The effect of mango bark and leaf extract solution additives on the corrosion inhibition of mild steel in dilute sulphuric acid - Part 2

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THE PERFORMANCE of bark and leaf solution extracts of mango (Mangifera Indica) on the corrosion inhibition of mild steel test specimen immersed in 0.2M dilute sulphuric acid at ambient temperature was investigated.

The experimental work was performed by using the weight-loss method and potential measurement technique. Solution extracts were made from the bark and leaves of the tree. The results obtained showed that the bark and the leaves, separately used, will provide very little inhibition. The combination of the two, however, at a concentration of 1.0ml/100ml of 0.2M dilute sulphuric acid, gave very good results that could make it a very useful inhibitor at the ambient temperature.

Part 1 of this paper, published in the March, 2001, issue, described the experimental procedure employed, and gave a discussion of the results from using the mango bark solution extract alone. The effects of the leaf solution, and of the combined solution, are discussed and analysed in Part 2, published below.

Results and discussion (continued)

Mango 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 immersed steel test specimen in 0.2M sulphuric acid with varied concentrations of added mango leaf solution extract.

In Fig.3, the test medium with 0.2ml of leaf solution extract presented the highest overall weight loss, indicating the magnitude of corrosion. A weight loss value of 2.295g was achieved on the 21st day of the experiment. Corrosion in the acid medium with this solution extract addition was far more than the corrosion observed in the test medium without the extract addition. The weight loss value in the latter on the 21st day of the experiment was 1.720g.

Just as for the bark solution extract of the same concentration, the effect of the leaf juice addition was that of corrosion increase or acceleration instead of corrosion inhibition. Up to the 9th day of the experiment, the test medium with 1.0ml of leaf solution extract addition gave lower values of weight loss when compared with 0.50ml of the extract addition. Both are lower in weight loss value than the test in the plain acid (without extract addition). From the 12th day to the 21st day of the experiment, both maintained very close values of weight loss.

In all the tests, there was increase of corrosion (as indicated by the weight-loss values) with the time of the experiment throughout the experimental period. This

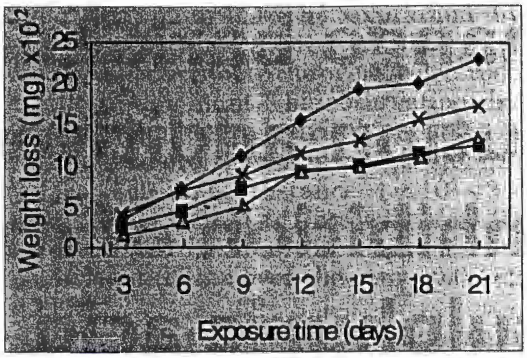

Fig.3. Variation of weight loss with exposure time for the steel specimen immersed in 0.2M H_2SO_4 with varied concentrations of mango leaf juice extract. Key as in Fig.1.

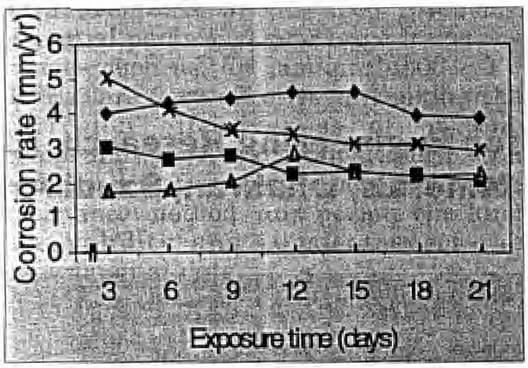

Fig.4. Variation of corrosion rate with exposure time for the steel specimen immersed in 0.2M H_2SO_4 with varied concentrations of mango leaf juice extract. Key as in Fig.1.

