Chapter 5
Results and Discussion

5.1. Weight loss method

In recent year, the natural products have been used as the best inhibitor in the field of corrosion. The weight loss process is ***undoubtedly the most commonly used method of primary calculation***. For the purpose of present study, mild steel samples were used in 1N HCl solution containing acid in the absence and presence of plant extract for 24 hours with various concentrations. Weight loss experiments were performed in triplicate and the results showed good reproducibility, the average values were taken and used in subsequent calculation.

The corrosion parameters obtained in the weight loss method (both in aqueous and alcoholic extract) were listed in ***Tables 10 - 15***. From the table, it was cleared that the corrosion rate was decreased with increasing concentration of the inhibitor and the inhibition efficiency increased with increasing the concentration of both extracts.

The observation of maximum surface coverage clearly suggests that the heteroatoms such as nitrogen and oxygen present in the inhibitor molecules can be able to bind with the metal ions by ***very strong adsorption and protect the metal ions*** from corrosive environment.

The corrosion process in acid medium can be attributed to the presence of OH^-, O_2, H_2 and Cl^-. Generally, the inhibitor molecules suppress the metal dissolution by forming a protecting film adsorbed on the metal surface and separate it from the corrosion medium. In such solution the surface film is insoluble but may be locally attacked by aggressive anions, particularly chlorides. Accordingly, chloride ions are first adsorbed on the metal surface in 1N HCl medium and consequently the metal surface becomes negatively charged. The corrosion suppressing ability of the inhibitor molecules (adsorption of inhibitor liked to presence of heteroatom and long carbon chain as well as pi bond or aromatic ring) originates from the tendency to form either strong or weak chemical bond with Fe atom using the lone pair of electron in the oxygen and pi electron or aromatic ring in their molecules structure.

Very good inhibition efficiency (IE %) was obtained at 20 v/v and this concentration was chosen to be the optimum concentration of the inhibitor. No significant increase in inhibition efficiency was to be above 20 v/v. The comparative inhibition effect was investigated at the optimum concentration (20 v/v) of the both extract. From the ***Table 10,*** it is evident that the aqueous extract of optimum

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concentration for ***Madhuca Longifolia leaves*** was found to be 20 v/v with maximum inhibition efficiency of ***97.14 %, barks*** at 20 v/v with maximum inhibition efficiency of ***82.98 %, fruits*** at 20 v/v with maximum inhibition efficiency of ***92.25 %, seeds peels*** at 20 v/v with maximum inhibition efficiency of ***91.04 %***. Also, for the alcoholic extract the highest inhibition efficiency was found to be ***92.95 %*** for ***leaves, barks at 85.16 %, fruits at 91.02 %, and seed peels at 90.34 %*** for a period of one day of immersion time.

From the ***Table 11,*** it is noted that the aqueous extract of optimum concentration for ***Gloriosa Superba Linn leaves*** was found to be 20 v/v with maximum inhibition efficiency of ***94.49 %, 92.83 % for stems, 88.90 % for flowers, and 92.92 % for tubers respectively.*** For alcoholic extract of the same plants, the highest inhibition efficiency of ***94.12 %*** was achieved for ***leaves, 92.13 % for stems, 90.18 % for flowers and at 90.35 % for tubers*** respectively**.**

As can be seen from the ***Table 12*** that the IE values increased for mild steel immersed in the aqueous extract of ***Pithecellobium dulce plants.*** The maximum IE values at optimum concentration (20 v/v) was found to be ***90.92 %*** for ***seeds, 89.07 %*** for ***leaves, 88.41 %*** for ***fruits*** and ***84.70 %*** for ***barks*** extracts respectively. On the other hand**,** for the alcoholic extract the obtained IE values are (***90.13, 84.46, 86.93 and 89.32 %***) for ***seeds, leaves, fruits and barks respectively.***

From the ***Table 13,*** it is evident that the highest inhibition efficiency was obtained for aqueous extract of ***Alangium lamarckii leaves*** at ***99.79 %, barks at 99.00 %, fruits at 99.42 % and seeds at 99.64 %.*** On the other hand**,** for the alcoholic extract the obtained IE values are (***98.50, 97.34, 97.13 and 99.22 %***) for ***leaves, barks fruits and seeds respectively.***

From the ***Table 14,*** it is evident that the maximum inhibition efficiencies that were obtained for the aqeous extract of ***Holoptelea integrifolia 84.39 % for leaves, 89.34 % for bark, 88.97 % for flowers and 88.04 % for seeds respectively.*** For alcoholic extract of the same plants, the highest inhibition efficiency of ***87.63 %*** was achieved for ***leaves, 86.36 % for barks, 88.23 % for flowers, and 89.21 % for seeds respectively.***

Table 15 showed that the aqueous extract of ***Schrebera swietenioides plants*** was found to be optimum IE for ***leaves*** at ***88.80 %, barks at 91.93 %, fruits at 90.74 % and seeds at 92.84 %.*** On the other hand**,** for the alcoholic extract, the IE obtained were for ***seeds*** at ***80.77 %, leaves at 89.25 %, fruits at 89.17 % and barks at 87.28 %.*** This result indicated that the plant extract could act as effective corrosion inhibitor for mild steel in 1N HCl. On comparison, optimum inhibition efficiency was found in ***Alangium lamarckii leaves*** extracts with ***99.79*** % at ***15 v/v*** concentration. All the ***aqueous and alcoholic extract shows excellent*** inhibitory character.

Table 10 Percentage of inhibition efficiency (IE %) and corrosion rate (CR) at different concentration of inhibitor in 1N HCl medium

Aqueous extracts of ML plants					**Alcoholic extracts of ML plants**			
Parts of (ML) plant	**Conc. of the extract (v/v)**	**Weight loss (g)**	**Corrosion rate (mmpy)**	**IE (%)**	**Conc. of the extract (v/v)**	**Weight loss (g)**	**Corrosion rate (mmpy)**	**IE (%)**
Madhuca Longifolia **leaves**	Blank	0.1203	37.218	-	Blank	0.1147	44.008	-
	5	0.1018	4.188	40.23	5	0.0111	6.628	55.45
	10	0.0204	2.486	57.55	10	0.0717	3.326	62.05
	15	0.0093	1.454	73.20	15	0.213	1.234	75.22
	20	0.0048	0.070	97.14	20	0.0115	0.070	92.95
Madhuca Longifolia **barks**	Blank	0.1445	20.830	-	Blank	0.0395	19.030	-
	5	0.0842	5.117	42.07	5	0.0246	4.077	57.91
	10	0.0549	2.018	58.18	10	0.0140	2.918	64.48
	15	0.0093	1.106	79.76	15	0.0099	1.303	78.29
	20	0.0061	0.981	82.98	20	0.0085	1.031	85.16
Madhuca Longifolia **fruits**	Blank	0.0850	19.110	-	Blank	0.0350	10.610	-
	5	0.0587	8.181	48.18	5	0.0274	3.817	60.12
	10	0.0354	4.136	63.13	10	0.0212	2.716	75.82
	15	0.0109	2.119	71.39	15	0.0105	1.216	82.17
	20	0.0047	1.045	92.25	20	0.0090	0.042	91.02
Madhuca Longifolia **seeds peel**	Blank	0.0849	10.281	-	Blank	0.0594	14.071	-
	5	0.0380	6.063	49.41	5	0.0189	`4.206	65.19
	10	0.0223	2.970	62.04	10	0.0103	2.140	72.04
	15	0.0144	1.450	78.76	15	0.0070	1.185	86.39
	20	0.0116	0.978	91.04	20	0.0055	0.980	90.34

Table 11 Percentage of corrosion rate (CR) and inhibition efficiency (IE %) at different concentration of inhibitor in 1N HCl medium

Aqueous extract of GSL plants					**Alcoholic extract of GSL plants**			
Parts of plant	**Conc. of the extract (v/v)**	**Weight loss (g)**	**Corrosion rate (mmpy)**	**IE (%)**	**Conc. of the extract (v/v)**	**Weight loss (g)**	**Corrosion rate (mmpy)**	**IE (%)**
Gloriosa Superba Linn **leaves**	Blank	0.2104	16.258	-	Blank	0.1101	34.258	-
	5	0.0211	2.938	72.60	5	0.0104	16.638	64.12
	10	0.0117	1.786	82.12	10	0.0097	10.986	79.64
	15	0.0103	1.354	89.31	15	0.0053	8.754	84.02
	20	0.0045	0.570	94.49	20	0.0037	1.870	94.12
Gloriosa Superba Linn **Stems**	Blank	0.0947	25.830	-	Blank	0.0622	25.830	-
	5	0.0238	4.801	70.18	5	0.0446	14.817	61.54
	10	0.0193	2.310	78.79	10	0.0241	8.318	69.02
	15	0.0096	1.017	82.14	15	0.0198	2.116	84.52
	20	0.0078	2.031	92.83	20	0.0103	1.031	92.13
Gloriosa Superba Linn **flowers**	Blank	0.0350	20.310	-	Blank	0.0480	20.310	-
	5	0.0283	9.817	59.13	5	0.0303	10.817	66.66
	10	0.0102	6.912	72.73	10	0.0202	8.116	69.45
	15	0.0099	3.108	80.18	15	0.0105	6.290	72.22
	20	0.0094	1.321	88.90	20	0.0080	4.321	90.18

(continued)

Table 11 (continued)

Gloriosa Superba Linn **tubers**	Blank	0.0641	29.281	-	Blank	0.0845	17.281	-
	5	0.0384	5.166	51.02	5	0.0680	14.166	31.15
	10	0.0303	3.170	71.70	10	0.0389	10.170	52.17
	15	0.0182	2.965	78.19	15	0.0236	6.965	73.48
	20	0.0100	1.385	92.92	20	0.120	4.900	90.35

Table 12 Data from Weight Loss Method for MS corroding in 1 N HCl solutions at various concentrations of PD leaves extract

Aqueous extract of PD plants					Alcoholic extract of PD plants		
Parts of (PD) plant	**Conc. of the extract (v/v)**	**Weigh t loss (g)**	**Corrosion rate (mmpy)**	**Inhibition efficiency (%)**	**Weight loss (g)**	**Corrosion rate (mmpy)**	**Inhibition efficiency (%)**
Pithecellobium Dulce **leaves**	Blank	0.3362	38.345	-	0.2409	26.258	-
	5	0.3041	25.030	16.06	0.2024	14.634	55.04
	10	0.2413	10.986	39.84	0.1837	10.206	61.69
	15	0.1243	7.754	71.35	0.0914	4.561	81.08
	20	0.0910	4.870	89.07	0.0880	3.708	84.46
Pithecellobium Dulce **barks**	Blank	0.2440	25.083	-	0.0632	12.830	-
	5	0.1064	14.817	40.86	0.0442	9.874	38.73
	10	0.0940	9.842	58.31	0.0361	6.318	69.37
	15	0.0824	6.137	69.02	0.0204	4.116	79.49
	20	0.0335	3.031	84.70	0.0135	3.030	89.32
Pithecellobium Dulce **fruits**	Blank	0.0650	20.310	-	0.0750	18.310	-
	5	0.0303	9.818	60.83	0.0512	5.817	70.78
	10	0.0202	4.210	78.94	0.0301	4.116	79.37
	15	0.0150	2.416	84.58	0.0245	3.290	84.75
	20	0.0111	2.221	88.41	0.0140	2.321	86.93
Pithecellobium Dulce **seeds**	Blank	0.0532	17.428	-	0.0446	22.312	-
	5	0.0402	11.106	48.58	0.0280	12.166	52.49
	10	0.0310	9.070	58.53	0.0169	9.170	79.66
	15	0.0120	6.113	78.97	0.0133	6.965	88.14
	20	0.090	2.583	90.92	0.0110	3.385	90.13

Table 13 Percentage of inhibition efficiency (IE %) and corrosion rate (CR) at different concentration of inhibitor in 1N HCl medium

Aqueous extract of AL plants					Alcoholic extracts of AL plants			
Parts of plant	**Conc. of the extract (v/v)**	**Weight loss (g)**	**Corrosion rate (mmpy)**	**Inhibition efficiency (%)**	**Conc. of the extract (v/v)**	**Weight loss (g)**	**Corrosion rate (mmpy)**	**Inhibition efficiency (%)**
Alangium Lamarckiii **leaves**	Blank	0.1107	14.258	-	Blank	0.4328	13.104	-
	5	0.0011	0.638	79.00	5	0.0102	4.986	80.58
	10	0.0017	0.986	84.58	10	0.0087	3.875	86.80
	15	0.0013	0.754	99.79	15	0.0067	2.754	89.04
	20	0.0015	0.870	87.80	20	0.0020	0.638	98.50
Alangium Lamarckiii **barks**	Blank	0.0445	25.830	-	Blank	0.0966	16.817	-
	5	0.0046	4.817	86.21	5	0.0047	2.358	88.18
	10	0.0040	2.318	89.88	10	0.0035	2.011	93.72
	15	0.0001	0.116	99.00	15	0.0022	0.106	97.34
	20	0.0035	2.031	92.13	20	0.0883	7.817	65.20
Alangium Lamarckiii **fruits**	Blank	0.0350	20.310	-	Blank	0.0140	22.321	-
	5	0.0083	4.817	76.28	5	0.0025	5.290	86.37
	10	0.0002	0.116	99.42	10	0.0012	0.934	97.13
	15	0.0005	0.290	98.57	15	0.0070	6.965	81.01
	20	0.0040	2.321	88.99	20	0.0020	3.385	90.24

Table 13 (continued)

Alangium Lamarckiii **seeds**	Blank	0.0849	19.281	-	Blank	0.0196	11.992	-
	5	0.0089	5.166	89.51	5	0.0010	0.170	98.31
	10	0.0003	0.170	99.64	10	0.0003	0.120	99.22
	15	0.0120	6.965	88.86	15	0.0134	3.203	87.65
	20	0.0110	6.385	87.04	20	0.0109	3.480	87.04

Table 14 Percentage of inhibition efficiency (IE %) and corrosion rate (CR) at different concentration of inhibitor in 1N HCl medium

Aqueous extract of HI plants					**Alcoholic extract of HI plants**		
Parts of (HI) plant	**Conc. of the extract (v/v)**	**Weight loss (g)**	**Corrosion rate (mmpy)**	**Inhibition efficiency (%)**	**Weight loss (g)**	**Corrosion rate (mmpy)**	**Inhibition efficiency (%)**
Holoptelea Integrifolia **leaves**	Blank	0.1003	34.105	-	0.3734	30.100	-
	5	0.0401	15.938	54.10	0.1100	10.389	70.15
	10	0.0297	10.546	77.58	0.0820	9.654	79.03
	15	0.0143	6.354	84.39	0.0643	8.525	87.63
	20	0.0195	8.470	80.13	0.0464	8.848	84.28
Holoptelea Integrifolia **barks**	Blank	0.5450	46.823	-	0.1050	18.830	-
	5	0.4689	19.417	46.21	0.600	9.417	43.22
	10	0.0408	12.318	69.88	0.0408	2.318	70.83
	15	0.0019	4.116	89.34	0.0219	1.116	86.36
	20	0.0035	5.009	82.67	0.0395	2.009	83.84
Holoptelea Integrifolia **flowers**	Blank	0.6510	20.310	-	0.0510	20.310	-
	5	0.0283	11.317	66.28	0.0390	2.317	86.61
	10	0.0192	10.026	69.12	0.0284	1.026	88.23
	15	0.0115	5.970	80.37	0.0421	0.970	82.70
	20	0.0102	4.321	88.97	0.0435	0.321	82.90
Holoptelea Integrifolia **seeds**	Blank	0.0492	19.281	-	0.0403	13.014	-
	5	0.0189	13.166	59.51	0.0289	7.103	55.73
	10	0.0033	12.070	62.73	0.0182	1.170	64.33
	15	0.0020	8.865	78.16	0.0108	0.865	76.92
	20	0.0010	6.385	88.04	0.0039	0.385	89.21

Table 15 Percentage of inhibition efficiency (IE %) and corrosion rate (CR) at different concentration of inhibitor in 1N HCl medium

Aqueous extract of SS plants					**Alcoholic extract of SS plants**		
Parts of (SS) plant	**Conc. of the extract (v/v)**	**Weight loss (g)**	**Corrosion rate (mmpy)**	**Inhibition efficiency (%)**	**Weight loss (g)**	**Corrosion rate (mmpy)**	**Inhibition efficiency (%)**
Schreabera swietenioids **leaves**	Blank	0.0347	24.902	-	0.2090	30.113	-
	5	0.0294	10.600	39.66	0.1314	10.638	58.39
	10	0.0157	6.986	64.09	0.0982	7.652	73.11
	15	0.0110	4.334	83.32	0.0630	4.286	84.57
	20	0.0015	3.100	88.80	0.0115	3.070	89.25
Schreabera swietenioids **barks**	Blank	0.0782	21.670	-	0.0445	23.137	-
	5	0.0546	14.908	40.01	0.0352	14.817	56.34
	10	0.0347	9.128	69.88	0.0223	5.318	78.56
	15	0.0091	2.116	89.60	0.0131	3.116	87.28
	20	0.0035	2.011	91.93	0.0195	4.030	82.55

(continued)

Table 15 (continued)

Schreabera swietenioids **fruits**	Blank	0.0370	18.560	-	0.0460	17.043	-
	5	0.0280	7.817	66.02	0.0383	8.189	52.67
	10	0.0182	5.116	79.11	0.0222	5.780	76.40
	15	0.0108	3.290	88.07	0.0135	2.236	86.76
	20	0.0099	2.301	90.74	0.0100	2.000	89.17
Schreabera swietenioids **seeds**	Blank	0.0641	29.021	-	0.0249	14.762	-
	5	0.0480	15.166	49.78	0.0189	8.112	50.40
	10	0.0203	9.170	63.46	0.0109	6.100	69.89
	15	0.0101	6.078	85.19	0.0087	4.965	78.86
	20	0.0082	3.385	92.84	0.0066	3.005	80.77

5.2. FT-IR Measurement

Among molecular vibrational spectroscopic techniques, FT-IR is most frequently used for the identification of organic functional groups. The surface film formed on the metal specimen examined by FT-IR spectra of the both (aqueous and alcoholic) extract of water - soluble and alcoholic – soluble fraction were recorded within the wavelength ranging between 4000 – 400 cm^{-1} using a Bruker alpha 8400 S models.

The FT-IR spectroscopy is ***not capable to firm exactly the main structure*** of the extract, but the evident shows that (what it) the more abundant chemical composites, it is ***very difficult to identify each compound separately*** to know the functional group present in the plants extracts, which contributed in effective working in the inhibitor.

FT-IR spectra of all the selected *plants* of various parts like leaves, barks, fruits, seed peels or roots and tubers of both extracts were shown in ***Figures 27 - 38***. For (***leaves, flowers, barks, fruits, tuber or stems and seed (or) seeds peels***) which contain bands corresponding 3301, 3272, 3396, 3170, 3308 cm^{-1} can be assigned to ***(hydroxyl group)*** and a strong band around 1738 cm^{-1} which reveals the presence of ***(carbonyl)*** stretching vibration respectively. Peak at 2130, 2191 cm^{-1} indicates the presence of ***CN group*** respectively. The peak at 1096.64 cm^{-1} is due to the ***oxygen atom*** present in the aromatic ring. For GSL, PD, AL, HI and SS plants of both extract, the similar kinds of functional groups are presented in there molecule. The band due to the protect film formed on the metal surface by aqueous and alcoholic extract clearly indicated that the mild steel has co-ordinated (***coordination between Fe^{2+} - organic constituent***) with the O – atom of the OH group, C = O group and the ring oxygen atom.

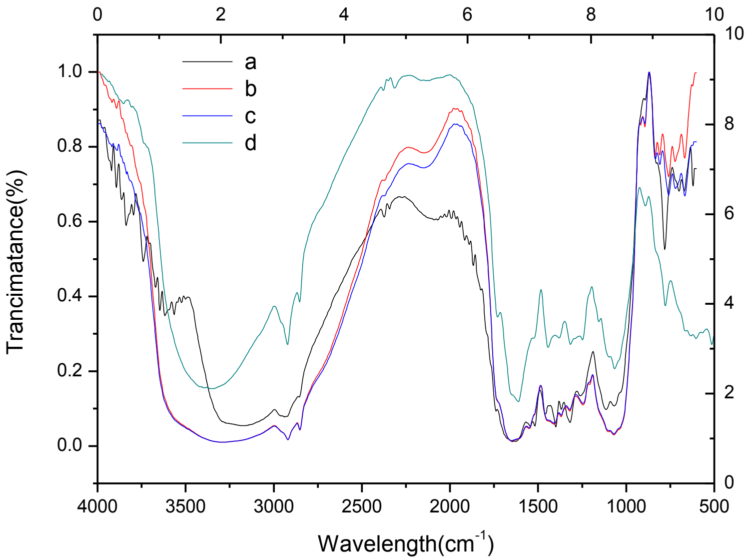


Fig. 27 FTIR spectra of ML plants (aqueous extract)

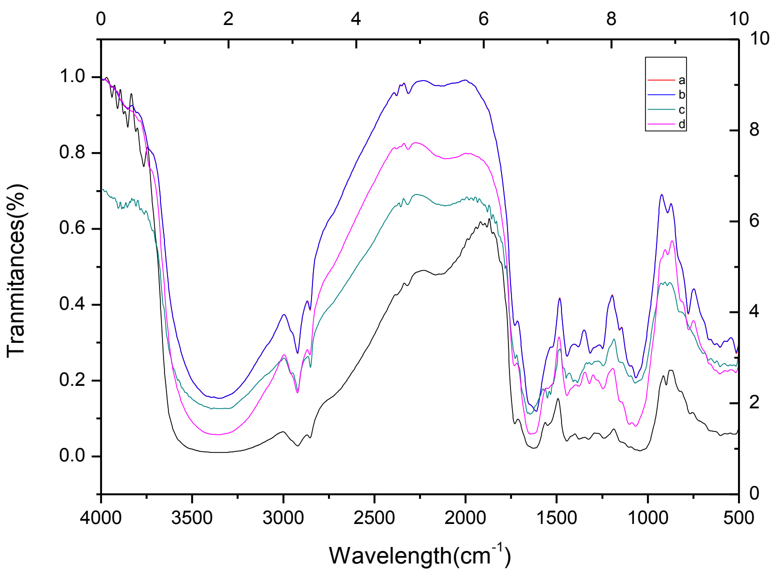


Fig. 28 FTIR spectra of ML plants (alcoholic extract)

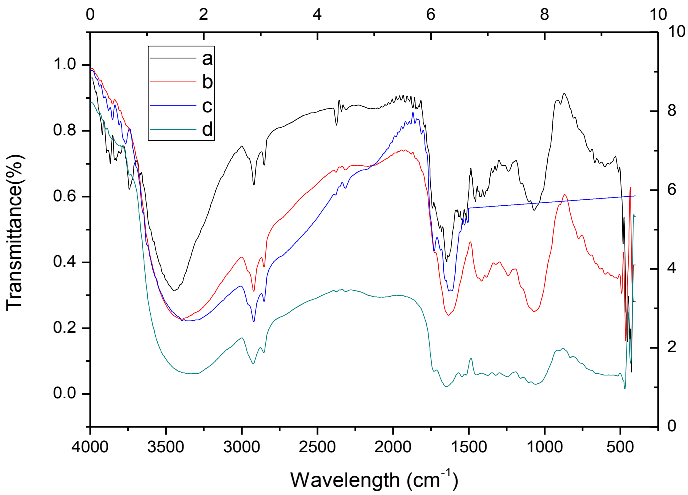


Fig. 29 FTIR spectra of GSL plants (aqueous extract)

