

Summary and Conclusion

The salient features of the present study entitled “**Corrosion Inhibition and Adsorption Potential of Biomass Extracts-Leaves and Flowers of *Heliconia rostrata* and *Canna indica* on Corrosion of Mild Steel/Aluminium in 1 M HCl**” are summarized below:

- Preliminary phytochemical screening tests reveal the presence of phytochemical constituents in the plant extracts.
- Various techniques namely FT-IR, UV-Vis and GC-MS were used for the Characterisation of the investigated plant inhibitors. The results confirmed the presence of N and O atoms which are the pre requisites for the extracts to act as corrosion inhibitors.
- The investigated inhibitors, performed in an effective manner to minimize the corrosion of **MS/AA1100** in HCl medium.
- The Potentiodynamic polarisation curves reflect that the anodic (b_a) and cathodic (b_c) curves shifted towards low corrosion current density values in the presence of the inhibitors. This supports the fact that the inhibitors were able to suppress both the anodic dissolution and cathodic hydrogen evolution.
- Considerable reduction in the I_{corr} values shows the inhibitive nature of studied inhibitors. The IE was found to increase with increase in concentration of the inhibitors.
- The impedance spectra obtained for **MS** in the presence and absence of the inhibitors at room temperature exhibited single capacitance loop indicating that the corrosion is controlled by charge transfer process. The diameter of the semi circle increased with increase in concentration of the studied inhibitors and the shape of the semi circle was similar in the presence of the inhibitors implying that there was no change in the mechanism of MS dissolution in the presence of the investigated inhibitors.
- In the case of **AA1100**, at room temperature, a capacitance loop at high frequency range and an inductive loop at the low frequency range were observed. The appearance of the inductive loop might be due to the relaxation of adsorbed species $H_{\text{ads}}^+ / Cl^- / O^{2-}$ ions /adsorbed phytoconstituents or redissolution of the oxide layer

surface or Al dissolution. Nevertheless the shape of the capacitive and inductive loops increase with increasing concentration of the inhibitors, thereby indicating the inhibitive properties of the inhibitors.

- The data obtained by impedance spectroscopy was analysed by proposing an equivalent circuit .Excellent fit for the results were obtained. The results reflected the increase of charge transfer resistance (R_{ct}) with increase in concentration of inhibitor. This might be due to the adsorption of the Phytochemical constituents onto the MS/AA 1100 surface. The value of C_{dl} decreased with inhibitor concentration which might be due to decreased value of dielectric constant and/or due to the adsorbed film formed at acid/metal interface.
- Analysis of the results of the mass loss measurements of **MS / AA 1100** infer that the inhibition efficiencies increased with increasing concentration of the inhibitors. Immersion studies reveal that as the time of immersion increases from ½ hr to 12h/6h the inhibition efficiency increases. After 12 h/6h there is a slight decline in the inhibition efficiency at 24 hrs. The decrease in inhibition efficiency at longer immersion time might be due to the desorption of the protective layer formed in the presence of the inhibitors on the metal surface. All the investigated inhibitors could furnish an efficiency of 90-98% at a maximum concentration of 0.7%.
- The Kinetic and mechanistic aspects of corrosion may be gained by studying the effect of temperature on the corrosion of **MS/AA1100** in the presence and absence of the inhibitors. It can be noted that the maximum I.E. obtained was in the range of 90- 94 percentage (313 K/333 K) in 1 M HCl and then a slight decrease was observed from 343K to 353K it was found to be at 80-85 percentage for the investigated inhibitors for MS. In the case of AA1100, the IE decreased with increase of temperature. This may be due to the adsorption of the inhibitor upto a particular temperature and then desorption of the inhibitor at higher temperature.
- Analysis of the mass loss data obtained from the investigated inhibitors using **SPSS** statistical package reflected the applicability of Langmuir adsorption isotherm.
- In the present investigation E_a values were found to be greater than those calculated in the absence of the inhibitors. The higher values of E_a in the inhibited solution can be correlated with the increased thickness of the double layer, which enhances the activation energy of the corrosion process.
- The positive value of the enthalpy of activation (ΔH_a°) reflected the endothermic nature of the metal dissolution process. The positive values of entropy of activation (ΔS_a°) in the presence of the inhibitors in 1 M HCl imply that the inhibitor molecules,

freely moving in the bulk solution are adsorbed in an orderly fashion onto the metal surface.