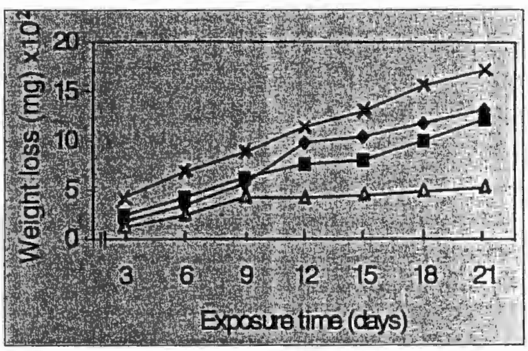

Fig.5. Variation of weight loss with exposure time for the steel specimen immersed in 0.2M H_2SO_4 with varied concentrations of mango bark and leaf juice extract. Key as in Fig.1.

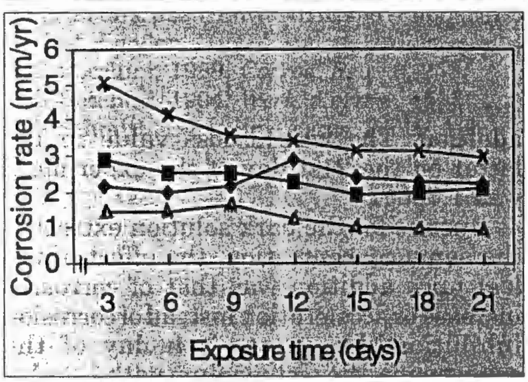

Fig.6. Variation of corrosion rate with exposure time for the steel specimen immersed in 0.2M H_2SO_4 with varied concentrations of mango bark and leaf juice extract. Key as in Fig.1.

phenomenon was an indication of active corrosion reactions throughout.

The corrosion rate in Fig.4 bears a close relationship with the weight loss in Fig.3, from which the data were derived by calculation. The lowest corrosion rates were recorded for the 1.0ml of leaf solution extract addition to the acid test medium and 0.5ml of leaf juice extracts. With 0.2ml of leaf juice addition, the corrosion rate had the highest values from the 6th day to the end of the experiment.

Mango bark and leaf solution extracts

A different trend of corrosion phenomena was recorded in Figs 5 and 6. Fig.5 shows the variation of weight loss with exposure time, while Fig.6 shows the variation of corrosion rate with exposure time for the steel specimen immersed in 0.2M H_2SO_4 with varied concentrations of added mango bark and leaf solution extracts. The weight loss values for the test in the plain dilute sulphuric acid - without juice extract addition - was higher than in the other test media (with varied concentrations of the added extracts), achieving a value of 1.327g on the 21st day of the experiment.

All the different concentrations of the combined solution extracts (bark and leaf) performed effectively in inhibiting the corrosion of the mild steel test specimen, though at different magnitudes. The best overall result here was achieved with the 1.0ml of combined bark and leaf solution extract addition to the acid test medium. The highest weight loss recorded for this test was only 500mg (0.50g) in 21 days of the experiment. The corrosion trend was very slightly that of continuous corrosion reactions, as the curve almost maintained a steady-state trend from the 9th to the 21st day of the experiment. The effective performance of these solution extract combinations here was clearly that of synergism, as the result obtained was far better than that obtained with the use of either the bark extract or the leaf extract alone.

The corrosion rate in Fig.6 showed the same trend for corrosion reactions and inhibition as in Fig.5. The corrosion rate was very low with the 1.0ml of bark and leaf solution extract addition to the acid test medium achieving a value of 0.877mm/yr in the 21 days of the experiment. Here, the corrosion rate decreased with the time of experiment from the 9th day to the end of the experiment on the 21st day. This indicates a very passive corrosion reaction due to the inhibitive effect of the added solution extracts. The corrosion rates for all the other combined extract concentrations, just like the weight loss in Fig.5, were much lower than those recorded for the bark and leaf solution extract used separately.

