

Corrosion Inhibition of Bitter Leaf (*Vernonia Amygdalina*) Extract on Mild Steel in Hydrochloric Acid Solution

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ABSTRACT

Mild steel which is widely used in industries at different temperatures and conditions is very susceptible to corrosion. The need for an eco-friendly way of reducing corrosion is therefore necessary. The effect of *Vernonia amygdalina* (bitter leaf) extract on corrosion of mild steel was investigated at varying extract concentration (0.1%, 0.2%, 0.3%, 0.4%, 0.5% v/v) and temperatures (303 K, 313 K, 323 K, 333 K) in acidic medium. Gravimetric analysis showed that the highest inhibition efficiency (IE) was achieved at a concentration of 0.5% at 333K. It was found that the inhibition efficiency increases with increase in concentration and temperature.

1. INTRODUCTION

Mild steel holds great significance in numerous engineering applications. However, its usage has been hampered by the undesirable condition of corrosion. The petroleum industry, in particular, faces significant challenges due to some corrosive substances associated with crude oil refinery. Corrosion readily affects exposed surfaces of metallic materials. To combat the detrimental effects of corrosion, various methods have been explored, with green corrosion inhibitors emerging as a major solution due to their environmentally friendly reaction (Oyewole *et al.*, 2021). These inhibitors have proven to be cost-effective and non-toxic, as highlighted by Abba-Aji *et al.* (2020). Extensive research has focused on studying the efficacy of green inhibitors derived from agricultural waste materials. This preference stems from their availability and eco-friendly nature.

Literature reports include the use of different green inhibitors, such as leaves extract of *osmanthus fragran* leaves extract (Li *et al.*, 2012), *C. papaya* leaves extract (Kavitha *et al.*, 2014), juniperus plants (Al-Mhyawi, 2014), bamboo leaves (Li *et al.*, 2014), aloe vera leaves extract (Pankaj and Gargi, 2014), neem leaves extract (Tuaweri *et al.*, 2015), watermelon waste (Odewunmi *et al.*, 2015), *gentiana olivieri* extract (Baran *et al.*, 2016), *sida acuta* (Umoren *et al.*, 2016), extracts of *origanum majorana* (Challouf *et al.*, 2016), pawpaw leaves (Omotioma and Onukwuli, 2017), *xanthium strumarium* leaves extract (Khadom *et al.*, 2018), pigeon pea leaf (Anadebe *et al.*, 2019), apple-based green inhibitor (Mehdi *et al.*, 2020), extracts of bitter leaf blends and honey (Abba-Aji *et al.*, 2020), *ficus exasperata* extract (Oyewole *et al.*, 2021), and *corchorius olitorius* stem (Oyewole *et al.*, 2021).

Despite the existing research, there is still a lack of sufficient data on the usage of bitter leaf (*Vernonia Amygdalina*) extract as inhibitor for mild steel, particularly at varying temperatures. Therefore, this study

aimed to investigate the effectiveness of *Vernonia Amygdalina* extracts as inhibitor of corrosion on mild steel in HCl solution.

2. METHODOLOGY

2.1 Materials

In this study, various materials and equipment were employed, including brushes, a grinder, and emery papers with different grades (80, 220, 800, and 1000). Sample storage was facilitated by a desiccator, and precise measurements were achieved using a digital weighing balance, water bath, measuring cylinders, beakers, and other glassware. To prepare the acids, researchers utilized Analar grade HCl (Hydrochloric Acid) with 98% purity, along with purified water obtained through distillation for the creation of the 1M acid solution.

2.2 Methods

Preparation of plant extract

Leaves of *Vernonia Amygdalina* were plucked and subjected to drying. Once dried, the leaves were pulverized and stored in a dry container. For the experiment, 10 g of the powdered leaves were measured and added to 100 ml of a pre-prepared 1 M HCl solution as shown in Figure 1, each in separate conical flasks. The conical flasks containing the mixture were then immersed in a water bath and kept at 363 K for 3 hours. Afterward, the flasks were taken out of the water bath and left to cool. The extract was obtained from the resulting mixture after filtration. Different stock solutions of *Vernonia Amygdalina* extract, with concentrations of 0.1%, 0.2%, 0.3%, 0.4%, and 0.5% (v/v), were prepared from the obtained filtrate.

