EVALUATION OF PALM KERNEL OIL AS ECO-FRIENDLY INHIBITOR AGAINST CORROSION OF MILD STEEL IN ACIDIC AND ALKALINE MEDIA

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Abstract: Corrosion inhibition property of palm kernel oil (PKO) in 1M HCl and 1M NaOH on mild steel was investigated using gravimetric and potentio-dynamic polarization methods. Cathodic and anodic Tafel constants changed with the presence of PKO; suggesting that the suppression of the required redox reaction for corrosion was due to the effect of inhibitor adsorption on the metal surface. The current density reduced with increasing quantities PKO in both media, leading to a reduction in corrosion rate. Corrosion rates of the tested mild steel coupons decreased with increasing amounts of PKO in both test media. As observed, maximum inhibitor efficiency of 97.8% occurred at 0.5% inhibitor concentration of PKO in 1M HCl; and 98.8% inhibitor efficiency occurred at 0.6% PKO concentration in 1M NaOH solution.

Keywords: Corrosion, inhibitor, palm kernel oil, acid (HCl), base (NaOH)

Introduction

Mild steel has several industrial applications in developing countries as well as the developed ones. However, the protection of mild steel from corrosion is one of the most challenging problems for industries (Al-otaibi *et al*., 2012). Acidic solutions are widely used in industries (Ashassi-Sorkhabi *et al*., 2009; Schmitt, 1984) and corrosion inhibitors are often required to reduce the corrosion rates of metallic materials in these acidic media (Abboud *et al*., 2006; Anand and Balasubramanian, 2011; Loto, 2013; Shetty and Shetty, 2017). Corrosion of metals can have huge impact on the economy of a country. For example, cost incurred on corrosion of metals in the US was estimated to be approximately $276 billion on an annual basis, which is several times greater than the normalized loss incurred due to natural disasters ($17 billion per annum). Reportedly, about 25-30% of the annual corrosion costs could be saved by means of optimum corrosion management practices (Al-otaibi *et al*., 2012; Palou *et al*., 2014).

Green-inhibitors are eco-friendly with little or no toxicity, readily available, affordable, efficient and currently attracting more research attention than their synthesized counterparts (Hameed *et al*., 2015; Palou *et al*., 2014; Sliem *et al*., 2019). Neem leaves (*Azadirachta indica*) extract, oil from neem tree fruits, natural honey, asoka tree leaves (*Polyalthia longifolia*) extract, garlic (*Allium sativum*) extract, palm oil (Arecaceae), wireweed leaves (*Sida acuta*) extract, Indian ash tree leaves (*Lannea coromandelica*) extract, etc are some green-materials that have been studied for use as corrosion inhibitor by researchers (Abdallah, 2000; Bhola *et al*., 2014; Daniyan *et al*., 2011; Eduok *et al*., 2012; Kebangsaan and Othman, 2015; Marathe *et al*., 2015; Parthipan *et al*., 2018; Swaroop *et al*., 2016; Tuaweri *et al*., 2015; Vasudha and Shanmuga, 2013). The corrosion inhibition of heat-treated mild steel with neem leaf (*Azadirachta indica*) extract using weight loss methods was investigated by (Tuaweri *et al*., 2015). As-reported, the neem leaf extract was a good corrosion inhibitor in the tested chloride environment as the corrosion rate of the mild steel decreased with 5 % inhibitor concentration. Corrosion rate was however reported to increase beyond this concentration for both as-received and heat-treated coupons. Inhibitor properties of natural honey on carbon steel as examined by (Abdallah, 2000) exhibited protection against corrosion in high saline water. Corrosion inhibition efficiency of dry Asoka tree (*Polyalthia longifolia*) leaves in 1M HCl medium was investigated using weight loss method between 35 – 75°C (Vasudha and Shanmuga, 2013). As-reported, increasing the concentration of the extract to 1.5% increased the inhibitor efficiency on the substrate to 87%.

