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Effect of Tobacco and Kola Tree Extracts on the Corrosion Inhibition of Mild Steel in Acid Chloride

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Corrosion and inhibitor protection of mild steel specimens immersed in acid chloride solution was investigated at ambient temperature by gravimetric and potential monitoring methods. The electrode potential monitoring was performed using a digital voltmeter and a saturated calomel electrode (SCE) as the reference electrode. Extracts of kola plant and tobacco in different concentrations were used as 'green' inhibitors. This paper reports the results obtained from the weight loss method, calculated corrosion rates and the observed electrochemical response from the electrochemical potential monitoring of the mild steel during the experiments. A reduction in the active corrosion reactions behaviour of the mild steel test specimens in the strong acid chloride was obtained with the addition of different concentrations of the plants extracts. There was a drastic reduction in the weight loss and in the corrosion rate of the test samples. This behaviour was attributed to the protective film provided on the steel's surface by the complex chemical constituents of the plants extracts. Effective protection of the mild steel was achieved in nearly all the extracts for the greater part of the experimental period. However, the most effective results were obtained from the tobacco extract and also from the extract of kola leaf.

Keywords: Inhibition, corrosion, mild steel, kola tree, tobacco, acid chloride, protection

1. INTRODUCTION

The use of plant extracts as inhibitors for the corrosion of metals/alloys, has gained very wide interest among researchers in recent time (1-7). In very many cases, the corrosion inhibitive effect of some plants' extracts has been attributed to the presence of tannin in their chemical constituents (7). Also associated with the presence of tannin in the extracts is the bitter taste in the bark and /or leaves of the plants.

Some previous work on extracts of tobacco (genus – *Nicotiana*: family- *Solanaceae*), as an environmental benign corrosion inhibitor (3 - 6, 8) had shown it to be effective in preventing the corrosion of steel and aluminium in saline environments; and in fact, exhibiting a greater corrosion inhibition effect than chromates (4 – 6). Tobacco plants produce ~ 4,000 chemical compounds – including terpenes, alcohols, polyphenols, carboxylic acids, nitrogen – containing compounds (nicotine), and alkaloids (8). These may exhibit electrochemical activity such as corrosion inhibition (3).

Similarly, kola nut tree's chemical composition consists of caffeine (2.0 - 3.5%), theobromine (1.0 – 2.5%), theophylline, phenolics – such as phobaphens, epicachins, D- catechin, tannic acid (tannin), sugar – cellulose, and water (9). As reported in some previous studies (2, 7), tannin is known to possess corrosion inhibitive properties on metals – particularly, mild steel.

With the very complex structural chemical compounds of the extracts of the two plants, a reasonable amount of corrosion inhibition of the mild steel in the very corrosive acid chloride environment used in this work is anticipated; and that could be of great technological and economic benefit.

2. EXPERIMENTAL PROCEDURE

The experimental procedure here follows that of other previous investigations (7). The mild steel specimens were obtained from Metal Samples Inc., Alabama. The nominal composition of the mild steel coupons of grade C1010 was :0.08 C, 0.34 Mn, 0.012 P, 0.008 S, 0.023 Si, 0.053 Al, 0.03 Cu, 0.002 Sn, 0.0024 N, 0.02 Cr and 0.01 Ni, the rest being iron.

The mild steel C1010 samples were cut into dimension of 20 x 40 x 1.5 mm. A 1.5 mm diameter hole was drilled about 5 mm from the top of the 20 mm edge. The test specimens were de-scaled using a wire brush; ground with silicon carbide abrasive papers of 240, 320, 400 and 600 grits; polished to 1 micron, thoroughly cleaned and rinsed in ultrasonic cleaner, and dried and kept in a desiccator for further tests. Selected specimens were, in turn spot welded to a connecting insulated flexible wires and mounted in araldite resin. They were subsequently used for potential measurement.

2.1. Preparation of test media and the plants extracts

The experiment was performed in acid chloride medium (0.5M H_2SO_4 + 5% NaCl of AnalaR grade). The separately extracted juices from the nuts and leaves of the kola tree and from tobacco were used as the corrosion inhibitor, in different concentrations.

The nuts and leaves of the Kola tree (Cola acuminata) and Tobacco (Nicotiana) with each weighing 1Kg were collected. The nuts were pounded and ground to a coarse powder. The leaves were cut, oven dried at 72^{o}C and blended to fine powders using a blending machine. The bark was cut, force-dried in an oven and blended to fine powder as well, while the tobacco (leaves) were first sun-dried for seven days, then blended to fine powder. The samples, each of 100g, were then separately soaked in different 400 ml containers containing ethanol. These were filtered and the solution was left to evaporate at room temperature for three days to concentrate the juice extracts. Each of the plant extract was stored in clean airtight bottles and refrigerated.

