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Investigation of The Inhibition Action of Talinum Triangulare on the Corrosion of Mild Carbon Steel in Seawater

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ABSTRACT

In many areas of technology and the economy, corrosion inhibitors are becoming more and more crucial for the anticorrosive protection of metals and their alloys. Despite the fact that several synthetic chemicals have good anticorrosive action, the majority of them are extremely harmful to both the environment and humans. The use of certain natural materials as corrosion inhibitors is motivated by the known harmful consequences of the majority of synthetic corrosion inhibitors. Thus, talinum triangulare extract was used as an inhibitor in an inquiry into the corrosion inhibition of mild steel in seawater. The mild steel bars were divided into coupons and suspended in a seawater solution in a container with different inhibitor concentrations (0, 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, and 7.0% v/v) added and allowed to stay in the sea water for 15, 30, 45, 60, and 7 days. After 15 days, the weight loss of each coupon was measured, and the inhibitor's rate of corrosion and level of protection was computed. As the inhibitor concentration increased, the rate of corrosion decreased until it reached a maximum of 4.0 v/v%. However, when the inhibitor's concentration rose, so did its effectiveness in providing protection (inhibition). The pairs of electrons found in the functional groups—the high concentration of saponin and tannin—were responsible for the inhibitor's adsorption onto the mild carbon steel. By directly suppressing the ongoing removal of atoms from the mild carbon steel foundation, this stabilizes the mild carbon steel and slows down the corrosion degradation process. This study has demonstrated that mild carbon steel can be protected against corrosion by using the plentiful talinum triangulare.

1. Introduction

corrosion is expensive since operational downtime is usually needed to replace parts Environmental harm, such as oil pipeline breaks in the petroleum industry, is another concern. Metallic surfaces react electrochemically with their surroundings to undergo corrosion, which results in surface deterioration and the loss of the metal's material qualities [1-5]. When an exposed metal or metal alloy is exposed to the elements, corrosion happens as a result of an uncontrollably occurring chemical reaction that eventually causes the material to oxidize or degrade [6–10]. On metals, various forms of corrosion may happen. There are many different types of corrosion, such as stressing corrosion, intergranular corrosion, cracking, pitting, general/uniform assault, decay corrosion, and galvanic/two-metal corrosion [8, 9]. One of the main causes of harm in the social and industrial spheres is corrosion [11]. The annual economic damage caused by metal component corrosion is estimated by the National Association of Corrosion Engineers (NACE) to be over US$2.5 trillion [12–15]. Maintenance (protection procedures) and equipment replacement costs, as well as indirect expenses like production losses, product contamination, equipment failure-related downtime, and environmental and human safety, can all be cut by 20% by using management techniques and corrosion control. To counteract rusting, many techniques have been employed. Planning ahead, choosing materials carefully, applying protective coatings, using electrochemical (anodic and cathodic protection), and adding corrosion inhibitors are all ways to stop corrosion. Among these, using a corrosion inhibitor is frequently said to be the most useful and least time-consuming [16–20].

Despite several synthetic chemicals having good anticorrosive action, the majority of them are extremely harmful to both the environment and humans. Because of the damage to the environment and more recently, environmental legislation, the use of chemical inhibitors has been restricted. These inhibitors, which include hydrazine, nitrites, dichromats, chromates, etc., may disrupt an enzyme system at a specific location in the body or cause reversible (temporary) or irreversible (permanent) damage to organ systems, such as the liver or kidneys [21, 22]. The toxicity could appear when the compound is being synthesized or when it is being used. In industry, corrosion inhibitors are frequently used to safeguard steel buildings and their alloys [38–42]. As a result, the need for inhibitors that are suitable for the environment, like vegetable inhibitors, is rising [15]. The demand for corrosion-resistant materials has increased along with technological advancements. Nowadays, it is thought to be more vital and desirable to produce non-toxic and effective corrosion inhibitors, also known as eco-friendly or green inhibitors, from a safety perspective. Natural products, which are safe and favourable to the environment, are now used as anticorrosion agents due to their harmful effects. Organic chemicals and rare earth elements are among the many alternatives to environmentally acceptable corrosion inhibitors that have been researched and created recently. The use of certain natural compounds as corrosion inhibitors is encouraged by the known harmful consequences of the majority of synthetic corrosion inhibitors [15].