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The effect of mango bark and leaf extract solution additives

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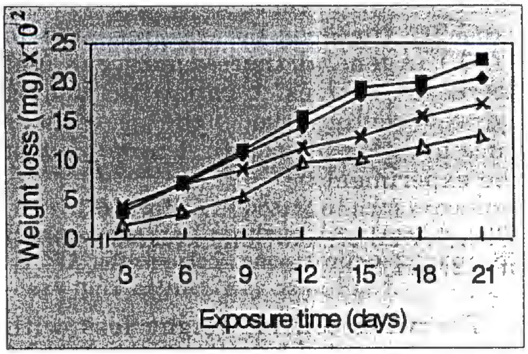

Fig.7. Variation of weight loss with exposure time for the steel specimen immersed in 0.2M H_2SO_4 and 0.2ml/100ml H_2SO_4 addition for the different mango juices.

Key:
◆ = *bark juice extract*
■ = *leaf juice extract*
Δ = *bark and leaf juice extract*
x = *without juice extract*

Comparative performance of the different solution extracts at different concentrations

The results for the comparative corrosion inhibition performance of the different solution extracts, that is, the bark, leaf, and the combination of the two, when added in different concentrations to the acid test environment, are presented in Figs 7 to 12. These consist of weight-loss measurements and their corresponding corrosion rates. These will be discussed in turn.

With 0.2ml extracts/100ml of 0.2M H_2SO_4

Fig.7 clearly shows the corrosion inhibition performance of each of the different extracts, relative to each other and to the test without extract addition. All the tests were performed with the test specimens immersed, separately, in the acid test medium with a fixed amount of 0.2ml of each of the extracts also added separately to the various tests. Clearly, the least weight loss was recorded for the test specimen exposed to the test medium with the addition of 0.2 ml of bark and leaf solution extracts. In the 21 days of the experiments, a weight-loss value of 1.327g was recorded. The combined extracts did not stop corrosion, but reduced it. At this concentration, the bark and the leaf solution extracts were observed to have increased (accelerated) corrosion of the test specimen, as indicated by their weight-loss values, which were more than that of the test without the extract addition. The performance of the bark and leaf together could therefore be associated with the

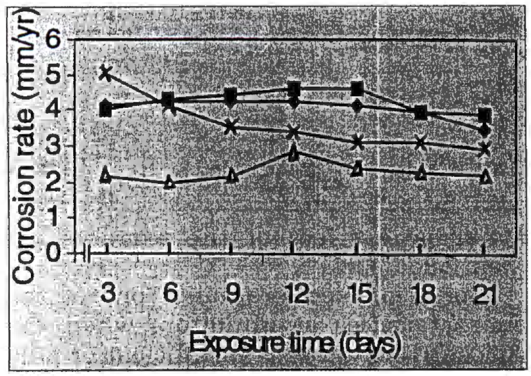

Fig.8. Variation of corrosion rate with exposure time for the steel specimen immersed in 0.2M H_2SO_4 and 0.2ml/100ml H_2SO_4 addition for the different mango juices. Key as in Fig.7.

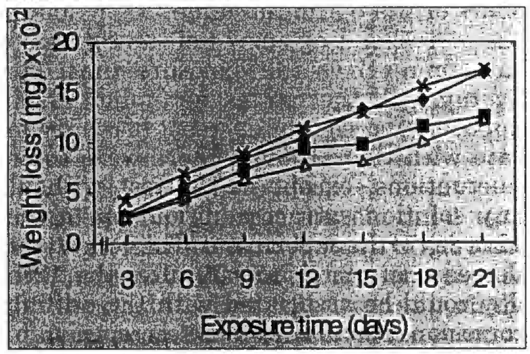

Fig.9. Variation of weight loss with exposure time for the steel specimen immersed in 0.2M H_2SO_4 and 0.5ml/100ml H_2SO_4 addition for the different mango juices. Key as in Fig.7.

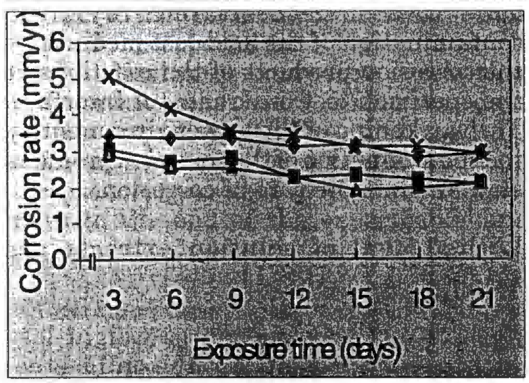

Fig.10. Variation of corrosion rate with exposure time for the steel specimen immersed in 0.2M H_2SO_4 and 0.5ml/100ml H_2SO_4 addition for the different mango juices. Key as in Fig.7.