2.2. The test media

150 ml of acid chloride solution (0.5 M sulphuric acid and 5% NaCl) was put into nineteen different 250ml beakers. The first beaker contained only the acid chloride test medium; it did not contain any extract solution. 20 ml each of the extracts in different concentrations of 100% (as obtained), 60% and 20% were put separately in the next three beaker containers for each of the extracts.

2.3. Weight loss experiment

Weighed test specimens were totally immersed in each of the test media contained in a 250ml beaker for 21 days. Experiments were performed with acid chloride test medium in which some had the solution extract added. Test specimens were taken out of the test media every 3 days, washed with distilled water, rinsed with methanol, air-dried, and re-weighed. Plots of weight loss versus the exposure time and of calculated corrosion rate versus time of exposure (Figs 1 to 6) were made. All the experiments were performed at ambient temperature(s). The percentage inhibitor efficiency, P, was calculated from relationship:

$$P = 100\ (1\text{-}W_2)/\ (W_1) \qquad (1)$$

-where, W_1 and W_2 are the corrosion rates in the absence and presence, respectively, of a predetermined concentration of inhibitor. The per cent inhibitor efficiency was calculated for all the inhibitors for every 3 days of the experiment, and the results are presented in Table 1.

2.4. Potential measurements

Potential measurements were performed on the mounted specimens in turns by immersing them in each of the acid test media with and without inhibitor (plant extract). The potential was recorded at 3 – day intervals using a digital voltmeter and saturated calomel reference electrode. Plots of variation of potential (vs. SCE) with the exposure time were made, and these are presented in Figs. 7 to 9.

2.5. Micrographs

Some optical micrographs of the test specimen before and after immersion in acid chloride were made in the experiments. The representative ones are presented in Figs. 10 and 11.

3. RESULTS AND DISCUSSION

3.1. Weight loss method

The results obtained for the variation of weight loss and corrosion rate with exposure time respectively for the mild steel test specimens immersed in 0.5M acid chloride with varied concentrations of added kola tree and tobacco extracts are presented in Figs. 1 to 6.

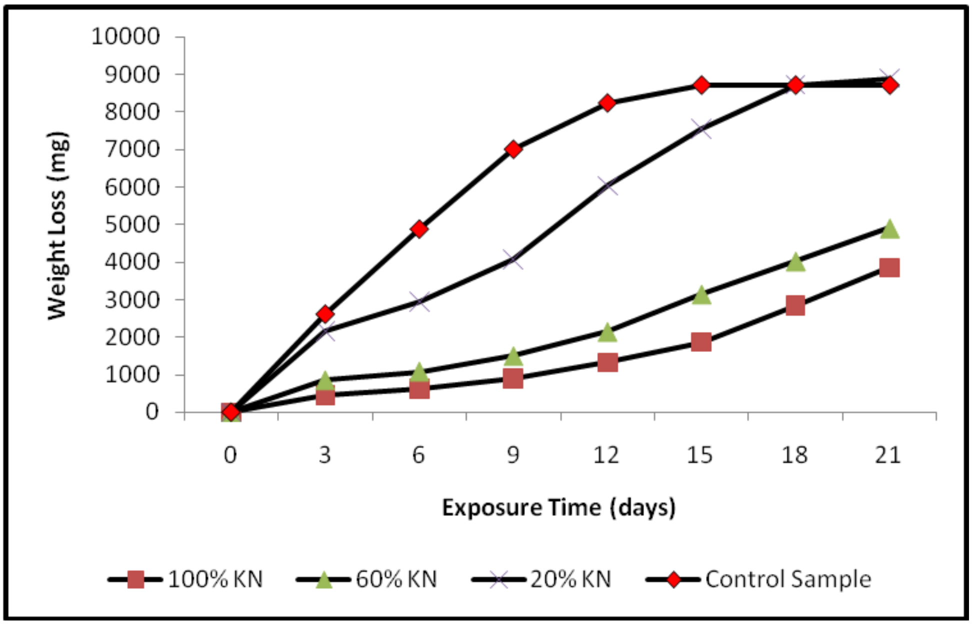


Figure 1: Variation of weight loss with exposure time for the mild steel specimen immersed in acid chloride, with varied percent concentrations of added kola nut extracts. (KN = kola nut extract)

