

## Comparative Study of Corrosion Inhibition of Mild Steel Using Bitter Leaf (*Vernonia amygdalina*) and Banana Stem (*Musa Acuminata*) Extracts In HCL Medium

OYEDEKO K.F.K<sup>1</sup>, LASISI M.K<sup>2</sup>., AKINYANJU A.S<sup>2</sup>.

<sup>1</sup>Department of Chemical Engineering, Lagos State University (LASU) Epe, Lagos, Nigeria.

<sup>2</sup>Department of Chemical and Petroleum Engineering, University of Lagos, Akoka, Lagos, Nigeria

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### ABSTRACT

In this work the corrosion inhibition properties of Bitter leaf (*Vernonia amygdalina*) and Banana stem (*Musa Acuminata*) extracts on corrosion of mild steel in acidic medium was investigated and the two inhibitive properties were compared using weight loss method, different corrosion rate of the sample, inhibition efficiency and observations through the FTIR and SEM. The FTIR was used to determine the functional groups presence in the extract and the SEM was used to determine the morphology of the mild steel before and after inhibition extract treatment. The effect of concentration at different temperature (303K -313K) was studied to determine the inhibitory potentials of the extracts. Characterization of both Bitter leaf (*Vernonia amygdalina*) and Banana stem (*Musa Acuminata*) was also carried out. The results showed that the inhibition efficiency (IE) increased with increase in concentration of the inhibitor (0.1g/l – 0.5g/l) but decreased with increase in temperature (303K -313K) for bitter leaf and banana stem extracts used. The SEM revealed that the mild steel with plants extract has no rough surface while the one without plant extract has rough surface indicating corrosion effect on the mild steel. The rough surface is less pronounced in case of BNE than in using BLE. Bitter leaves extracts have better inhibitory efficiency than Banana stem extracts. This means that BLE is more effective than BNE.

**KEYWORDS:** Blend extract, Bitter leaves, Banana stem, Inhibition efficiency

### I. INTRODUCTION

Most environments are corrosive, corrosion as a natural process makes metals to be prone to it. This causes metals to react with their environment to form more stable compounds. The electrochemical process returns metals to their natural states through interactions with some aggressive media [1],[2],[3],[4],[5]. The unique mechanical properties and economic viability of metal which made it one of the most versatile construction materials used in various industrial applications. Also the affordability and weld ability give it such a popular choice of steel for oil and gas sector [6]. Mild steel is often exposed to the attack of acid solutions during industrial processes.

The increased industrial applications of acid solutions such as acid picking acid cleaning and acid oil well acidizing has increased interest in research of mild steel corrosion [7]. Several pollutants all of which could influence, in isolation or combined, the behaviour of mild steel (MS) in seawater [8],[9]. Since corrosion is impracticable to eliminate, the effective corrosion science and engineering lies in controlling rather than preventing it [2], [10], [11]. A significant amount can be saved by improved application of inhibitors as is the most efficient and cost effective among the various methods of corrosion control. Corrosion inhibitors reduce corrosion by either acting as a barrier by forming an adsorbed layer or retarding the cathodic and/or anodic process [3].

There are different types of inhibitors, which are organic and inorganic however, sequel to toxic nature, high cost and increasing awareness and strict environmental regulations of some of these compounds, the use of natural product of plant origin as corrosion inhibitor is receiving attention. Corrosion inhibitors derived from plant extract are biodegradable and do not contain heavy metals or other toxic compounds [12]

Extract of various plants have been investigated for use as green inhibitor such as *Azadirachita indica*, *carica papaya*, *guar gum*, *opuntia ficus indica*, *delonix regia* etc [13][14][15][16]. The yield of these compounds as well as the corrosion inhibition abilities vary widely depending on the part of the plant and its geographical location and the efficiency is justified by the phytochemical analysis carried to determine the compounds present therein with molecular and electronic structures bearing close similarity to conventional organic inhibitor molecules.[17]

Bitter leaf plant (*Vernonia amygdalina*) is a commonly available plant in most parts of the tropical nations in Africa and Asia. *Vernonia amygdalina* extract has been reported to have inhibitory effect on mild steel [18], [19]. In a study, it was revealed that *Vernonia amygdalina* has high protein (33.3%), fat (10.1%),

crude fibre (29.2%), ash (11.7%), and mineral (Na, K, Ca, Mg, Zn, & Fe), phylate (1015.4 mg/100 g) and tannin (0.6%) content, while it contains low cyanide (1.1 mg/kg). Bitter leaf is known to contain tannin, among others, which has been variously associated with corrosion inhibition in aqueous and acidic environments. [20],[11]

This study investigates the inhibition effectiveness of extract from Bitter leaf (*Vernonia amygdalina*) and Banana stem (*Musa Acuminata*) in 1M HCl on mild steel as environmental friendly corrosion inhibitors using weight loss method in comparison of concentration of Bitter leaf (*Vernonia amygdalina*) with Banana stem (*Musa Acuminata*) extract, with the effect of temperature on corrosion of mild steel.

## **II. MATERIALS AND METHODS**

### **2.1 Materials**

Mild steel, bitter leave, banana stem. **Reagent used**, HCl, Ethanol, Acetone, Distilled water

### **2.2. Apparatus/Equipments**

Electronic weighing balance, fourier transform infrared spectroscopy (FTIR), scanning electronic microscope (SEM), measuring cylinder, timple, oven, water bath, soxhlet extractor, heating mantle, sieves, sample bottles, electronic miller, trays, paper tape, nose mask, marker.

