhibitor NaCl and the other showing the acidic corrosion inhibitors HCl respectively as substances that can neutralize acidic and alkaline substances in the water, reduce the hydrogen ion concentration and increase the hydrogen evolution over potential. The reduction of hydrogen ions on the metal surface is hindered and corrosion is slowed down.

3.4 Effects of UV Radiation on the Mild Steels

Fig. 1-8 presents results of immersion tests in 1200ml of each of NaCl and HCl under UV light irradiation and without UV light respectively. The purpose of the designed tests was to ascertain the critical period of time at which corrosion took place on the samples with and without the UV light irradiation respectively and to know if there would be any changes on the corrosion of the coupons. As demonstrated, the UV light affected the corrosion behaviors of NaCl and HCl differently as shown in the Fig. The UV light increased the anti-corrosion property of both media. It was seen that the corrosive nature of the coupons reduced drastically after subjecting them under the UV light at a week interval.

4. CONCLUSION AND RECOMMENDATION

The introduction of *Ocimum gratissimum* extract into the acidic and salt environment improved the corrosion inhibition of mild steel or retarded the corrosion rate. The exposure of UV radiation showed that the extract was effective for both the acidic and the salt environment.

Following the findings of this research, the following recommendations were made:

- The exposure of UV radiation showed that the extract was effective for both the acidic and the salt environment.
- With the results pictorially, it is evident that *Ocimum gratissimum* is a good inhibitor and can be used both in an acidic and salt environment to reduce corrosion. I will hereby recommend it for further use to reduce corrosion.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/117126