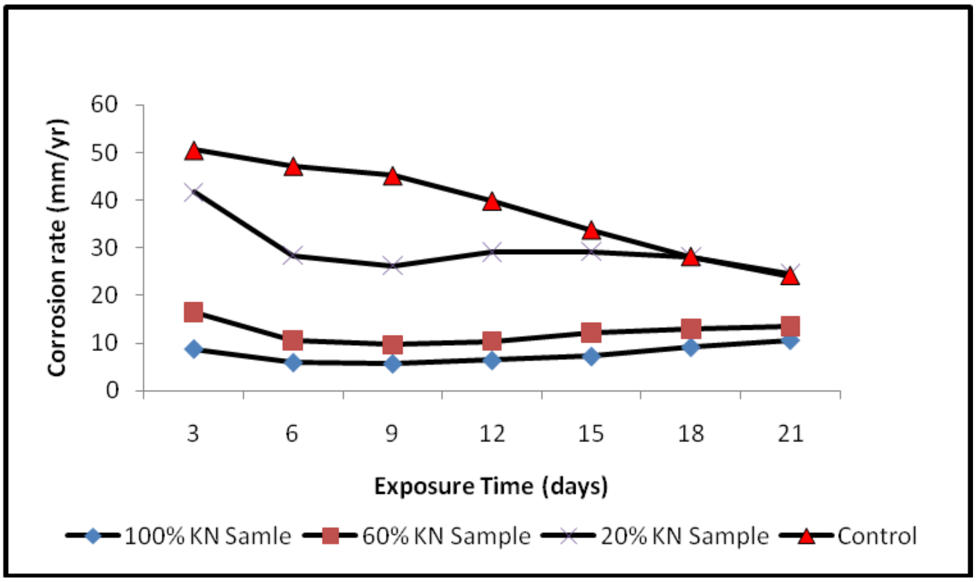


Figure 2: Variation of corrosion rate with exposure time for the mild steel specimen immersed in acid chloride, with varied percent concentrations of added kola nut extracts. (KN = kola nut extract)

The acid test medium with 20% concentration of kola nut extracts addition had the least corrosion inhibition effect of the immersed specimens. The entire specimen was completely consumed by the end of the 21st day achieving a weight loss value of 8.895g. This was not unexpected due to the very strong and aggressive corrosion reactions of the acid chloride. The combination of chloride ions (Cl^-) and sulphate ions ($SO4^=$) caused the intense corrosion of the mild steel test specimen in the environment where the very low concentration of extracts could not provide adequate inhibitive film barrier for corrosion protection. The added 60% concentration of the same extract gave a better corrosion inhibition performance, achieving just 4.912g weight loss value at the end of the 21st day of the experiment. The acid test medium with the added 100% concentration of the same extracts recorded the lowest weight loss with a value of 3.849g..

The corresponding corrosion rate vs. the exposure time results in Fig.2 gave a good correlation with the results in Fig.1. The corrosion rate did not increase proportionally with time. This indicates some stifling of corrosion reactions due to the contamination of the acid medium with the corrosion product. The test medium with added 100% concentration of solution extract gave the least corrosion rate, which ranged between 5.74 mm/yr on the 9th to 10.64mm/yr on the 21st day. The test medium with 20% concentration of solution extract addition gave the highest overall corrosion rate.

3.2. Kola (Cola Acuminata) leaf solution extract

Figs.3 and 4 show the results obtained for the variation of weight loss and of corrosion rate with exposure time, respectively, for the steel test specimen immersed in 0.5M acid chloride with varied concentrations of added kola leaf solution extract.

The results obtained follow the same trend as in Figs. 1 and 2. The acid test medium with 20% concentration extract addition presented the highest overall weight loss. The entire specimen was completely consumed by the end of the 21st day achieving a weight loss value of 8.9197g.

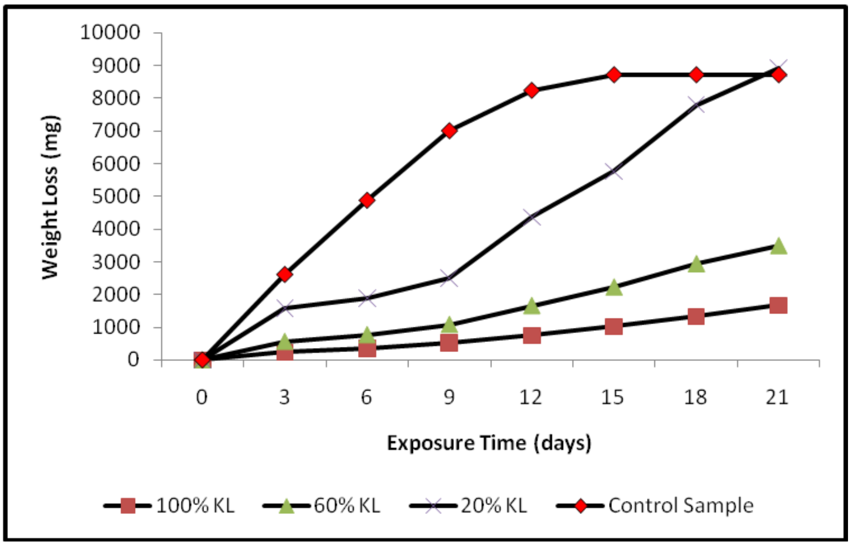


Figure 3: Variation of weight loss with exposure time for the mild steel specimen immersed in acid chloride, with varied percent concentrations of added kola leaf extracts. (KL = kola leaf extract)