Preparation of test samples

A sheet of Mild steel was obtained from a local market. The sheet was polished using emery paper to smoothen the surfaces, as shown in Figure 2. The polished sheet was cut into coupons, each with dimensions approximately 2 cm in length, 1 cm in width, and 1.2 cm in height. The coupons were then degreased using acetone and cleaned using distilled water. The prepared coupons were added into the solutions with plant extract concentrations ranging from 0.1% to 0.5%, as shown in Figure 2.

Weight loss measurement

The conventional weight loss method involves initially weighing the coupons, immersing them in the test solutions for a specific period, and then re-weighing them. Gravimetric studies were conducted on pre-weighed samples immersed in 250 ml capacity conical flasks containing 100 ml of the test solutions, which were maintained at temperatures of 303 K, 313 K, 323 K, and 333 K using a thermostat-controlled bath. The coupons were kept in the solutions for 4 hours. The concentration of the corrosion inhibitor was varied while maintaining the same temperature to examine the temperature's impact on the corrosion rate. The weight loss was determined by deducting the weight after immersion from the weight before immersion.

Determination of corrosion inhibitor efficiency

The primary analysis involved measuring the weight loss for each steel coupon retrieved. The weights of the coupons before and after it was immersed were carefully recorded to assess the corrosion rate. To calculate the inhibition efficiency (%I.E) of a substance, the corrosion rate with and without the substance was compared, as described by Olusegun *et al.* (2004) as presented in equation (1).

$$IE\% = \left[1 - \frac{W_1}{W_2} \right] \times 100 \quad (1)$$

Here W_1 and W_2 are the recorded weight changes for coupon with and without corrosion inhibitor respectively.



Figure 1: Weighing of pulverized leafs



Figure 2: Prepared extracts concentrations with coupons in 0.1 – 0.5%

3. RESULTS AND DISCUSSION

The parameters of inhibition efficiency (IE %) which were obtained using weight loss experimental method are listed in Tables 1 and 2 at different inhibitors concentrations and temperatures. The corrosion rate observed showed a reducing trend with an increment in the concentrations of the inhibitors. The lowest corrosion rates were achieved when the highest concentration (0.5 g/l) of the extract was added, regardless of the temperature being investigated. This trend is clearly depicted in Figures 3 to 6. Additionally, the inhibition efficiency (%IE) values (Figure 7) for each of the investigated inhibitors were compiled in Table 2. It was realized that the inhibition efficiency increased with higher concentrations of inhibitors and temperatures.

Oguzie (2007) demonstrated that corrosion inhibition occurs due to the displacement of adsorbed water molecules by inhibitor species which causes adsorption of the inhibitor on the material surface. However, it was found out that the inhibition efficiency reduced with increasing temperature. This decrease can be attributed to the formation of a dimeric film on the metal surface, as reported by Noor (2005). Consequently, with rising temperature, there was desorption of the surface layer of the dimeric inhibitor film from the metal surface, causing some non-uniformity in the inhibition efficiency. Moreover, the data presented in the Figures 3 - 6 indicated that the weight loss increased with higher temperatures but decreased with a rise in the concentrations of the inhibitor.

Figures 3 – 6 describe the weight loss measurements for each tested coupon at various extracts concentrations and temperatures. Generally, there is decrease in weight loss as the extract concentrations

increases and temperature decreases. This is an indication that the inhibitor worked best at a temperature of 333K and 0.5% inhibitor's concentration. At an elevated temperature of 333 K, corrosion was found to be highest in the 0.1% inhibitor concentration. This observation is likely due to the increase in the rate at which the surface of the metal adsorb molecules of the inhibitor at this temperature. The presence of tannin in the plant extract facilitates its adsorption on the surface of the mild steel, effectively blocking the active sites on the surface. As a result, the rate of corrosion is minimized in the medium (Ayeni et al., 2012). On the other hand, a significant decrease in the corrosion rate was observed at the 0.5% inhibitor concentration. This can be attributed to the molecular adsorption of the inhibitor on the mild steel surface. The presence of tannin in the plant extract acted as a physical barrier, restricting the diffusion of ions to and from the metal surface. Consequently, it prevents the metal atoms (ions) from engaging in further cathodic or anodic reactions, leading to a reduction in the rate of corrosion (Loto, 2003).