- The negative values of $\Delta G^{\circ}_{\text{ads}}$ demonstrate that the inhibitors are spontaneously adsorbed onto the MS/AA 1100 surface. In the present study, the calculated values of $\Delta G^{\circ}_{\text{ads}}$ obtained for the investigated systems range between -12 kJ/mole to -18 kJ/mole indicating that the adsorption of the inhibitors on the surface of the metal was through physical means of adsorption but chemisorption cannot be excluded.
- The negative sign of $\Delta H^{\circ}_{\text{ads}}$ indicated that the adsorption of the inhibitors on metal surface was exothermic in nature. The positive sign of $\Delta S^{\circ}_{\text{ads}}$ arose from substitutional process, which can be attributed to the increase in the solvent entropy and more positive water desorption entropy. This lead to an increase in disorder due to the fact that more water molecules can be desorbed from the metal surface by one inhibitor molecule. The negative values of entropy ($\Delta S^{\circ}_{\text{ads}}$) in the presence of the inhibitors in 1 M HCl implied the inhibitor molecules, freely moving in the bulk solution are adsorbed in an orderly fashion onto the metal surface.
- Surface morphology of the metal indicated that the surface of the metal was found to be rough after subjecting the **MS/AA 1100** specimens in the acid medium and this reflected the aggressive nature of the inhibitors under study. The inhibited surface was found to be smooth and this revealed that the surface of the metal was protected by the adsorption of the active constituents of the plant species. The EDX patterns corroborated the results of SEM analysis.
- FT IR spectrum implied the presence of O and N atom containing functional groups, that act as a prerequisite for a molecule to function as a corrosion inhibitor.
- UV spectral data confirmed the formation of protective layer of metal-inhibitor complex on the metal surface.
- The morphology of the specimens using XRD and 3D Optical Profiler further confirmed the inhibitive nature of the inhibitors under study

Conclusion

- Tafel studies, linear polarization and impedance studies revealed that the inhibitors act as mixed type inhibitors
- The investigated inhibitors act as potential benign inhibitors for the corrosion of **MS/AA1100** in 1 M HCl.
- The inhibition efficiency increased with increase in concentration of the inhibitors.

- The adsorption of the inhibitors was found to obey Langmuir and Temkin adsorption isotherms.
- Thermodynamic parameters confirmed strong interaction of the inhibitor with the MS/AA 1100 steel surface
- Quantum chemical studies ,confirmed ,the probable adsorption centers through which the metal atom is linked to form metal – inhibitor complex
- FTIR and UV-Visible spectroscopic studies confirmed the formation of metal-inhibitor complex.
- SEM –EDAX, XRD, 3 D Laser profilometry studies ascertained the inhibitive nature of the inhibitors under study.
- The biomass extracts investigated are attractive and desirable features for next generation corrosion inhibitors.

Scope for further study

- Isolation of specific phytochemicals from the crude plant extracts to exactly pin point the components responsible for corrosion inhibition.
- The effectiveness of the investigated inhibitors on various concentration of HCl may be studied.
- Further utilisation of Impedance spectroscopy to analyse the influence of exposure time on the corrosion of MS and AA1100 and the pitting potential statistics.
- Corrosion inhibition studies may also be carried out using the investigated inhibitors in phosphoric acid medium, nitric acid medium, in alkaline and neutral medium.
- The investigated inhibitors may be tested as corrosion inhibitor in other metals – carbon steel, copper, brass and zinc etc.,
- Gasometric techniques, cyclic voltametry studies may also be conducted using the investigated inhibitors.
- Theoretical analysis involving molecular simulation may be carried out.
- Apply mathematical equations to find out the theoretical investigation of corrosion inhibition studies.
- The investigated inhibitors may be tried as corrosion inhibitors in electroplating industries.