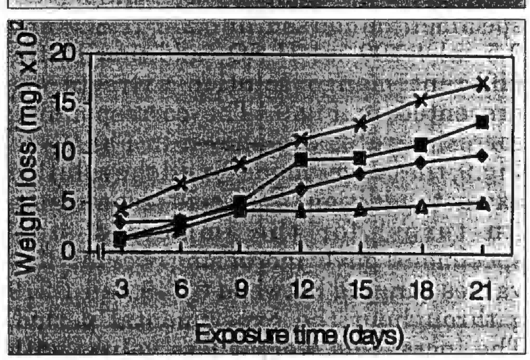

Fig.11. Variation of weight loss with exposure time for the steel specimen immersed in 0.2M H_2SO_4 and 1ml/100ml H_2SO_4 addition for the different mango juices. Key as in Fig.7.

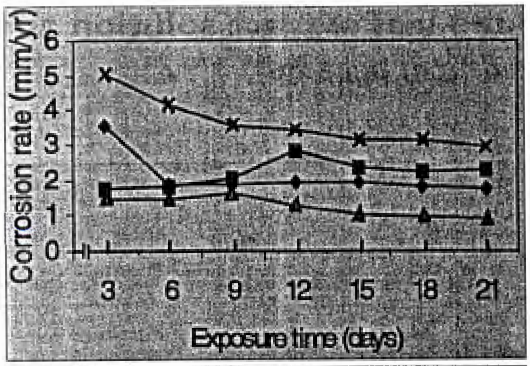

Fig.12. Variation of corrosion rate with exposure time for the steel specimen immersed in 0.2M H_2SO_4 and 1ml/ 100ml H_2SO_4 addition for the different mango juices. Key as in Fig.7.

synergistic effect of the extracts, as mentioned earlier.

Corrosion acceleration is one of the characteristics of inhibitors when the concentration used is insufficient or falls short of the optimum value. Fig.8 shows the corresponding curves of the corrosion rate (mm/yr) vs the exposure time. On average, all the curves here showed no apparent increase or decrease of corrosion rate with time, though there were some fluctuations, except in the test without any solution extract addition, up to the 12th day of the experiment. The very slight decrease in corrosion rate after the 12th day could be associated with the stifling corrosion reaction of the test specimen. This was necessitated by the contamination of the acid test medium by the corrosion products of the reactions at the specimen/test environment interface. The weakening of the test environment by the contamination of the corrosion products slowed down the rate of corrosion.

With 0.50ml of solution extracts per 100ml of 0.2M H_2SO_4

Results of the variation of weight-loss with exposure time for the mild steel specimen immersed in 0.2M H_2SO_4 and 0.5 ml / 100 ml H_2SO_4 addition of the different mango solution extracts are presented in Fig.9. The corresponding corrosion rates are shown in Fig.10. In Fig.9, the curves made for all the solution extracts addition to the acid test medium (in turns) for the immersed steel specimens gave increasing weight loss values ranging between 0.243 and 1.219 g throughout the experimental period. The increasing weight loss values with time of exposure are an indication of continuous active corrosion reactions. However, this was not up to the values recorded for the test without any solution extract addition. It did not stop the corrosion of the test specimen, but it reduced the magnitude of corrosion. At this concentration of 0.5 ml of solution extract / 100 ml of H_2SO_4, the performances of the other extracts - bark and leaf in inhibiting corrosion could not be described as effective. The corresponding corrosion rate versus exposure time curves are presented in Fig.10. In general, there was a very slight decrease in corrosion rate with time. It was very well observed in the test without juice addition for the first nine days of the experiment.