The use of natural substances referred to as non-toxic chemicals, or "green inhibitors," as corrosion inhibitors is becoming more and more popular, according to the literature [15, 21–26]. Natural compounds have been employed as environmentally acceptable corrosion inhibitors, such as extracts from readily available plants and trees. Numerous organic chemicals found in plant extract have the ability to reduce corrosion. There have been reports of plant extracts from various sections acting as corrosion inhibitors in acidic conditions [25–29]. Because most plants and plant extracts are inexpensive, safe, and biodegradable, they can be utilized in place of hazardous organic inhibitors. The extraction process is also affordable and simple. Plant parts such as pulp, leaves, bark, roots, seeds, and peels can all be used to make corrosion inhibitors that are kind to the planet's ecosystems. "Phytochemicals" are non-nutritional elements of a plant's chemical composition that furthermore contribute to the scent, taste, and colour of the plant. The electrical structures of major synthetic organic corrosion inhibitors and phytochemicals are similar [30–32]. Because their heteroatoms and Pi(π)-electrons adsorb onto the surface of metals and alloys, these organic compounds act as a barrier against corrosion [33–37]. In southern Nigeria, talinum triangulare, often known as water leaf, is a popular vegetable. Although talinum triangulare needs a rainy season to thrive, because South-South Nigeria experiences little dry season, it can be grown year-round with less watering effort. It can therefore be used profitably as a corrosion inhibitor. The least understood technique is one which allows engineers to use Nigeria's abundant talinum triangulare to create engineering materials, but finding the appropriate technology to do so has proven to be an enormous task. The fact that talinum triangulare is widely accessible and has the ability to function as an organic inhibitor further helps to narrow down the study's focus. It has been established that tannins, which are found in the majority of plant extracts, prevent corrosion.

2. Materials and Methods

2.1 Collection and Preparation of Samples

For this investigation, mild carbon steel with 0.15% weight carbon was utilized. The steel came from a Okada, Edo State, neighborhood market. The 40 x 40 x 6 mm mild steel samples served as coupons for the corrosion investigation. The coupons were first mechanically polished using emery papers ranging in grit from 600 to 1000. After being cleaned with ethanol, the samples were dried, weighed, and kept in a desiccator. Every sample's initial weight was measured and noted. Laser-induced breakdown spectroscopy (LIBS) was utilized in the laboratory to ascertain the chemical composition of mild carbon steel. The Escravos River in Delta State provided the seawater that was used. As seen in Figure 1, the talinum triangulare was gathered from a garden and kept at room temperature.

Figure 1. Picture of Talinum Triangulare

Using a Retsch Planetary Ball Mill PM 400, the talinum triangulare was crushed. In the planetary ball mill, the grinding jars are positioned eccentrically on the sun wheel. The sun wheel moves in the opposite direction from the grinding jars at a 1:2 ratios. High dynamic energies are released as a result of the interaction between the frictional and impact forces caused by the balls' and grinding jars' varying speeds. The planetary ball mill's high and incredibly effective degree of size reduction is the result of these forces interacting. Following the pulverization, 500 g of the ground talinum triangulare were placed in a 1000 ml round-bottom flask and sufficient ethanol was added to serve as an extraction solvent. A stopper was placed over the round bottom flask and it was left for two (2) days. The talinum triangulare was then extracted from the extract using the decantation process. A concentration of 1.0-7.0 v/v was calculated from this.

2.2 Phytochemical Analysis of Talinum Triangulare Extract

Tannin was ascertained using the procedure described in [43]. The method for figuring out saponin content by [45,47] was applied. Using the methods of [42], cardiac glycosides and terpenoid were extracted from the talinum triangulare extract. While a colorimeter assay created by [44,46] was used to assess the flavonoid content of the banana peduncle plant extract.