### **2.3 Preparation of Metal Specimen**

The mild steel was cut into 51 various pieces of the same measured dimensions of 3 mm thickness, length 26mm, breath 17mm. A piece was analyzed with the aid of a spectrometer. The specimens were thoroughly cleaned using abrasive paper to remove all the debris on the mild still after which it was rinsed with analytical ethanol. Acetone was used to degrease (clean) the mild steel so as to remove any oil or grease particles on the steel which might interfere with the investigations. After drying the specimen in the oven at 40°C, the specimens were cooled and weighed to obtain their initial weights. The volume of test solution was relatively large enough to be able to see any appreciable changes in corrosives during the test, either through exhaustion of corrosive constituents or accumulation of corrosion products. The prepared mild steel should be kept in desiccators to prevent dust from dropping on it and then used for the experiment immediately after preparation.[18]

### **2.4 Preparation of Bitter Leaf (powder form)**

Bitter leaf was plucked from its tree in the garden on campus. It was washed and dried in the oven at 45°C for 1 day after which the drying temperature was increased to 105°C for 48 hours. The dried bitter leave was milled with a miller to get the bitter leave into powder form. The powdered bitter leaf was sieved with a 10mm mesh size sieve so as to obtain a fine particle. The fine particles were stored in an airtight jar and placed inside the desiccator. [18]

### **2.5 Preparation of Banana Stem (powder form)**

Banana stem was gotten from a Farm on campus. It was cut into pieces and washed so as to remove the sand particles and stones from it. It was dried under the sun for 2 days so as to reduce the moisture content to appreciable level. It was further subjected to drying in a standard oven at 105 °C for 72 hours. After 72 hours, it was milled into powder and sieved with 10 mm sieve so as to get fine particles size of the dried milled banana stem. The sieved banana stem was stored in an air tight container and placed inside a desiccator. [18]

### **2.6 Preparation of plants extracts (corrosion inhibitor)**

One hundred grams (100g) of the milled bitter leave and banana stem was packed inside a 150 mm filter paper. The packed filter paper was loaded into the feed compartment of a 500 ml soxhlet extractor. About 400 ml of analytical grade ethanol was poured inside the soxhlet extractor flask and placed on a regulated heating mantel. The extraction was carried out at heating temperature of 80 °C for 6 hours so as to have total extraction of the entire component inside the plants. The extraction process was carried out on different ratio of the plant mixture and it was stored separately. After the extraction process was complete, the extracts were subjected to evaporation so as to remove the ethanol and obtain a pure liquid of the extracts. The pure extracts were stored in well labelled sample bottles and placed inside the fridge for further use.

### **2.7 Corrosion inhibition of mild steel**

1M of HCl was prepared inside a volumetric flask using distilled water. 100ml of the prepared HCl was measured into 10 beakers and placed inside a water bath. 10ml of the plant extracts was added to each of the beakers. A weighed mild steel sample was placed inside each of the beakers. At 1 hour intervals, the mild steel was removed from the beaker and weighed. The new weight was recorded and this process was carried out at different temperature.

### **2.8 Weight Loss (WI) Measurement**

The steel samples were retrieved at 1-hour interval progressively for 30days. After each exposure time, the steel was removed, cleaned with analytical acetone and dried thoroughly to remove the corrosion product (Rust Stain)

with a piece of clean cotton cloth. The steel was re-weighed to determine the weight loss, in gram by the difference of steel weight before and after immersion. The corrosion rates (CR) in the absence and presence of the inhibitors was determined. Weight loss was determined by calculating the difference between weight of each steel sample before and after immersion.

$$W = W_b - W_a \tag{1}$$

Where W is weight loss,  $W_b$  = weight of Steel Sample before immersion,  $W_a$  = Weight of steel sample after immersion

**2.10 Determination of Corrosion Rate**

$W_b$  is the weight before immersion (g),  $W_a$  is the weight after immersion (g). While the corrosion rate (CR) in absence and presence of inhibitors was calculated using equation 2.

The corrosion rate (CR) in mm/year;

$$CR = \frac{K \times W}{A \times T \times D} \tag{2}$$

Where,  $W$  = weight loss (g),  $K$  = corrosion rate constant =  $8.76 \times 10^4$ ,  $A$  = area of specimen ( $cm^2$ ),  $D$  = density of Steel ( $g/cm^3$ ) =  $7.86g/cm^3$ ,  $T$  = time of exposure in hours = 24 hours, Where  $W$  is the weight loss (g) after exposure time  $t$ ,  $A$  is the area of the specimen ( $cm^2$ ),  $t$  is time of exposure in hours and CR is the corrosion rate corrosion rate obtained in the absence and presence of inhibitor.  $CR_o$  is the corrosion rate of mild steel without inhibitor, while  $CR_1$  is the corrosion rate of mild steel with inhibitor.

Inhibition Efficiency (IE %) was calculated using equation (3) below:

$$IE (\%) = \frac{\text{Weight loss without inhibitor} - \text{weight loss with inhibitor}}{\text{weight loss without inhibitor}} \times 100 \tag{3}$$

Where IE (%) is inhibition efficiency.

Surface coverage  $\theta$  was calculated by using following formula

$$\theta = \frac{\text{Weight loss without inhibitor} - \text{weight loss with inhibitor}}{\text{weight loss without inhibitor}} \tag{4}$$

**III. RESULTS AND DISCUSSION**

Figures 1 to 12 shows the results of corrosion rate, inhibition efficiency and surface coverage for 0.1g/l to 0.5g/l extract at 303k to 323k. Figures 5 to 8 shows that corrosion rate decreases with time for different extracts. The behavior is attributed to higher adsorption level of active inhibitor molecules from the extracts on the metal surface forming a thin film on metal surface to prevent further attack from the corrosive environment, thereby reducing weight loss by specimen, which is in agreement with the findings [1],[19]. It is noted that the inhibition efficiency depends on temperature and decrease with the rise of temperature, indicating that at higher temperature, dissolution of mild steel predominates on the surface. This effect can be explained by the decrease of the strength of the adsorption process at high temperature, suggesting physical adsorption[1],[12],[20].