With 1.0 ml of solution extracts / 100ml of 0.2M H_2SO_4

The variation of weight loss with exposure time for the mild steel specimen immersed in 0.2M sulphuric acid and 1.0ml of solution extract per 100ml of H_2SO_4 of different mango extracts is presented in Fig.11. Comparatively, the results obtained here are better than the two described above for the 0.2ml and 0.5ml solution extracts. The highest weight-loss value obtained for the bark and leaf combined solution extracts was 1.007g on the 21st day of the experiment. A significant improvement in corrosion inhibition was achieved when this is compared with the 0.2ml juice extract of 2.058g and with the 0.5ml juice extract with a weight-loss value of 1.70g.

The bark and leaf extracts also performed better when rated with the test medium without any juice addition; and the bark solution extract had a better performance than the leaf extract. A plausible explanation for this observation might be that there was more concentration of the active inhibiting species, assumed to be tannin in the bark juice than in the leaf juice. The better performance of the combined juices from the bark and leaf extracts can once again be associated with synergistic effect of the inhibiting property of the combined extracts.

The curves of the corrosion rate vs the exposure time for the mild steel specimen immersed in 0.2M H_2SO_4 and 1ml of solution extract per 100ml of H_2SO_4 addition of the different mango juices are presented in Fig.12. The curve of the test without extract addition decreases in corrosion rate with time. This phenomenon indicates more contamination of the test environment by the corrosion products, which resulted from the higher magnitude of corrosion. As previously explained, the corrosion product contaminants weakened the test environment and slowed down the rate of corrosion. This curve has the highest

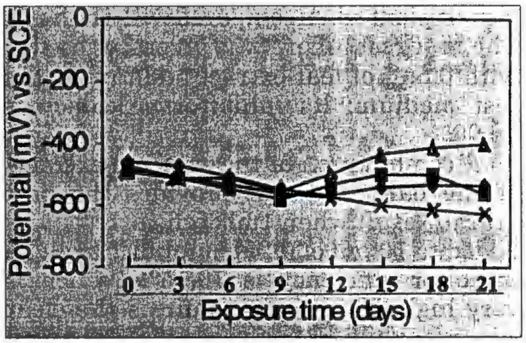

Fig.13. Variation of potential with exposure time for the steel specimen immersed in 0.2M H_2SO_4 with varied concentrations of mango bark juice extract. Key as in Fig.1.

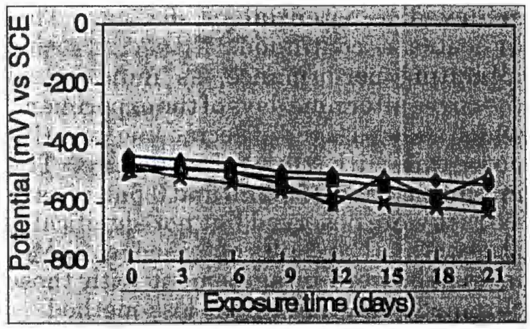

Fig.14. Variation of potential with exposure time for the steel specimen immersed in 0.2M H_2SO_4 with varied concentrations of mango leaf juice extract. Key as in Fig.1.

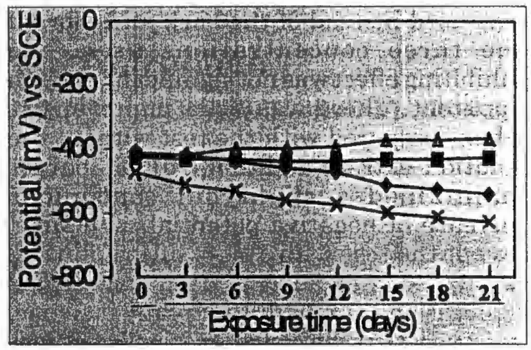

Fig.15. Variation of potential with exposure time for the steel specimen immersed in 0.2M H_2SO_4 with varied concentrations of mango bark and leaf juice extract. Key as in Fig.1.

corrosion rate, ranging between 5.034mm/yr on the third day and 2.938mm/yr on the 21st day (end) of the experiment.