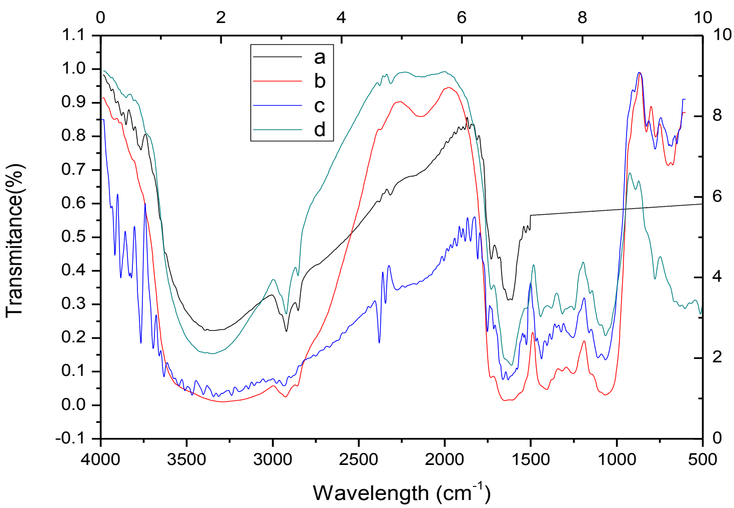


Fig. 30 FTIR spectra of GSL plants (alcoholic extract)

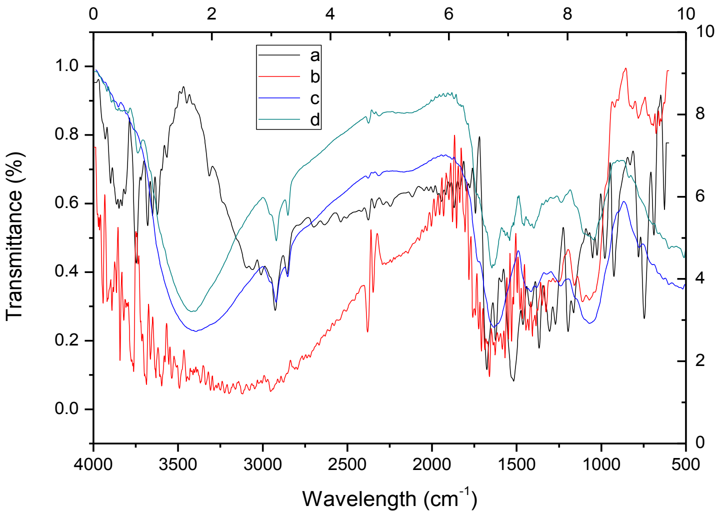


Fig. 31 FTIR spectra of PD plants (aqueous extract)

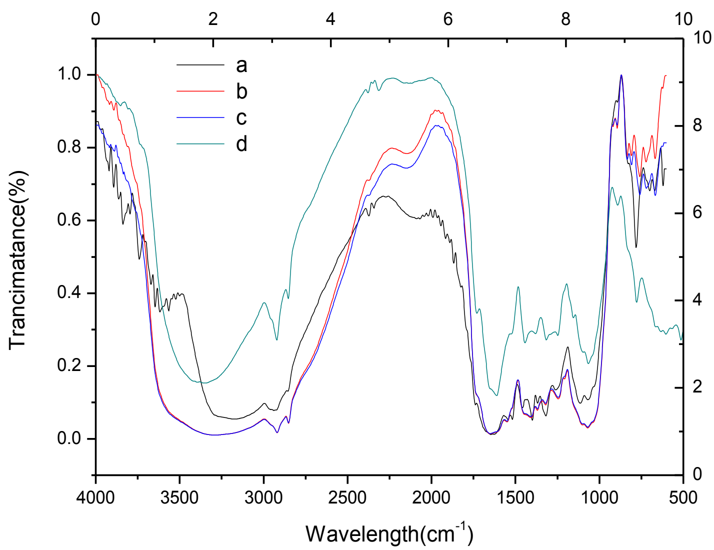


Fig. 32 FTIR spectra of PD plants (alcoholic extract)

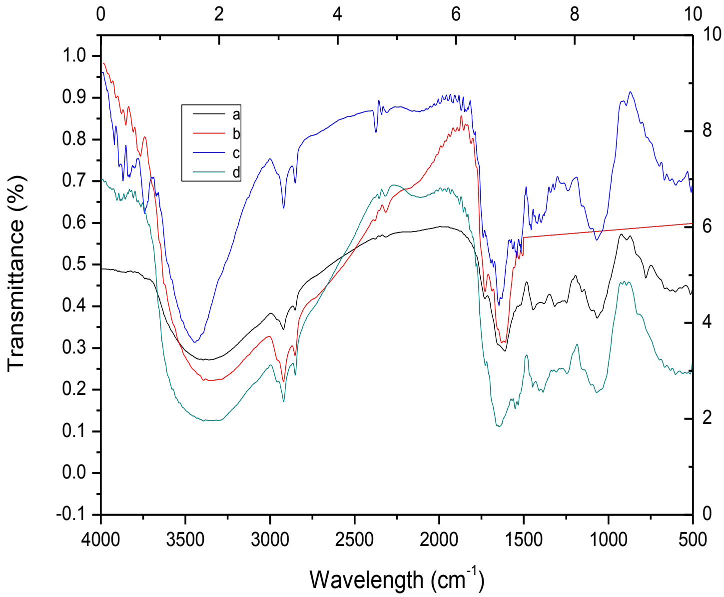


Fig. 33 FTIR spectra of AL plants (aqueous extract)

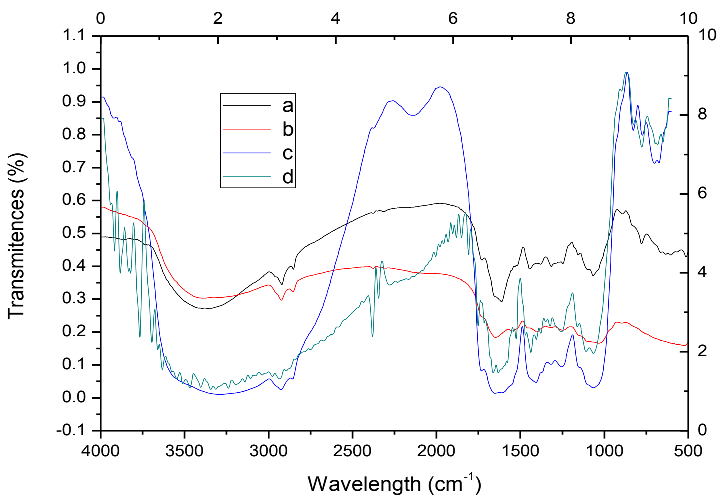


Fig. 34 FTIR spectra of AL plants (alcoholic extract)

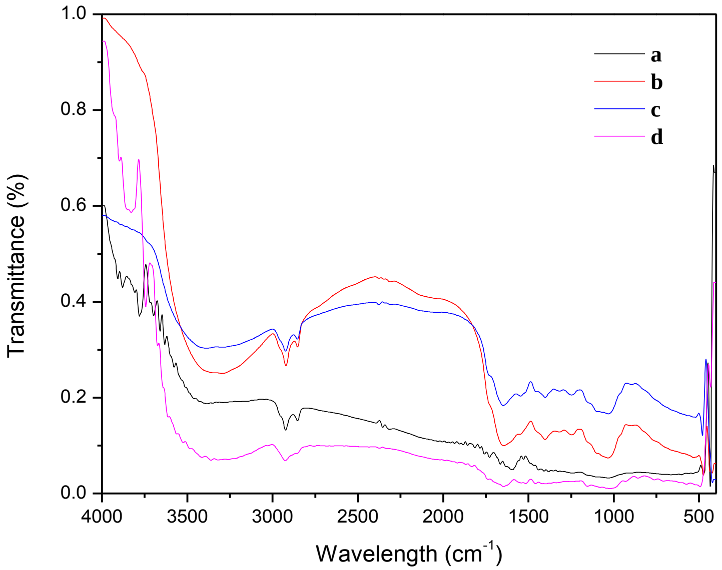


Fig. 35 FTIR spectra of HI plants (aqueous extract)

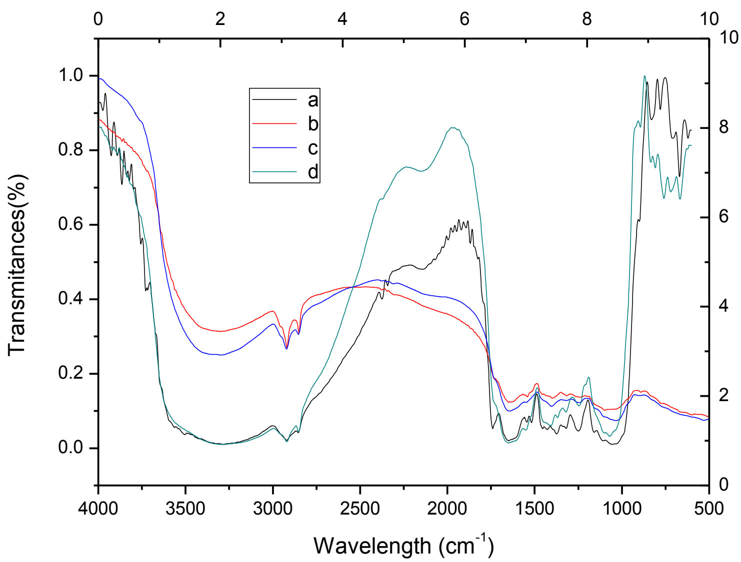


Fig. 36 FTIR spectra of HI plants (alcoholic extract)

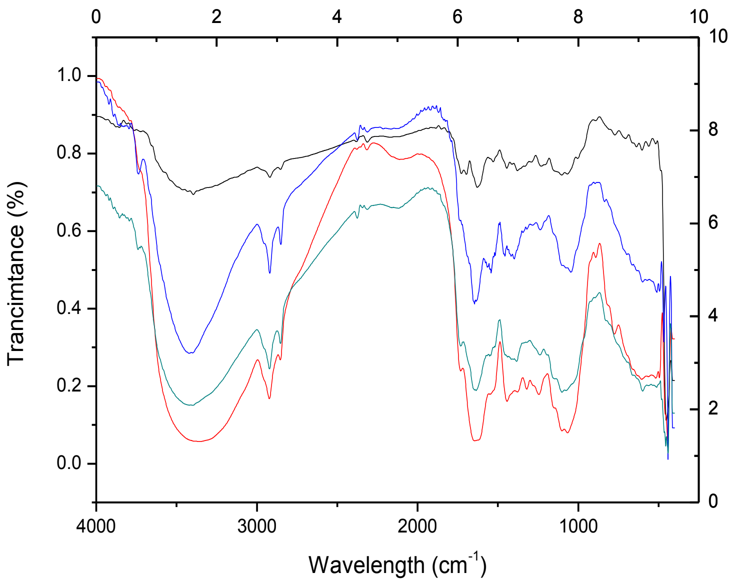


Fig. 37 FTIR spectra of SS plants (aqueous extract)

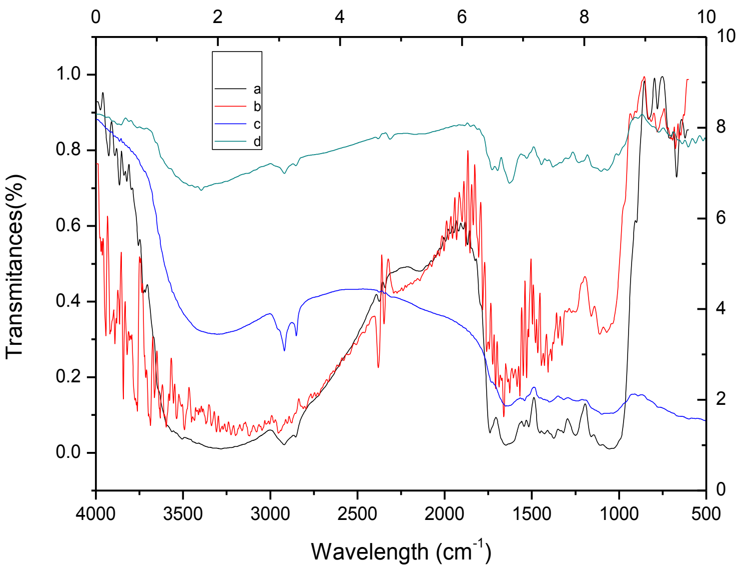


Fig. 38 FTIR spectra of SS plants (alcoholic extract)

5.3. Potentiodynamic polarization methods

The effect of aqueous and alcoholic extracts of various concentration on the anodic and cathodic polarization behaviour of mild steel in 1N HCl solution has been studied by polarization measurents and the recorded Tafel slopes datas are given in ***Tables 16 – 21*** and their polarization curves are shown in ***Figures 39 - 50.*** The displayed data clearly showed that the corrosion current density (I_{corr}) value has been decreased in the presence of plant extract indicates that the corrosion process of steel has supported in 1N HCl acid media.

It is noted that the lowest (I_{corr}) values are observed in the presence of extract possess strongest inhibitive properties and suggesting that natural plant extract could serve as effective green corrosion inhibitor. From the ***Tables 16 – 21,*** it is observed that there is not much variation in the E_{corr} values among the studied system. However, the shift in the values of corrosion potential (E_{corr}) for both plant extract is not significant.

The corrosion kinetic parameters such as corrosion potential (E_{corr}) and corrosion current density (I_{corr}), anodic Tafel slope (b_a) and cathodic Tafel slopes (b_c) obtained from Tafel values are given in ***Table 16*** for ML plant extracts. From the table, it is observed that the I_{corr} values are found to decrease with increase in the inhibitor concentrations (both extract), ranging from 5 to 20 v/v. The maximum inhibition efficiency of ***90.63*** % was observed for ***Madhuca Longifolia leaves*** at 20 v/v, for ***barks*** with ***67.30*** % at 20 v/v, ***fruits*** with ***94.25*** % at 15 v/v, and for ***seeds peels*** with ***90.66 %*** at 20 v/v of the extract. For the alcoholic extract, the maximum IE of ***96.87*** % was obtained for leaves at 15 v/v, ***barks*** with ***78.90*** % at 20 v/v, ***fruits*** with ***96.80*** % at 20 v/v and for ***seeds peels*** with 97.00 % at 20 v/v of the extract. This observation from ***Fig. 39*** and ***Fig. 45*** clearly showed that the inhibition of mild steel in the presence of the ***ML*** extracts control both cathodic and anodic reaction and thus the inhibitor acts like mixed type inhibitors.

The extrapolation method for the polarization curve was applied for ***Gloriosa Superba linn*** plant extracts and the corrosion parameters viz., I_{corr}, E_{corr}, b_a, b_c are shown in ***Table 17.*** From the results, it is found that increase in the concentration of the plant extract alters the values of corrosion potential (E_{corr}) with respect to the mode of action of the inhibitor. ***Fig. 40*** and ***Fig. 46*** showed that the addition of GSL inhibitor did not affect the values of E_{corr} large extent but both anodic dissolution of mild steel and cathodic reduction reaction was observed, indicating that the inhibitor could be classified as mixed type inhibitor. From the ***Table 17,*** it is noted that the maximum inhibition efficiency of ***96.38 %*** was observed for ***Gloriosa Superba linn tubers*** at 15 v/v, for ***flower*** with ***92.34 %*** at 10 v/v, ***stems*** with ***87.65 %*** at 20 v/v, and for leaves with ***93.19 %*** at 15 v/v of the extract and the alcoholic extract showed a maximum inhibition efficiency of ***75.98 %*** for ***tubers*** at 10 v/v, for ***flower*** with ***90.67 %*** at 20 v/v, ***stems*** with 73.33 % at 20 v/v, and for ***leaves*** with ***80.97 %*** at 20 v/v of the extract. From the tables it is found that for the both extracts, E_{corr} values are shifted in both positive and negative sides and are not shifted much remain closer to the OCP (open circuit potential) value, acting as a mixed type of inhibitor.

It is observed from the ***Table 18*** that the addition of the aqueous extract of

Pithecellobium dulce plants decreases the corrosion dissolution process and the maximum inhibition efficiency that was obtained for ***fruits*** at ***99.80 %, barks at 99.63 %, seeds at 99.21 % and leaves at 76.19 %.*** On the other hand**,** for the alcoholic extract, IE obtained for ***seeds*** at ***94.89 %, leaves at 88.67 %, fruits at 84.90 % and barks at 89.33 % respectively.*** It can be observed from the figure (***Fig. 41*** and ***Fig. 47***) that the addition of ***PD*** extracts at all the studied concentration decreased the anodic and cathodic current densities and resulted in significant decline in the I_{corr}. This indicates that ***PD*** extracts shifted to smaller I_{corr} values in both anodic and cathodic branches of the curve, thus, acting as a mixed type inhibitor and the decrease is more pronounced with the increase in the inhibitor concentration. By comparing polarization curves in the absence and in the presence of various concentrations of ***PD*** extracts, it was observed that, increase in concentration of the inhibitor shift the corrosion potential (E_{corr}) in the positive direction and reduces both anodic and cathodic process.

It is noted from the ***Table 19*** that the addition of ***Alangium lamarckii*** plant extract decreases the dissolution rate of mild steel in 1N HCl acid media. It is evident that the optimum IE of the aqueous extract of ***Alangium lamarckii*** **leaves** was at ***95.74 %, barks*** at ***95.57 %, fruits*** at ***91.45 %, and seeds*** at ***98.23 %***. Also, for the alcoholic extract the highest IE was obtained for ***leaves*** at ***90.30 %, barks at 80.22 %, fruits at 87.65 %, and seeds at 90.42 % respectively.*** This observation from ***Fig. 42*** and ***Fig. 48*** clearly showed that the inhibition of mild steel in the presence of the ***AL*** extracts control both cathodic and anodic reaction and thus the inhibitor acts like mixed type inhibitors.

The examination of ***Fig. 43*** and ***Fig. 49*** showed that the addition of ***HI*** inhibitor did not affect the values of E_{corr} large extent but both anodic dissolution of mild steel and cathodic reduction reaction was observed, indicating that the inhibitor could be classified as mixed type inhibitor. It should be noted from the ***Table 20*** that the optimum inhibition efficiencies that were obtained for the aqueous extract of ***Holoptelea integrifolia*** **leaves** at ***97.45 %, barks*** at ***99.89 %, flowers*** at ***99.56 %, seeds*** at ***98.97 %***. Also, for the alcoholic extract, the highest IE was obtained for the ***leaves*** at ***66.66 %, barks at 86.78 %, flowers at 88.00 %, and seeds at 88.90 % respectively.*** The maximum inhibition efficiency detected at higher inhibitor concentration shows that more inhibitor molecules are adsorbed on the metal surface, which provides more surface coverage for the active sites of MS where direct attack occurs and migrates the corrosion attack.

As can be seen from the ***Table 21*** that the optimum inhibition efficiencies were that obtained for the aqueous extract of ***Schrebera swietenioides*** **leaves** at ***95.21 %, barks*** at ***96.34 %, fruits*** at ***96.36 %, seeds*** at ***97.86 %***. Also, for the alcoholic extract, the highest IE was achieved for ***leaves*** at ***92.76 %, barks at 96.01 %, fruits at 93.33 %, and seeds at 96.89 % respectively.*** This observation clearly showed that the (***Fig. 44*** and ***Fig. 50)*** inhibition of mild steel in the presence of the ***SS*** extracts control both cathodic and anodic reaction and thus the inhibitor acts like mixed type inhibitors. The corrosion current density values decreased considerably for green inhibitor in the acid medium. This results shows that the both extract inhibits the corrosion mechanism by controlling predominantly the anodic and cathodic reaction sites in the metal surface.

Generally, inhibitor can be classified as cathodic or anodic type if the shift of corrosion potential in the presence of the inhibitor was more than 85 mV, with respect to that in the absence of the inhibitor. From these results, the charges of E_{corr} values are less than 85 mV for studied plants extract, which indicates that the selected plant extracts act as a ***mixed type inhibitor*** and more anodic in nature and does not alter the reaction mechanism for the corrosion of mild steel in 1N HCl medium. The corrosion prevention and protection has supported the mixed type of inhibitors is generally represented by organic compounds with donor atom Se, N, O, S, P instead of having reactive functional group which latch onto the metal, may have an important role on the corrosion inhibition of mild steel.

Table 16 Electrochemical parameters from polarization measurement and calculated values of inhibition efficiency

Aqueous extract of ML plants							**Alcoholic extract of ML plants**				
Parts of plant	**Conc. (v/v)**	**E_{corr}/ mV/ SCE**	**I_{corr}/ mA/cm^2**	**b_c mV/de**	**b_a mV/de**	**IE (%)**	**E_{corr}/ mV/ SCE**	**I_{corr}/ mA/cm^2**	**b_c mV/de**	**b_a mV/de**	**IE (%)**
ML **Leaves**	Blank	-0.471	$4.7x10^{-3}$	208	153	*	-0.504	$1.5x10^{-4}$	128	87	*
	5	-0.468	$3.3x10^{-3}$	184	133	29.78	-0.468	$1.2x10^{-5}$	64	66	92.04
	10	-0.469	$1.3x10^{-3}$	166	101	72.34	-0.453	$4.7x10^{-5}$	147	68	96.87
	15	-0.483	$8.5x10^{-4}$	162	115	81.91	-0.455	$2.4x10^{-5}$	134	68	90.68
	20	-0.476	$4.4x10^{-4}$	132	093	90.63	-0.458	$2.0x10^{-5}$	129	69	90.70
ML **Barks**	Blank	-0.471	$5.2x10^{-3}$	199	140	*	-0.504	$1.5x10^{-4}$	128	87	*
	5	-0.469	$3.2x10^{-3}$	180	127	36.46	-0.444	$1.5x10^{-5}$	265	90	23.90
	10	-0.466	$3.3x10^{-3}$	203	136	38.57	-0.456	$2.7x10^{-5}$	135	67	57.89
	15	-0.469	$1.7x10^{-3}$	174	104	67.30	-0.459	$2.1x10^{-5}$	130	69	65.16
	20	-0.474	$1.8x10^{-3}$	172	125	67.30	-0.460	$1.8x10^{-5}$	127	71	78.90
ML **Fruits**	Blank	-0.471	$4.0x10^{-3}$	208	153	*	-0.504	$1.5x10^{-4}$	128	87	*
	5	-0.469	$1.5x10^{-3}$	171	118	62.50	-0.462	$2.4x10^{-5}$	120	70	90.45
	10	-0.486	$2.6x10^{-4}$	141	088	93.58	-0.460	$1.8x10^{-5}$	115	70	93.58
	15	-0.475	$2.4x10^{-4}$	152	098	94.25	-0.460	$1.4x10^{-5}$	114	72	94.89
	20	-0.491	$5.3x10^{-4}$	137	098	86.70	-0.461	$1.2x10^{-5}$	112	75	96.80
ML **Seed peels**	Blank	-0.471	$4.0 x10^{-3}$	208	153	*	-0.504	$1.5x10^{-4}$	128	87	*
	5	-0.479	$1.5x10^{-3}$	167	122	74.87	-0.460	$1.3x10^{-5}$	115	74	95.88
	10	-0.479	$6.7x10^{-4}$	146	097	83.79	-0.462	$1.2x10^{-5}$	115	76	96.99
	15	-0.482	$1.1x10^{-3}$	157	118	90.56	-0.463	$1.1x10^{-5}$	116	77	96.99
	20	-0.485	$9.7x10^{-7}$	148	110	90.57	-0.464	$1.0x10^{-5}$	116	80	97.00

Table 17 Polarization measurement and calculated values of IE (%) at different concentration of GSL extract