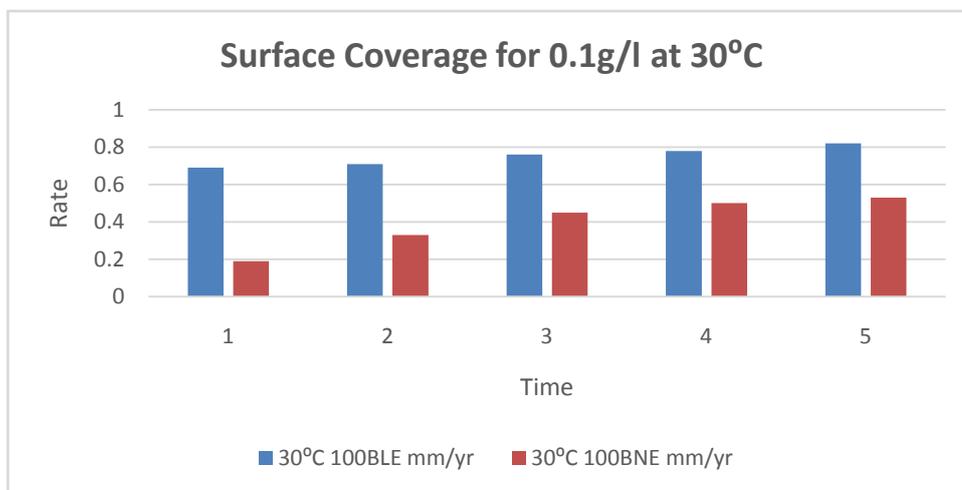


Figure 1 Graph of surface coverage for 0.1g/l at 30 °C

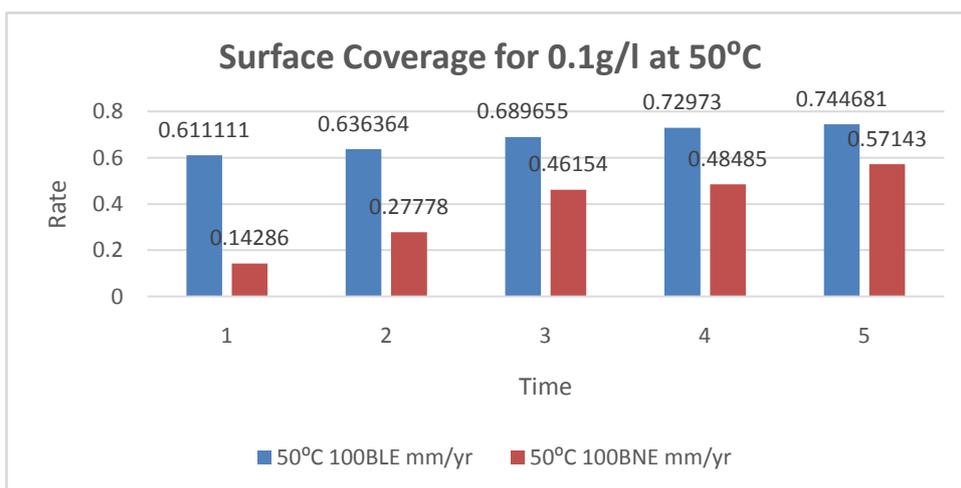


Figure 2 Graph of surface coverage for 0.1g/l at 50 °C

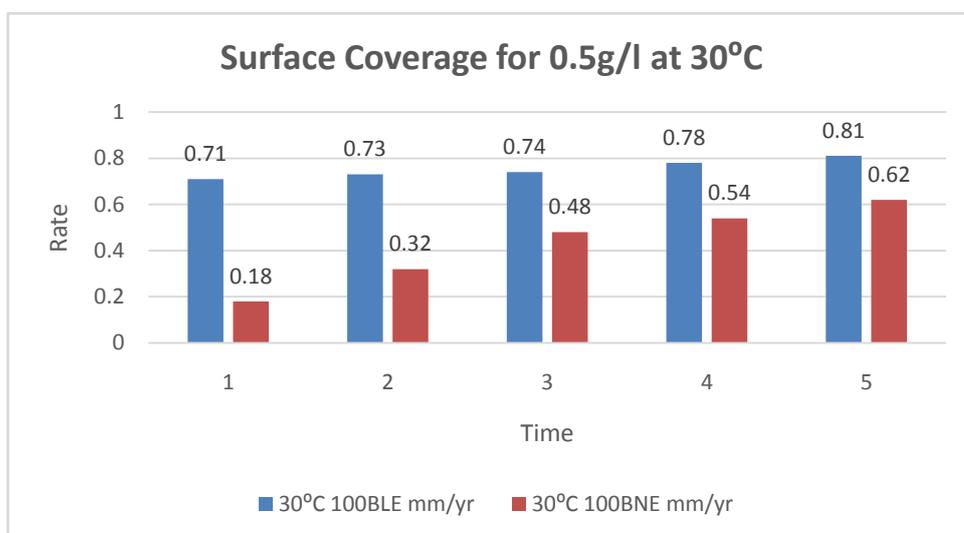


Figure 3 Graph of surface coverage for 0.5g/l at 30 °C

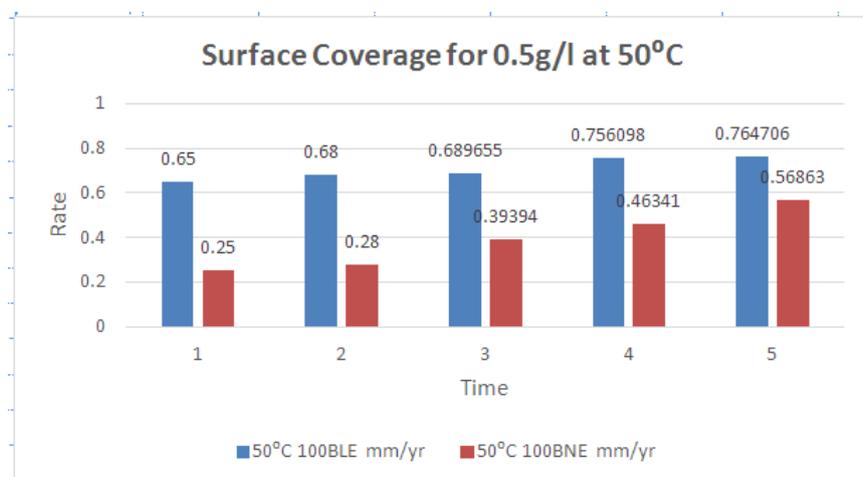


Figure 4 Graph of surface coverage for 0.5g/l at 50 °C

The increase of surface coverage is higher for BNE than for BLE as time increases as well as temperature increases from 30 °C to 50 °C. This is more pronounced at higher concentration as shown in figure 1 to 4