Both palm oil and palm kernel oil (PKO) are oil derivatives from palm tree (Arecaceae). Over the years, the use of palm oil as corrosion inhibitor have been studied by a number of researchers (Daniyan *et al*., 2011; Kebangsaan and Othman, 2015); however, studies on the use of PKO as corrosion inhibitor is still very rare. In a recent research, Siti Rahimah *et al*. (Kebangsaan and Othman, 2015) reported reduction in corrosion rate of steel sample with surface coated with palm oil compared to the one not coated with same. This shows the possibility of using oil derivatives from palm tree for the purpose of eco-friendly inhibitor against corrosion of ferrous metals. On the other hand, the inhibitive effect of PKO on the corrosion of steel found in the literature only addresses corrosion in alkaline solution (Zulkaflia *et al*., 2013). The ability of PKO to act as inhibitor against corrosion of steel is further evaluated in this study with a view to addressing other areas using both acidic and basic media.

Materials and Methods

The materials used for this research work include: palm-kernel oil (PKO), sulphuric acid (H_2SO_4), sodium hydroxide (NaOH), hydrochloric acid (HCl), mild steel coupons, distilled water, beakers (25, 50, 250, 600 and 1000 ml), volumetric flask (1000 ml), reagent bottle, spatula, emery paper (silicon carbide paper of 60, 220, 320, 400, 600 and 800 grit sizes), syringes (20 ml graduated in 1 ml), D.C power supply, alligator clips and strips of 1.5 mm cable wire, cleaning materials (detergent, tissue paper), masking tape, air-tight containers, pH meter, multimeter, zero resistance ammeter and positive metal analyser.

Sample preparation

Mild steel samples were ground and polished using different grit sizes of silicon carbide paper from 60 to finer 1200 grit size. Samples were washed with distilled water and dipped into dilute H_2SO_4 for about 3 min. Degreasing was done using heated acetone to remove organic materials on the surface of the samples. 1 molar solution of HCl was prepared by making up 83 ml of concentrated hydrochloric acid with distilled water in 1000 ml volumetric flask; and 1M of sodium hydroxide solution was prepared by dissolving 40 g of NaOH pellets in 1000 ml of distilled water. The PKO was commercially obtained from Ibadan, Nigeria (Fig. 1). The palm kernel nuts were cold-pressed to extract the oil. Fourier-transform infrared spectroscopy (FTIR) was used to characterize the oil.

Fig. 1: Picture showing some palm kernel nuts from which the oil was extracted

Glass beakers of 250 ml capacity containing 1M HCl solution and 1M NaOH solutions were labeled accordingly. Test samples (prepared mild steel samples) were immersed in the solutions for 49 days; then taken out of the media and weighed. Corrosion rate was determined by weight loss over the given time period. The weight loss value was obtained as the difference between the initial and final weights; hence the corrosion rate (CR) was calculated using Equation (1):

$$CR= \left(\frac{86.7\,W}{DAT}\right) \qquad (1)$$

Where: W is the weight loss in grams, D is the density in (g/cm^3), A is the area in cm^2 and T is the time in hours

The percentage inhibitor efficiency (% IE) was calculated using Equation 2:

$$\%\ IE= 1\text{-}\left(\frac{R2}{R1}\right)\ x\ 100\% \qquad (2)$$

Where: R_1 is uninhibited corrosion rate (mm/yr) and R_2 is inhibited corrosion rate (mm/yr)

The surface coverage was calculated using Equation 3:

$$\theta= 1\text{-}\left(\frac{W2}{W1}\right) \qquad (3)$$

Where: W_1 and W_2 are the weight loss of the mild steel substrate with and without specific concentration of palm kernel oil respectively and θ is the amount of palm kernel oil adsorbed on the surface of the steel.

Results and Discussion

The characterized composition of the mild steel sample is presented in Table 1. The FTIR result in Fig. 2 shows the peak of the carbon double bond functional group in examined palm kernel oil at 1744.40 cm^{-1} indicated the existence of a carbonyl functional group(C=O). Notably, there are two major functional groups present in the triglycerol molecule of oil: the carbonyl group and the carbon-carbon double bond (C=C) (El-Etre, 2008). The presence of a thin layer that covered the mild steel coupon surfaces is an evidence of the corrosion inhibitor molecules, which helped to reduce the corrosion rates. The corrosion rates of the mild steel in HCl was observed to decrease abruptly with the addition of increasing amounts of the palm kernel oil in both acidic and alkaline media (Tables 2 – 3, Figs. 2 – 6).