Aqueous extract of GSL plant							**Alcoholic extract of GSL plant**				
Parts of *GSL* plant	**Conc. v/v**	**E_{corr}/ mV/ SCE**	**I_{corr}/ mA/cm^2**	**b_c mV/dec.**	**b_a mV/dec.**	**IE (%)**	**E_{corr}/ mV/ SCE**	**I_{corr}/ mA/cm^2**	**b_c mV/dec**	**b_a mV/dec**	**IE (%)**
GS Linn **leaves**	Blank	-0.471	4.7x10^{-3}	208	153	*	-0.477	1.5x10^{-3}	128	87	*
	5	-0.468	1.0x10^{-3}	160	115	78.72	-0.463	0.9x10^{-4}	138	72	40.02
	10	-0.475	7.2x10^{-4}	165	90	84.68	-0.471	0.7x10^{-5}	138	72	53.33
	15	-0.476	3.2x10^{-4}	131	100	93.19	-0.475	0.4x10^{-5}	135	66	73.49
	20	-0.465	6.0x10^{-4}	146	90	87.23	-0.469	0.7x10^{-6}	147	65	80.97
GS Linn **flowers**	Blank	-0.471	4.7x10^{-3}	208	153	*	-0.477	1.5x10^{-3}	128	87	*
	5	-0.455	8.8x10^{-4}	155	93	81.27	-0.445	0.9x10^{-5}	134	67	76.95
	10	-0.444	1.3x10^{-3}	191	104	92.34	-0.467	0.3x10^{-4}	142	67	84.65
	15	-0.451	1.5x10^{-3}	174	116	89.08	-0.489	0.6x10^{-4}	139	66	90.67
	20	-0.448	5.5x10^{-4}	188	87	88.29	-0.478	0.6x10^{-4}	139	66	90.67
GS Linn **stems**	Blank	-0.471	4.7x10^{-3}	208	153	*	-0.477	1.5x10^{-3}	128	87	*
	5	-0.477	8.9x10^{-4}	166	86	51.08	-0.477	0.9x10^{-6}	150	90	74.32
	10	-0.461	1.6x10^{-3}	179	129	65.95	-0.486	0.6x10^{-6}	143	100	60.00
	15	-0.482	1.2x10^{-3}	160	138	74.46	-0.472	0.7x10^{-6}	154	90	73.33
	20	-0.475	5.8x10^{-4}	143	94	87.65	-0.472	0.8x10^{-6}	154	89	73.33
GS Linn **tubers**	Blank	-0.471	4.7x10^{-3}	208	153	*	-0.477	1.5x10^{-3}	128	87	*
	5	-0.479	4.5x10^{-4}	153	84	33.90	-0.483	1.6x10^{-6}	87	125	60.89
	10	-0.462	3.6x10^{-3}	178	128	56.67	-0.474	1.2x10^{-6}	137	96	75.98
	15	-0.474	7.3x10^{-4}	156	87	89.54	-0.462	2.6x10^{-6}	146	88	53.78
	20	-0.477	1.0x10^{-3}	163	122	96.38	-0.469	2.6x10^{-6}	133	89	53.78

Table 18 Electrochemical parameters from polarization measurement, calculated values of inhibition efficiency

Aqueous extract of PD plants							**Alcoholic extract of PD plants**				
Parts of PD plant	**Conc. (v/v)**	**E_{corr}/ mV/ SCE**	**I_{corr}/ mA/cm^2**	**b_c mV/ dec**	**b_a mV/dec**	**IE (%)**	**E_{corr}/ mV/ SCE**	**I_{corr}/ mA/cm^2**	**b_c mV/dec.**	**b_a mV/dec.**	**IE (%)**
PD **leaves**	Blank	-0.471	5.2 x10^{-3}	199	140	*	-0.504	1.5 x10^{-4}	128	87	*
	5	-0.477	2.0x10^{-4}	127	093	33.97	-0.240	1.7x10^{-9}	126	54	88.67
	10	-0.493	1.8x10^{-4}	121	095	41.72	-0.315	0.7x10^{-7}	112	112	53.34
	15	-0.502	1.2x10^{-4}	116	090	61.65	-0.313	1.0x10^{-7}	113	112	53.34
	20	-0.510	7.5x10^{-5}	112	092	76.19	-0.375	1.4x10^{-7}	101	115	50.56

(continued)

Table 18 (Continued)

PD **barks**	Blank	-0.471	5.2x10^{-3}	199	140	*	-0.504	1.5 x10^{-4}	128	87	*
	5	-0.473	5.9x10^{-4}	174	86	76.00	-0.345	2.0 x10^{-7}	87	127	86.86
	10	-0.461	7.2x10^{-4}	165	82	99.63	-0.367	1.6x10^{-7}	97	116	89.33
	15	-0.465	4.0x10^{-4}	167	68	99.59	-0.365	2.2x10^{-7}	89	126	85.33
	20	-0.474	2.5x10^{-4}	152	73	85.29	-0.378	2.1x10^{-7}	95	120	85.34
PD **fruits**	Blank	-0.446	3.7x10^{-3}	203	132	*	-0.504	1.5x10^{-4}	128	87	*
	5	-0.449	2.8x10^{-3}	194	124	86.00	-0.455	2.3x10^{-5}	139	66	84.90
	10	-0.458	1.9x10^{-3}	173	119	99.79	-0.463	2.3x10^{-4}	79	83	84.89
	15	-0.459	1.5x10^{-3}	171	117	99.80	-0.392	2.6x10^{-7}	74	118	83.67
	20	-0.461	1.1x10^{-3}	167	107	91.01	-0.477	3.3x10^{-5}	134	34	80.90
PD **seeds**	Blank	-0.471	4.7x10^{-3}	208	153	*	-0.540	1.5x10^{-4}	128	87	*
	5	-0.462	6.5x10^{-4}	171	080	90.44	-0.335	1.4x10^{-7}	154	91	89.58
	10	-0.476	4.0x10^{-4}	142	097	99.21	-0.337	1.7x10^{-7}	105	130	88.89
	15	-0.469	1.4x10^{-4}	159	063	84.50	-0.330	1.2x10^{-7}	105	63	92.00
	20	-0.476	3.9x10^{-4}	131	101	99.00	-0.439	1.1x10^{-5}	148	36	94.89

Table 19 Electrochemical parameters from polarization measurement and calculated values of inhibition efficiency

Aqueous extract of AL plants							**Alcoholic extract of AL plants**				
Parts of AL Plant	**Conc. (v/v)**	**E_{corr}/ mV/ SCE**	**I_{corr}/ mA/cm^2**	**b_c mV/dec.**	**b_a mV/dec**	**IE (%)**	**E_{corr}/ Mv SCE**	**I_{corr}/ mA/cm^2**	**b_c mV/dec**	**b_a mV/dec**	**IE (%)**
AL **Leaves**	Blank	-0.446	3.7x10^{-3}	203	132	*	-0.471	4.7x10^{-3}	208	153	*
	5	-0.445	1.4x10^{-3}	197	104	61.14	-0.468	1.0x10^{-3}	160	115	73.70
	10	-0.445	1.2x10^{-3}	192	101	66.80	-0.475	7.2x10^{-4}	165	90	80.45
	15	-0.454	1.6x10^{-3}	184	124	95.74	-0.476	3.2x10^{-4}	131	100	90.39
	20	-0.452	6.9x10^{-4}	159	097	81.71	-0.465	6.0x10^{-4}	146	90	82.33
AL **Barks**	Blank	-0.471	5.2x10^{-3}	199	140	*	-0.471	4.7x10^{-3}	208	153	*
	5	-0.460	4.5x10^{-4}	174	070	91.33	-0.455	8.8x10^{-4}	155	93	80.22
	10	-0.479	6.1x10^{-4}	146	094	88.21	-0.444	1.3x10^{-3}	191	104	72.34
	15	-0.474	4.6x10^{-4}	145	091	91.10	-0.451	1.5x10^{-3}	174	116	68.08
	20	-0.477	2.3x10^{-4}	136	074	95.57	-0.448	5.5x10^{-4}	188	87	58.29
AL **Fruits**	Blank	-0.466	3.7x10^{-3}	203	132	*	-0.471	4.7x10^{-3}	208	153	*
	5	-0.450	1.0x10^{-3}	147	073	71.96	-0.477	8.9x10^{-4}	166	86	81.06
	10	-0.466	7.2x10^{-4}	133	091	80.83	-0.461	1.6x10^{-3}	179	129	65.95
	15	-0.464	3.2x10^{-4}	137	075	91.45	-0.482	1.2x10^{-3}	160	138	74.46
	20	-0.492	6.0x10^{-4}	133	102	83.96	-0.475	5.8x10^{-4}	143	94	87.65

(Continued)

Table 19 (Continued)

AL **Seeds**	Blank	-0.472	$6.4x10^{-3}$	208	168	*	-0.471	$4.7x10^{-3}$	208	153	*
	5	-0.464	$4.0x10^{-3}$	205	132	38.01	-0.479	$4.5x10^{-4}$	153	84	90.42
	10	-0.464	$2.8x10^{-3}$	199	126	56.58	-0.462	$3.6x10^{-3}$	178	128	72.34
	15	-0.472	$1.1x10^{-5}$	168	111	98.23	-0.474	$7.3x10^{-4}$	156	87	84.47
	20	-0.470	$1.7x10^{-3}$	166	111	97.32	-0.477	$1.0x10^{-3}$	163	122	78.72

Table 20 Electrochemical parameters from polarization measurement and calculated values of inhibition efficiency

	Aqueous extract of HI plants						**Alcoholic extract of HI plants**				
Parts of plant	**Conc. (v/v)**	**E_{corr}/ (mV/ SCE)**	**I_{corr}/ (mA/cm^2)**	**b_c (mV/dec.)**	**b_a (mV/dec.)**	**IE (%)**	**E_{corr}/(mV/ SCE)**	**I_{corr}/ (mA/cm^2)**	**b_c (mV/dec.)**	**b_a (mV/dec.)**	**IE (%)**
HI **leaves**	Blank	-0.471	$4.7 x10^{-3}$	208	153	*	-0.504	$1.5x10^{-4}$	128	87	*
	5	-0.468	$1.0 x10^{-4}$	160	115	77.32	-0.472	$1.3x10^{-4}$	138	72	13.33
	10	-0.475	$7.2 x10^{-4}$	165	090	97.45	-0.472	$1.3x10^{-4}$	138	72	13.33
	15	-0.476	$3.2 x10^{-3}$	131	100	93.05	-0.474	$0.5x10^{-4}$	135	66	66.66
	20	-0.465	$6.0 x10^{-4}$	146	096	87.08	-0.455	$0.6x10^{-4}$	147	65	60.00
HI ***barks***	Blank	-0.471	$4.0 x10^{-3}$	208	153	*	-0.504	$1.5x10^{-4}$	128	87	*
	5	-0.479	$4.5 x10^{-4}$	153	084	66.01	-0.462	$2.2x10^{-5}$	134	67	85.33
	10	-0.462	$3.6 x10^{-3}$	178	128	98.90	-0.455	$3.0x10^{-5}$	142	64	80.00
	15	-0.474	$7.3 x10^{-4}$	156	087	99.89	-0.455	$2.3x10^{-5}$	139	66	84.67
	20	-0.477	$1.0 x10^{-3}$	163	122	84.30	-0.456	$2.0x10^{-5}$	136	66	86.78
HI **flowers**	Blank	-0.471	$4.0 x10^{-3}$	208	153	*	-0.504	$1.5x10^{-4}$	128	87	*
	5	-0.471	$7.6x10^{-4}$	159	100	82.77	-0.445	$3.9x10^{-5}$	150	61	74.90
	10	-0.479	$7.6 x10^{-4}$	146	101	98.01	-0.446	$2.8x10^{-5}$	143	64	81.34
	15	-0.479	$3.4 x10^{-4}$	138	085	99.56	-0.447	$3.8x10^{-5}$	154	62	76.67
	20	-0.476	$1.4 x10^{-3}$	167	128	90.99	-0.452	$1.8x10^{-5}$	134	64	88.00

(Continued)

Table 20 (Continued)

HI **seeds**	Blank	-0.472	6.4 x10-3	208	168	*	-0.504	1.5x10-4	128	87	*
	5	-0.464	4.0 x10-3	205	132	88.41	-0.403	1.8x10-7	87	125	88.90
	10	-0.464	2.8 x10-3	199	126	98.67	-0.454	2.5x10-5	137	86	83.33
	15	-0.472	1.1 x10-3	168	111	85.59	-0.451	4.2x10-5	146	75	72.53
	20	-0.470	1.7 x10-3	166	111	95.22	-0.457	2.2x10-5	133	74	70.78

Table 21 Electrochemical parameters from polarization measurement and calculated values of inhibition efficiency

Aqueous extract of SS plants							**Alcoholic extract of SS plants**				
Parts of SS plant	**Conc. (v/v)**	**E_{corr}/ (mV / SCE)**	**I_{corr}/ (mA/cm^2)**	**b_c (mV/dec.**	**b_a (mV/dec**	**IE (%)**	**E_{corr}/ (mV / SCE)**	**I_{corr}/ (mA/cm^2)**	**b_c (mV/dec.**	**b_a (mV/dec)**	**IE (%)**
SS leaves	Blank	-0.474	3.1 x10-4	108	101	*	-0.504	1.5x10-4	128	87	*
	5	-0.476	2.4 x10-5	103	098	92.07	-0.111	0.6x10-6	202	386	60.00
	10	-0.478	2.0 x10-5	097	095	93.57	-0.103	0.7x10-6	281	420	83.33
	15	-0.482	1.7 x10-5	095	093	94.53	-0.098	1.1x10-6	252	386	92.66
	20	-0.505	1.5 x10-5	098	094	95.21	-0.113	1.2x10-6	261	416	92.67
SS barks	Blank	-0.472	6.4 x10-3	208	168	*	-0.504	1.5x10-4	128	87	*
	5	-0.482	1.8 x10-3	168	124	72.17	-0.354	0.3x10-6	78	123	80.00
	10	-0.474	8.0 x10-4	155	091	94.98	-0.298	0.6x10-6	151	78	96.01
	15	-0.470	5.8 x10-4	167	081	96.34	-0.378	1.3x10-6	61	182	91.33
	20	-0.475	5.4 x10-4	141	090	82.00	-0.362	1.7x10-6	57	171	88.96
SS fruits	Blank	-0.446	3.7 x10-3	203	132	*	-0.504	1.5x10-4	128	87	*
	5	-0.445	1.4 x10-3	197	104	84.64	-0.370	0.9x10-6	80	165	40.09
	10	-0.445	1.2 x10-3	192	101	96.36	-0.348	1.0x10-6	82	152	93.33
	15	-0.454	1.6 x10-3	184	124	95.22	-0.374	1.0x10-6	79	152	93.33
	20	-0.452	6.9 x10-4	159	097	93.99	-0.376	1.1x10-6	80	150	92.87

(Continued)

Table 21(Continued)

SS seeds	Blank	-0.471	$5.2x10^{-3}$	199	140	*	-0.504	$1.5x10^{-4}$	128	87	*
	5	-0.460	$4.5\ x10^{-4}$	174	70	86.40	-0.269	$2.0x10^{-8}$	85	123	86.66
	10	-0.479	$6.1\ x10^{-4}$	146	94	94.67	-0.357	$1.5x10^{-7}$	89	126	90.00
	15	-0.474	$4.6\ x10^{-4}$	145	91	80.55	-0.344	$1.3x10^{-7}$	88	114	91.34
	20	-0.477	$2.3\ x10^{-4}$	136	74	97.86	-0.249	$0.6x10^{-7}$	120	86	96.89

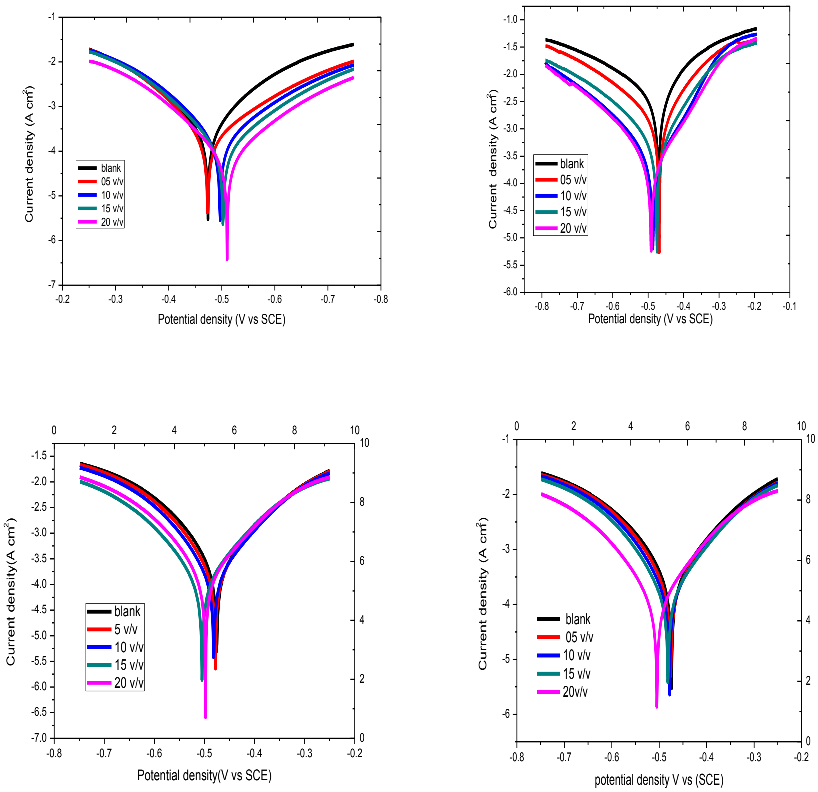


Fig. 39 Potentiodynamic polarization (Tafel) curves for mild steel in 1N HCl solution in the absence and presence of different concentration of Madhuca Longifolia (aqueous) extracts of (a) leaves (b) barks (c) fruits (d) seeds peel

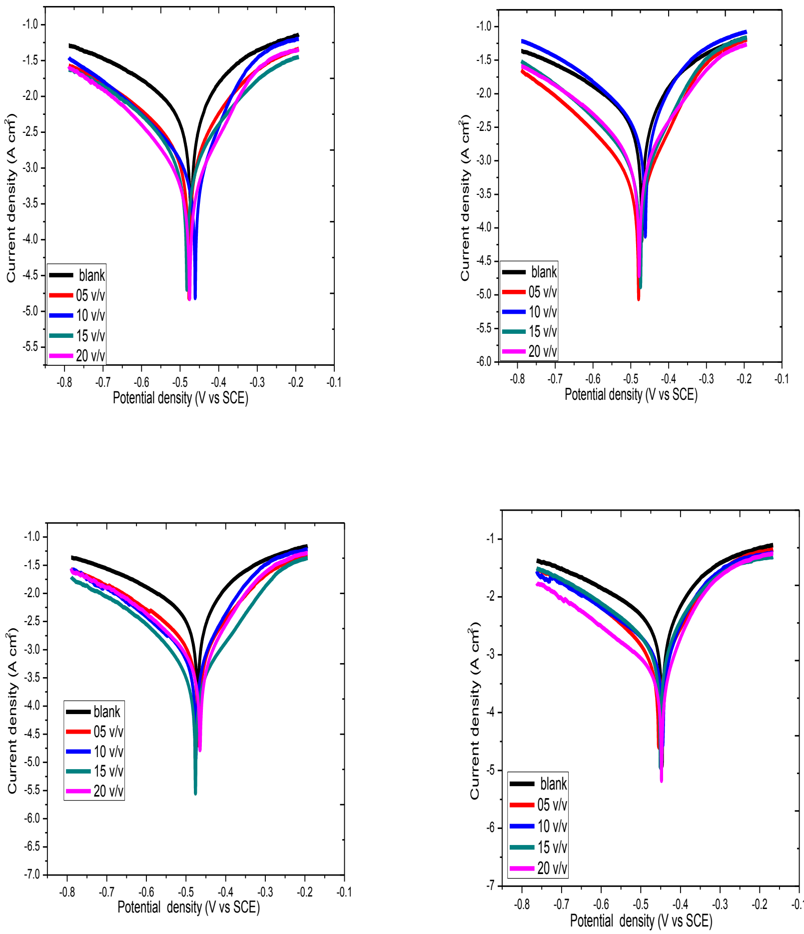


Fig. 40 Potentiodynamic polarization (Tafel) curves for mild steel in 1N HCl solution in the absence and presence of different concentration of Gloriosa Superba Linn (aqueous) extracts of (a) leaves (b) stems (c) flowers (d) tubers

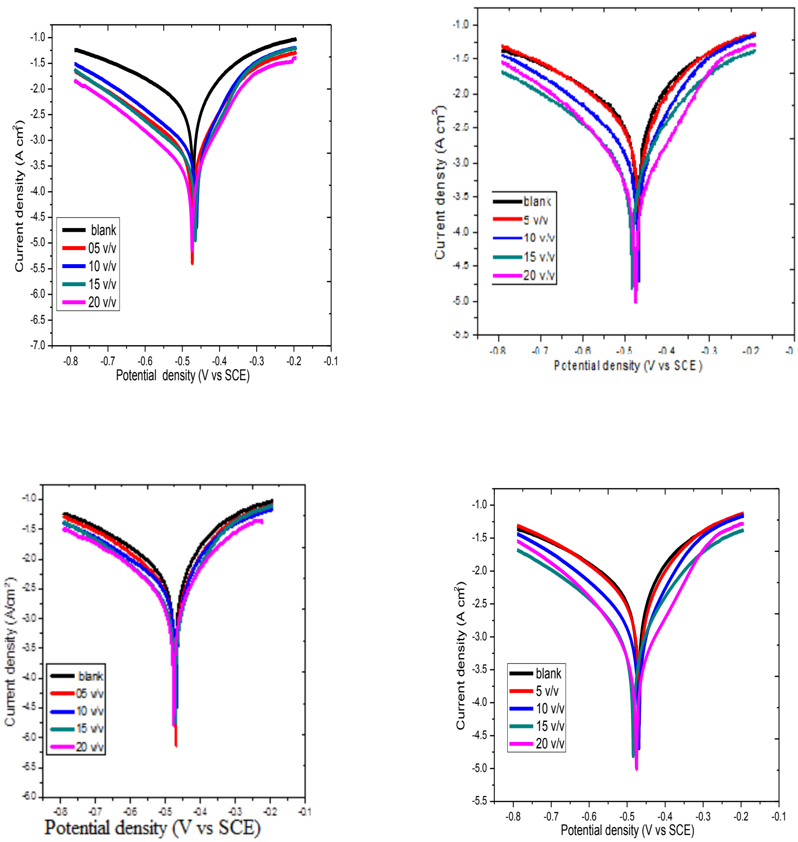


Fig.41 Potentiodynamic polarization (Tafel) curves for mild steel in 1N HCl solution in the absence and presence of different concentration of PD (aqueous) extracts of (a) leaves (b) barks (c) fruits (d) seeds

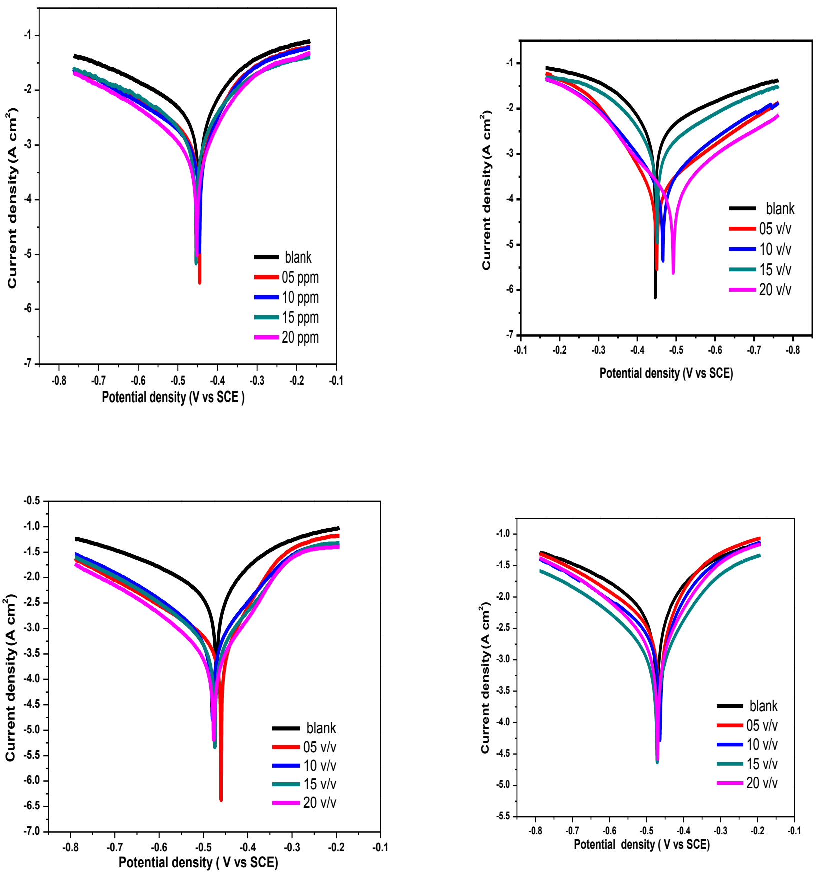


Fig. 42 Potentiodynamic polarization (Tafel) curves for mild steel in 1N HCl solution in the absence and presence of different concentration of Alangium lamarckiii (aqueous) extracts of (a) leaves (b) barks (c) fruits (d) seeds

