CHAPTER - V

SUMMARY AND CONCLUSIONS

The relevant observations and the important findings of the present investigation on corrosion inhibition of aluminium in alkaline medium using leaves extracts are summarized and the main conclusions drawn from the study are given below:

i. All the examined leaves extracts inhibit the corrosion rate of aluminium in 1M NaOH at all concentrations under study. The corrosion rate is found to depend on the concentration of the inhibitor.

ii. Results obtained for %IE of all the leaves extracts revealed that CALE has a greater effect in retarding the dissolution of aluminium in 1M NaOH medium. Inhibitive action of the leaves extracts follows the order: Coleus aromaticus > Solanum nigrum > Moringa oleifera > Vitex negundo > Mentha piperita

iii. Weight loss of Al specimen and corrosion rate of aluminium decreased whereas IE and degree of surface coverage increased with increase in the concentrations of the inhibitors. All the tested leaves extracts are found to exhibit inhibitive action over the studied concentration range.

iv. The corrosion rate of aluminium in 1M NaOH increased when the immersion time is increased from 1 h to 4 h both in the absence and presence of inhibitors. Desorption of the adsorbed layer occurred with increasing immersion time and the inhibitive action of the leaves extract is reduced. All the tested inhibitors showed similar behaviour for the increasing immersion time of the aluminium specimen in free and inhibited sodium hydroxide solution.

v. The corrosion rate of aluminium increases with increase in temperature when tested over a temperature range of 303-333 K. All the tested inhibitors show a decrease in the (%) IE with increasing temperature. Desorption is aided by increasing temperature and physisorption mechanism is shown by all the inhibitors.
vi. With CALE, SNLE, MOLE, VNLE and MPL, the activation energies in the presence of inhibitors are greater compared to that of free alkali.

vii. The higher values of $E_a$ obtained for the leaves extracts revealed the raised energy barrier for aluminium dissolution process and physisorption mechanism is proposed.

viii. Positive values of enthalpy of activation obtained for all the inhibitors reflect the endothermic nature of the aluminium dissolution reaction.

ix. Large and negative values of entropy of activation for all the studied inhibitors indicated the increase in orderliness that occurred during the aluminium–inhibitor activated complex formation.

x. The adsorption characteristics tested by using different adsorption isotherms described that the leaves extracts adopt Langmuir adsorption isotherm. It is obvious that adsorbing species of all the leaves extracts occupy typical adsorption site at the metal/solution interface.

xi. The values of $K_{ads}$ are low and decreasing with increase in temperature. This suggests the fact that adsorption strength decreases at higher temperatures and this is due to physical adsorption of inhibitor molecules on aluminium metal surface.

xii. The large negative values of $\Delta G^0_{ads}$ obtained for all the leaves extracts indicate the spontaneity of the adsorption process.

xiii. Corrosion of aluminium in alkaline solution is accompanied with hydrogen gas evolution. Volume of $H_2$ gas evolved varies linearly with time.

xiv. The volume-time plots obtained for the inhibitor solutions fall well below that of free alkali. Corrosion rate of aluminium determined by monitoring the $H_2$ gas evolution rate provided information concerning the chemical nature of the surface film in situ at the metal corroding interface.

xv. Both the cathodic and anodic curves recorded by Tafel extrapolation method show lower current density in the presence of leaves extracts than those obtained in the inhibitor free alkali solution.

xvi. The cathodic and anodic Tafel slope values obtained in the presence of inhibitor solutions are lower than that of blank solution.

xvii. All tested leaves extracts exhibit inhibition effect on both cathodic and
anodic reactions of the corrosion process. Hence the leaves extracts are classified as mixed type inhibitors with CALE and SNLE showing predominant anodic action.

xviii. All the inhibitors shift the corrosion potential of Al in 1M NaOH in the positive direction probably suggesting that the marked effect of these leaves extracts on the local anode. Since the shift in corrosion potential with all studied leaves extracts at all concentrations is less than $\pm$ 80 mV the studied inhibitors are considered as mixed type inhibitors.

xix. Electrochemical impedance spectroscopy provided mechanistic and kinetic analysis of the processes that occur at metal solution interface during the corrosion of Al in 1M sodium hydroxide solution.

xx. The Nyquist plots obtained are semicircles both in the absence and presence of leaves extracts. The diameter of the semicircle increases with increase in inhibitor concentration. The general shape of the curves is very much similar for all samples. The shape is maintained throughout the whole concentration range indicating that almost no change in the corrosion mechanism occurred due to inhibitor addition.