Table 1: Average nominal composition (wt. %) of the mild steel material used for the study

Element	C	Mn	Cu	Si	Ni	P	S	Co	Cr	Fe
Wt. %	0.112	0.723	0.021	0.040	0.037	0.024	0.022	0.020	0.015	Balance

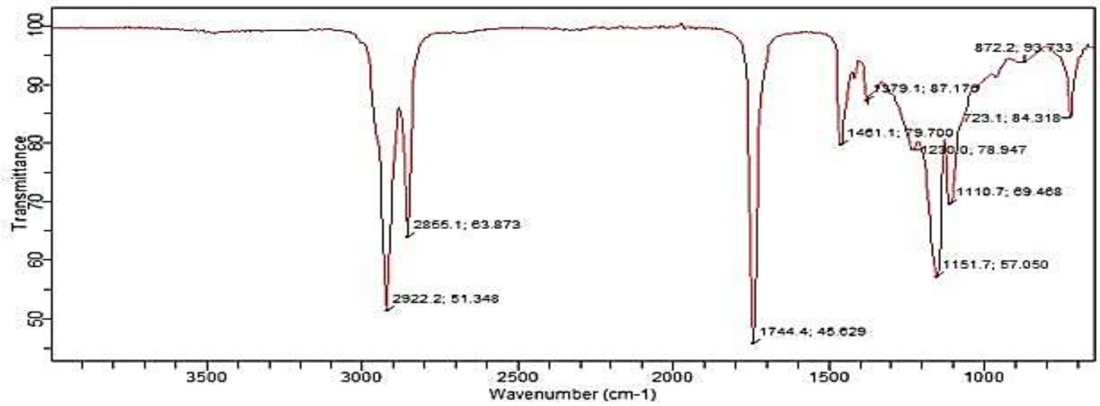

Fig. 2: FTIR result for examined palm kernel oil

Table 2: Weight loss data for mild steel after 1176 hours (49 days) in 1M HCl (in the presence of specific concentrations of palm kernel oil)

Sample	Inhibitor Conc. (ppm)	Weight Loss (g)	Corrosion Rate (mm/yr)	Inhibitor (%)	Inhibitor Eff. (%)
A	0	3.060	0.020	0.00	0.0
B	200	2.312	0.015	0.10	25.0
C	400	0.494	0.00324	0.20	83.8
D	600	2..828	0.012	0.30	40.0
E	800	2.960	0.011	0.40	45.0
F	1000	0.067	4.393×10^{-4}	0.50	97.8
G	1200	2.239	0.015	0.60	25.0

Table 3: Weight loss data for mild steel after 1176 hours (49 days) in 1M NaOH (in the presence of specific concentrations of palm kernel oil)

Sample	Inhibitor Conc. (ppm)	Weight Loss (g)	Corrosion Rate (mm/yr)	Inhibitor (%)	Inhibitor Eff. (%)
A	0	1.412	92.590×10^{-4}	0.00	0.0
B	200	0.038	2.492×10^{-4}	0.10	97.3
C	400	0.055	3.607×10^{-4}	0.20	96.1
D	600	0.065	4.260×10^{-4}	0.30	95.4
E	800	0.031	2.33×10^{-4}	0.40	97.8
F	1000	0.551	36.130×10^{-4}	0.50	61.0
G	1200	0.015	0.984×10^{-4}	0.60	98.8