Based on the graph of efficiency against concentrations at various temperatures (Figure 7), a clear trend was observed, the inhibition efficiency increased with an increase in inhibitor concentration and temperature. The highest inhibition efficiency of 84% was achieved at a 0.5% inhibitor concentration and a temperature of 333 K. At this specific temperature, the inhibitor demonstrated its greatest effectiveness. This observed behavior can be attributed to the molecular adsorption of the inhibitor on the metal surface, which becomes more pronounced at elevated temperatures like 333 K. A physical barrier which is enabled by the tannin in the extracts restricts the ionic diffusion towards and from the metallic surface. Consequently, the metallic atoms (ions) are hindered from further cathodic or anodic reactions, leading to a decrease in the overall corrosion rate (Ayeni et al., 2012; Loto, 2003).

Table 1: Corrosion rate in 1M HCl

Concentration Of inhibitor % (v/v)	Weight Loss (g)			
	303k	313k	323k	333k
Blank	0.014	0.021	0.046	0.074
0.1	0.011	0.012	0.018	0.021
0.2	0.010	0.011	0.015	0.017
0.3	0.009	0.009	0.013	0.015
0.4	0.007	0.008	0.012	0.014
0.5	0.006	0.007	0.010	0.012

Table 2: Inhibitor Efficiency for 1M HCl

Concentration of inhibitor %(v/v)	Inhibition efficiency (%)			
	303k	313k	323k	333k
0.1	21	43	61	72
0.2	29	48	67	77
0.3	36	57	72	79
0.4	50	62	74	81
0.5	57	67	78	84