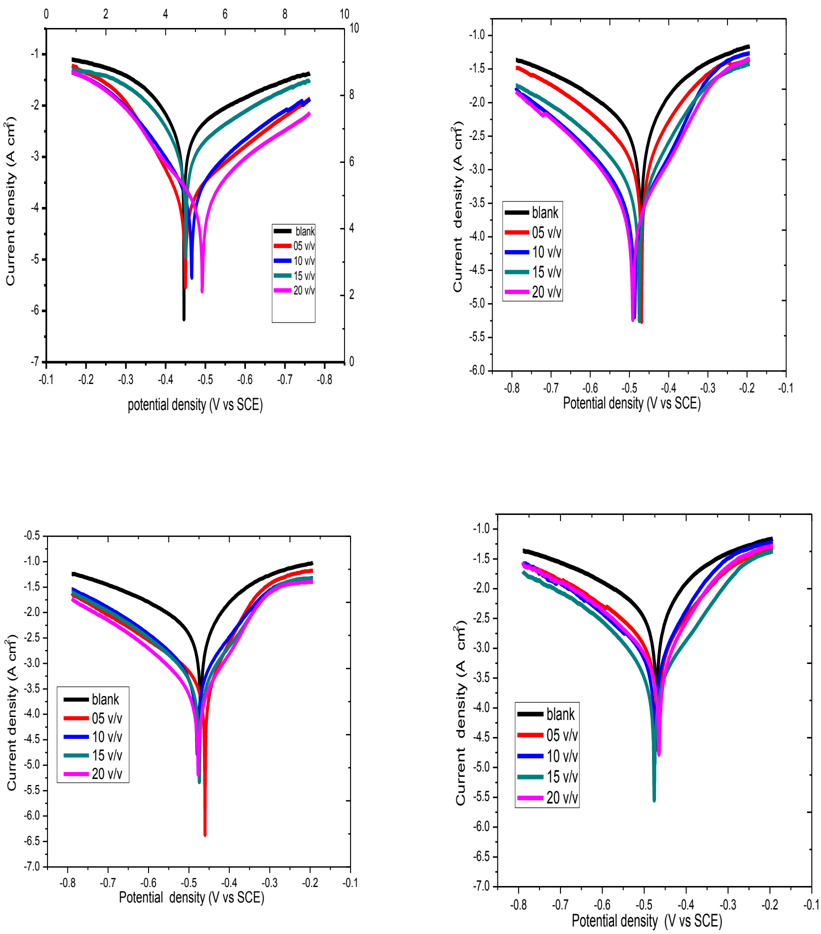


Fig. 43 Potentiodynamic polarization (Tafel) curves for mild steel in 1N HCl solution in the absence and presence of different concentration of Holoptelea Integrifolia (aqueous) extracts of (a) leaves (b) barks (c) flowers (d) seeds

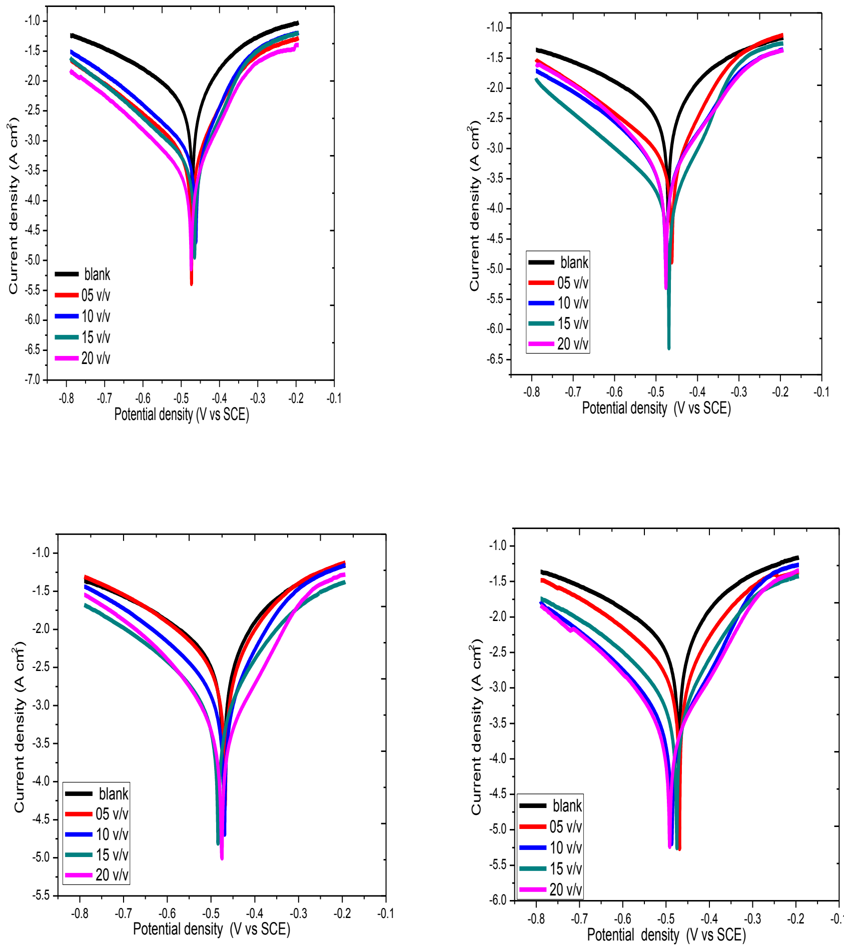


Fig. 44 Potentiodynamic polarization (Tafel) curves for mild steel in 1N HCl solution in the absence and presence of different concentration of SS (aqueous) extracts of (a) leaves (b) barks (c) fruits (d) seeds

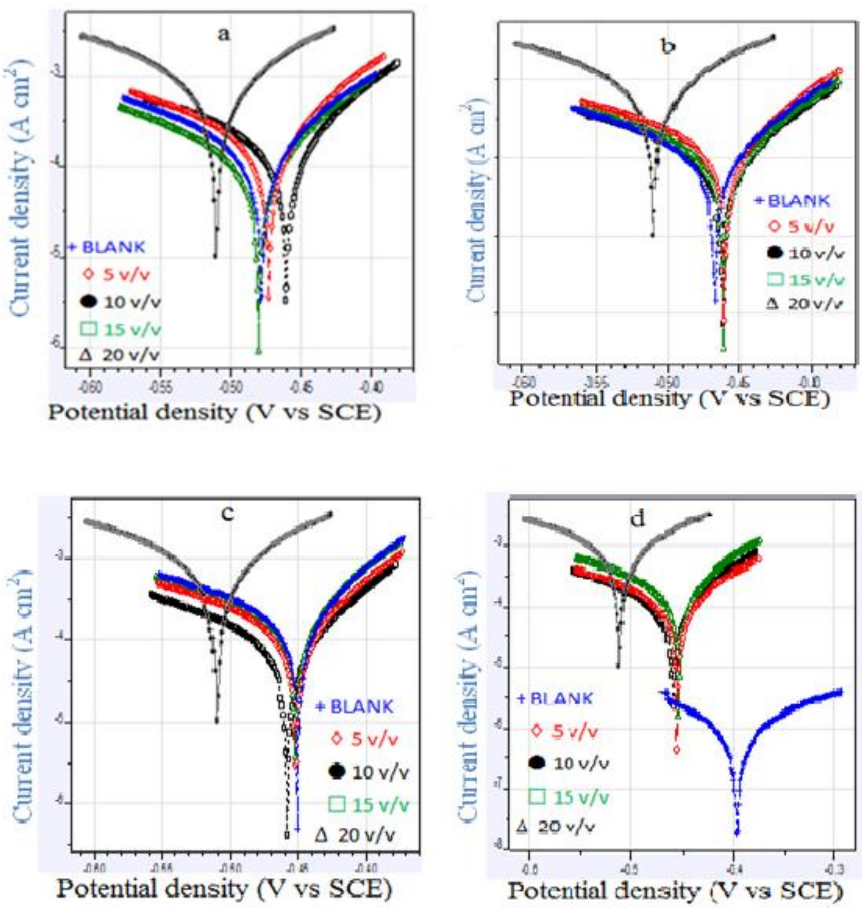


Fig. 45 Potentiodynamic polarization (Tafel) curves for mild steel in 1N HCl solution in the absence and presence of different concentration of Madhuca Longifolia (alcoholic) extracts of (a) leaves (b) barks (c) fruits (d) seed peels

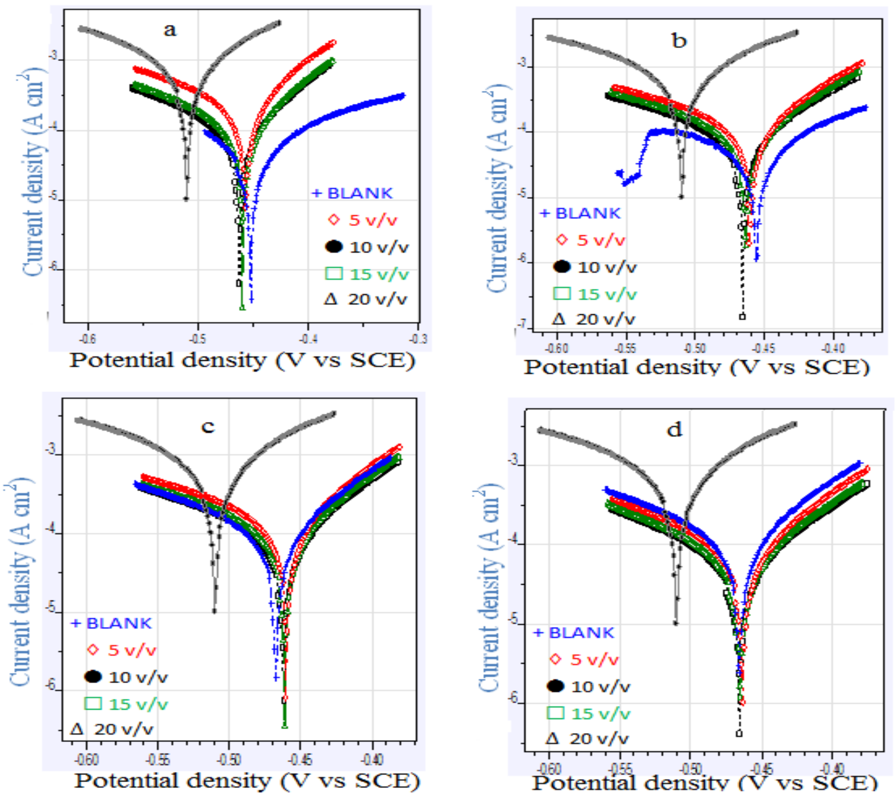


Fig. 46 Potentiodynamic polarization (Tafel) curves for mild steel in 1N HCl solution in the absence and presence of different concentration of Gloriosa Superba Linn (alcoholic) extracts of (a) leaves (b) stems (c) flowers (d) tubers

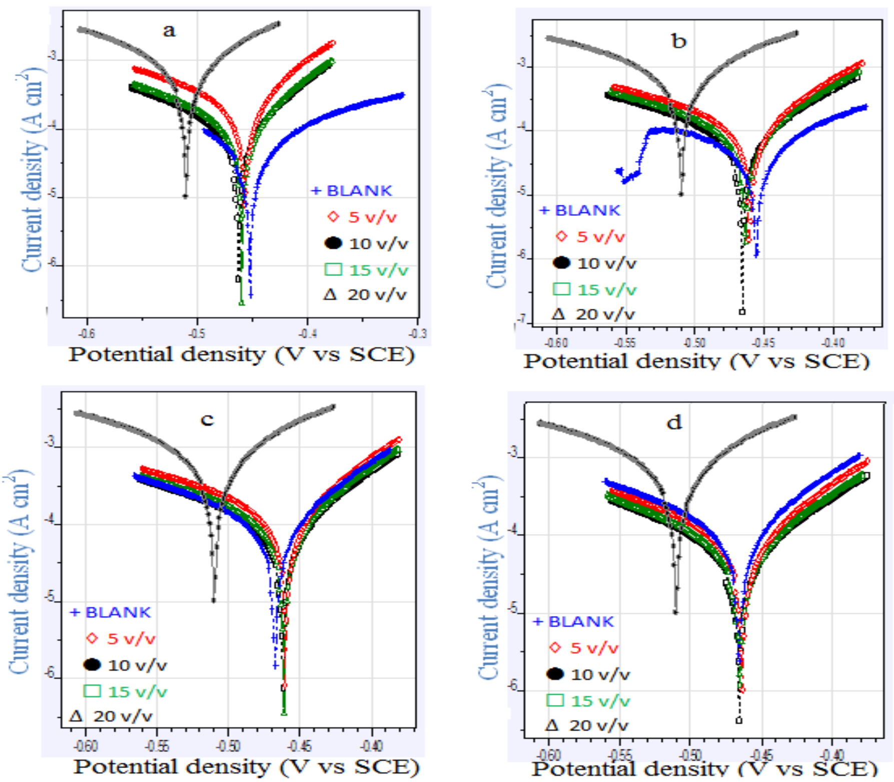


Fig. 47 Potentiodynamic polarization (Tafel) curves for mild steel in 1N HCl solution in the absence and presence of different concentration of Pithecellobium Dulce (alcoholic) extracts of (a) leaves (b) barks (c) fruits (d) seeds

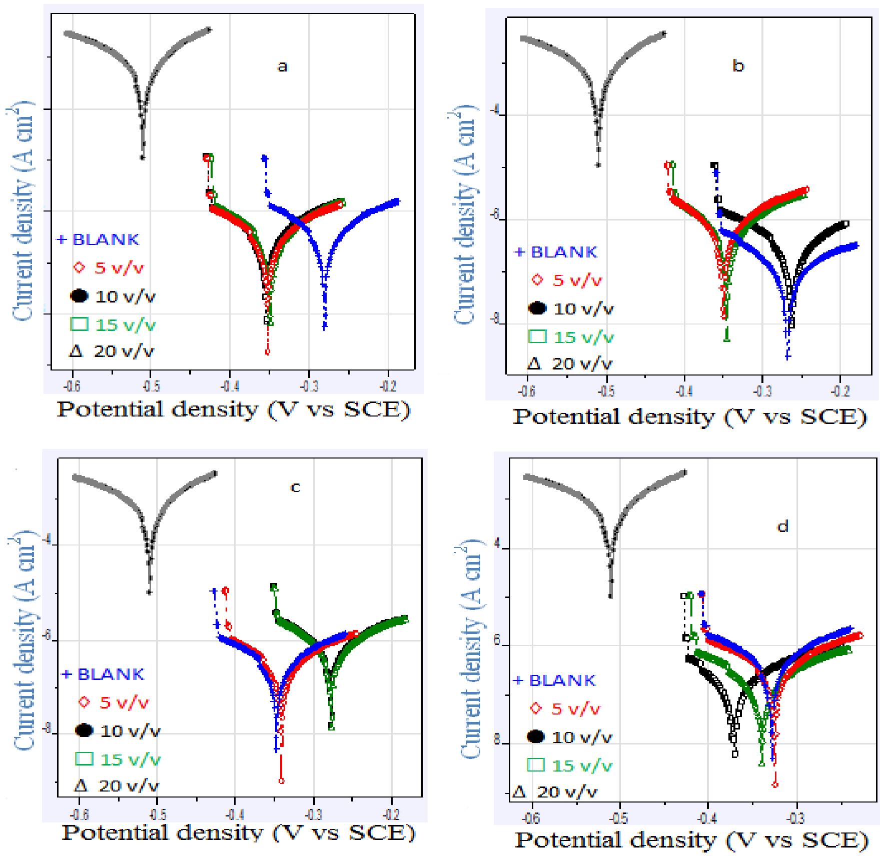


Fig.48 Potentiodynamic polarization (Tafel) curves for mild steel in 1N HCl solution in the absence and presence of different concentration of Alangium lamarckiii (alcoholic) extracts of (a) leaves (b) barks (c) fruits (d) seeds

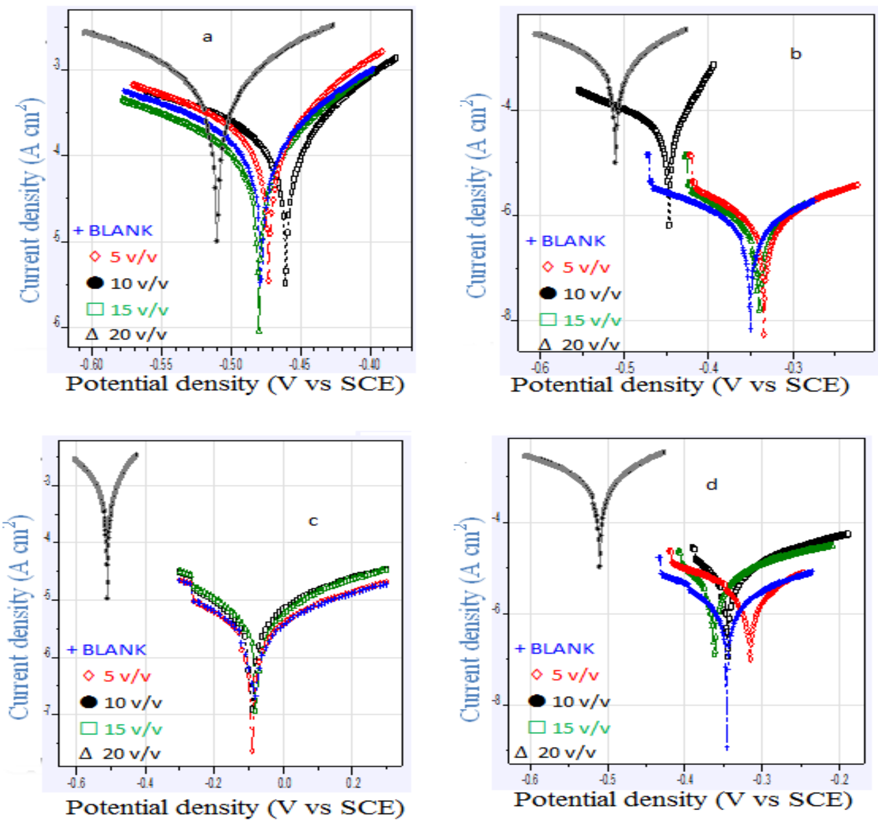


Fig. 49 Potentiodynamic polarization (Tafel) curves for mild steel in 1N HCl solution in the absence and presence of different concentration of Holoptelea Integrifolia (alcoholic) extracts of (a) leaves (b) barks (c) flowers (d) seeds

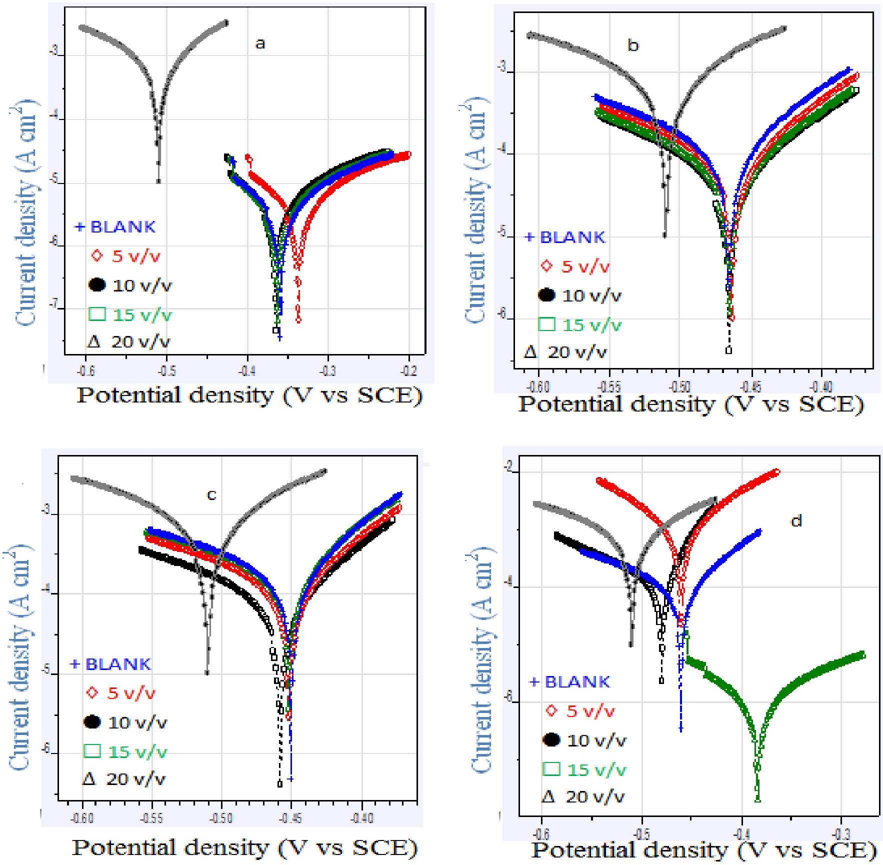


Fig. 50 Potentiodynamic polarization (Tafel) curves for mild steel in 1N HCl solution in the absence and presence of different concentration of SS (alcoholic) extracts of (a) leaves (b) barks (c) fruits (d) seeds

5.4. Electrochemical impedance studies

Impedance spectroscopy is one of the most simple and consistent techniques and also used to study the characterization of electrode (surface) behaviour in 1N HCl solution in the absence and presence of the plants (aqueous and alcoholic) extracts at room temperature are shown in ***Figures 51 - 62.*** Nyquist plot over a wide range of frequency was obtained after 20 min. Figures 51 – 62 showed the Nyquist plots of various parts of plants extracts like leaves, flowers, fruits, barks (tubers) and seed peels or stems at various concentrations. The different corrosion parameters derived from EIS measurement are presented in ***Tables 22 - 27.*** It is worth noting that the presence of extract did not alter the profiles of the impedance spectra show a single semicircle. It is evident from the data shown in Tables that the values of R_{ct} ***are increased***

(formation of protective film) and C_{dl} values are decreased in the presence of plant extract could be attributed to the adsorption of the phytoconsistutents or presence of plant extract over the mild steel surface as organic compounds. This indicates that the adsorption mainly controls the corrosion of mild steel surface retards the electron transfer reaction and form strong protective film. ***Yan li et al [226]*** studied that the irregular value of C_{dl} at the inhibitor concentration was not defined.

Nyquist plots with no loops suggest that the mild steel – inhibition system under R_{ct} control and the inhibitor is selectively adsorbed on the surface of the mild steel. It can be expected that the R_{ct} value enhanced with both extract inhibitor concentration and consequently the IE increases. Alcoholic extract of Nyquist plots ***[see Fig. 57-62]*** are not perfect (depressed) semi circles. ***Jutter et al [566]*** studied that this type of behaviour was attributed to metal surface roughness. The result obtained from the polarization region in acid - alcoholic solution was in ***good agreement with those obtained from the EIS, with slight variation***. However, deviation from slightly depressed nature of semicircles (due to the presence of pores on the inhibitor on the electrode surface) indicated that the ***extracts inhomogeneity of roughness*** on the mild steel surface. This increase in size of semicircle as the inhibitor concentration increase demonstrates the corrosion inhibition properties of these alcoholic extract. Thus, the inhibitors do not alter the electrochemical reaction responsible for corrosion; but inhibit corrosion primarily through adsorption of inhibitor molecules on the metal surface.