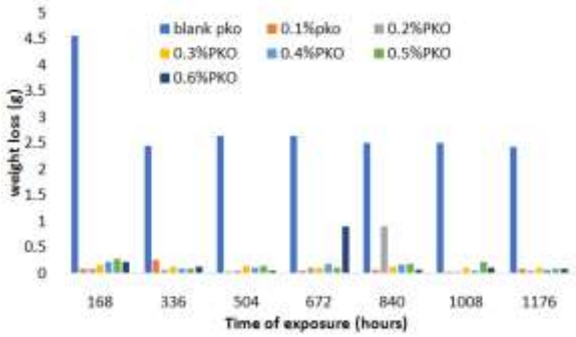

Fig. 3: Variation of weight loss with time of exposure for varied percentage concentrations of palm kernel oil in 1M HCl

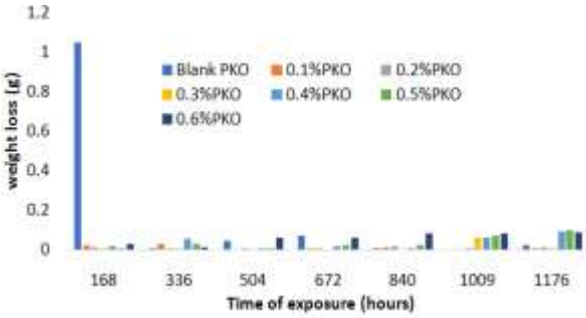

Fig. 4: Variation of weight loss with time of exposure for varied percentage concentrations of palm kernel oil in 1M NaOH

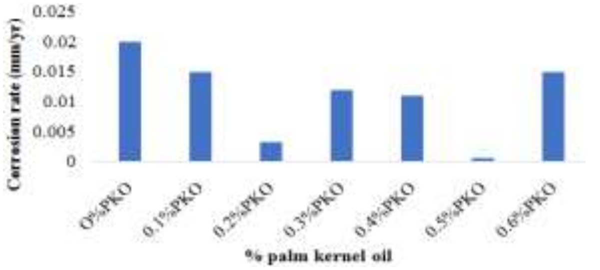

Fig. 5: Effect of % concentrations of palm kernel oil on the corrosion rate of mild steel in 1M HCl

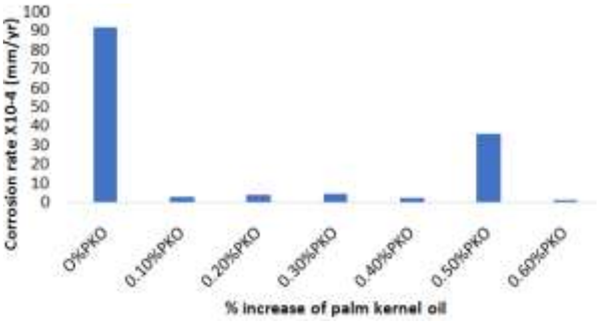

Fig. 6: Effect of % concentration of PKO on the corrosion rate of mild steel in 1M NaOH solution

Figure 5 shows that maximum corrosion inhibition effect (lowest corrosion rate) in the acidic environment was observed at palm kernel oil concentration of 0.50 %, which was equivalent to 1000 ppm. While Fig. 6 reveals that the maximum corrosion inhibition effect (least corrosion rate) was observed at palm kernel oil concentration of 0.60% (equivalent to 1200 ppm).

Table 4: Potentio-dynamic polarization data for mild steel in 1M HCl solution for control sample and optimum percentage concentration of palm kernel oil

Sample	Corrosion Potential, E_{corr} (v)	Current Density I_{corr} (A/cm^2)	Tafel Cathodic Constant (V)	Tafel Anodic Constant (V)	Polarization Resistance, R_p (Ω)	Corrosion Rate (mm/yr)	Inhibitor Efficiency (%)
Control	-0.519	3.8×10^{-4}	0.721	0.666	396.050	2.509×10^{-4}	0
0.5% Conc.	0.465	1.79×10^{-4}	0.137	0.104	1536.310	1.182×10^{-4}	62.89

Table 5: Potentio-dynamic polarization data for mild steel in 1M NaOH solution for control sample and optimum percentage concentration of palm kernel oil