2.3 Microstructural Analysis of the Mild Steel

The surface morphology of the mild carbon steel was determined using the energy dispersive spectrometer (EDS) in conjunction with the scanning electron microscope (SEM) JEOL JSM-6480LV. The scanning electron microscope was used to look directly at the mild steel's surface. After thorough cleaning and air drying, the sample was SEM-observed at 20 kV.

2.4 Determination of Chemical Composition of Sea Water

To ascertain the chemical composition, a piece of the sample of seawater obtained from Escravos, Delta State, Nigeria, was brought to the laboratory.

2.5 Experimental Test

The experiment was run for 75 days at room temperature (that is, 15, 30, 45, 60, and 75 days). The samples were dried, weighed, and cleaned in distilled water at each interval. We computed the weight loss, corrosion rate, inhibition efficiency, and surface coverage degree. Equation (1) was utilized as the standard expression for measuring the corrosion rate in mills per year (mpy).

$$Corrosion\ rate\ (mm/day) = \frac{87.6w}{DAT} \quad (1)$$

where A is the coupon's area (cm^2), t is the exposure period (h), D is the mild steel's density (g/cm^3), and w is the corrosion weight loss of mild carbon steel (mg). Inhibition efficiency was calculated using Equation (2).

$$I.E\ (\%) = \frac{W_0 - W}{W_0} \quad (2)$$

Where W and W_o are the corrosion rates with and without inhibitor respectively
The degree of surface coverage was computed from Equation (3)

$$Degree\ of\ surface\ coverage\ (\Theta) = \frac{1}{\%IE} \quad (3)$$

3. Results and Discussion

Table 1 displays the findings of the phytochemical examination of the talinum triangulare extract. Table 1 shows that the extract has a respectable concentration of flavonoids (2.88 mg/g), saponins (45 mg/g), and tannins (2.54 mg/g). It follows that the extract has the potential to be employed as a corrosion inhibitor due to the high concentration of these organic components

Table 1. Result of phytochemical analysis of talinum triangulare extract

Component (%)	Extract
Glycoside	1.32mg/kg
Phenol	1.03 mg/g
Flavonoids	2.88 mg/g
Saponins	45 mg/g
Tannin	2.54 mg/g
Alkaloids	1.20 mg/g
Steroid	2.04mg/g
Terpenoid	0.82 mg/kg

The chemical makeup of mild carbon steel as a percentage of weight is presented in Table 2. The findings indicate that the main constituents of low-carbon steel are silicon, iron, carbon, manganese, sulfur, titanium, chromium, nickel, copper, vanadium, and tungsten. With the exception of iron, the overall percentage weight composition of the components found in mild carbon steel was 1.829. This suggests that the low-carbon steel sample utilized in this study has an iron content of 98.171.

Table 2. Chemical composition of the mild carbon steel sample (wt. %)

Element Present	Percentage Weight (%)
Carbon (C)	0.15
Silicon (Si)	0.30
Manganese (Mn)	0.85
Phosphorous (P)	0.025
Sulphur (S)	0.027
Titanium (Ti)	0
Copper (Cu)	0.33
Nickel (Ni)	0.04
Chromium (Cr)	0.07
Molybdenum (Mo)	0.004
Vanadium (V)	0
Aluminium (Al)	0.023
Tungsten (W)	0.005
Niobium (Nb)	0
Nitrogen (N)	0.005

Table 3 shows the chemical composition of seawater. From the results analysis, the pH of the sea water was gotten as 7.43 (m), conductivity of 894 (µs/cm), TDS of 447 (mg/l), total alkalinity of 1.66 (mg/l), chloride of 2677.5 (mg/l), sulphate of 293 (mg/l), nitrate of <0.01 (mg/l), phosphate of 0.001, and salinity of 2988 (mg/l).