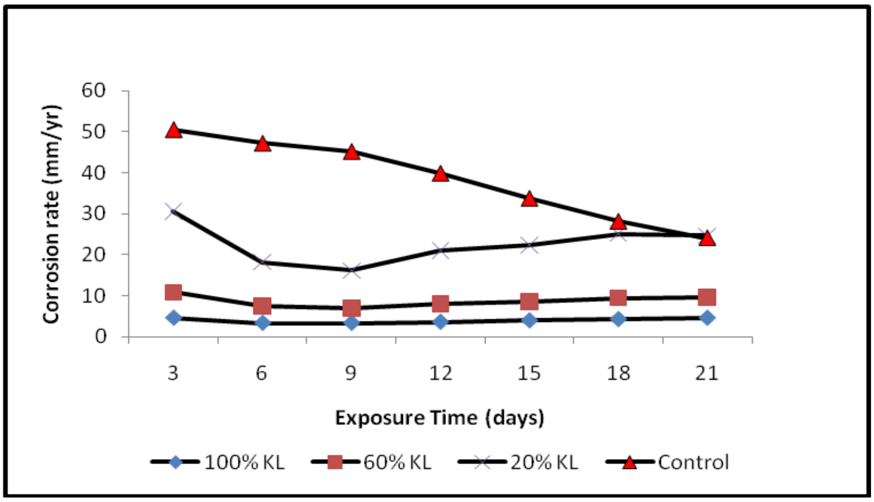


Figure 4: Variation of corrosion rate with exposure time for the mild steel specimen immersed in acid chloride, with varied percent concentrations of added kola leaf extracts. (KL = kola leaf extract)

The weight loss recorded throughout the experimental period for the corrosive acid medium with added 60% concentration of solution extract was far less than that of the 20% concentration of solution extract. At the end of the experiment on the 21st day, the weight loss achieved a value of 3.4836g. The acid test medium with 100% concentration of solution extract addition recorded the lowest weight loss with a value of 1.671g. The kola leaf extract could be considered to be effectively inhibitive relatively for the mild steel in this aggressive test environment.

The corresponding corrosion rate vs. the exposure time results in Fig.4 gave a good correlation with the results in Fig.2. The corrosion rate did not increase proportionally with time. This indicates some stifling of corrosion reactions due to the contamination of the acid medium with the corrosion product. The test medium with added 100% concentration of solution extract gave the least corrosion rate, which ranged between 4.62 mm/yr on the 2nd 4.29 mm/yr on the 21st day. The test medium with 20% concentration of solution extract addition gave the highest corrosion rate.

3.3. Tobacco (Nicotiana) solution extract

The results obtained for the variation of weight loss with exposure time for the mild steel test specimen immersed in 0.5M acid chloride with varied concentration of added tobacco extract (20%, 60%, 100% concentrations) are presented in Fig. 5. The corresponding corrosion rate vs. the exposure time curves are presented in Fig. 6. The acid test medium with 20% concentration extract addition achieved a weight loss value of 2.4991g. The weight loss recorded at the end of the experiment for the corrosive acid medium with added 60% concentration of solution extract was more than that of the 20% concentration of solution extract, with a value of 3.4845g. The acid test medium with 100% concentration of solution extract addition recorded the lowest weight loss with a value of 0.5051g.

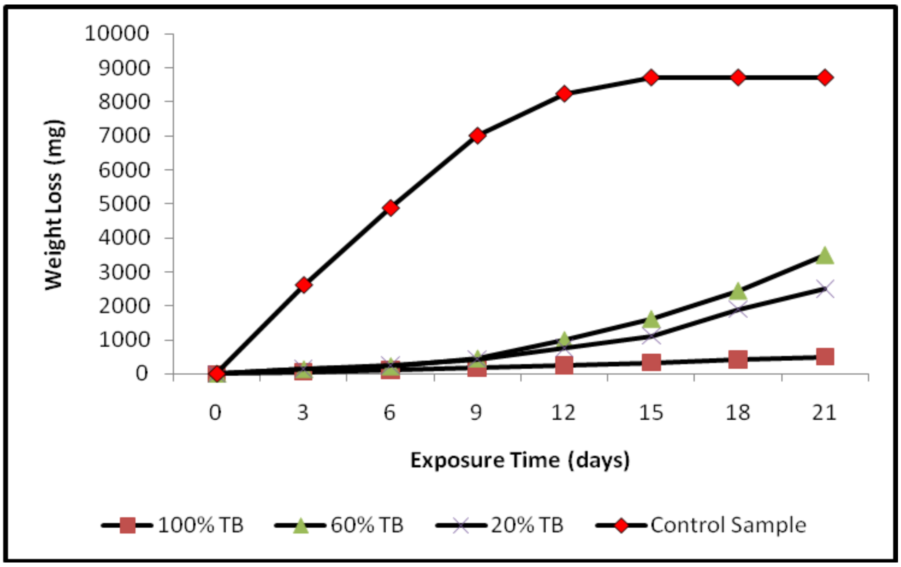


Figure 5: Variation of weight loss with exposure time for mild steel test specimen immersed in acid chloride, with varied per cent concentration of added tobacco leaf extracts. (TB = tobacco leaf)

