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Temperature Effects on the Corrosion Inhibition of Mild Steel in Crude Oil Medium by the Seed Extract of Persea Americana (Avocado Tree)

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Abstract

Weight-loss method was used in assessing the response to corrosion of samples of mild steel inserted in various concentrations (400, 600, 800 and 1000 ppm) of avocado seed extract in crude oil medium under various high temperature of 303, 313, 323, and 333 Kelvin. The results show a negative correlation between temperature and corrosion inhibitor efficiency, with increased temperature leading to reduced corrosion effectiveness across all concentrations. Conversely, a positive correlation is observed between concentration and corrosion effectiveness, with higher concentrations resulting in enhanced corrosion protection. The findings suggest that elevated temperatures reduce the effectiveness of the avocado seed oil extract due to reduced solubility, reduced inhibitor adsorption rate on metal surface and potential degradation. The study highlights the importance of considering temperature and concentration factors when evaluating natural products as corrosion inhibitors in industrial applications, and suggests that avocado seed extract is an effective biodegradable corrosion inhibitor at high temperature.

Keywords: Corrosion, Weight-loss method, Inhibition, Adsorption.

1 | Introduction

The Temperature plays a crucial role in influencing the performance of corrosion inhibitors, affecting their effectiveness in protecting metal surfaces from deterioration. Generally, corrosion inhibitors function optimally within specific temperature ranges, and variations outside these limits can impact their efficiency [1]. At elevated temperatures, corrosion reactions tend to accelerate, posing a greater challenge for inhibitors

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to effectively mitigate the process. High temperatures can alter the physical and chemical properties of both the metal substrate and the inhibitor itself, potentially reducing the inhibitor's adsorption onto the metal surface. This diminished adsorption capability can compromise the inhibitor's ability to form a protective barrier, allowing corrosion to progress more rapidly [2].

Conversely, lower temperatures can also impact corrosion inhibitor performance. Cold temperatures may lead to reduced solubility of inhibitors, limiting their dispersion and coverage on metal surfaces. Additionally, the decreased kinetic energy at lower temperatures may hinder the inhibitor molecules' ability to interact with the metal, diminishing their overall effectiveness [3]. In summary, the temperature environment significantly influences corrosion inhibitor performance. Understanding these temperature-dependent effects is crucial for selecting and designing inhibitors that can maintain their protective properties across a range of operating conditions, ensuring the longevity and integrity of metal structures [4].

To this end, this research aims at determining the effect of high temperature on the inhibition of corrosion on mild steel while using the seed extract of avocado as inhibitor in crude oil environment. The goal is to further understand how high temperature affects the performance of this environmentally friendly and biodegradable inhibitor developed from avocado seed extract.

2 | Oil Extraction from Avocado Seed

Oil extraction is a delicate issue as the aim is to maximize the oil yield. In order to maximize the yield (quantity) of oil extracted from the seed of avocado plant, the parts of avocado seed used were pulverised. This was done in a bid to increase the surface area of the particles so as to allow for more percolation of the extraction solvent and thus increase substituent extraction in terms of volume. After pulverisation, the particles were put in a soxhlet apparatus with petroleum ether as the extraction solvent. After extraction, the solvent was allowed to evaporate in room temperature so as to remove the petroleum ether and have pure extract. *Fig. 1* shows the pulverised avocado seed while *Fig.2* shows the soxhlet extraction process with its product.

Fig. 1. Pulverised avocado seed.

Fig. 2. Avocado seed oil and Soxhlet apparatus.

3 | Materials and Methods

Equipment and materials were used in accomplishing the aim of this research. These are discussed thus.

3.1 | Materials and Equipment

I. Mild steel coupons: mild steel coupon specimens that are representative of the material to be used were obtained. The coupons were typically in the form of flat rectangles.