Table 3. Chemical composition of seawater used

S/N	Parameters	Result
1	pH	7.43
2	Conductivity, µs/cm	894
3	TDS, mg/l	447
4	Total alkalinity, mg/l	1.66
5	Chloride, mg/l	2677.5
6	Sulphate, mg/l	293
7	Nitrate, mg/l	< 0.01
8	Phosphate, mg/l	0.07
9	Salinity, mg/l	2988

The findings of the corrosion rate change with inhibitor concentration are displayed in Figure 2. It is evident that the addition of talinum triangulare extract and exposure duration reduced the mild steel's corrosion rate (CR). The corrosion rate decreased when exposure times were extended from 15 to 75 days.

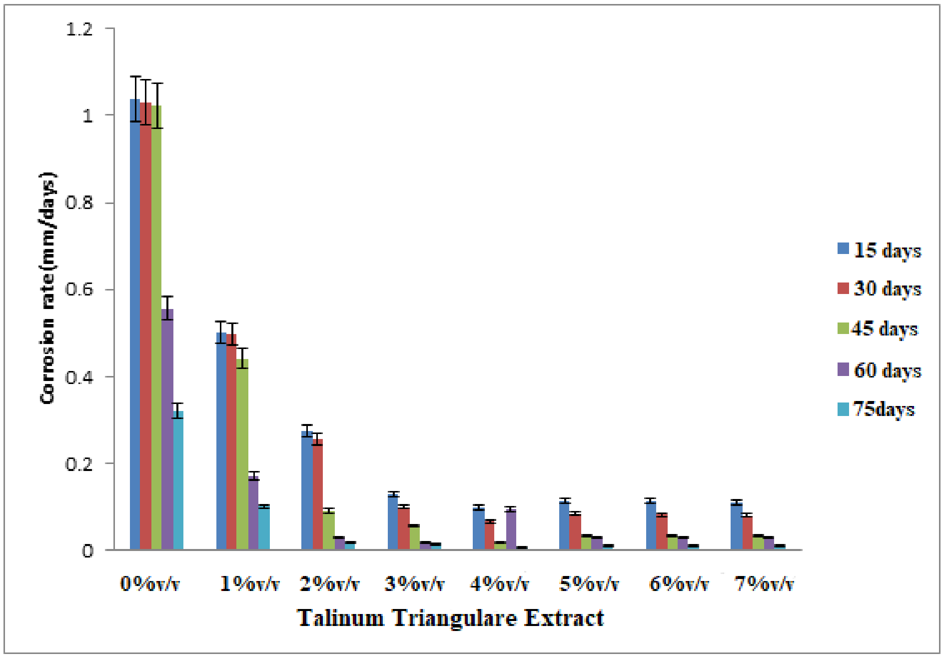

Figure 2. Variation of Corrosion rate with inhibitor concentration

The degree of surface covering and inhibitory efficiency (IE) are displayed in Figures 3 and 4. Up to a maximum of 4.0% v/v, it was shown that the degree of surface coverage and inhibition efficiency both increased with exposure time and inhibitor concentration. For example, a higher percentage of IE at 4.0 v/v talinum triangulare extract addition was calculated to be 97.57% during an exposure time of 75 days. For both the 15- and 75-day exposure times, corrosion rate/IE was determined to be 0.0988 mm/day/90.48% and 0.0067 mm/day/97.57% at 4.0 v/v inhibitor concentration, respectively. On the other hand, mild steel's corrosion resistance in 4.0 v/v talinum triangulare extract is greater than it is at other concentrations. The development of thin oxides, which obstruct anodic and cathodic processes, has been linked to this behavior. As a result, pit formation and expansion become challenging. The rate of corrosion is reduced as a result of the thin coating of oxides sticking to the metal surface.