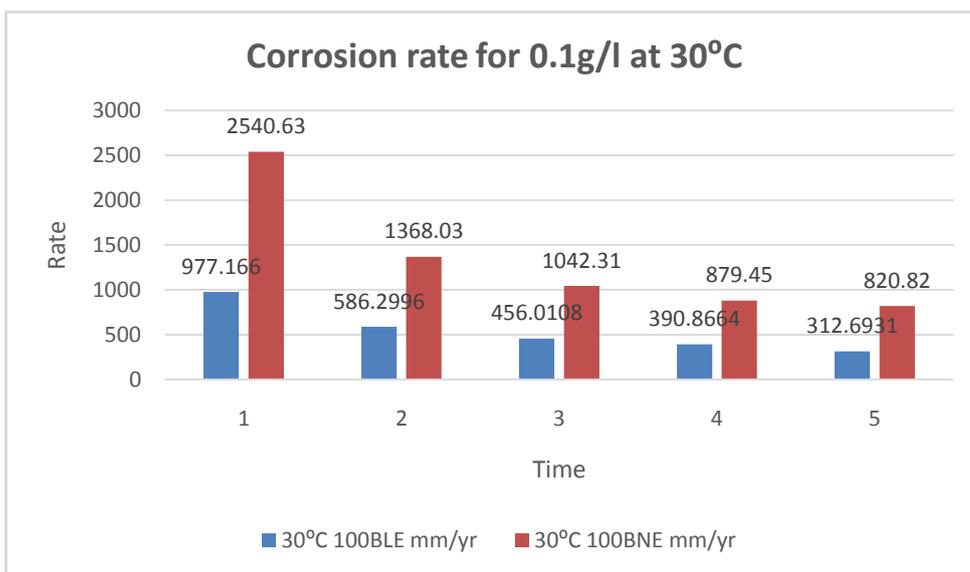


Figure 5 Graph of Corrosion rate for 0.1g/l at 30 °C

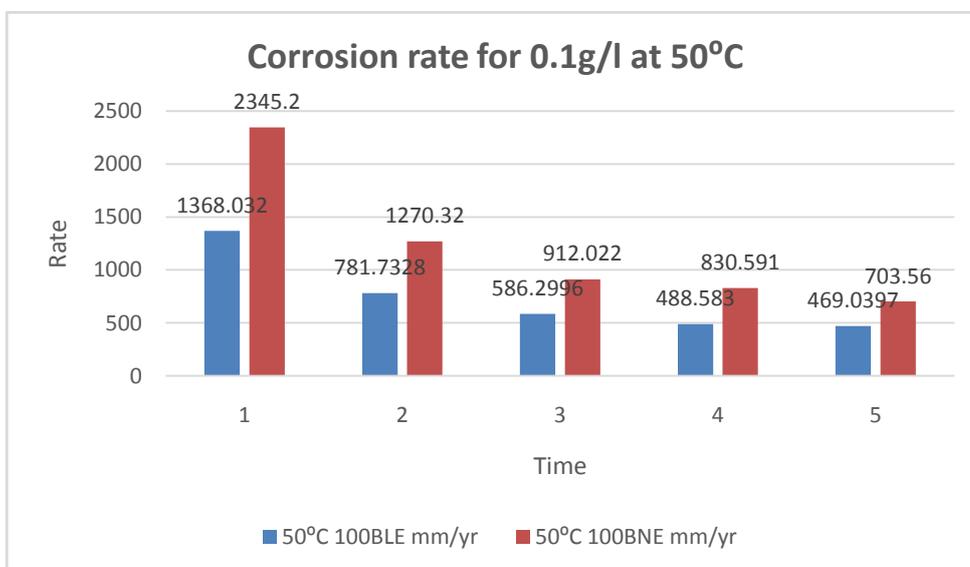


Figure 6 Graph of Corrosion rate for 0.1g/l at 50 °C

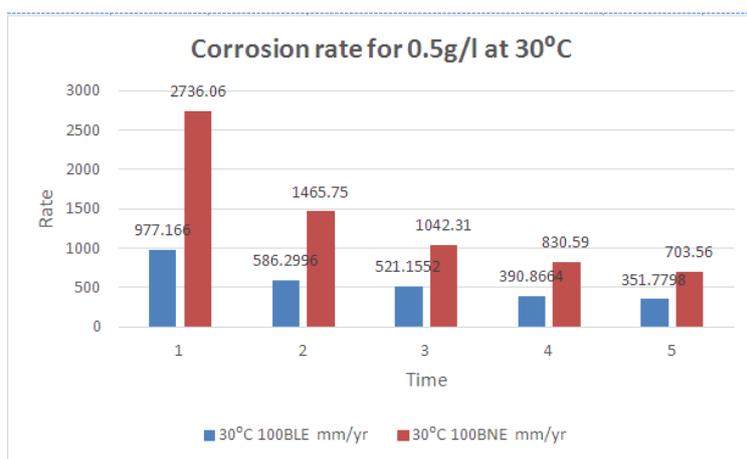


Figure 7 Graph of Corrosion rate for 0.5g/l at 30 °C

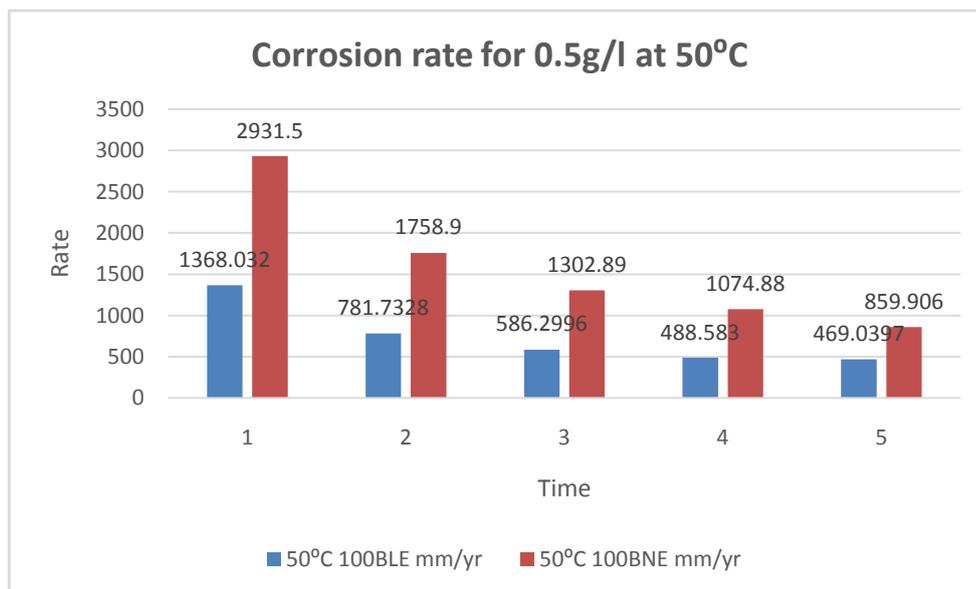


Figure 8 Graph of Corrosion rate for 0.5g/l at 50 °C

The effect of temperature on the corrosion rate of mild steel in plain acidic medium and in the presence of different concentrations of the inhibitor was studied in the temperature range of 30°C to 50°C. As shown in Figure (1 to 8), it was observed that the rate of corrosion of mild steel in plain acidic medium solution increases with increase in temperature. The corrosion rate decreases with increase in time but increases with temperature. The higher corrosion rate is in BNE than in BLE. The effect of increase of extract concentration shows that the corrosion rate decreases for both BLE and BNE but more pronounced in BLE.