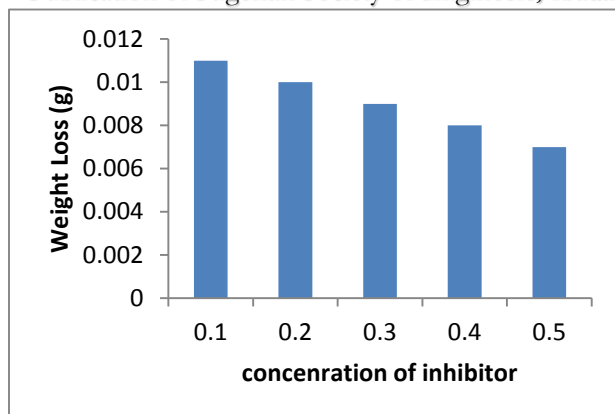


Figure 3: Weight loss in HCl solution at 303K

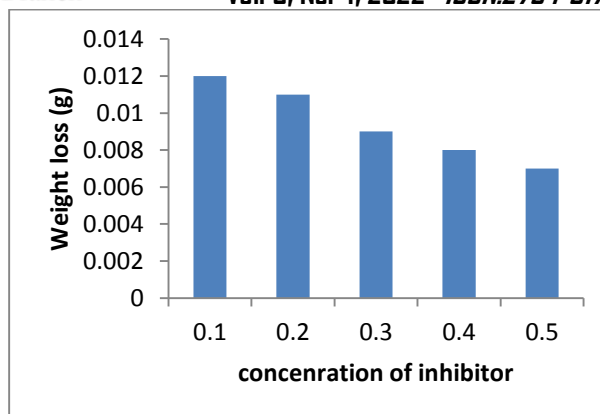


Figure 4: Weight loss in HCl solution at 313K

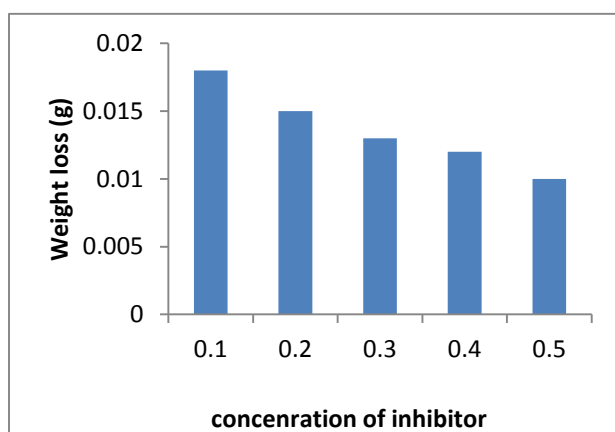


Figure 5: Weight loss in HCl solution at 323K

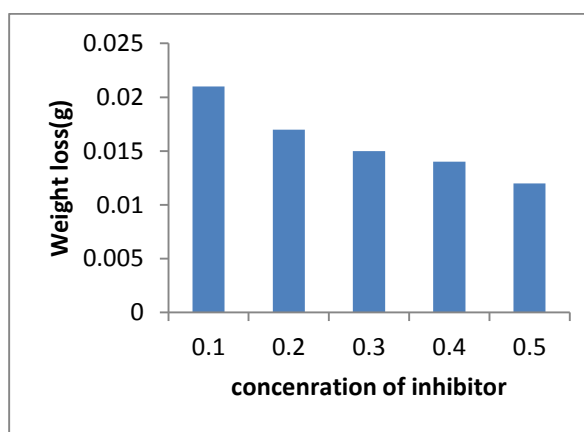
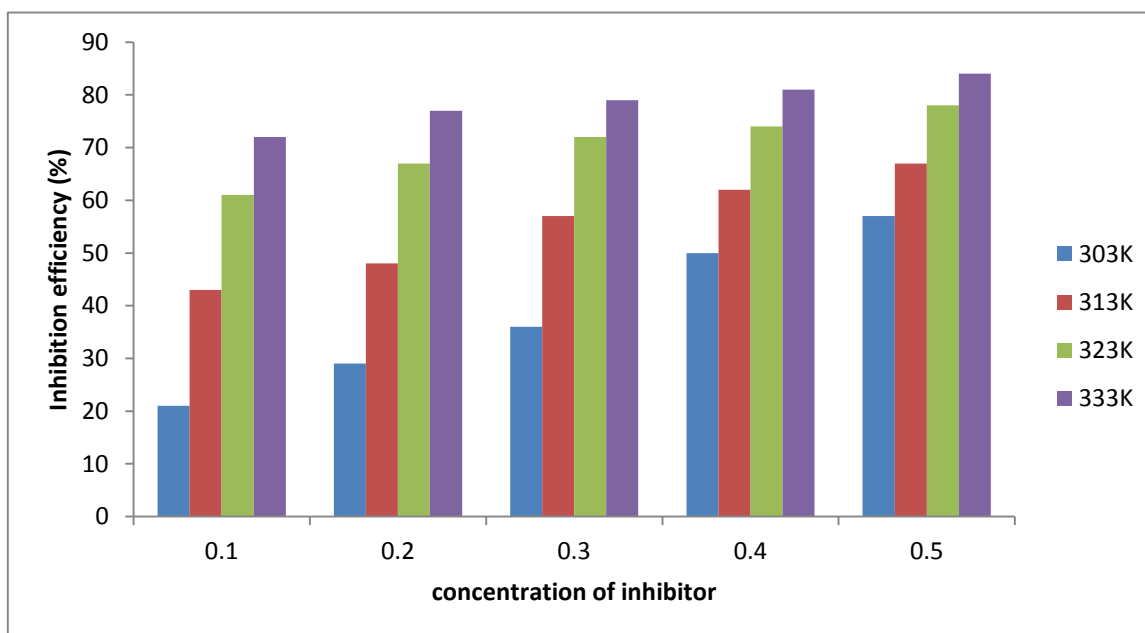


Figure 6: Weight loss in HCl solution at 333K

Figure 7: Inhibition efficiency against concentration extract of *Vernonia Amygdalina* at different temperatures.

4. CONCLUSION

Based on the accomplishments of this study, it was realized that bitter leaf extracts (*Vernonia amygdalina*) exhibited corrosion inhibition properties on mild steel when exposed to 1M HCl solution, with the most effective inhibition observed at a higher temperature of 333K and a concentration of 0.5% inhibitor. The interaction mechanism between mild steel and the inhibitor is primarily through physical adsorption. The molecular inhibitor attaches itself to the surface of the mild steel, effectively obstructing active corrosion sites, particularly at elevated temperatures like 333K. These findings indicate the potential of bitter leaf extracts as a viable and efficient corrosion inhibitor for mild steel under specific conditions, offering valuable insights for further applications and research.

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