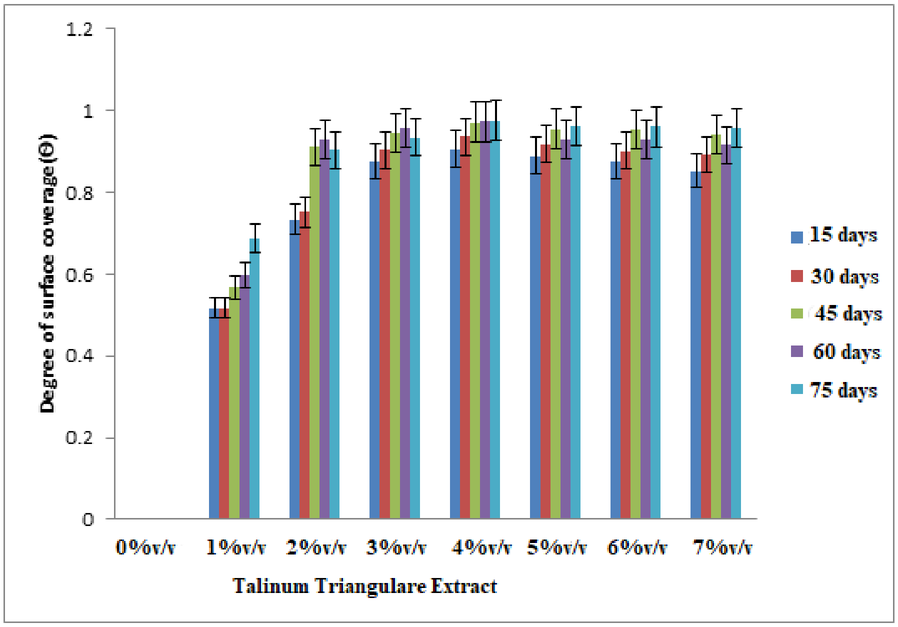

Figure 3. Variation of Degree of surface coverage with inhibitor concentration

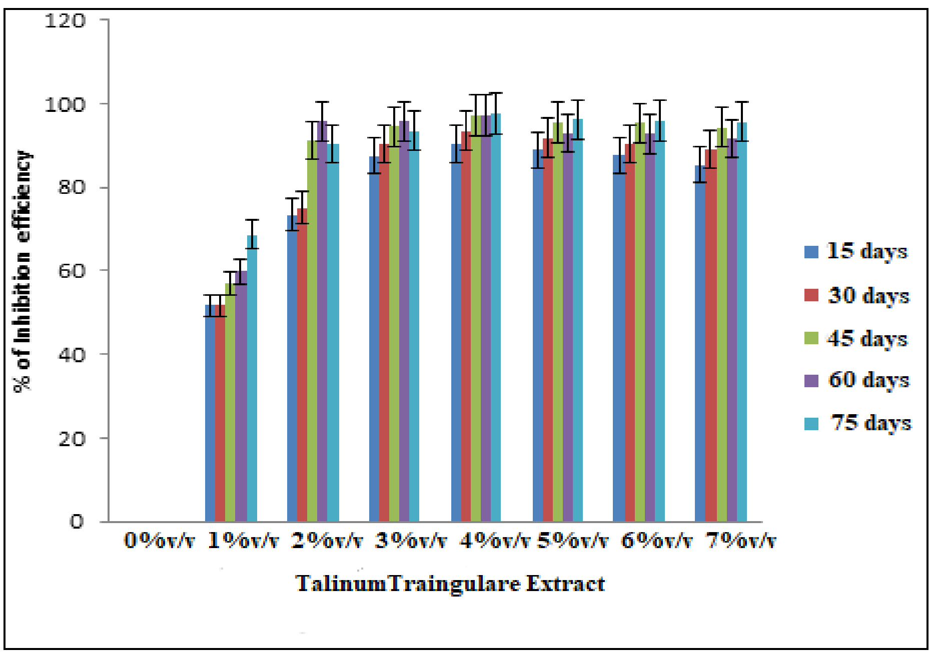

Figure 4. Variation of inhibitor efficiency with inhibitor concentration

The mild steel used in the corrosion experiment was analyzed using an energy dispersive spectrometer (SEM) and scanning electron microscopy (SEM/EDS) as shown in Figure 5. The pearlite (black) phase in the ferrite matrix (white) is clearly seen in the SEM morphology. In the SEM, the ferrite phase region is bigger than the pearlite phase. Major peaks of Fe and C were found using an energy dispersive spectrometer, along with a few minor peaks of Mn, Si, and Cr. The usage of mild carbon steel was validated by the high peaks of Fe and C.