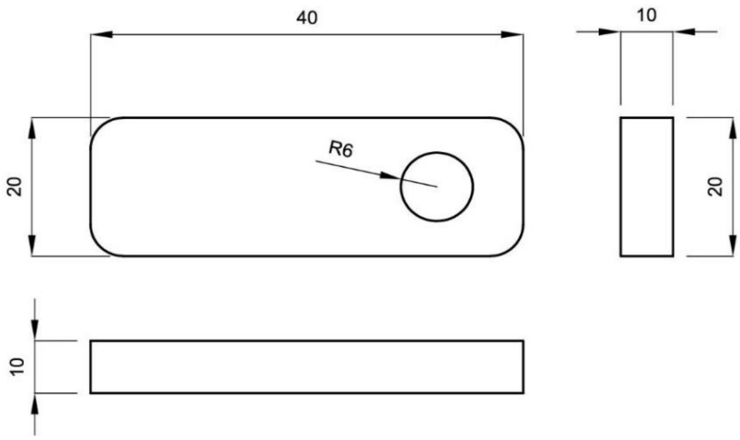
II. Abrasive material: abrasive materials (sandpaper, emery cloth, etc.) were used to remove surface impurities, rust, or scale from the mild steel coupons.

III. Solvent or cleaning solution: the coupons were cleaned thoroughly using a solvent (e.g., acetone or isopropyl alcohol) to remove residual oils, grease, or contaminants.

IV. Deionized water: the cleaned coupons were rinsed with deionized water to eliminate any remaining traces of cleaning solution [5].

3.2 | Surface Preparation

The surface of the rectangular mils steel plate selected were grinded to achieve a smooth finish. This step helped in obtaining consistent and uniform corrosion results. The mild steel coupons had standardized dimensions which allowed for accurate, consistent comparisons between different tests and studies [6]. The *Fig. 3.a* and *Fig. 3.b* show the schematic and realistic views of the mild steel coupons with dimensions adopted for this experiment.



a.

b.

Fig 3. The views of the mild steel coupons.

a. Schematic diagram of mild steel coupon; b. realistic view of mild steel test coupons.

4 | Weight Loss Method for Corrosion Analysis

The weight loss method is a common and straightforward technique used for corrosion analysis. This method involves measuring the loss of mass of a metal specimen over time due to corrosion [7]. It is widely employed to determine the corrosion rate and evaluate the corrosive effects of various environments on different materials, including metals like mild steel. Here is an overview of the weight loss method for corrosion analysis:

I. Selection of specimens: metal specimens (coupons) made of the material to be studied was selected.

II. Exposure to corrosive environment: the metal specimens were placed in the chosen corrosive environment in this case which is a crude oil environment with varying concentration of the inhibitor (avocado extract) concentrations of 400, 600, 800 and 1000 ppm.

III. Duration of exposure: the specimens were allowed to be exposed to the corrosive environment for a predetermined period of 4 hours.

IV. Removal and cleaning: after the exposure period, the mild steel coupons were carefully removed from the high temperature environment, cleaned to remove corrosion products, residual solution, or contaminants. The coupons were cleaned with water and acetone, brushed to remove surface dirt and kept in a desiccator prior to weighing with the digital weighing device.

V. Measurement of weight loss: each specimen was weighed accurately using a balance before and after exposure. The weight loss is calculated by subtracting the final weight from the initial weight.

VI. Calculation of corrosion rate: According to Srivastava [8], the corrosion rate was determined using the following formula:

$$\mathrm{C.R}\left(\frac{\mathrm{mm}}{\mathrm{year}}\right) = \text{Weight Loss} * \text{Exposure Time} * \text{Metal Density}, \quad (1)$$

Where CR = corrosion rate

The weight loss method is a simple yet effective way to assess corrosion. However, it is important to note that the method provides an average corrosion rate over the entire exposed surface and may not capture localized corrosion effects [9]. Additionally, for more accurate results, it's crucial to use statistically significant sample sizes and carefully control experimental variables [10].

5 | Temperature Assessment of Mild Steel Coupons in Presence of Avocado Seed Inhibitor in Crude Oil Medium

5.1 | Exposure Setup

A drier was used to provide the required high temperatures of 303K, 313K, 323K and 333K. The mild steel coupons immersed in crude oil environment in conjunction with varying concentrations of 400, 600, 800 and 1000 ppm of the avocado seed extract. This high temperature equipment is shown in *Fig. 5*. The temperature of the setup is gradually raised until it reaches the desired level. It ensures that the temperature of the setup was stable and accurately controlled throughout the experiment. The temperature was monitored continuously to track any fluctuations. The mild steel coupon was periodically inspected during the exposure time. Record observations were recorded relating to corrosion morphology, inhibitor performance, and any visible changes in the coupons.