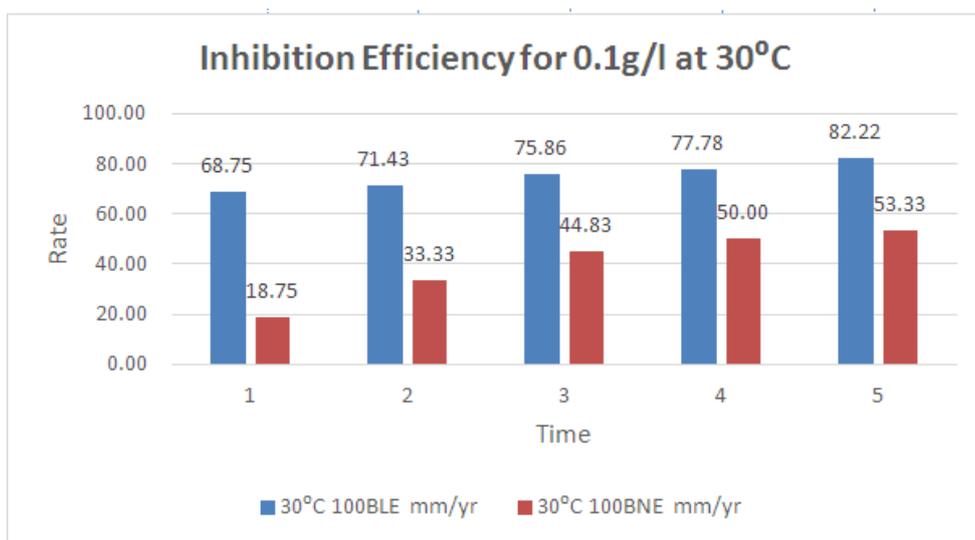


Figure 9 Graph of Inhibition Efficiency for 0.1g/l at 30 °C

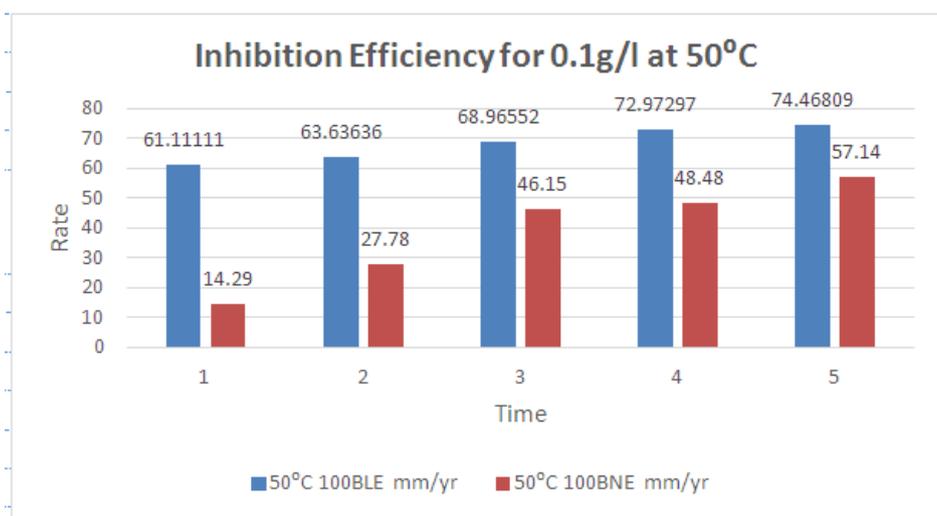


Figure 10 Graph of Inhibition Efficiency for 0.1g/l at 50 °C

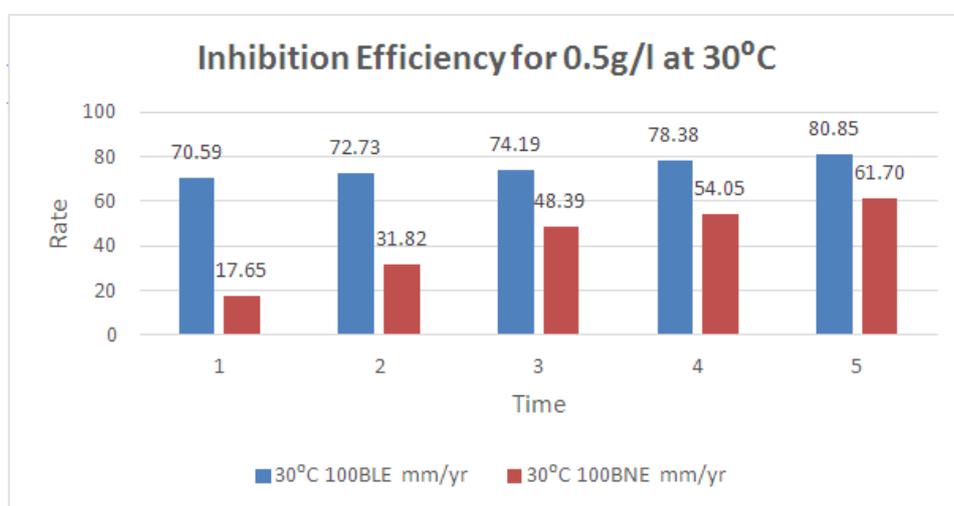


Figure 11 Graph of Inhibition Efficiency for 0.5g/l at 30 °C

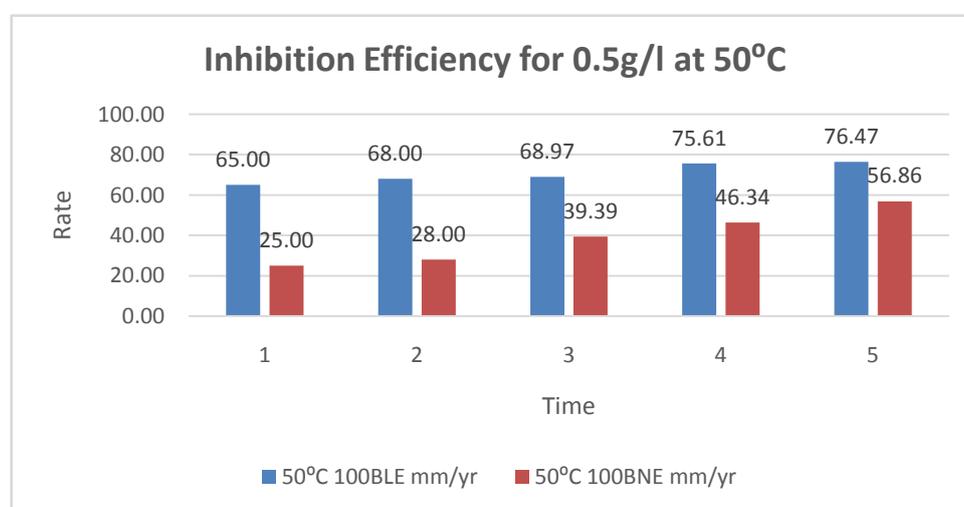


Figure 12 Graph of Inhibition Efficiency for 0.5g/l at 50 °C

Inhibition efficiency increases with time but tend to attain equilibrium at certain time. Inhibition efficiency decreases with increase in temperature[1],[2],[3],[9] Also inhibition efficiency increases with increase

in concentration As shown in Figures 9 to 12. This is more pronounced in BLE than in BNE. This means that BLE extract is more effective as inhibitor than BNE extract.

However, the corrosion rate is much decreased for the inhibited acid solution than in the plain acidic medium solution. This shows that as temperature increases, the rate of corrosion of mild steel also increases as a result of increase in the average kinetic energy of the reacting molecules. The decrease in the corrosion rate for the inhibited acid solution is as a result of the mitigating effect of the plant extract on the corrosion rate of the mild steel.