As seen from the ***Table 22,*** the maximum R_{ct} value of (***51.008, 15.452, 103.26, 32.093***) Ω cm^2 and the minimum C_{dl} values (***1.19×10^{-4}, 2.08×10^{-3}, 4.25×10^{-5}, 4.44×10^{-4}***) µ F/cm^2 were obtained at the optimum concentration of ***ML*** plant of (***leaves, barks, fruits, seeds peels***) aqueous extract, which gave the maximum inhibition efficiency of (***83.88, 57.41, 90.86 and 70.28 %***) respectively. The same experiment was repeated in the presence of alcoholic extract (***same plant, same parts***) and was found to be the R_{ct} value of (***60.00, 70.60, 124.60, 98.81***) Ω cm^2 and the minimum C_{dl} values (***1.01×10^{-6}, 1.4×10^{-4}, 5.4×10^{-5}, 5.1×10^{-6}***) µ F/cm^2, which gave the maximum inhibition efficiency of (***65.55, 70.67, 83.38 and 79.05 %***) respectively. These observations suggest that ***ML*** plant extract functioned by adsorption at the metal surface thereby causing decrease in C_{dl} values and increase in R_{ct} values. The higher R_{ct} value obtained for higher inhibitor concentration suggests that a protective film is formed on the surface of the metal.

From the inspection of data listed in ***Table 23,*** it was observed that the maximum values of R_{ct} (***66.849, 38.800, 40.866 and 49.722***) Ω cm^2 and the minimum C_{dl} values (***9.82×10^{-5}, 2.78×10^{-4}, 2.85×10^{-4}, 5.67×10^{-4}***) µ F/cm^2 was obtained at the optimum concentration of aqueous extract of ***GSL*** plant for ***leaves, flowers, stems and tubers***, which gave the maximum inhibition efficiency of (***84.78, 77.75, 84.01 and 78.63 %***) respectively. The same experiment was repeated in the presence of alcoholic extract (***same plant, same parts***) and was found to be the R_{ct} value of (***53.38, 49.80, 82.40 and 72.12***) Ω cm^2 and the minimum C_{dl} values (***3.3×10^{-6}, 1.8×10^{-7}, 6.1×10^{-6}, 6.8×10^{-7}***) µ F/cm^2, which gave the maximum inhibition efficiency of (***61.22, 57.83, 74.87 and 71.29 %***) respectively.

It should be noted from the ***Table 24*** that the highest R_{ct} values of (***510.09,***

57.915, 18.471 and 92.053) Ω cm^2 and the minimum C_{dl} values (***1.978 x 10^{-2}, 1.287 x 10^{-4}, 1.149 x 10^{-3},5.408 x 10^{-5}***) µ F/cm^2 was obtained at the optimum concentration of aqueous extract of ***PD*** plants (***leaves, barks, fruits and seeds***), which gave the maximum inhibition efficiency of (***89.26, 78.92, 83.11 and 71.20 %***) respectively. The same experiment was repeated in the presence of alcoholic extract (***same plant, same parts***) and was found to be the R_{ct} value of (***108.60, 80.80, 116.12, 95.90***) Ω cm^2 and the minimum C_{dl} values (***5.9 x 10^{-5}, 6.0 x 10^{-5}, 9.6 x 10^{-6}, 1.0 x 10^{-5}***) µ F/cm^2, which gave the maximum inhibition efficiency of (***80.93, 74.38, 82.17 and 78.41 %***) respectively.

Table 25 shows that the maximum R_{ct} values (***31.03, 72.73, 203.40, 28.95***) Ω cm^2 and the minimum C_{dl} values (***4.487 x 10^{-4}, 8.604 x 10^{-5}, 1.026 x 10^{-5}, 6.961 x 10^{-4}***) µ F/cm^2 were obtained at the optimum concentration of aqueous extracts of ***AL*** plant (***leaves, barks, fruits and seeds***), which gave the maximum inhibition efficiency of (***75.53, 91.22, 96.32 and 83.87 %***) respectively. The same experiment was repeated in the presence of alcoholic extract (***same plant, same parts***) was found to be the R_{ct} value of (***66.849, 38.800, 40.866 and 49.722***) Ω cm^2 and the minimum C_{dl} values (***9.82 x 10^{-5}, 2.78 x 10^{-4}, 2.85 x 10^{-4}, 1.81 x 10^{-4}***) µF/cm^2, which gave the maximum inhibition efficiency of (***84.78, 73.62, 81.77 and 73.64 %***) respectively.

From the ***Table 26,*** it is clear that the maximum values of R_{ct} (***65.453, 49.123, 62.663 and 28.959***) Ω cm^2 and the minimum C_{dl} values (***9.830 x 10^{-5}, 8.438 x 10^{-4}, 1.67 x 10^{-3} and 2.1 x 10^{-4}***) µ F/cm^2 were obtained at the optimum concentration of aqueous extract of ***HI*** plants (***leaves, barks, flowers and seeds***), which gave the maximum inhibition efficiency of (***86.42, 73.90, 87.62 and 69.54 %***) respectively. The same experiment was repeated in the presence of alcoholic extract (***same plant, same parts***) and was found to be the R_{ct} value of (***57.60, 83.97, 94.27 and 64.33***) Ω cm^2 and the minimum C_{dl} values (***1.19 x 10^{-4}, 8.65 x 10^{-5}, 7.40 x 10^{-5} and 4.55 x 10^{-5}***) µ F/cm^2, which gave the maximum inhibition efficiency of (***64.07, 75.34, 79.10 and 67.82%***) respectively.

As can be seen from the ***Table 27,*** the impedance data indicated that the maximum R_{ct} value of (14***5.091, 38.276, 22.006 and 72.372***) Ω cm^2 and the minimum C_{dl} values (***7.185 x 10^{-3}, 2.917 x 10^{-4}, 4.487 x 10^{-4} and 2.385 x 10^{-4}***) µ F/cm^2 was obtained at the optimum concentration of aqueous extract of ***SS*** plant (***leaves, barks, fruits and seeds***), which gave the maximum inhibition efficiency of (***71.43, 69.85, 86.78, 70.58 %***) respectively. The same experiment was repeated in the presence of alcoholic extract (***same plant, same parts***) and was found to be the R_{ct} value of (***72.46, 95.96, 121.10 and 87.90***) Ω cm^2 and the minimum C_{dl} values (***3.01 x 10^{-5}, 5.3 x 10^{-5}, 1.0 x 10^{-5} and 5.0 x 10^{-7}***) µ F/cm^2 was obtained, which gave the maximum inhibition efficiency of (***71.43, 78.42, 82.90 and 76.45 %***) respectively. The results showed that the R_{ct} significantly increases with increase in concentration of the inhibitor and C_{dl} tends decrease. In fact, in the presence of the plant extracts, the charge transfer resistance (R_{ct}) values have enhanced and the values of double layer capacitance (C_{dl}) were brought down to the maximum extent. The decrease in C_{dl} showed that the adsorption of the inhibitor takes place on the metal surface in acidic solution. The increase in R_{ct} values is attributed to the formation of protective film at the metal solution interface.

Table 22 Impedance parameter for mild steel in 1 N HCl acid solution in the absence and presence of varied concentration of ML inhibitor

Aqueous extract of ML plants					**Alcoholic extract of ML plants**		
Parts of Madhuca Longifolia plant	**Conc (v/v)**	**R_{ct} (ohm cm^2)**	**C_{dl} ($\mu F/cm^2$)**	**IE (%)**	**R_{ct} (ohm cm^2)**	**C_{dl} ($\mu F/cm^2$)**	**IE (%)**
Madhuca Longifolia **leaves**	Blank	8.221	6.79×10^{-4}	*	20.70	1.5×10^{-5}	*
	5	9.182	6.66×10^{-4}	11.68	52.30	9.1×10^{-5}	60.42
	10	19.202	1.20×10^{-4}	57.18	49.63	2.1×10^{-5}	58.29
	15	31.031	4.49×10^{-4}	73.50	59.32	5.3×10^{-1}	65.10
	20	51.008	1.74×10^{-4}	83.88	60.00	1.0×10^{-6}	65.55
Madhuca Longifolia **barks**	Blank	6.581	1.19×10^{-2}	*	20.70	1.5×10^{-5}	*
	5	10.236	5.10×10^{-3}	39.82	21.95	4.6×10^{-5}	05.69
	10	10.966	4.29×10^{-3}	40.45	60.18	8.1×10^{-5}	65.60
	15	13.969	2.29×10^{-3}	52.88	70.60	1.2×10^{-4}	70.67
	20	15.452	2.08×10^{-3}	57.41	68.40	1.4×10^{-4}	69.73
Madhuca Longifolia **fruits**	Blank	9.436	6.89×10^{-3}	*	20.70	1.5×10^{-5}	*
	5	18.225	1.65×10^{-3}	48.22	73.20	6.6×10^{-5}	71.72
	10	83.448	7.28×10^{-5}	88.69	99.30	6.2×10^{-5}	79.15
	15	42.037	2.90×10^{-4}	77.55	113.7	5.9×10^{-5}	81.79
	20	103.26	4.25×10^{-5}	90.86	124.6	5.4×10^{-5}	83.38
Madhuca Longifolia **seed peels**	Blank	9.633	6.43×10^{-3}	*	20.70	1.5×10^{-5}	*
	5	16.560	1.66×10^{-3}	41.82	31.10	5.9×10^{-5}	33.44
	10	32.420	4.44×10^{-4}	70.28	67.60	1.0×10^{-5}	69.37
	15	24.093	8.60×10^{-4}	60.01	74.67	8.2×10^{-5}	72.27
	20	22.126	8.47×10^{-4}	56.46	98.81	5.1×10^{-6}	79.05

Table 23 EIS parameter for MS in 1N HCl acid solution without and with the varied concentration of GSL plant extract

Aqueous extract of GSL plants					**Alcoholic extract of GSL plants**		
Parts of *GSL* plant	**Concentraion (v/v)**	**R_{ct} (ohm cm^2)**	**C_{dl} ($\mu F/cm^2$)**	**IE(%)**	**R_{ct} (ohm cm^2)**	**C_{dl} ($\mu F/cm^2$)**	**IE (%)**
Gloriosa Superba Linn **leaves**	Blank	10.622	6.2385	*	20.70	1.0×10^{-5}	*
	5	23.091	9.72×10^{-4}	55.96	33.09	8.2×10^{-5}	37.44
	10	25.416	6.57×10^{-4}	59.99	35.42	6.4×10^{-5}	41.55
	15	66.849	9.82×10^{-5}	84.78	46.85	7.2×10^{-5}	55.81
	20	32.213	4.43×10^{-4}	68.43	53.38	3.3×10^{-6}	61.22
Gloriosa Superba Linn **flowers**	Blank	10.622	6.2385	*	20.70	1.0×10^{-5}	*
	5	29.125	5.29×10^{-4}	70.36	29.14	5.9×10^{-7}	28.96
	10	22.899	9.35×10^{-4}	62.30	42.90	6.5×10^{-7}	52.91
	15	14.960	1.8530	42.29	48.67	1.3×10^{-7}	57.46
	20	38.800	2.78×10^{-4}	77.75	49.80	1.8×10^{-7}	57.83

(Continued)

Table 23 (Continued)

Gloriosa Superba Linn **Stems**	Blank	10.622	6.2385	*	20.70	$1.0x10^{-5}$	*
	5	18.093	1.6131	63.88	28.91	$1.1\ x10^{-7}$	28.39
	10	25.926	$7.29x10^{-4}$	74.79	52.93	$4.3x10^{-6}$	60.89
	15	28.411	$7.51x10^{-4}$	77.00	82.40	$6.1x10^{-6}$	74.87
	20	40.866	$2.85x10^{-4}$	84.01	60.87	$4.9x10^{-8}$	65.99
Gloriosa Superba Linn **tubers**	Blank	10.622	6.2385	*	20.70	$1.0x10^{-5}$	*
	5	49.722	$1.81x10^{-4}$	78.63	38.27	$1.9x10^{-5}$	45.91
	10	17.856	3.5388	40.51	47.57	$3.4\ x10^{-7}$	56.48
	15	28.342	$5.67x10^{-4}$	62.52	58.89	$5.8x10^{-7}$	64.84
	20	25.597	$7.51x10^{-4}$	58.50	72.12	$6.8x10^{-7}$	71.29

Table 24 Impedance parameter for mild steel in 1 N HCl acid solution in the absence and presence of varied concentration of PD inhibitor

Aqueous extract of PD plants					**Alcoholic extract of PD plants**		
Parts of PD plant	**Conc. (v/v)**	**R_{ct} (ohm cm^2)**	**C_{dl} (μF/cm^2)**	**IE(%)**	**R_{ct} (ohm cm^2)**	**C_{dl} (μF/cm^2)**	**IE (%)**
Pithecellobium Dulce **leaves**	Blank	115.40	$8.312\ x10^{-2}$	*	20.70	$1.0x10^{-5}$	*
	5	150.40	$3.667\ x10^{-2}$	62.08	52.30	$9.1x10^{-5}$	60.42
	10	249.80	$2.424\ x10^{-2}$	70.84	94.74	$1.0x10^{-4}$	78.15
	15	407.30	$2.200\ x10^{-2}$	82.48	67.30	$5.6x10^{-5}$	69.24
	20	510.09	$1.978\ x10^{-2}$	89.26	108.6	$5.9x10^{-5}$	80.93
Pithecellobium Dulce **barks**	Blank	6.742	$1.110\ x10^{-2}$	*	20.70	$1.0x10^{-5}$	*
	5	38.712	$2.892\ x10^{-4}$	69.34	56.40	$6.8x10^{-6}$	63.29
	10	27.075	$5.910\ x10^{-4}$	60.29	73.60	$9.4x10^{-6}$	71.87
	15	41.087	$2.556\ x10^{-4}$	40.03	65.57	$5.2x10^{-5}$	68.43
	20	57.915	$1.287\ x10^{-4}$	78.92	80.80	$6.0x10^{-5}$	74.38
Pithecellobium Dulce **fruits**	Blank	7.129	$7.203\ x10^{-3}$	*	20.70	$1.0x10^{-5}$	*
	5	9.827	$4.30\ x10^{-3}$	61.04	22.95	$5.5x10^{-5}$	09.80
	10	12.802	$2.70\ x10^{-3}$	75.00	62.20	$3.1x10^{-5}$	66.72
	15	14.328	$1.865\ x10^{-3}$	76.98	103.10	$6.8x10^{-6}$	79.92
	20	18.471	$1.149\ x10^{-3}$	83.11	116.12	$9.6x10^{-6}$	82.17
Pithecellobium Dulce **seeds**	Blank	8.739	$7.239\ x10^{-3}$	*	20.70	$1.0x10^{-5}$	*
	5	26.30	$6.232\ x10^{-4}$	71.20	29.60	$1.9x10^{-5}$	30.06
	10	56.351	$1.563\ x10^{-4}$	39.09	69.10	$8.0x10^{-6}$	70.04
	15	92.053	$5.408\ x10^{-5}$	64.44	95.90	$1.0x10^{-5}$	78.41
	20	55.698	$1.286\ x10^{-4}$	57.59	82.40	$6.7x10^{-6}$	74.87

Table 25 Impedance parameter for mild steel in 1 N HCl acid solution in the absence and presence of varied concentration of AL inhibitor

Aqueous extract of AL plants					Alcoholic extract of AL plants		
Parts of Alangium lamarckiii plant	**Conc. (v/v)**	**R_{ct} (ohm cm^2)**	**C_{dl} (μF/cm^2)**	**IE (%)**	**R_{ct} (ohm cm^2)**	**C_{dl} (μF/cm^2)**	**IE (%)**
Alangium lamarckiii **leaves**	Blank	7.64	$6.763x10^{-3}$	*	10.622	6.2385	*
	5	21.23	$9.549x10^{-4}$	64.06	23.091	$9.72x10^{-4}$	55.96
	10	22.06	$8.723x10^{-4}$	65.27	25.416	$6.57x10^{-4}$	59.99
	15	15.46	$1.241x10^{-3}$	50.58	66.849	$9.82x10^{-5}$	84.78
	20	31.03	$4.487x10^{-4}$	75.53	32.213	$4.43x10^{-4}$	68.43
Alangium lamarckiii **barks**	Blank	6.38	$1.162x10^{-3}$	*	10.622	6.2385	*
	5	36.67	$3.183x10^{-4}$	82.59	29.125	$5.29x10^{-4}$	65.08
	10	31.75	$4.246x10^{-4}$	79.89	22.899	$9.35x10^{-4}$	52.80
	15	42.88	$2.358x10^{-4}$	85.11	14.960	1.8530	40.99
	20	72.73	$8.604x10^{-5}$	91.22	38.800	$2.78x10^{-4}$	73.62
Alangium lamarckiii **fruits**	Blank	7.46	$6.835x10^{-3}$	*	10.622	6.2385	*
	5	111.2	$3.481x10^{-5}$	93.28	18.093	1.6131	60.25
	10	82.98	$6.332x10^{-5}$	90.99	25.926	$7.29x10^{-4}$	72.65
	15	203.4	$1.026x10^{-5}$	96.32	28.411	$7.51x10^{-4}$	75.33
	20	166.3	$1.621x10^{-5}$	95.51	40.866	$2.85x10^{-4}$	81.77
Alangium lamarckiii **seeds**	Blank	4.670	$2.148x10^{-2}$	*	10.622	6.2385	*
	5	8.557	$6.276x10^{-3}$	45.43	49.722	$1.81x10^{-4}$	73.64
	10	10.06	$4.140x10^{-3}$	53.57	17.856	3.5388	37.00
	15	28.95	$6.961x10^{-4}$	83.87	28.342	$5.67x10^{-4}$	59.42
	20	14.37	$2.194x10^{-3}$	67.54	25.597	$7.51x10^{-4}$	56.51

Table 26 Impedance parameter for mild steel in 1 N HCl acid solution in the absence and presence of varied concentration of HI inhibitor

Aqueous extract of HI plants					Alcoholic extract of HI plants		
Parts of plant	**Conc. (v/v)**	**R_{ct} (ohm cm^2)**	**C_{dl}(μF/cm^2)**	**IE (%)**	**R_{ct} (ohm cm^2)**	**C_{dl} (μF/cm^2)**	**IE (%)**
Holoptelea Integrifolia **leaves**	Blank	8.935	$7.047 x10^{-3}$	*	20.70	$1.57x10^{-5}$	*
	5	22.734	$1.007 x10^{-3}$	60.66	42.90	$4.09x10^{-5}$	51.74
	10	34.009	$6.870 x10^{-4}$	64.99	52.40	$1.66x10^{-4}$	60.49
	15	65.453	$9.830 x10^{-5}$	86.42	54.50	$2.97x10^{-5}$	62.01
	20	31.098	$4.417 x10^{-4}$	71.03	57.60	$1.19x10^{-4}$	64.07
Holoptelea Integrifolia **barks**	Blank	9.295	$7.047 x10^{-3}$	*	20.70	$1.57x10^{-5}$	*
	5	49.123	$1.826 x10^{-4}$	59.11	49.71	$7.24x10^{-5}$	56.95
	10	7.803	$8.046 x10^{-3}$	60.36	62.62	$8.51x10^{-5}$	66.94
	15	27.188	$5.810 x10^{-3}$	50.99	75.34	$8.44x10^{-5}$	72.52
	20	22.421	$8.438 x10^{-4}$	73.90	83.97	$8.65x10^{-5}$	75.34
Holoptelea Integrifolia **flowers**	Blank	8.418	$7.315 x10^{-3}$	*	20.70	$1.57x10^{-5}$	*
	5	32.14	$4.231 x10^{-4}$	33.89	56.46	$2.50x10^{-4}$	63.33
	10	31.609	$4.56 x10^{-4}$	57.90	61.68	$1.26x10^{-4}$	66.43
	15	62.663	$1.170 x10^{-4}$	80.08	50.73	$7.41x10^{-5}$	59.19
	20	17.089	$1.670 x10^{-3}$	87.62	94.27	$7.40x10^{-5}$	79.10

(Continued)

Table 26 (Continued)

Holoptelea Integrifolia **seeds**	Blank	4.670	2.148 x10^{-2}	*	20.27	1.57x10^{-5}	*
	5	8.557	6.276 x10^{-3}	64.09	64.33	4.55x10^{-5}	67.82
	10	10.060	4.140 x10^{-3}	50.21	57.53	2.47x10^{-5}	64.76
	15	28.959	6.961 x10^{-4}	65.89	57.23	2.29x10^{-5}	64.58
	20	14.375	2.194 x10^{-4}	69.54	57.11	4.95x10^{-1}	64.57

Table 27 Impedance parameter for mild steel in 1 N HCl acid solution in the absence and presence of varied concentration of SS inhibitor

Aqueous extract of SS plants					**Alcoholic extract of SS plants**		
Parts of SS plant	**Concentration (v/v)**	**R_{ct} (ohm cm^2)**	**C_{dl} (μF/cm^2)**	**IE (%)**	**R_{ct} (ohm cm^2)**	**C_{dl} (μF/cm^2)**	**IE (%)**
SS **leaves**	Blank	41.763	8.312 x10^{-3}	*	20.70	1.5x10^{-5}	*
	5	69.669	8.094 x10^{-3}	15.85	35.60	4.6x10^{-5}	41.85
	10	78.871	8.714 x10^{-3}	32.27	45.23	6.1x10^{-1}	54.23
	15	97.652	7.974 x10^{-3}	47.33	64.90	4.6x10^{-5}	68.10
	20	145.091	7.185 x10^{-3}	71.43	72.46	3.0x10^{-5}	71.43
SS **Barks**	Blank	05.574	1.817 x10^{-2}	*	20.70	1.5x10^{-5}	*
	5	13.318	2.470 x10^{-3}	50.29	38.30	5.4x10^{-5}	45.95
	10	27..068	5.995 x10^{-4}	64.70	44.30	5.9x10^{-4}	53.27
	15	32.740	4.139 x10^{-4}	53.94	95.96	5.3x10^{-5}	78.42
	20	38.276	2.917 x10^{-4}	69.85	65.90	1.0x10^{-5}	68.58
SS **Fruits**	Blank	07.642	6.763 x10^{-3}	*	20.70	1.5x10^{-5}	*
	5	21.239	9.549 x10^{-4}	60.19	36.30	1.8x10^{-5}	42.97
	10	22.006	8.723 x10^{-4}	72.00	46.90	1.8x10^{-5}	55.86
	15	15.465	1.241 x10^{-3}	74.63	94.10	1.1x10^{-5}	78.00
	20	31.034	4.487 x10^{-4}	86.78	121.10	1.0x10^{-5}	82.90
SS **Seeds**	Blank	06.384	1.162 x10^{-3}	*	20.70	1.5x10^{-5}	*
	5	36.672	3.183 x10^{-4}	68.11	39.00	1.4x10^{-7}	50.51
	10	31.751	4.246 x10^{-4}	39.93	56.90	1.2x10^{-5}	63.62
	15	42.888	2.358 x10^{-4}	70.58	80.90	2.9x10^{-5}	74.41
	20	72.732	8.604 x10^{-5}	49.56	87.90	5.0x10^{-7}	76.45