The test involving the combined solution extracts of the bark and leaf had the lowest corrosion rate, at 1.437mm/yr on the third day and 0.877mm/yr on the 21st day of the experiment. This observation indicates an apparent inhibiting property by synergism of the tested material in that particular acid.

Potential measurements

Presented in Figs 12 to 15 are the curves of the variation of potential (mV) vs saturated calomel electrode (SCE) with the exposure time for mild steel specimen immersed in 0.2M sulphuric acid with different concentrations of mango bark, leaf, and bark and leaf solution extracts respectively. The results obtained with the bark juice extract, shown in Fig.13, did not present a distinct corrosion reaction for the mild steel test specimens for all the different concentrations of added solution extract to the test medium in the first nine days of the experiment.

A distinct corrosion reaction phenomenon was observed after nine days of the experiment. The test medium without the solution extract addition increased negatively in potential after nine days to the end of the experiment, and

Juice extract	Concentration of juice extract (mils/100mils of 0.2M H_2SO_4)	Corrosion rate (mm/yr)	Inhibitor efficiency (%)
Bark	0.2	3.508	-19.40
Bark	0.5	2.911	0.919
Bark	1.0	1.720	39.07
Leaf	0.2	3.916	-33.29
Leaf	0.5	2.089	28.90
Leaf	1.0	2.297	21.82
Bark and leaf	0.2	2.222	24.37
Bark and leaf	0.5	2.080	29.20
Bark and leaf	1.0	0.877	70.15

achieved a potential of -627mV. This indicates a continuous active corrosion inhibiting performance, as indicated in the curve after nine days of the experiment, which shows a trend of decreasing negative potential with time of exposure. The inhibiting effect of 0.2ml and 0.5ml of bark extract were observed but not significant. In general, the results obtained, as shown in Fig.13, were in agreement with those obtained from the weight-loss method.

In Fig.14, where the leaf juice extract was used instead of the bark juice, for all the three concentrations used, the inhibiting effect was not significant, though apparent. There was little improvement when compared with the test without the solution extract addition. All the curves maintained a slight but continuous increase of negative potential with time, except the test with 1ml of juice addition, which recorded a fluctuating curve. This fluctuation is difficult to explain; it seems, however, that the concentration of the leaf solution extract used was not strong enough to maintain a stable passivity.

The curves of the variation of potential with exposure time for the mild steel test specimen immersed in 0.2M H_2SO_4 with different concentrations of the combined bark and leaf extracts, Fig.15, the present results that are distinctly clear. Here, the test without solution extract addition maintained distinct active corrosion reactions throughout the experimental period as earlier indicated. A clear inhibiting effect was observed in the test with 1.0ml of extract addition. This was closely followed by the 0.5ml of the combined juice addition. These two concentrations were effective throughout the whole experimental period, but with the former having a better performance. The test with 0.2ml of combined extract addition became susceptible to corrosion after three days of the experiment. The effect of the combined solution extract addition on the corrosion inhibition of the test metal is very much noticeable here, which is in agreement with the weight-loss method. Again, a very good result was obtained by the synergistic effect of the combination of the extracts.

Inhibitor efficiency

The results of the inhibitor efficiency obtained by calculations are presented in Table 1. The best result obtained for the bark juice was with the 1.0ml of extract addition, which has an inhibitor efficiency of 39.07%. The juice from the leaf appears less efficient when compared with the bark. The best result here was given by the test with 0.5ml of leaf extract addition to the test medium: its inhibitor efficiency is 28.90%.

A combination of the solution extracts of the bark and leaf provides the best overall result when 1ml of the extract was added to 100ml of 0.2M sulphuric acid; its inhibitor efficiency is 70.15%, which is very high. This again confirms the clear synergy exhibited by the combined solution extracts as an effective corrosion inhibitor. The results in Table 1 are in agreement with all the results previously discussed in this paper.

Mechanistically, the combined extracts from the mango bark and leaves behave as an inhibitor by attaching the polar molecules to the mild steel test specimen's surface in the acid test environment. The inhibitive constituent in the mango juices is believed to be tannin.