At the end of the exposure period, the mild steel coupons were carefully removed from the high-temperature environment. Weight loss measurements were conducted using a digital weighing balance to determine the corrosion rates. The corrosion weights of the inhibited and uninhibited samples were compared [11]. Data collected was evaluated to assess the response of the corrosion inhibitor to the high-temperature environment. The inhibitor's efficiency, corrosion rates, were observed.

Fig. 5. High temperature equipment.

6 | Results and Discussion

After the weight loss experiment, the chart in data in *Table 1* was created. This data set was used in preparing the chart shown in *Fig. 6* which is a pictorial representative of the relationship between the different concentrations of the inhibitor (avocado seed) and increase in temperature in relation to corrosion inhibitor effectiveness.

Table 1. Degree of surface coverage (θ) and percentage inhibition efficiency (% IE) of Seed in Crude Oil at 303-333 K, obtained from weight loss measurement after 4 hours.

Temp. (K)	Inhibitor	W (g)	FW (g)	WL (mg)	CR (mm/y)	θ	IE%	Log CR
303	Blank	12.792	10.892	1.9	0.3065	0	0	-0.51357
	400ppm	12.641	11.441	1.2	0.19362	0.36842	36.8421	-0.71304
	600ppm	12.721	11.771	0.95	0.15328	0.5	50.0	-0.81451
	800ppm	12.633	12.023	0.61	0.09842	0.67895	67.895	-1.0069
	1000ppm	12.814	12.023	0.58	0.09358	0.69474	69.474	-1.0228
	Blank	12.705	10.405	2.3	0.37111	0	0	-0.43050
313	400ppm	12.614	11.114	1.5	0.24203	0.34783	34.783	-0.61613
	600ppm	12.712	11.812	0.9	0.14522	0.60870	60.870	-0.8378
	800ppm	12.543	11.842	0.7	0.11295	0.69565	69.565	-0.94711
	1000ppm	12.654	12.154	0.5	0.08067	0.7826	78.261	-1.09329
	Blank	12.801	9.901	2.9	0.46791	0	0	-0.3298
323	400ppm	12.632	10.632	2.0	0.32270	0.31034	31.034	-0.4912
	600ppm	12.702	10.802	1.9	0.30656	0.34482	34.482	-0.51348
	800ppm	12.545	11.345	1.2	0.1936	0.5862	58.621	-0.71309
	1000ppm	12.623	11.823	0.8	0.12908	0.72414	72.414	-0.88914
	Blank	12.745	9.445	3.3	0.5325	0	0	-0.2737
333	400ppm	12.715	10.215	2.5	0.40338	0.24242	24.2424	-0.39429
	600ppm	12.605	10.605	2.0	0.32270	0.39393	39.3939	-0.49120
	800ppm	12.543	10.743	1.8	0.29043	0.45454	45.4545	-0.5370
	1000ppm	12.712	11.512	1.2	0.19362	0.63636	63.6363	-0.71305