The inhibition of the corrosion of mild steel in by Banana stem (*Musa genus*) extracts and Bitter leaf (*Vernonia amygdalina*) in 1M HCl was investigated using weight loss method. The results showed that the corrosion rate of mild steel in 1M HCl decreases with increase in concentration of the extracts. The results obtained showed that 100 BLE has the highest corrosion inhibition capacity. The results also showed 100% BNE has the lowest inhibitory capacity when compared with 100BLE. However, the inhibitory tendency of Banana stem (*Musa genus*) extract increases with the concentration of Bitter leaf (*Vernonia amygdalina*) in the extract

### Infrared (IR) Characterization of the Extracts

Fourier transform infrared transmission is a powerful analyzer for identifying different functional groups in plant extracts. Bitter leaf (*V. amygdalina* leaf) and Banana stem (*Musa genus*) extract were analyzed using FTIR (Model Nicolet iS10). The extracts were analyzed using KBr standard procedure to obtain IR spectra in the scanning wave number ranging from 350 to 4400  $\text{cm}^{-1}$ . The spectra obtained for the extract was interpreted with a chart for characteristics infrared absorption frequencies of functional groups. The Fourier Transform Infrared (FTIR) investigations showed the characteristic wavelengths and spectra of the 100 % Banana stem extract (100 BNE), 1:1 BLE/BNE and 100% Bitter leaf extracts are presented in figure 13 and figure 14

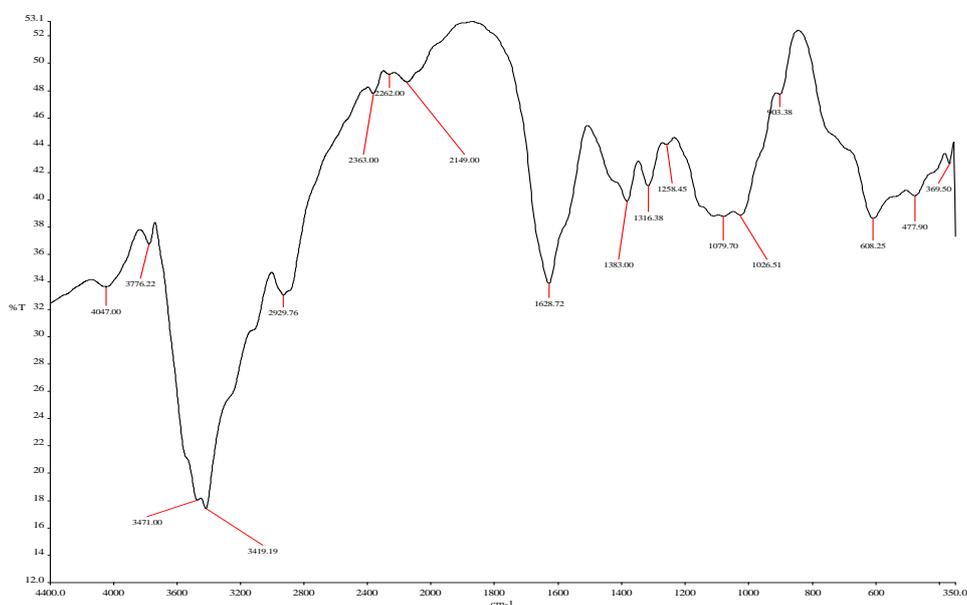


Figure 13 FTIR spectra of 100 % Bitter Leaf Extract (100% BLE)

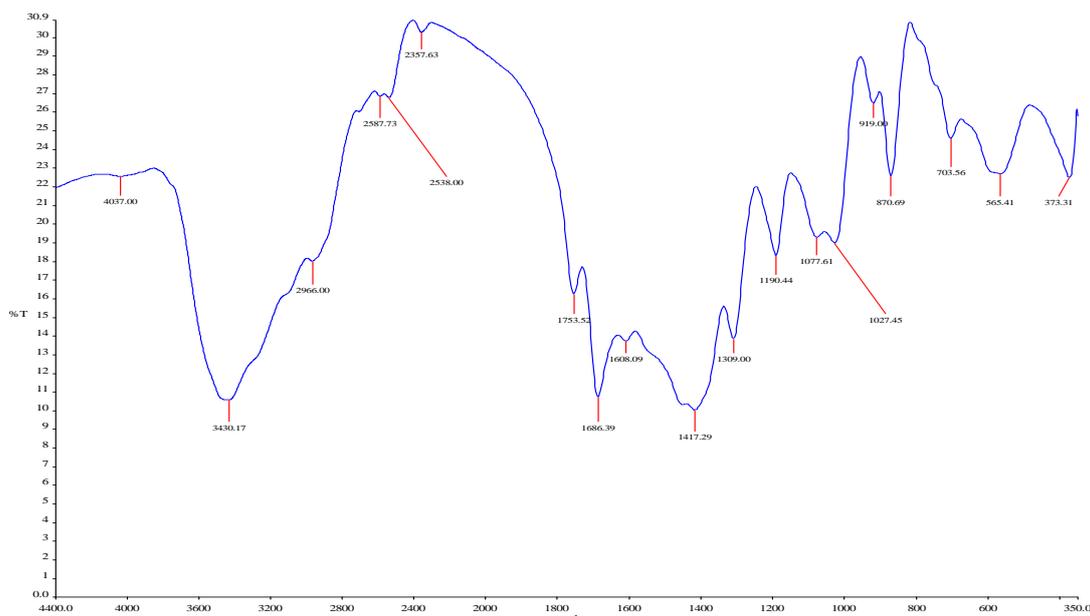


Figure 14 FTIR spectra of 100 % Banana Stem Extract (100% BNE)

### Surface Morphology of Mild Steel

The equipment used to study the morphology of mild steel is Joel scanning microscope (SEM) with model JSM 7600F. The surface analysis was carried out using SEM for the mild steel surface immersed in 1M HCL solution in the absence of inhibitor and then in the presence of inhibitor. The SEM images of the mild steel in 1M HCL without inhibitor is given in figure 15. A significant surface damage was observed on the mild steel, which was immersed in 1M HCL solution indicating that the surface is highly corroded. The surface of the corroded area of the mild steel was protected with the addition of the inhibitor figure 16 as is evident from the surface morphology and the presence of the inhibitor at the optimum concentration exhibit a smooth surface indicating restricted corrosion unlike figure 15. The SEM images clearly indicate that the mild steel surface was protected from corrosion in the presence of plant extract which is acting as corrosion inhibitor.