xxi. An opposite trend for polarisation resistance and double layer capacitance is noted for the increasing concentration of the inhibitors. Increase in polarisation resistance with corresponding decrease in the thickness of the double layer is noted for all studied leaves extracts. These observations indicated that corrosion inhibition occurred by geometric blocking of the Al surface.

xxii. FT-IR spectrum recorded for the dry powder of all the leaves extracts when compared with the spectrum of the inhibitor film formed on the Al metal surface revealed the interaction of the aluminium metal surface and inhibitor molecules.

xxiii. The presence of different functional groups in the leaves extracts are ascertained by shifting of bands to different wavelengths, absence of original bands and presence of new bands in the FT-IR spectra recorded for the scraped films of CALE, SNLE, MOLE, VNLE and MPLF formed on Al metal surface.
xxiv. The optical micrographs recorded in the presence of CALE, SNLE, MOLE, VNLE and MPLLE proved the existence of adsorption film formed by the inhibitors. The adsorbed film on the metal surface acted as a coating and prevented the entry of aggressive anions of the corrosive medium into the metal/solution interface.

xxv. The corrosion resistance of aluminium in the presence of tested inhibitors is attributed to the different organic compounds that are present in the various phytochemicals of the leaves extracts.

The objective of the present research work in corrosion science oriented towards the development of green corrosion inhibitors with good inhibition efficiencies without causing any environmental pollution has been achieved.

Further work

A Natural inhibitors can be applied in coating formulations. Efficient inhibitors may be tested as good alternatives for organic substances by comparing the structures of the inhibitors with that of polymeric coatings.

A Application of natural inhibitors for fighting crevice, intergranular, and stress corrosion processes may be investigated.

A New techniques can be employed for the interpretation of corrosion and inhibition mechanisms. Surface analysis can be made with the help of new contributions that will provide better understanding of inhibition processes.
Appendix-1
List of publications

Solanum trilobatum as a green inhibitor for aluminium corrosion in alkaline medium
S. Geetha, S. Lakshmi, K. Bharathi, Journal of Chemical and Pharmaceutical

Corrosion Inhibition of Aluminium in Alkaline Medium using Vitex negundo
Leaves Extract, S. Geetha, S. Lakshmi, K. Bharathi, International journal of

Inhibitive effect of Morinda citrifolia L. leaves extract on aluminium corrosion in
HCl medium, K. Bharathi, S. Lakshmi, S. Geetha, Journal of Chemical and

Calotropis Procera as potential corrosion inhibitor for commercial Aluminium in
HCl medium K. Bharathi, S. Lakshmi, S. Geetha, International journal of Advance
Scientific and industrial Research, 3 (3) (2013) 248-256.
Appendix - II

Paper presented in national seminar
Vigna mungo as a green inhibitor for aluminium corrosion in alkaline medium
S.Geetha , K. Bharathi, S.Lakshmi, organised by Regional Science Congress at Kongunadu Arts and Science College (Autonomous), Coimbatore, India held on December 15-16, 2012.

International conference attended
Attended the ‘International conference on Coordination and Organometallic Chemistry’ organised by Department of Chemistry, at Bharathiar University, Coimbatore, India, held on 19-20 March 2009.

National Workshop/ conference attended
National workshop on ‘Advanced techniques for corrosion studies’ organised by Department of chemistry, Alagappa University, Karaikudi, Tamil Nadu, India held on January 5-7, 2006.

National workshop on ‘Chemistry in the Techno-world’ organised by Department of Chemistry, Vivekanandha college of Arts and Sciences for women, Tiruchengodu, Tamil Nadu, India held on February 11, 2006.

National Conference on ‘Advances in Surface and Interface Analysis’ organised by Department of chemistry, Periyar University, Salem, Tamil Nadu, India held on December 13-14, 2007.

National workshop on ‘Research methodology for teacher scholars’ organised by Academic staff college, Pondicherry University, Puducherry, India held on September 24-25, 2009.

National conference on ‘Recent Advances in Textile and Electrochemical Sciences’ organised by Department of Industrial Chemistry, Alagappa University, Karaikudi, Tamil Nadu, India held on December 4-5, 2009.
National workshop on ‘Electroanalytical Techniques’ organised by Department of Industrial Chemistry, Alagappa University, Karaikudi, Tamil Nadu, India and Sinsil International Mumbai in cooperation with CH Instruments, Inc., USA during 11.10.2010- 13.10.2010. at Alagappa University, Karaikudi, Tamil Nadu, India.

National Science Academies’ lecture workshop on ‘Modern trends in chemistry’ organised by Department of chemistry, Periyar University, Salem, Tamil Nadu, India held on 13.0.12 and 14.08.12