Conclusion

At the ambient working temperature, the juice solution extracts of mango from the bark and leaves can separately (i.e., when used alone) inhibit corrosion of mild steel in 0.2M sulphuric acid at (low) concentrations of 1ml for the bark and 0.5ml for the leaf in 100ml of the acid. The effective inhibition performance at these two concentrations is, however, below average, as shown by the results and the calculated inhibitor efficiency.

The best corrosion inhibition performance was obtained by the use of a combination of the two solution extracts, that is, the bark and leaf together, at a concentration of 1.0ml of the combined extracts/100ml of sulphuric acid. The percentage inhibitor efficiency obtained for this is 70.15. This combined solution extract was also effective for corrosion inhibition at the lower concentration of 0.2 and 0.5ml/100ml of H_2SO_4, but the magnitude of inhibitive efficiency was below average.

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References

1. G.H.Booth and S.J.Mercer, 1964. *Corros. Sci. J.*, 4, 425.
2. C.A.Loto and M.A.Adesomo, 1988. *African J. of Sci. and Techn.* (AJST), series A, 7.1, p.9.
3. C.A.Loto and M.A.Matanmi, 1989. *Br. Corros. J.*, **24**, 1, 36.
4. C.A.Loto, 1990. *Corrosion Prevention & Control*, **37**, 5, p.131.
5. C.A.Loto, 1994. *Discovery and Innovation J.*, **6**, 1, p.42.
6. G.H.Booth, 1960. *J.Appl. Bacterial.*, **23**, 125.
7. C.A.Loto, 1993. *Discovery and Innovation J.*, **5**, 3, p.249.
8. C.A.Loto, 1998. *Nig Corros. J.*, **1**, 9, pp 19-28.
9. Britannica Micropaedia, 1997. **7**, p. 773, (18th Edition).
10. J.E.L.Walker, 1975. The biology of plant phenolics. Edward Arnold, publisher, p. 36.
11. Britannica Micropaedia, 1997. **11**, p.546, (18th Edition).

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2. A.L.Bayer, 1939. US Patent 2,147,395.
3. H.Lamprey, 1939. US Patent 2,147,409.
4. M.A.Stranick, 1982. Proc. 4th Int. Conf., p123.
5. M.A.Stranick, 1984. *Corrosion*, **40**, p296.
6. T.R.Weber, M.A.Stranick, and M.S.Vukasovich, 1986. *Corrosion*, **42**, p542.
7. Y.J.Qian and S.Turgoose, 1987. *Brit. Corr. J.*, **22**, pp268-271.
8. S.Rajendran, B.V.Apparao, and N.Palaniswamy, 1998. *J. Electrochem. Soc.*, 47, p43.
9. S.Rajendran, B.V.Apparao, and N.Palaniswamy, 1998. *Anti.Corrosion Methods Mater.*, **45**, p397.
10. U.R.Evans, 1936. *Trans. Electrochem. Soc.*, **69**, p213.
11. U.R.Evans and E.Chyzewski, 1939. *Trans. Electrochem. Soc.*, **76**, p215.
12. H.B.Jonassen, 1958. *Corrosion*, **15**, p375.
13. F.A.Cotton, G.Wilkinson, C.Murrillo, and M.Bochmann, 1999. Advanced inorganic chemistry. John Wiley & Sons, New York, p604.
14. V.S.Shastri, 1999. Corrosion inhibitors - principles and applications. John Wiley & Sons, UK, p715.
15. A.Nyquist, A.Richard, and K.O.Ronald, 1971. Infra-red spectra of inorganic compounds. Academic Press, USA, pp 3 and 335.
16. J.Golden and J.E.O.Mayne, 1978. *Brit. Corr. J.*, **13**, p45.
17. C.M.Mustafa, S.M.Shahinoor, and D.Islam, 1997. *Brit. Corr. J.*, **32**, p133.
18. N.Kazuo, 1978. Infra-red and Raman spectra of inoganic and coordination compounds. John Wiley & Sons Inc., p297.