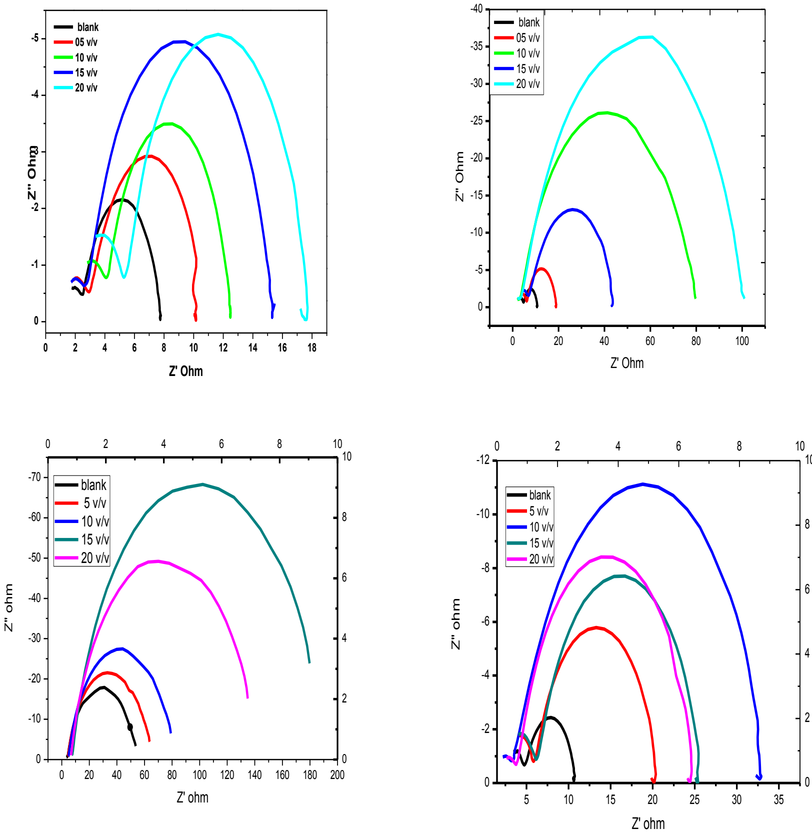


Fig. 51 Nyquist plots for mild steel in 1N HCl acid solution without and with presence of different concentration of Madhuca Longifolia (aqueous) extract of (a) leaves (b) bark (c) fruits (d) seeds

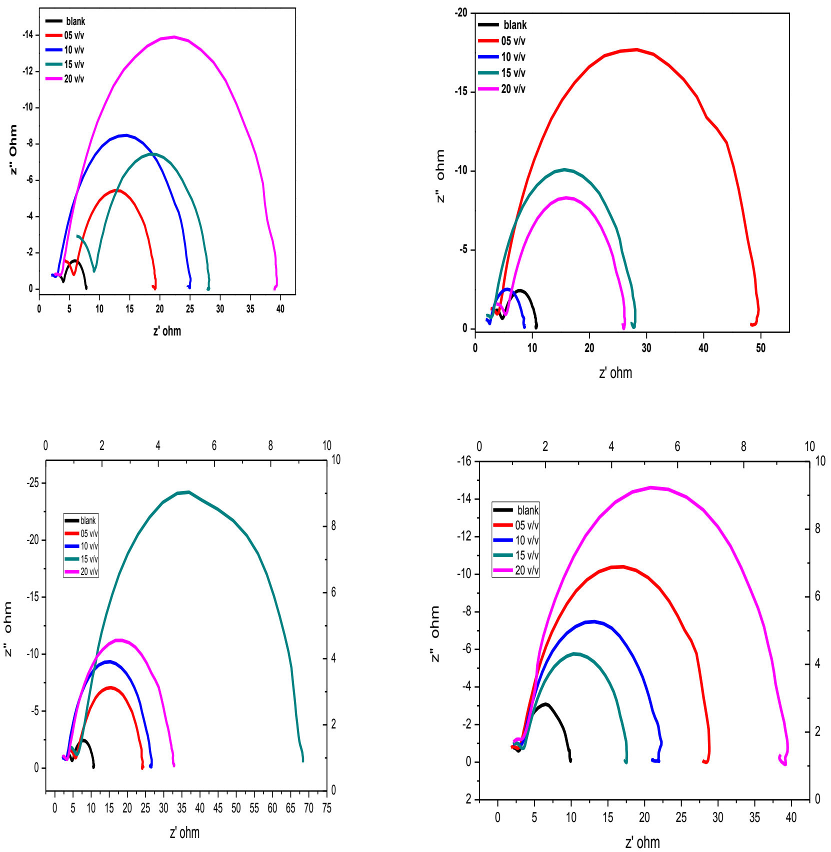


Fig. 52 Nyquist plots for mild steel in 1N HCl acid solution without and with presence of different concentration of Gloriosa superba linn (aqueous) extract of (a) leaves (b) stems (c) flowers (d) tubers

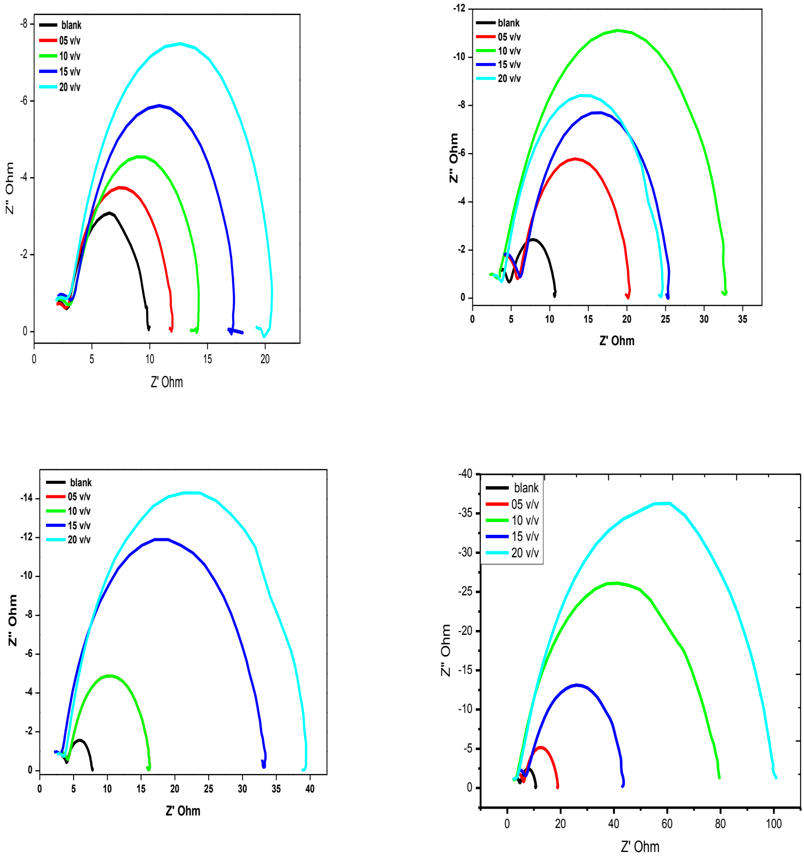


Fig. 53 Nyquist plots for mild steel in 1N HCl acid solution without and with presence of different concentration of PD (aqueous) extract of (a) leaves (b) bark (c) fruits (d) seeds

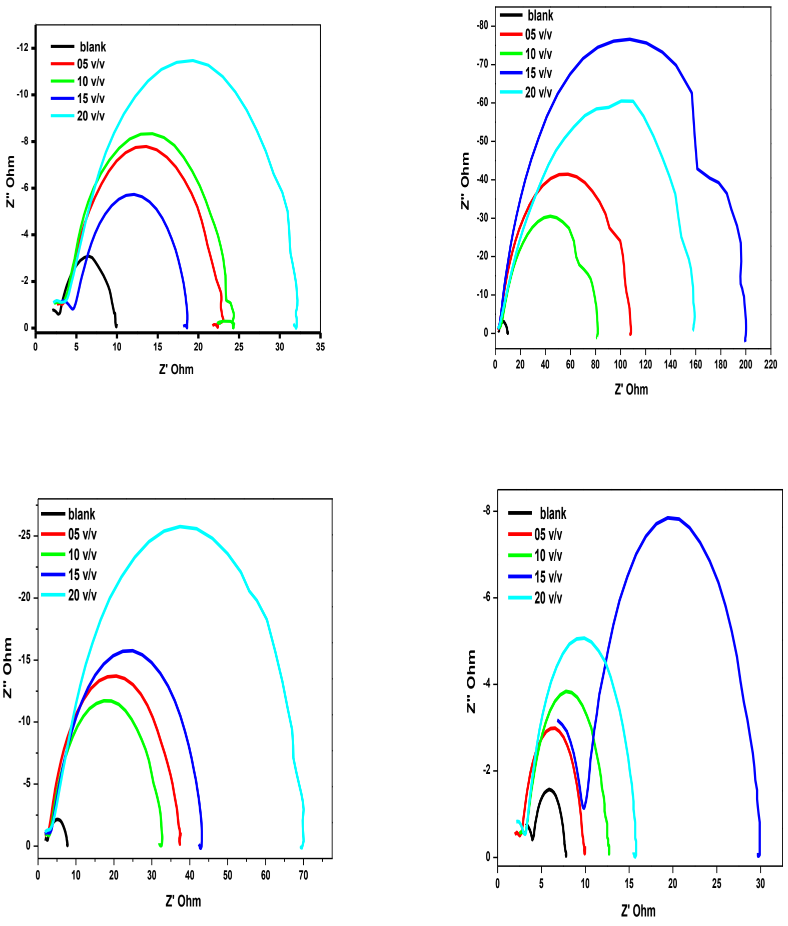


Fig. 54 Nyquist plots for mild steel in 1N HCl acid solution without and with presence of different concentration of Alangium lamarckiii (aqueous) extract of (a) leaves (b) bark (c) fruits (d) seeds

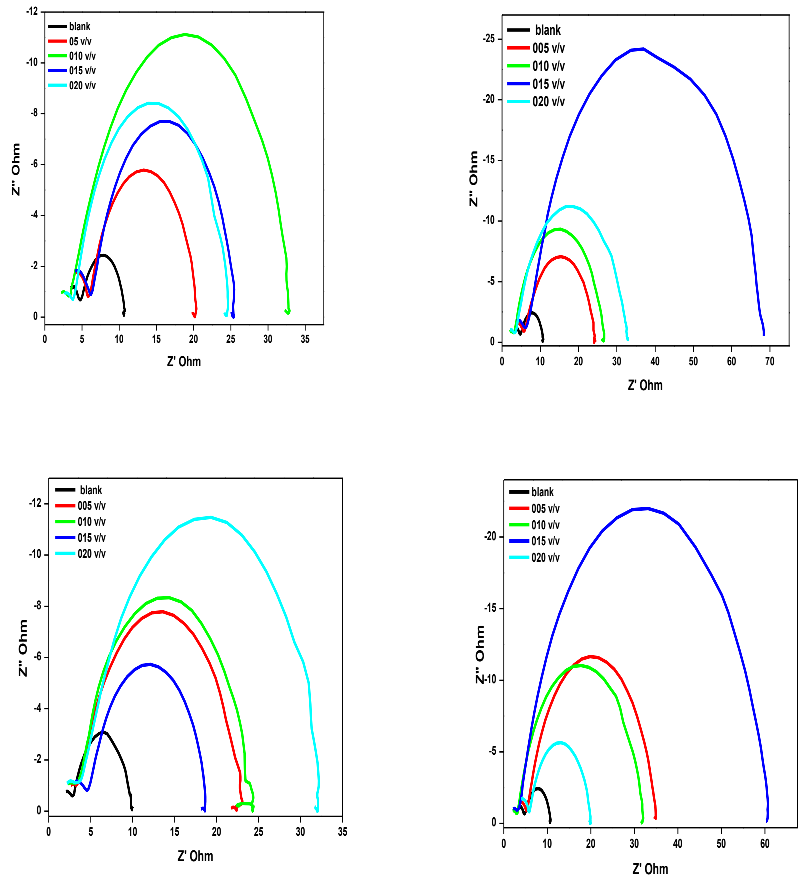


Fig. 55 Nyquist plots for mild steel in 1N HCl acid solution without and with presence of different concentration of HI (aqueous) extract of (a) leaves (b) bark (c) flowers (d) seeds

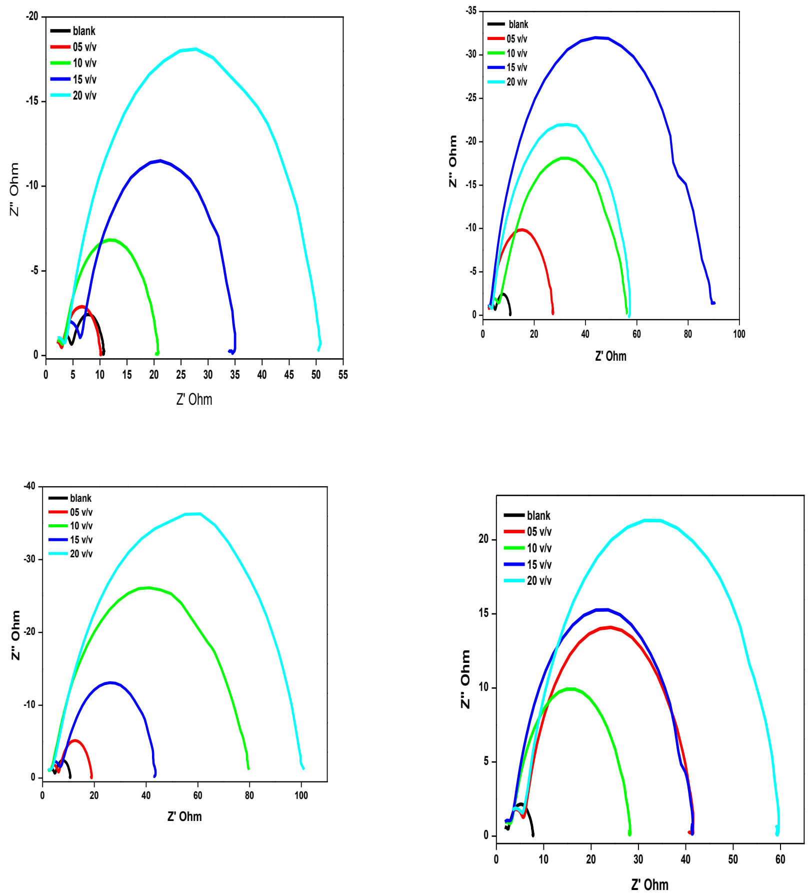


Fig. 56 Nyquist plots for mild steel in 1N HCl acid solution without and with presence of different concentration of SS (aqueous) extract of (a) leaves (b) bark (c) fruits (d) seeds

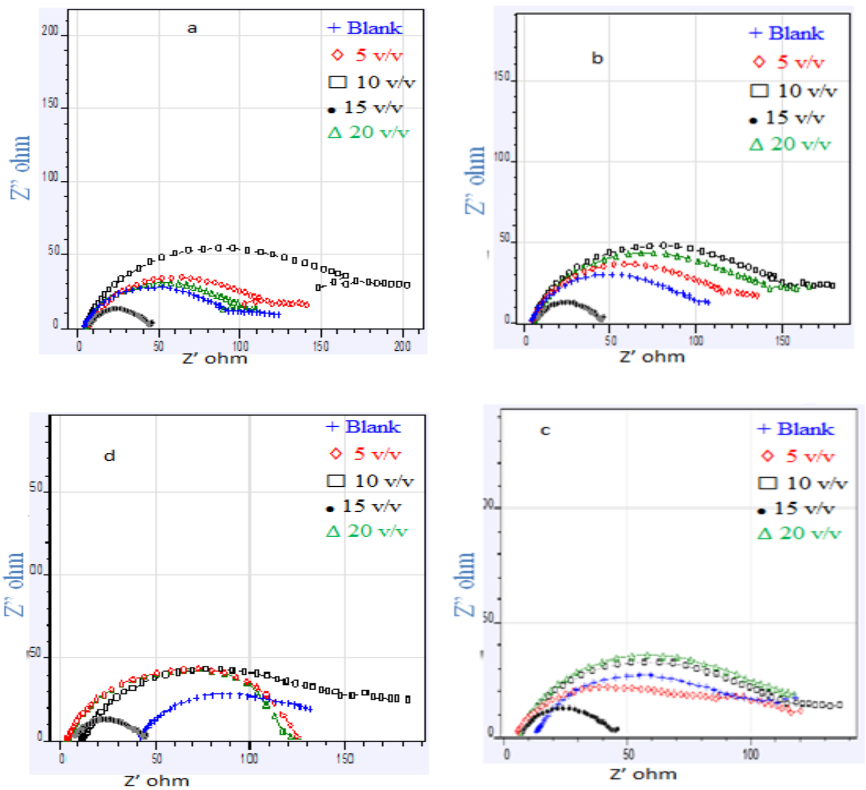


Fig. 57 Nyquist plots for mild steel in 1N HCl acid solution without and with presence of different concentration of Madhuca Longifolia (alcoholic) extract of (a) leaves (b) bark (c) fruits (d) seed peels

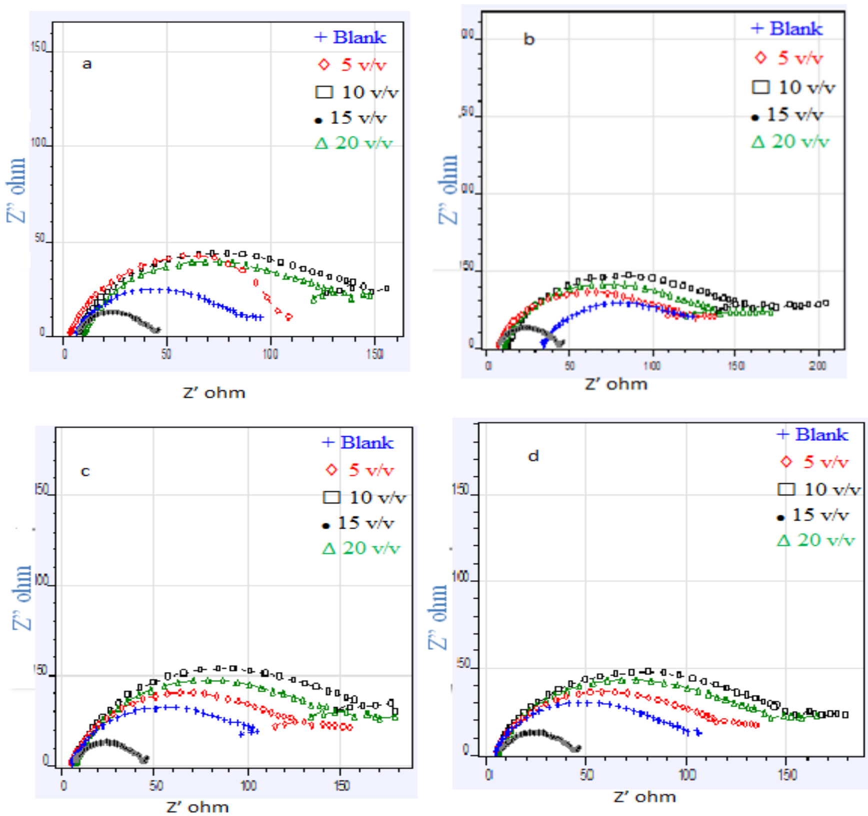


Fig. 58 Nyquist plots for mild steel in 1N HCl acid solution without and with presence of different concentration of Gloriosa superba linn (alcoholic) extract of (a) leaves (b) stems (c) flowers (d) tubers

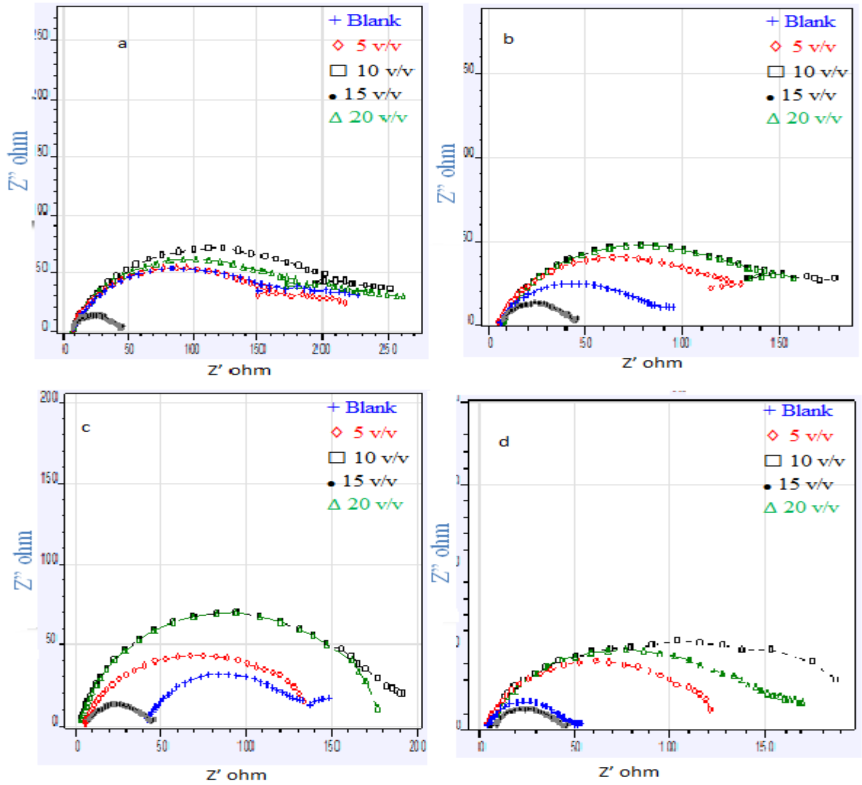


Fig. 59 Nyquist plots for mild steel in 1N HCl acid solution without and with presence of different concentration of PD (alcoholic) extract of (a) leaves (b) bark (c) fruits (d) seeds.

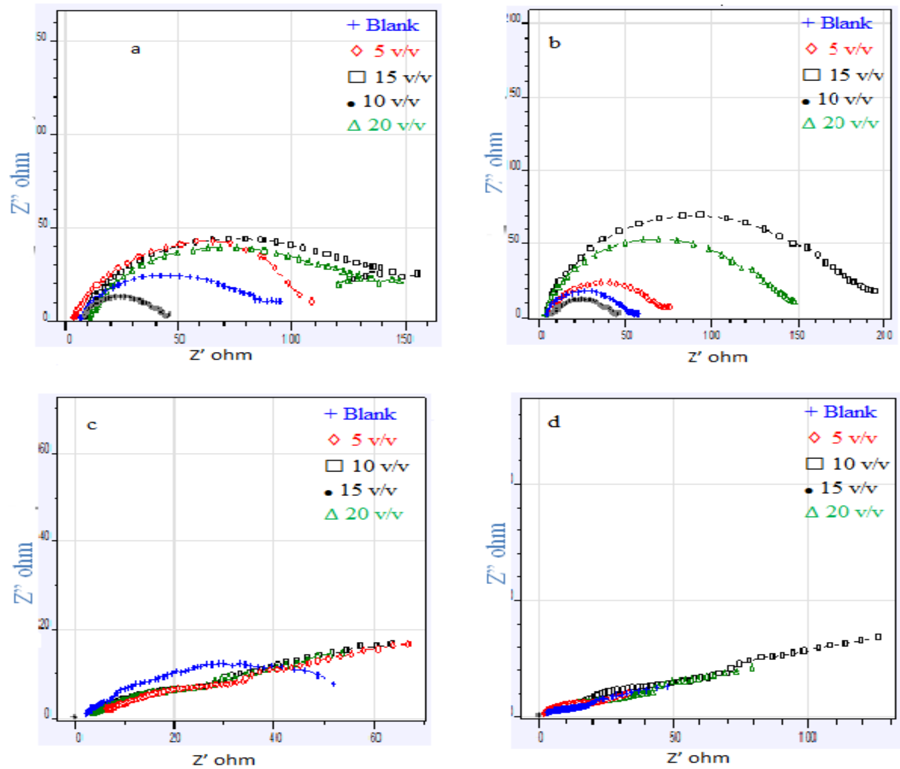


Fig. 60 Nyquist plots for mild steel in 1N HCl acid solution without and with presence of different concentration of Alangium lamarckiii (alcoholic) extract of (a) leaves (b) bark (c) fruits (d) seeds

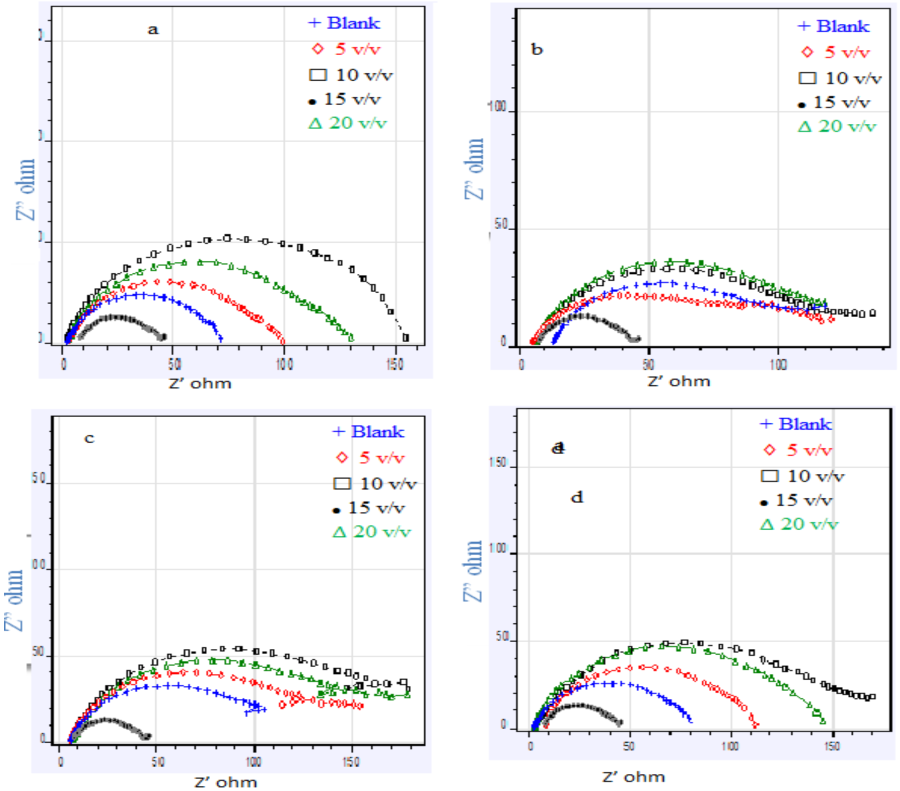


Fig. 61 Nyquist plots for mild steel in 1N HCl acid solution without and with presence of different concentration of HI (alcoholic) extract of (a) leaves (b) bark (c) flowers (d) seeds.