It is clear from these results that the test medium with 60% concentration of solution extract provided the least inhibition of the three concentrations. This result seemed to be out of trend with those of 20 and 100%. This is difficult to explain. However, it could be due to instrumentation/experimental abnormality. The test with 100% concentration solution extract addition, however, presented the most positive result of inhibiting corrosion throughout the experimental period at ambient temperature.

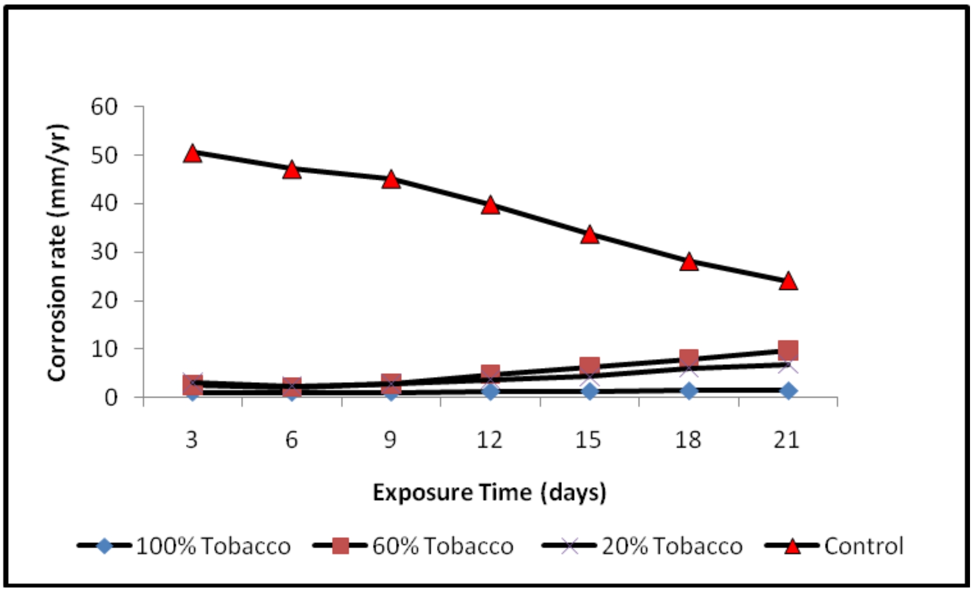


Figure 6: Variation of corrosion rate with exposure time for the mild steel specimen immersed in acid chloride, with varied percent concentrations of added tobacco leaf extracts.

The 100% concentration of solution extract addition provided a concentration of the inhibitor that was very effective for corrosion inhibition.

The corresponding corrosion rate vs. the exposure time results in Fig. 6 gave a good correlation with the results in Fig. 5. The test medium with added 100% concentration of extract gave the least corrosion rate, which ranged between 1.063 mm/yr on the 3rd day to 1.38 mm/yr on the 21st day.

3.4. Potential measurement

Potential readings for the mild steel specimens were taken over a period of 21 days at an interval of 3 days. The curves obtained for the variation of potential (mV) vs. saturated calomel electrode (SCE) with the exposure time are presented in Figs 7 to 9.