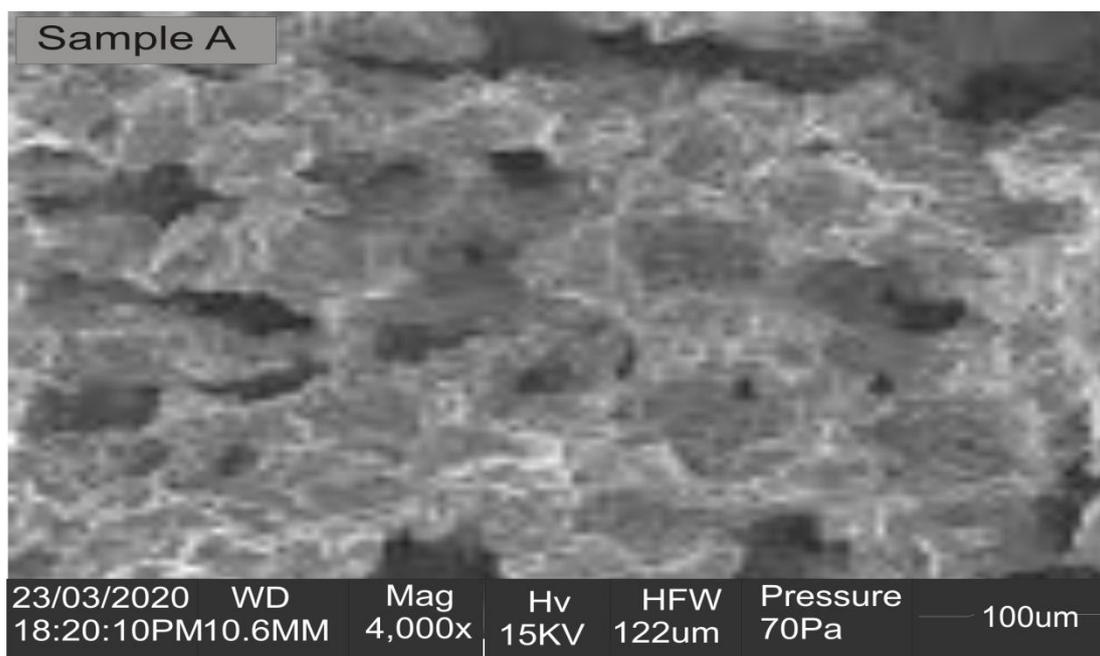


Figure 15 SEM IMAGE OF MILD STEEL BEFORE CORROSION X4,000

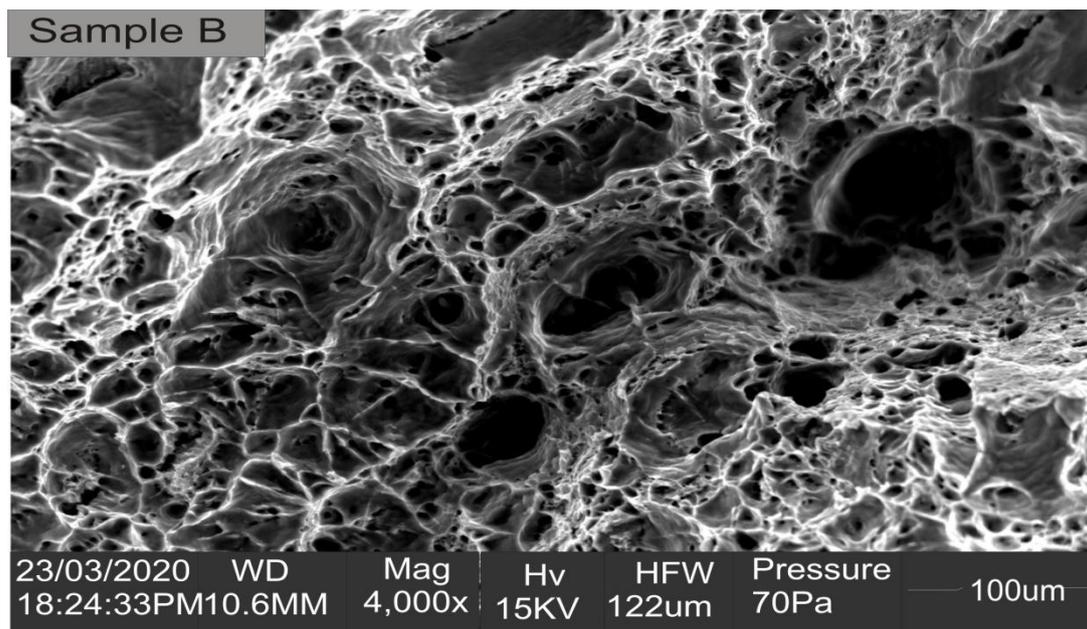


Figure 16 sem image of mild steel after corrosion X4,000

#### IV. CONCLUSION

The result of this research shows that the extract of bitter leaf (*Vernonia amygdalina*) and banana stem (*Musa Acuminata*) are good inhibitor for the corrosion of mild steel in HCl. However, bitter leaf extract has better inhibitory capacity than banana stem extracts. 100 % BLE has highest corrosion inhibition effectiveness for different concentrations of the extracts and for all the range of temperature used. 100 BNE has the lowest corrosion inhibitory effectiveness when compared with 100 % BLE.

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