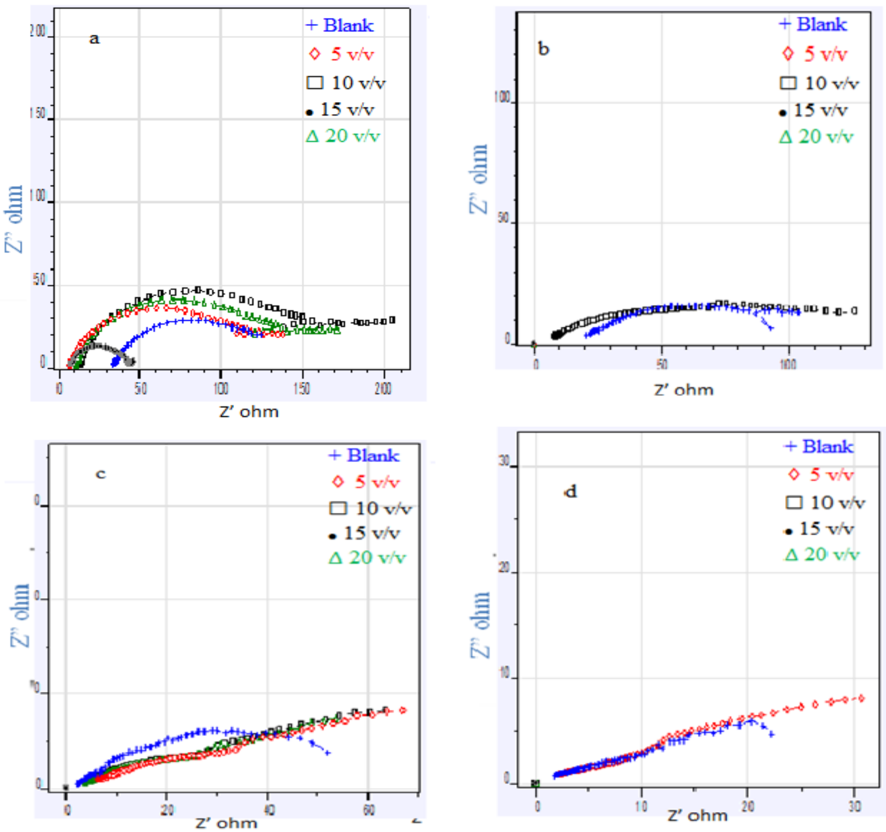


Fig. 62 Nyquist plots for mild steel in 1N HCl acid solution without and with presence of different concentration of SS (alcoholic) extract of (a) leaves (b) bark (c) fruits (d) seeds.

5.5 Bode plots

Bode plots (***Figures 63 – 74)*** shows resistive region at high frequencies and capacitive region at intermediate frequencies but do not show a clear resistive region (horizontal line and a phase angle = 0°) at low frequencies. It is reported in literature that the capacitor phase angle and slope value should be ***-90°*** and -1 respectively ***[567].*** These plots showed two overlapped phase maxima at low frequencies. In the bode plot, the impedance is plotted with log of frequencies on the X axis and both the log of absolute value of ***the impedance and the phase shift*** on the Y-axis. Unlike the Nyquist plot, the ***phase angle does not reach 90°*** as it is for pure capacitive impedance.

In the bode plot at the highest frequencies, log (R_s+R_{ct}) appears as a horizontal plateau.However, in our present case deviation occured from ideal capacitive behavior. This deviation from the ideality is due to the rough electrode surface. This roughness on the electrode surface is due to accumulation of corrosion products (rust and scale) on the mild steel surface in the acid solution. From the bode plots of the both extract it is ***depicted that the phase angle remarkably increased in the presence of inhibitor suggesting that the MS surface*** was less corroded in the presence of inhibitor because the inhibitor form a ***superior protective film*** on ***MS*** surface in acid solution and protect free from acid corrosion. From these figure, it was found that the phase angle of the both (aqueous and alcoholic) inhibitor solution is around 50 - 60° respectively.

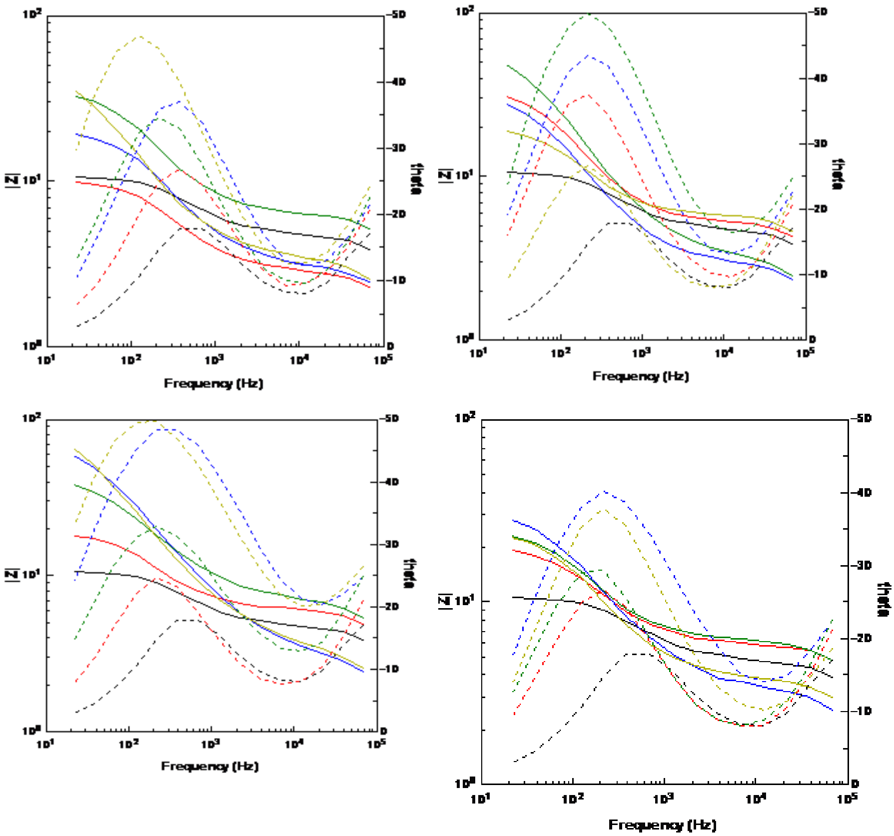


Fig. 63 Bode plots of mild steel in ML plant (aqueous extract)

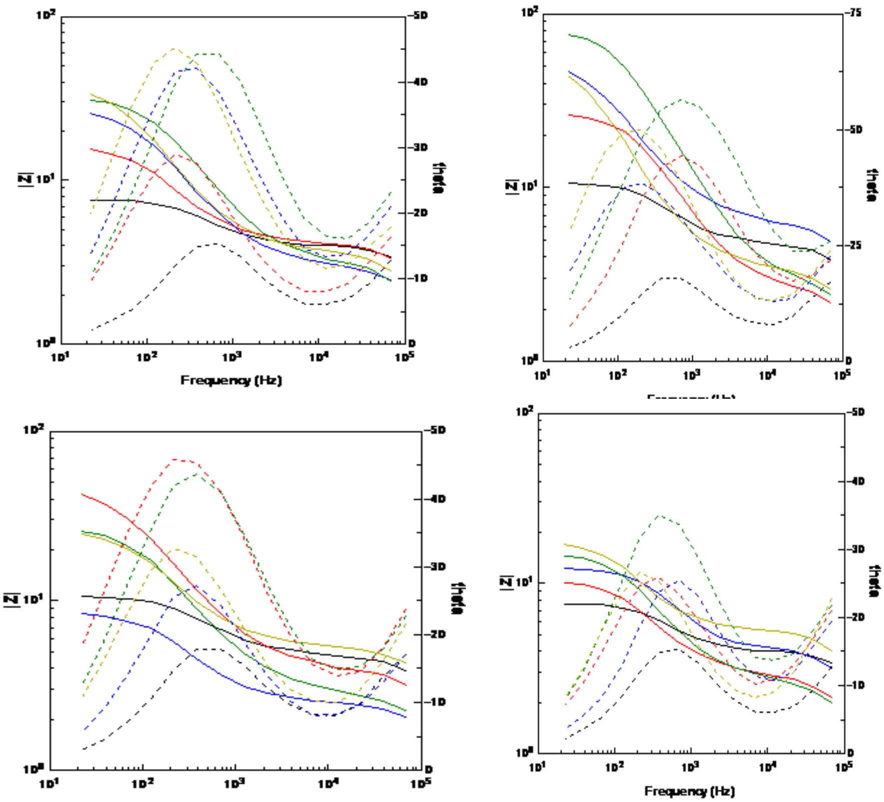


Fig. 64 Bode plots of mild steel in GSL plant (aqueous extract)

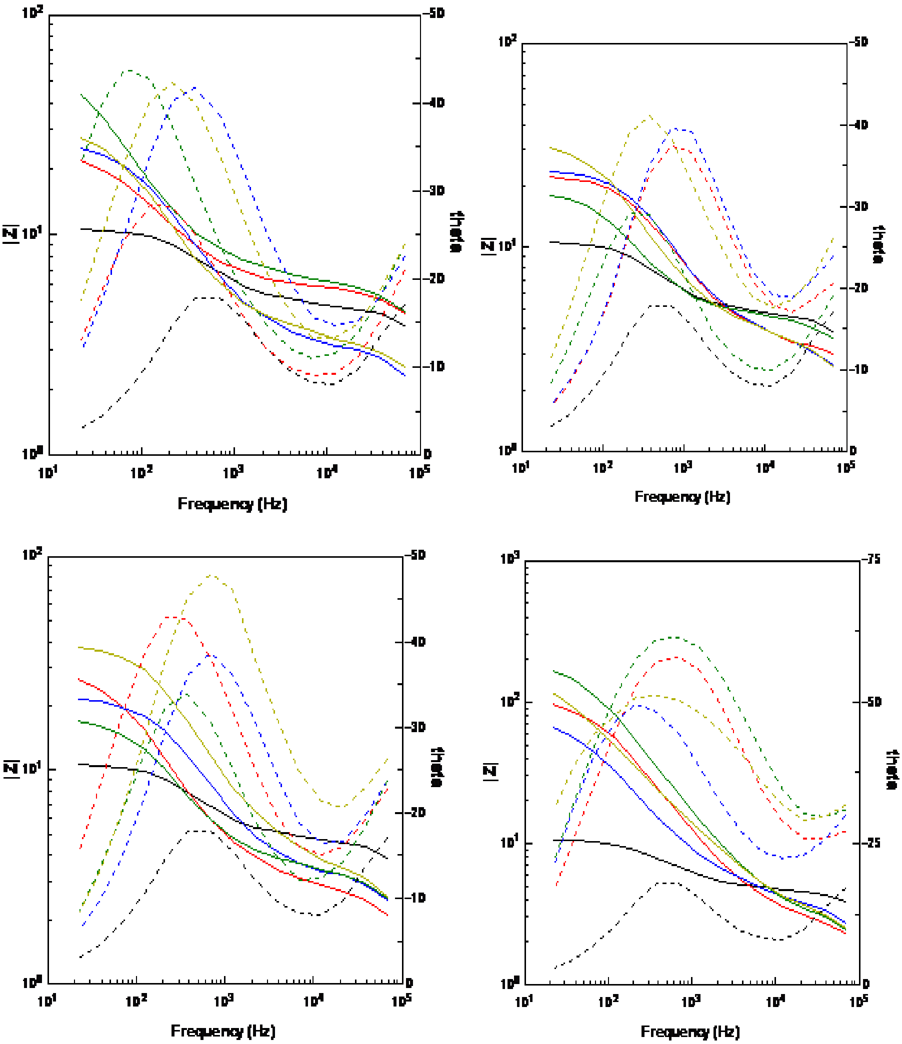


Fig. 65 Bode plots of mild steel in PD plant (aqueous extract)

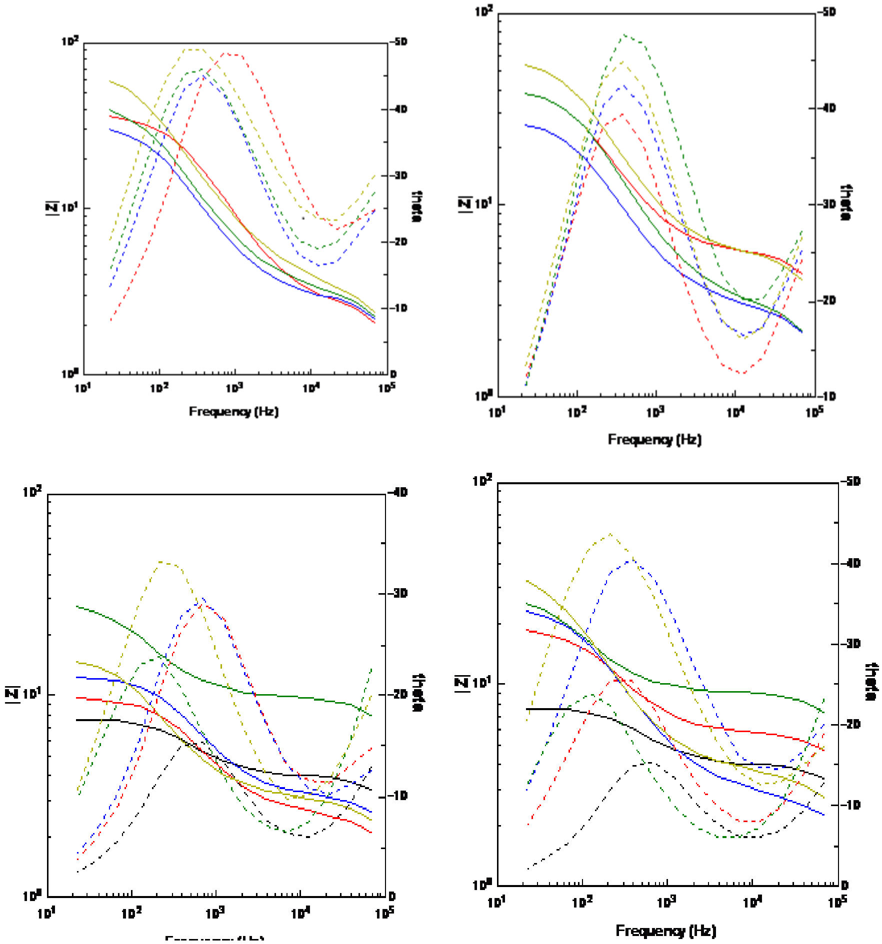


Fig. 66 Bode plots of mild steel in AL plant (aqueous extract)

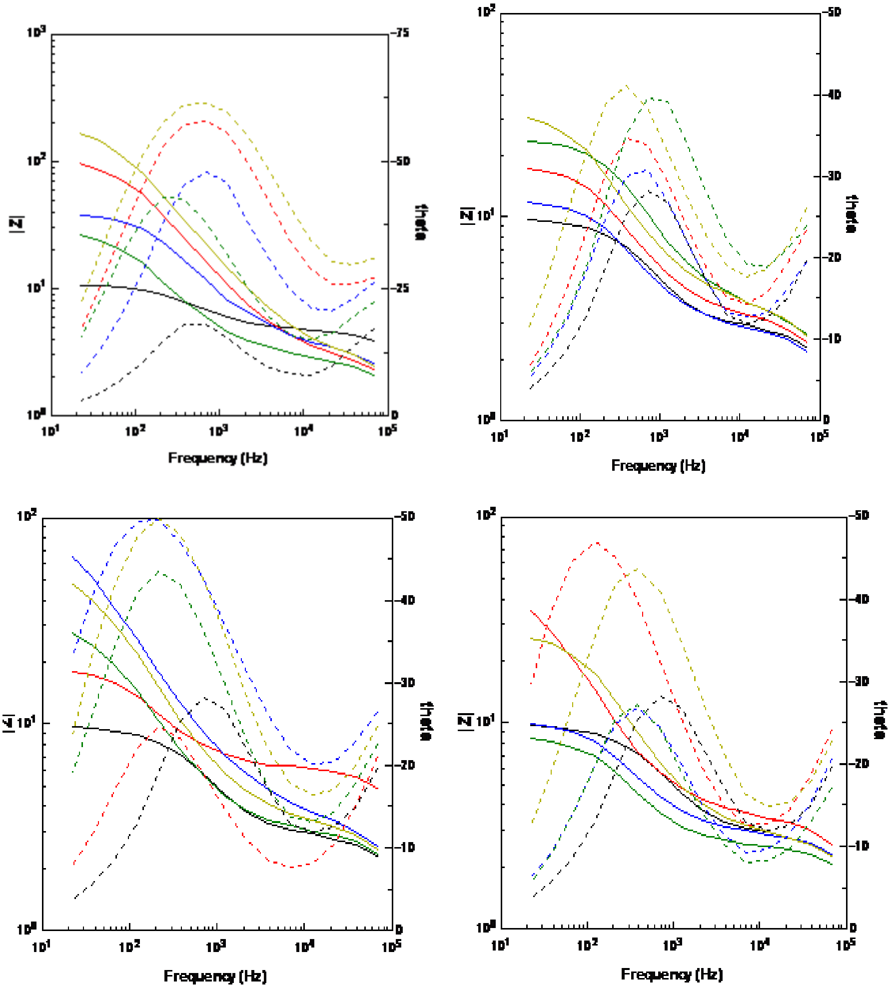


Fig. 67 Bode plots of mild steel in HI plant (aqueous extract)

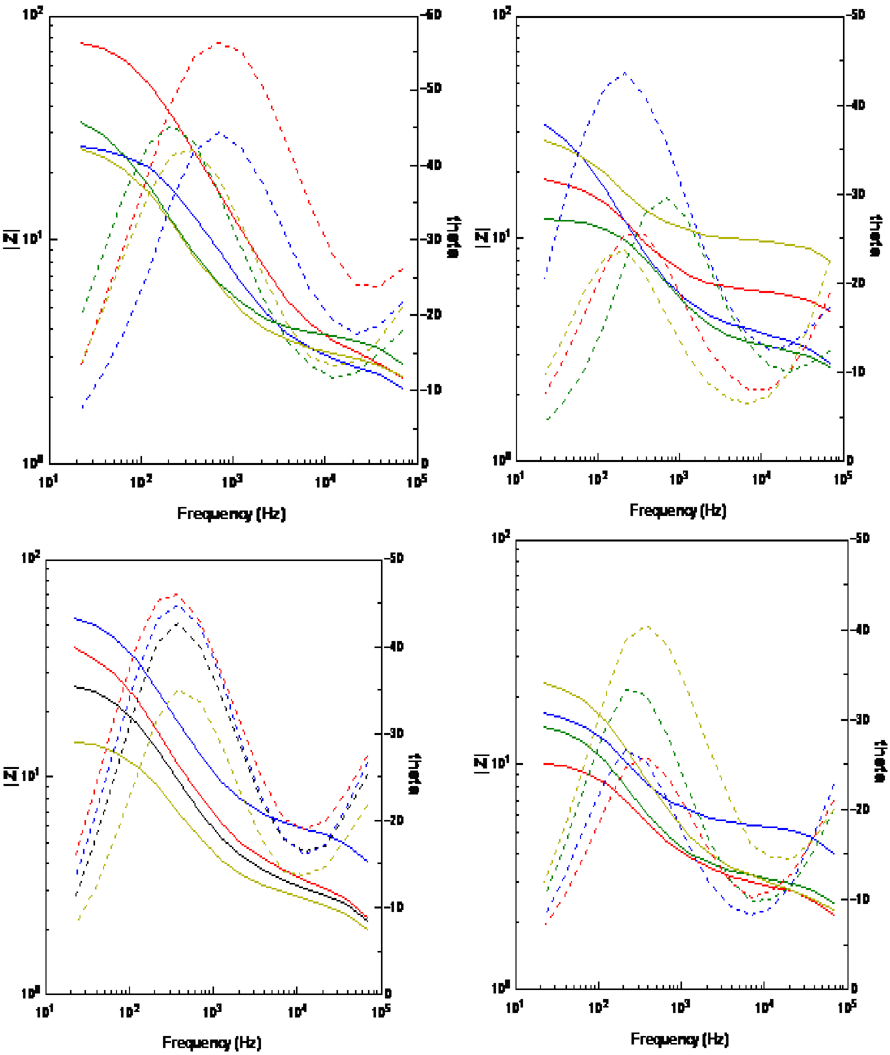


Fig. 68 Bode plots of mild steel in SS plant (aqueous extract)

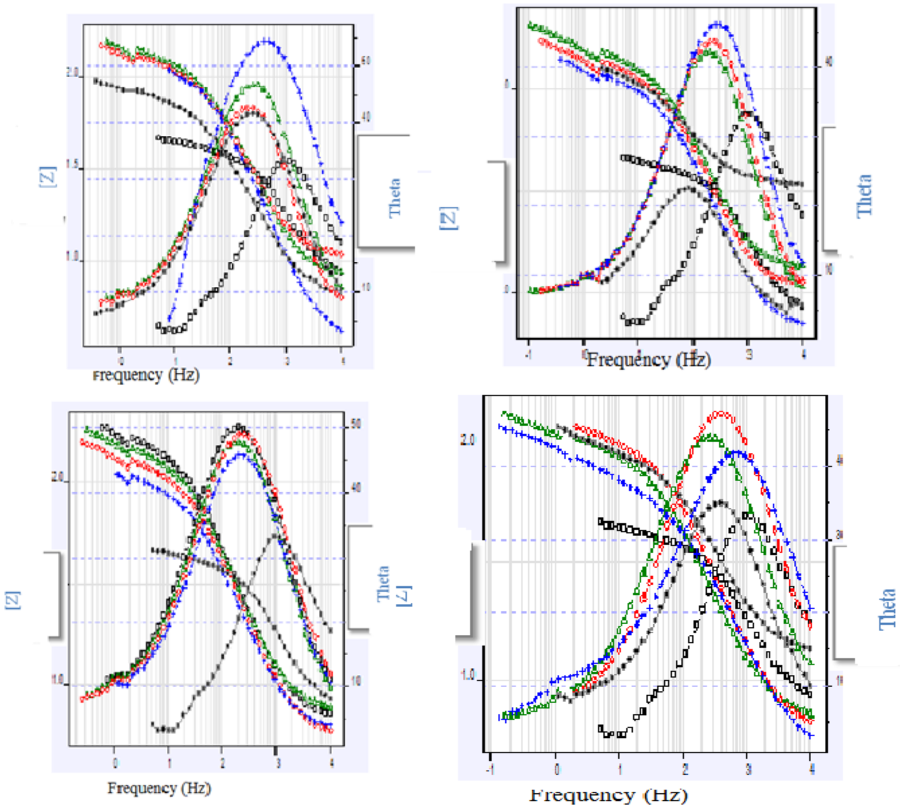


Fig. 69 Bode plots of mild steel in ML plant (alcoholic extract)