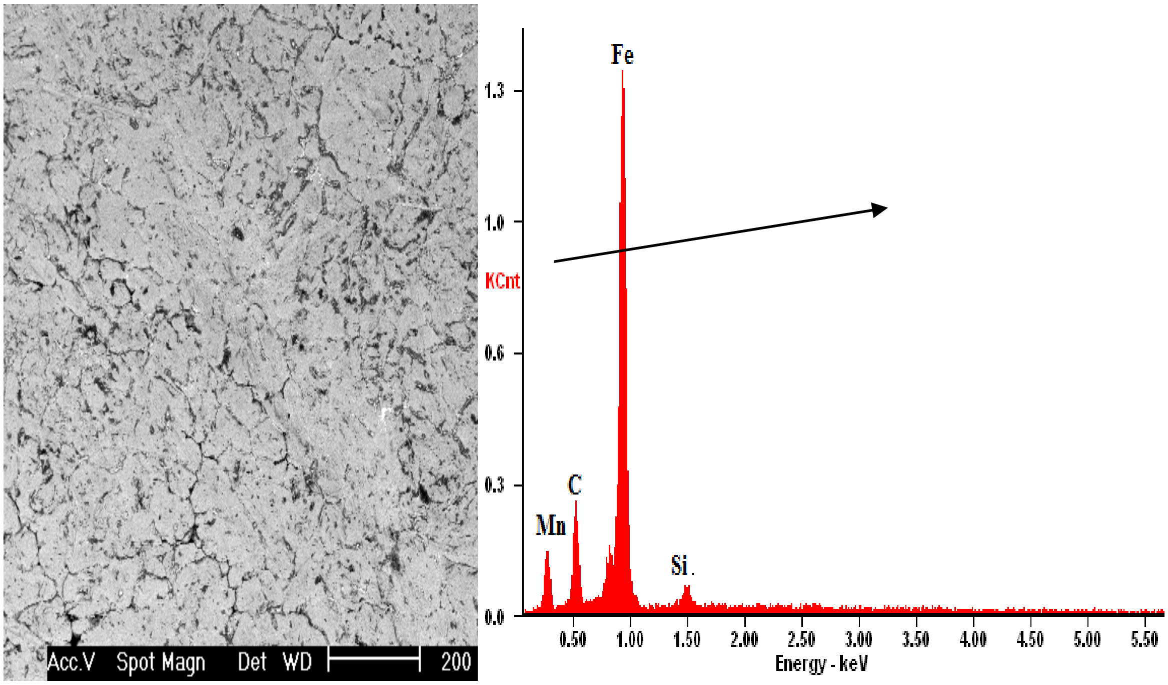

Figure 5. SEM/EDS morphology of the mild carbon steel

4. Conclusion

Metals corrode on a daily basis due to corrosion. There are numerous methods for taking it down. But some of these processes are expensive, dangerous, and environmentally harmful. However, the corrosion inhibitors made from talinum traingulare plant extract have a great chance of effectively resolving these issues. The talinum triangulare extract used in this investigation contains organic components that may function as inhibitors, such as tannins, alkaloids, saponins, terpenoids, etc. When the inhibitor concentration is increased, the inhibition efficiency rises to a maximum of 4.0 v/v% before beginning to decline. Additionally, when inhibitor concentrations rise, so do the corrosion potential (Ecorr) and polarization resistance (Rp). Consequently, the application of talinum tringulare extract as an organic inhibitor may lessen the need for mild carbon correction.

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