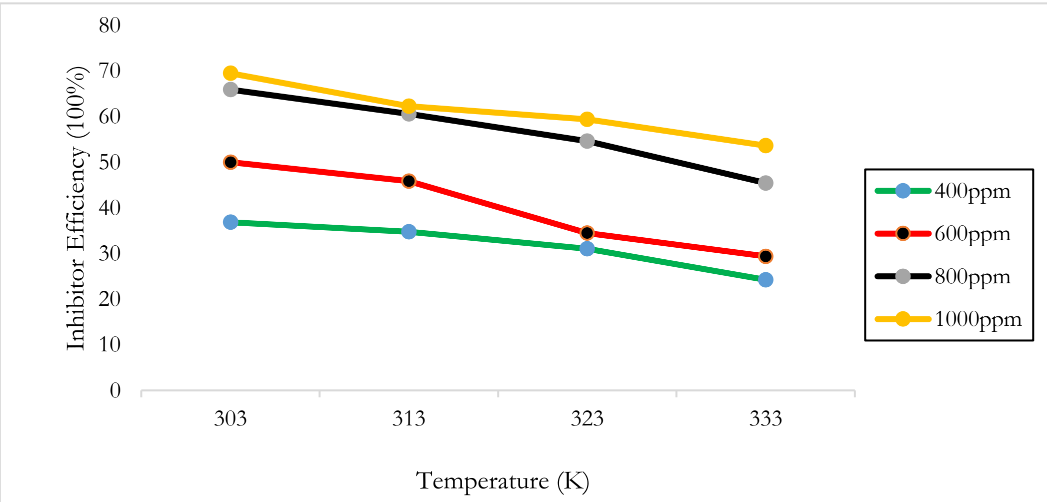


Fig. 6. Variation of inhibitor efficiency with temperature for mild steel in crude oil in the presence of various concentration of seed extract.

6 | Discussion

Fig. 6 shows result for weight loss analysis at elevated temperatures of 303, 313, 323 and 333 K for immersion time of 4 hours in crude oil with different concentrations (400, 600, 800 and 1000 ppm) of avocado seed extracts.

The experiment demonstrated a negative correlation between temperature and corrosion efficiency of avocado seed oil extracts in crude oil environments, where increasing temperature led to a reduction in corrosion effectiveness for all concentrations. This can be attributed to the increased thermal energy that enhances the mobility of metal ions and molecules at the metal-solution interface, ultimately reducing the effectiveness of the seed oil extract as a corrosion inhibitor. Moreover, as temperature increases, the solubility of the seed oil extract in crude oil decreases, resulting in reduced availability of the active components at the metal surface. Additionally, elevated temperatures can also lead to degradation or breakdown of the seed oil extract's chemical structure, rendering it less effective as a corrosion inhibitor.

On the other hand, the positive correlation between concentration of seed oil extract and corrosion effectiveness can be explained by the increased availability of active compounds that are more effective at inhibiting corrosion as their concentration increases. This suggests that higher concentrations of seed oil extract provide a stronger barrier against corrosion, thereby enhancing its effectiveness in protecting mild steel from corrosion in crude oil environments. Overall, these findings highlight the importance of considering temperature and concentration factors when evaluating the effectiveness of natural products like avocado seed oil as corrosion inhibitors in industrial applications. These findings are in line with works of [12].

7 | Conclusion

From the results obtained from the experiment, it is obvious to see that the inhibitive efficiency of avocado seed oil in mild steel in crude oil environment is relatively high and as such, avocado seed oil is a good corrosion inhibitor that can be used in high temperature environment.

Also, avocado seed oil demonstrates notable potential as a corrosion inhibitor, offering a sustainable and eco-friendly alternative to traditional inhibitors. The unique composition of avocado oil, rich in monounsaturated fatty acids and antioxidants, contributes to its effectiveness in preventing corrosion on metal surfaces. The formation of a protective barrier on the metal, attributed to the oil's molecular structure, inhibits the corrosive processes and enhances the material's resistance to degradation.

Furthermore, the natural origin of avocado oil aligns with the growing demand for environmentally conscious corrosion inhibitors, reducing the reliance on synthetic and potentially harmful chemicals. Its biodegradability and non-toxic nature make it a favourable option for industries seeking greener alternatives without compromising performance.

While research in this area is ongoing, the promising results suggest that avocado oil could play a significant role in corrosion prevention across various applications. Continued exploration of its mechanisms and long-term effects will contribute to a deeper understanding of its potential as a corrosion inhibitor, paving the way for sustainable solutions in the field of materials protection.

Author Contribution

Emmanuel Okon Wilson conducted the experiments, provided the data used for the research, wrote the abstract and proofread the entire work, Ambgari Charles wrote the introduction and Essien Promise wrote the data analysis and conclusions.

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Data Availability

The data used for this research was gotten via experiment conducted at the Post-graduate laboratory, Mechanical Engineering Department, University of Uyo.

Conflicts of Interest

There is no conflict of interest whatsoever.

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