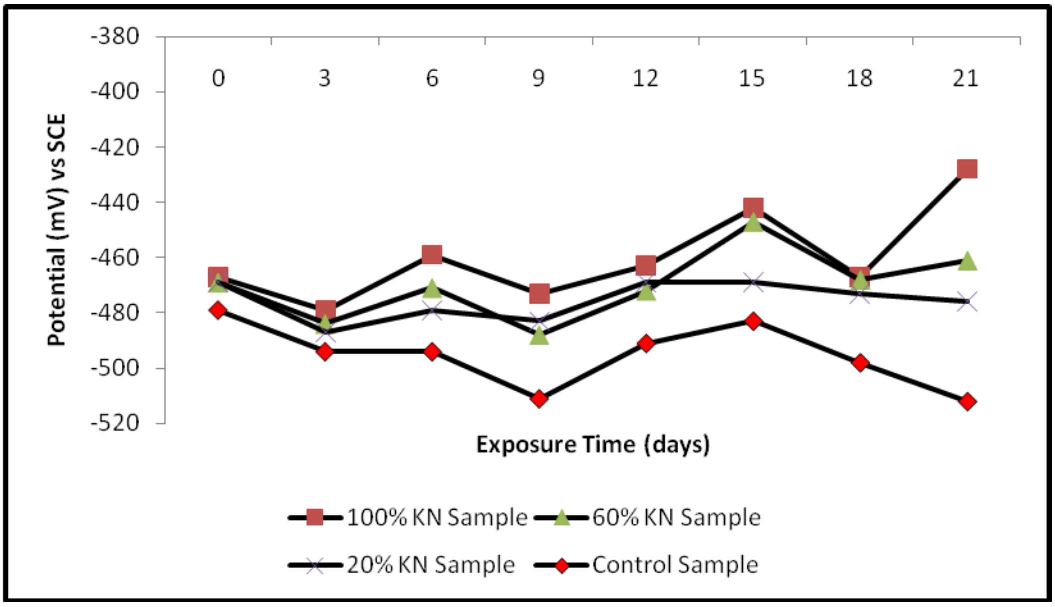


Figure 7: Variation of potential with exposure time for the mild steel specimen immersed in acid chloride, with varied percent concentrations of added kola nut extracts. (KN = kola nut extract)

The specimens were immersed separately, in acid chloride (0.5M H_2SO_4 + 5% NaCl solution) with different extract concentrations of kola nut, kola leaf and tobacco. The test medium without the solution extract addition increased negatively in potential and attained a value of -512mV at the end of the 21 days. The potential curve, Fig. 7, for the solution extract of kola nut extract at 100% concentration gave a very reasonable corrosion inhibition performance with the potential values ranging between – 460 and -420mV from the beginning to the end of the experiment.

In Figs 8, the kola leaf extracts addition at the concentration of 100% performed fairly well in inhibiting the corrosion of mild steel in acid chloride solution used. It recorded, though with fluctuations, potential values that ranged between -468 and -471 mV from the start to the end of the experiment.

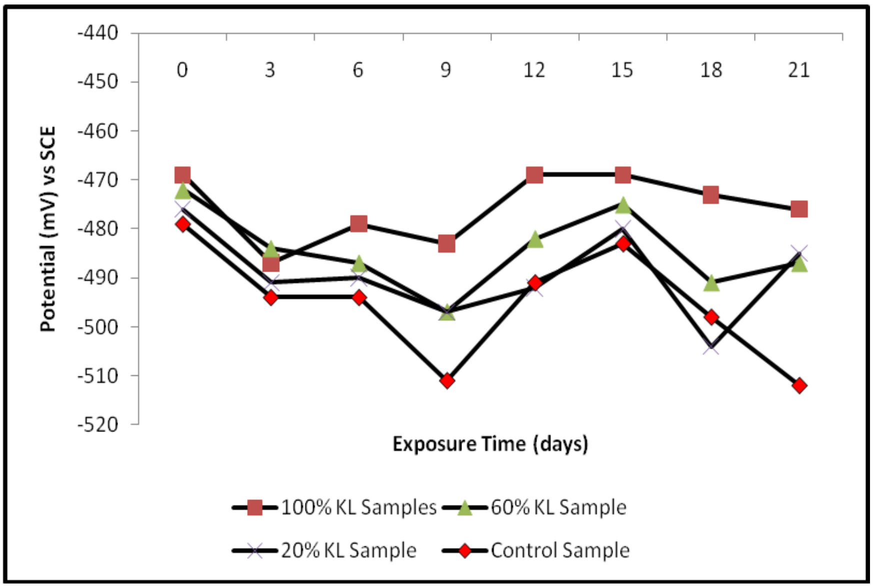


Figure 8: Variation of potential with exposure time for the mild steel specimen immersed in acid chloride, with varied percent concentrations of added kola leaf extracts. (KL = kola leaf extracts)

The added 60% concentration also gave good indication of fair corrosion inhibition performance. There was little improvement at 20% concentration when compared with the test sample without the solution extract addition. The curves for the variation of potential with exposure time in the acid chloride media with addition of tobacco solution extract at different concentrations, Fig. 9, provided similar fluctuation as that of the kola leaf solution extract. The 60% concentration recorded a potential value of -470mV at the end of the experiment.