Sample	Corrosion Potential, E_{corr} (v)	Current Density I_{corr} (A/cm^2)	Tafel Cathodic Constant (V)	Tafel Anodic Constant (V)	Polarization Resistance, R_p (Ω)	Corrosion Rate (mm/yr)	Inhibitor Efficiency (%)
Control	-0.460	1.35×10^{-4}	0.817	0.916	1390.780	8.914×10^{-4}	0
0.6% Conc.	-0.587	7.08×10^{-5}	0.237	0.382	898.170	4.675×10^{-4}	94.76

Figures 7 and 8 are produced from Tables 4 and 5, respectively. Results in Tables 4 and 5 indicate that the introduction of the optimum concentrations of palm kernel oil in the acid and base which are 0.5 and 0.6% PKO, respectively, remarkably shifted the corrosion potential (E_{corr}) (Eduok *et al*., 2012). Also, the corrosion current densities of the inhibited sample decreased significantly compared to the control. Observably, the palm kernel oil significantly inhibited the corrosion of mild steel in 1M HCl solution at 62.89% for HCL solution at 1000 ppm and 94.76% in 1M NaOH solution at the same 1000 ppm.

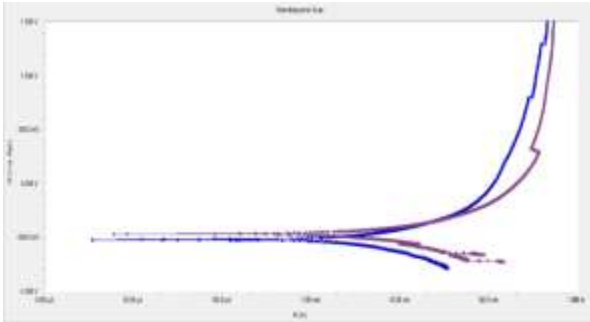

Fig. 7: Potentio-dynamic curves for mild steel in 1M HCL solution for inhibited and uninhibited samples

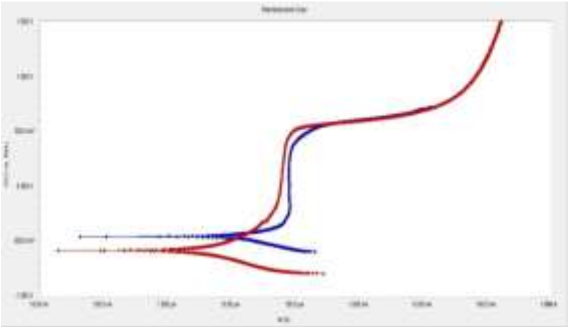

Fig. 8: Potentio-dynamic curves for mild steel in 1M NaOH solution for inhibited and uninhibited samples

The curves obtained in Figs. 7 and 8 show high values of inhibitor efficiency of palm kernel oil concentration at 1000 ppm concentration of palm kernel oil for 1M HCl solution; and 1200 ppm for NaOH solution. The observed trend in the efficiency of inhibition is attributable to the electrochemical reactions that occurred at the metal-solution interface between the charged inhibitor molecules and the anions of the electrolyte; which inhibited the diffusion of anions to the metal surface and at the same time, equally inhibited the diffusion of metallic ions to the solution.

Conclusion

The corrosion inhibition and adsorption characteristic of palm kernel oil (PKO) in 1M HCl and 1M NaOH solutions were investigated. Palm kernel oil was observed to be an effective eco- friendly inhibitor due to the following observations:

1) Palm kernel oil significantly inhibited the corrosion of mild steel in 1M HCl solution with a percentage concentration value of 62.89% at 1000 ppm and 94.76% in 1M NaOH solution at same 1000 ppm.
2) The inhibitor efficiency of PKO was observed to be relatively higher in 1M NaOH solution than in 1M HCl solution.
3) Different concentrations of PKO examined led to decreases in the current density, weight loss and corrosion rate of the mild steel in both acidic an alkaline media.
4) The most effective inhibitor percentage value for corrosion mitigation in HCl was 0.5% PKO, while 0.6% concentration of PKO was most effective in NaOH.

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Conflict of Interest

Authors have declared that there is no conflict of interest reported in this work.

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