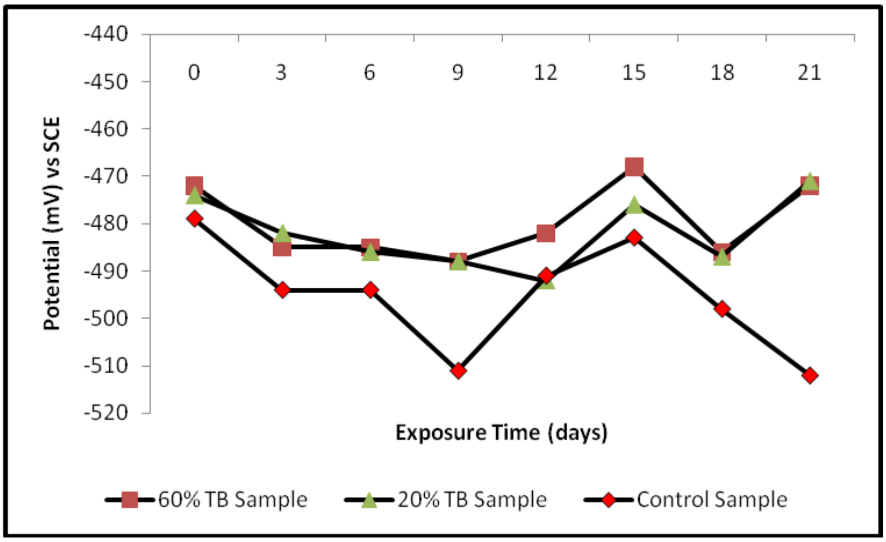
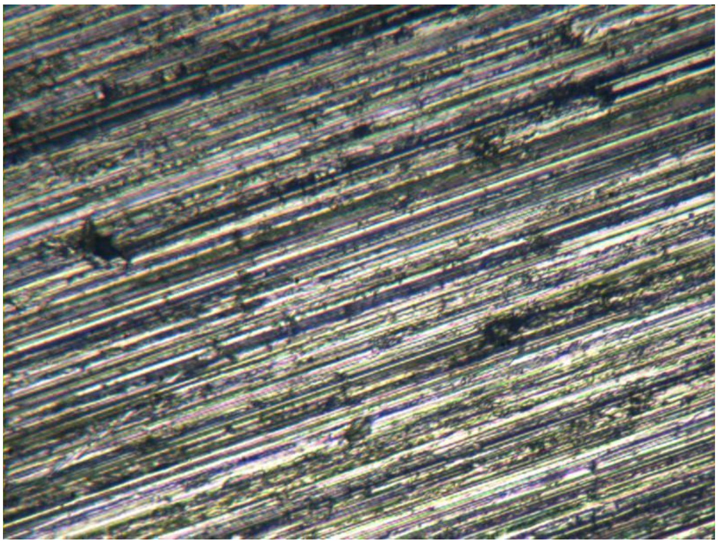


Figure 9: Variation of potential with exposure time for the mild steel specimen immersed in acid chloride, with varied percent concentrations of added tobacco leaf extracts. (TB = Tobacco leaf extracts)

3.5. Photomicrographs

Some of the micrographs made before and after immersion of the test specimens in acid chloride and also with and without the use of the plants' extracts are presented in Figs. 10 to 11. The inhibitive action of tobacco extracts in particular, Fig. 10(b), even at 60% concentration is apparent. There was clear corrosion of the tested specimen, particularly where very low concentration of extract was used, Fig. 11(b). Such was not so much visible in Figs. 10(b) and 11(a) that were 'protected' by the higher concentrations of kola and tobacco extracts.



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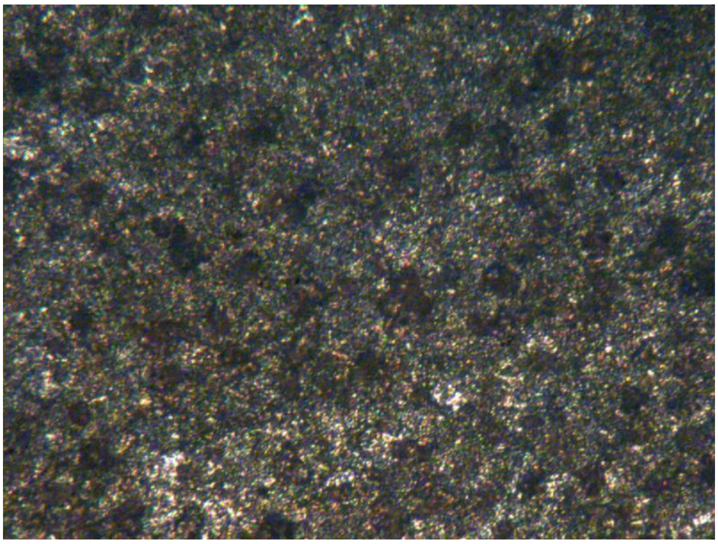
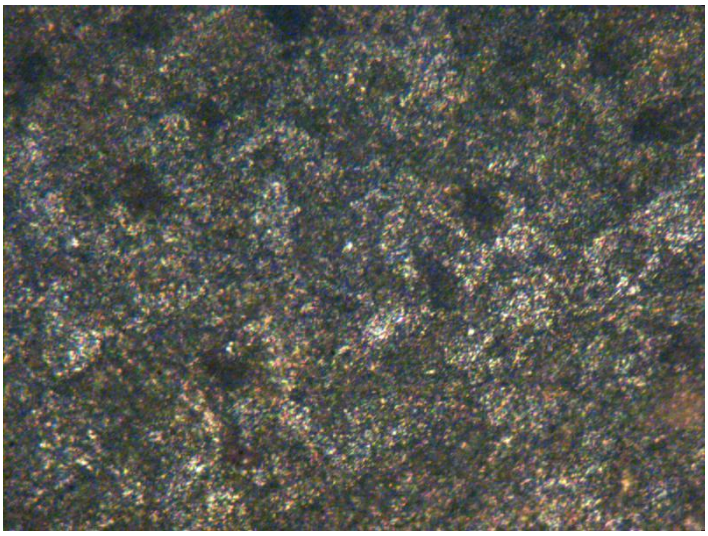


B

Figure 10: Mild steel specimen: (a) Before immersion; (b) After 21 days immersion in acid chloride with 60% concentration of tobacco leaf solution extract.

The overall corrosion and inhibition profile showed that a good corrosion inhibition was achieved with the use of these extracts. The potential values obtained as presented in the curves bear correlation with the results obtained gravimetrically. The potential values obtained for the kola leaf and tobacco extracts alone and the combined kola tree extracts with tobacco's fell within the accepted range for fairly good protection for mild steel with reference to saturated calomel electrode.



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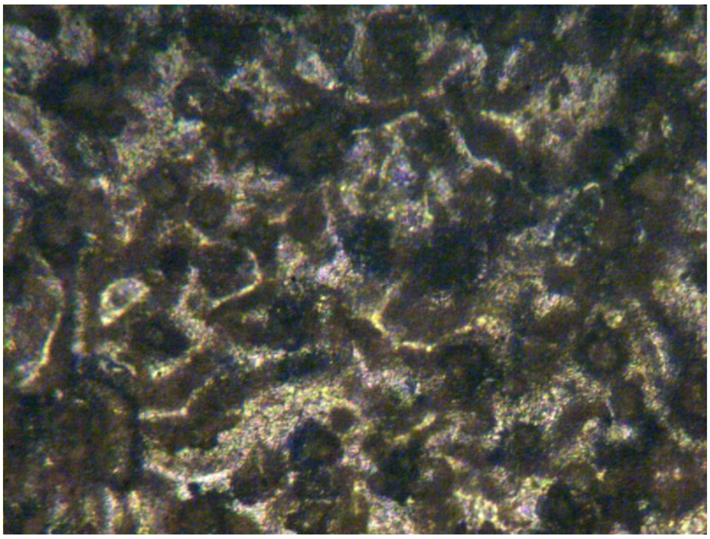

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Figure 11: Mild steel test specimen: (a) after 21- day immersion in 60% kola leaf; (b) after 21- day immersion in 20% concentration of tobacco extracts.

In general, the effective corrosion inhibition performance of kola tree and tobacco extracts could be associated with their complex chemical compounds which include tannin. Also for kola leaf and nut extracts, constituents such as epicatechin, D-catechins, theophylline and theobromine contained in their constituents could be, or act as inhibiting passive film formers on the steel substrate. The formed film would act as a barrier between the steel and corrosive environment interface and thus preventing and/or stifling corrosion reactions. Similarly, the very complex structural compounds and the multifarious constituent composition of tobacco which consists of about 4,000 chemical compounds would have provided a more stable adherent film on the surface of the steel specimen to hinder active corrosion reactions and hence hindering the penetration of the Cl^- and $SO4^=$ ions reacting species through the surface film barrier. The synergistic action/reaction of these compounds on the surface of the steel could hinder the chloride ion species, promote more stable passive film formation on the surface of the steel and hence inhibit and stifle corrosion reactions at the steel / environment interface.

Table 1: Inhibitor Efficiency for mild steel in the various media

Plant Extracts	Concentration of extracts	Corrosion rate (mm/yr)	Inhibitor Efficiency (%)
Kola nut extract	20%	24.5876	-2.01
	60%	13.5778	43.67
	100%	10.6389	55.86
Kola leaf extract	20%	24.6554	-2.29
	60%	9.6292	60.05
	100%	4.6189	80.84
Tobacco extract	20%	6.9079	71.34
	60%	9.6317	60.04
	100%	1.3962	94.21

3.6. Inhibitor Efficiency

The results of the inhibitor efficiency obtained by calculations are presented in Table 1. The best result obtained for mild steel was provided by tobacco extract at 100% concentration with an efficiency of 94.21%. Kola leaf extract alone at 100% concentration addition also gave a very good corrosion inhibition performance with an inhibitor efficiency of 80.84%.

4. CONCLUSION

At the ambient working temperature, the best corrosion inhibition performance for mild steel was obtained using the solution extracts of tobacco at 100% concentration in 0.5M acid chloride media. The use of tobacco for the inhibition of corrosion of mild steel in the acid chloride environment proved very effective with an inhibitor efficiency of 94.21%. Kola leaf alone had a very fairly good performance at 80.84% inhibitor efficiency. The test environment used was a very strong one; I recommend that these extracts should therefore be further considered for research work at optimizing their corrosion inhibition versatility.

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