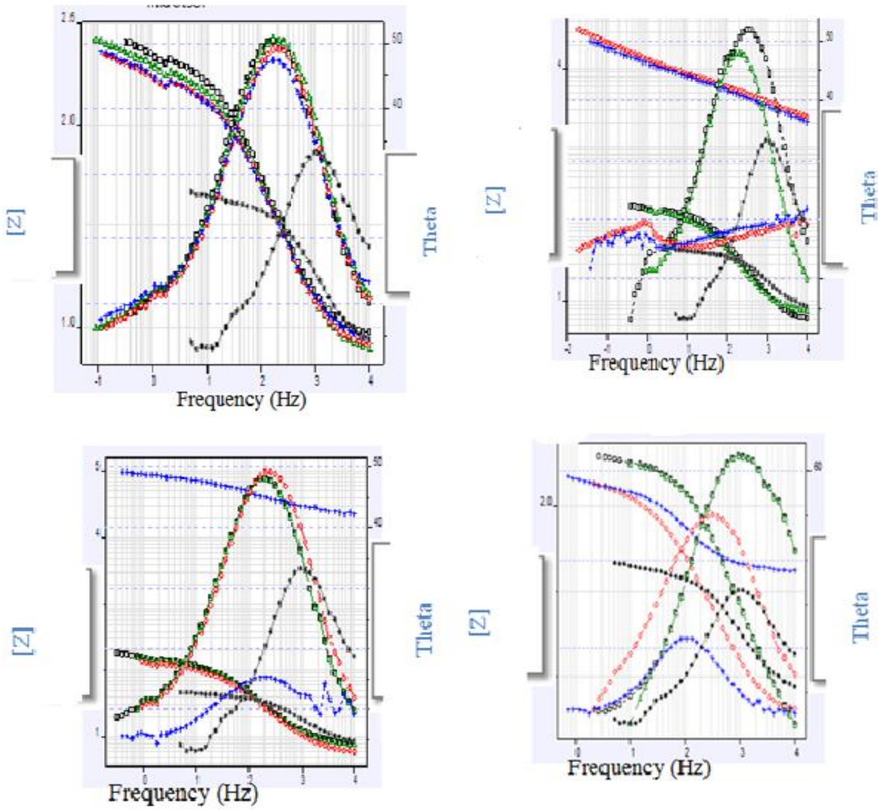


Fig. 70 Bode plots of mild steel in GSL plant (alcoholic extract)

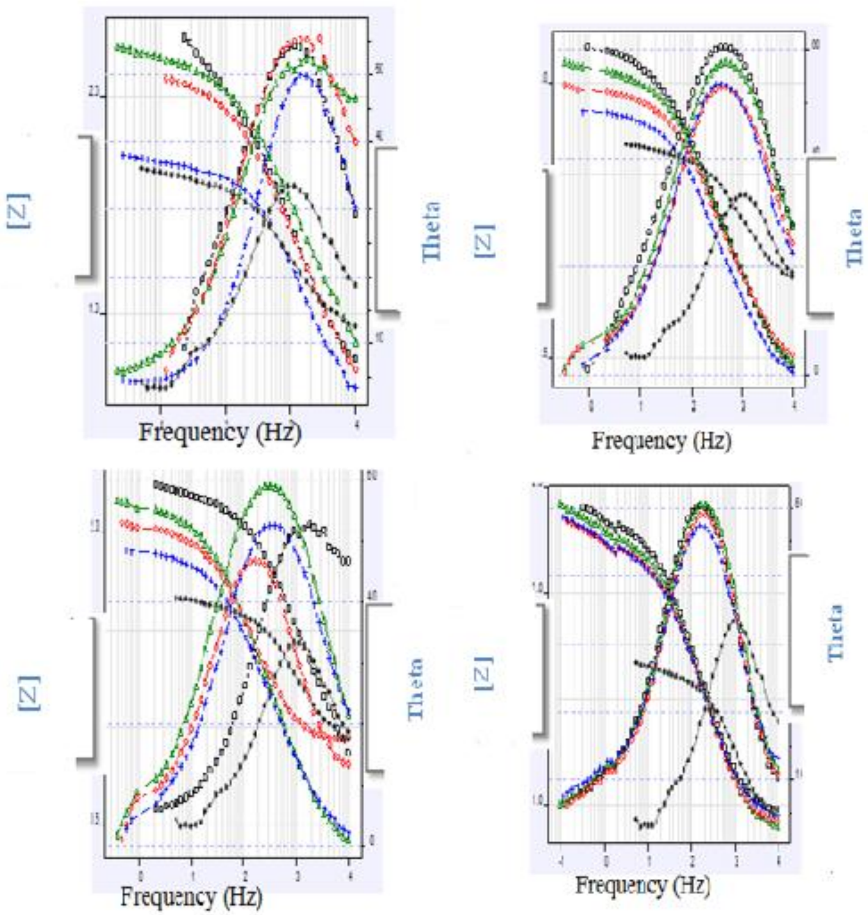


Fig. 71 Bode plots of mild steel in PD plant (alcoholic extract)

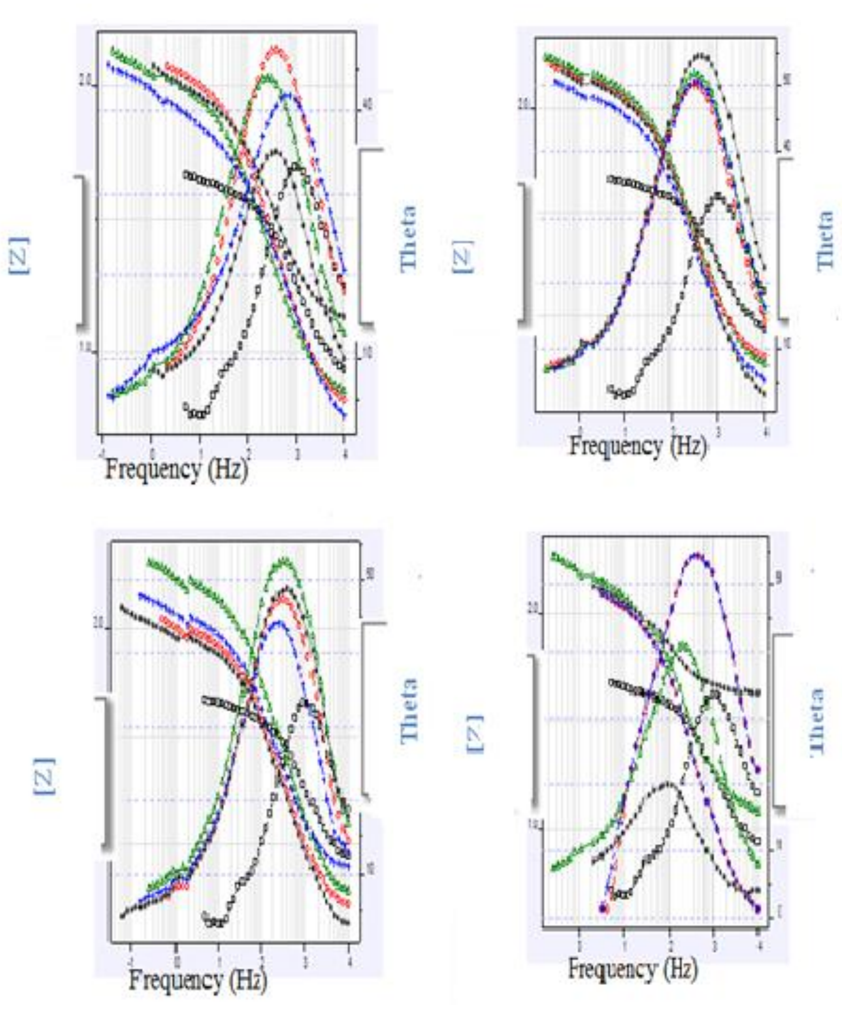


Fig. 72 Bode plots of mild steel in AL plant (alcoholic extract)

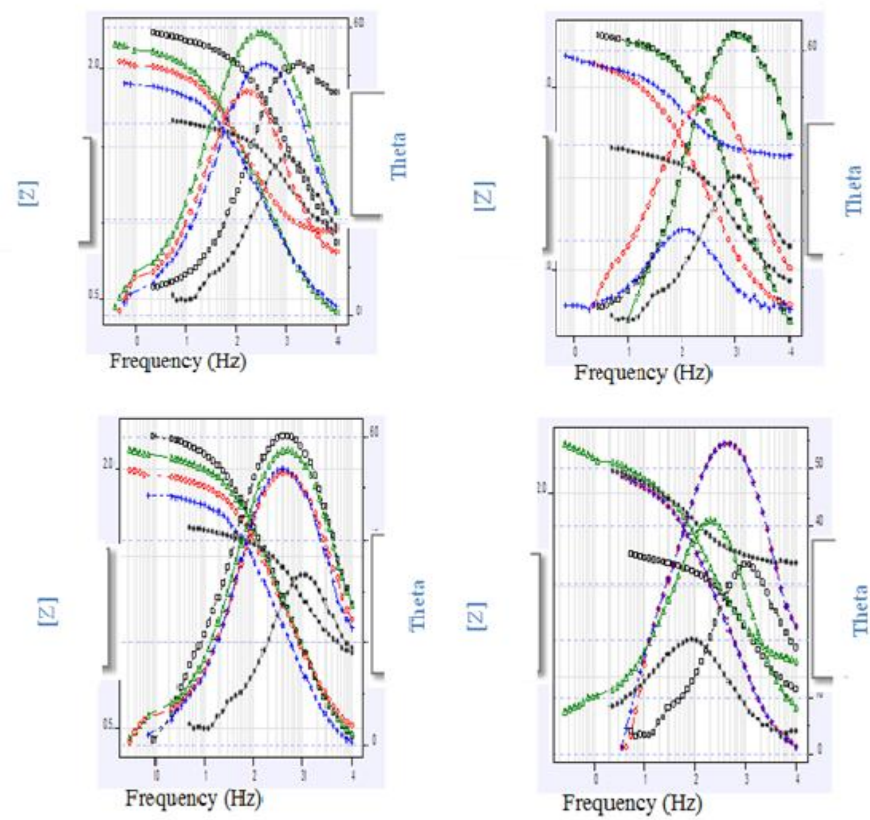


Fig. 73 Bode plots of mild steel in HI plant (alcoholic extract)

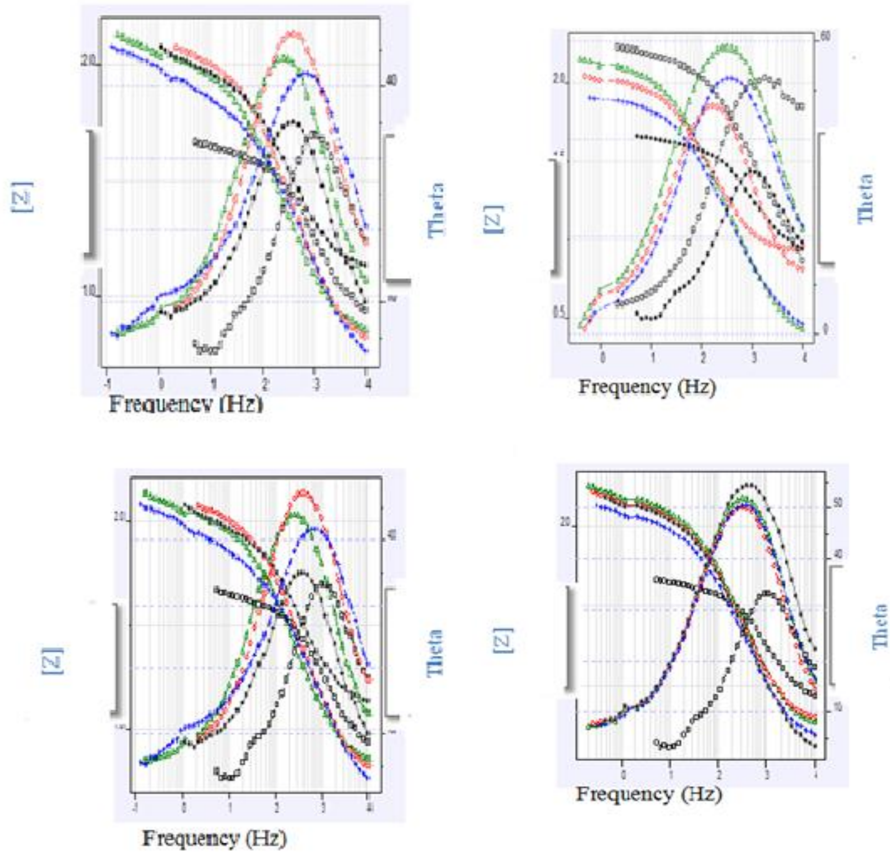


Fig. 74 Bode plots of mild steel in SS plant (alcoholic extract)

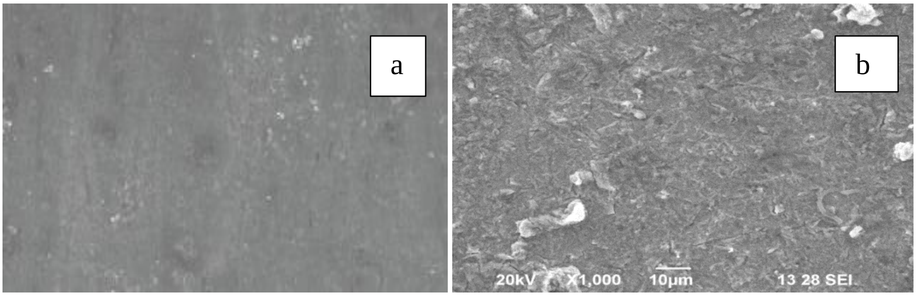
5.6 Surface Analysis & EDAX Measurement

It is well known, that the green inhibitor like plants contains numerous organic compounds. It is rather difficultly to understand the mechanism of inhibition for a cluster of different compounds. Present study in the plant extract investigation and observation of the mild steel specimen was carried out by using ***scanning electron microscope***. Figures ***75-86*** shows the SEM image of mild steel surface after immersed in 1N HCl in the absence and presence of selected aqueous and alcoholic extract of six plants ***(ML, GSL, PD, AL, HI, SS)*** for 24 hours. Examination of ***Fig. 75 a*** observed that the ***very strong corroded (pits and crack) and uneven (heavy damage) metal*** surface obtained when the metal was kept immersed in 1N HCl in the absence of inhibitor. In the presence of inhibitor (GSL plant aqueous) the metal surface shows (***Fig. 75 b – d) smoother (mild steel surface was covered with the protective layer***

formed by the inhibitor) with clearly different morphology (surface covered means no pits and cracks). But, in inhibited solution, the rate of corrosion is suppressed, as the electrode surface is nearly free from corrosion due to the adsorption of the inhibitor on the MS surface.

Examination of ***Figure 76 a*** showed ***very strong corroded (pits and crack) and uneven (heavy damage) metal*** surface obtained when the metal was kept immersed in 1N HCl in the absence of inhibitor confirms an attack of the aggressive medium on the mild steel surface. In the presence of inhibitor (GSL plant alcoholic) the metal surface shows (***Fig. 76 b – d) smoother (mild steel surface was covered with the protective layer formed by the inhibitor) with clearly different morphology (surface covered means no pits and cracks)***.

The goal of this section was to confirm the results obtained from chemical and electrochemical measurement that a protective surface film of inhibitor is formed on the electrode surface. The corresponding energy dispersive EDAX profile analysis is presented in ***Figures 77 - 86***. The EDAX survey spectra were used to determine which elements of extract components were exposure to acid solution and inhibitor treatment. It is noticed that the existence of the EDAX spectra in the sample exposed to the extract, could be attributed to the adsorption of organic molecules at the mild steel surface. The figure shows that the Fe peaks are considerably suppressed relative to the samples prepared in 1N HCl solution, and this suppression increases with increasing extract concentration and immersion time. The suppression of the Fe lines occurs because of the overlying extract film. These results have been confirmed by those from polarization measurement which suggest that a surface film inhibited the metal dissolution, and it has hence retarded the hydrogen evolution reaction. This surface film also increases the charge transfer resistance of the anodic dissolution of mild steel and down the corrosion rate. Therefore, EDAX examination of the electrode surface supports the results obtained from chemical and electrochemical methods that the plants extract is a good inhibitor for acid solution.



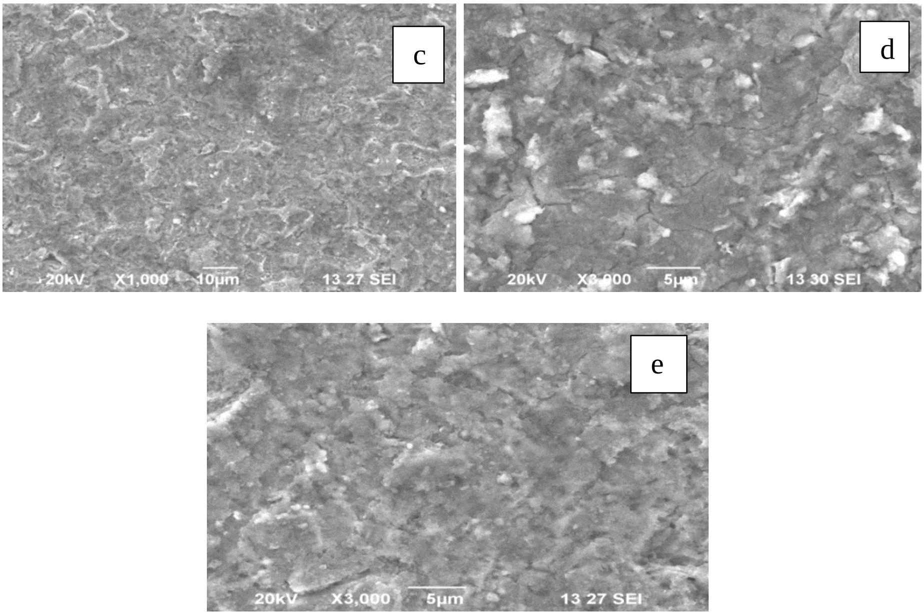
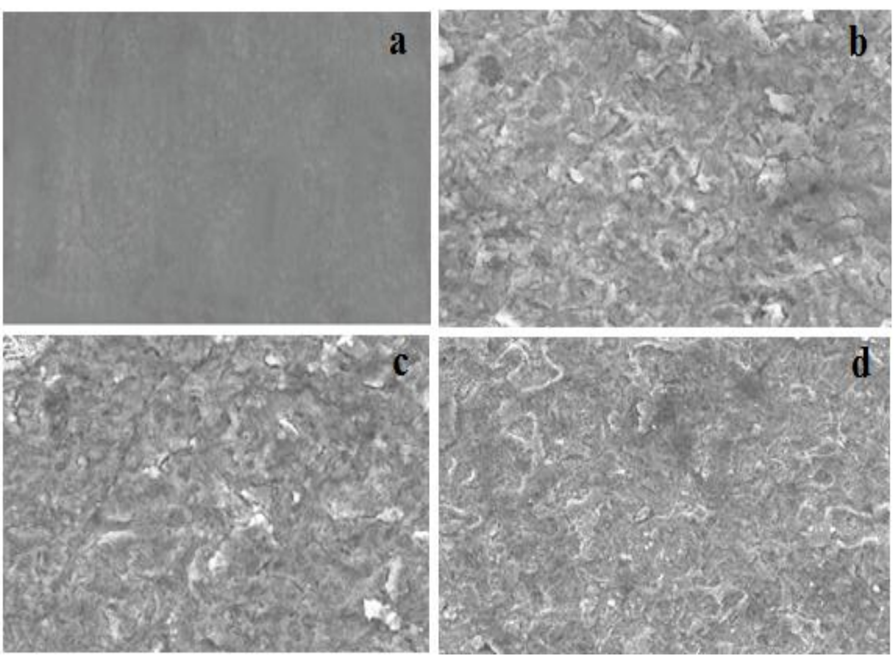


Fig. 75 SEM image of the surface of mild steel after immersion for 24 hours in 1N HCl solution (a) blank and (ii) in the presence of optimum concentration of the GSL plant aqueous extracts from (b) Stem, (c) Leaves, (d) Flowers and (e) Tubers.



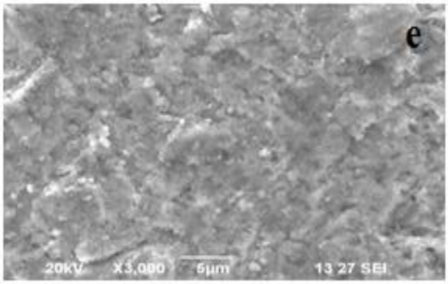


Fig. 76. SEM image of the surface of mild steel after immersion for 24 hours in 1N HCl solution (a) blank and (ii) in the presence of optimum concentration of the GSL plant alcoholic extracts from (b) Stem, (c) Leaves, (d) Flowers and (e) Tubers.

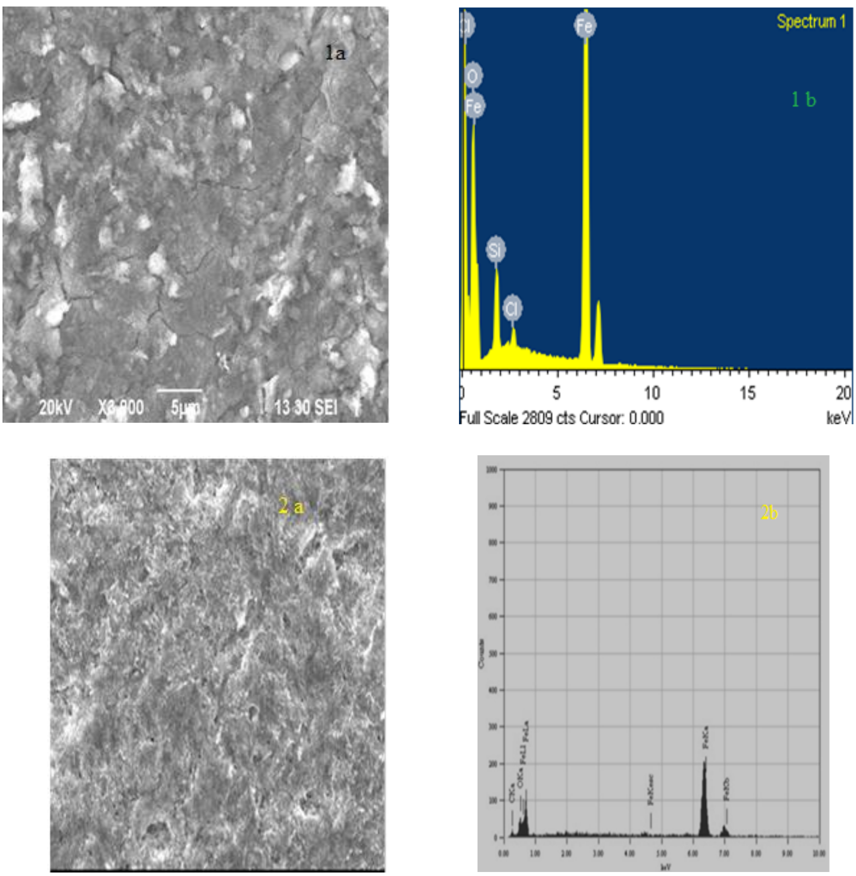


Fig. 77 SEM with EDAX image of MS in 1N HCl in presence of ML plant (aqueous & alcoholic) 1a and 1b for aqeous and 2a & 2b for alcoholic extract (leaves) at optimum concentration of inhibitor

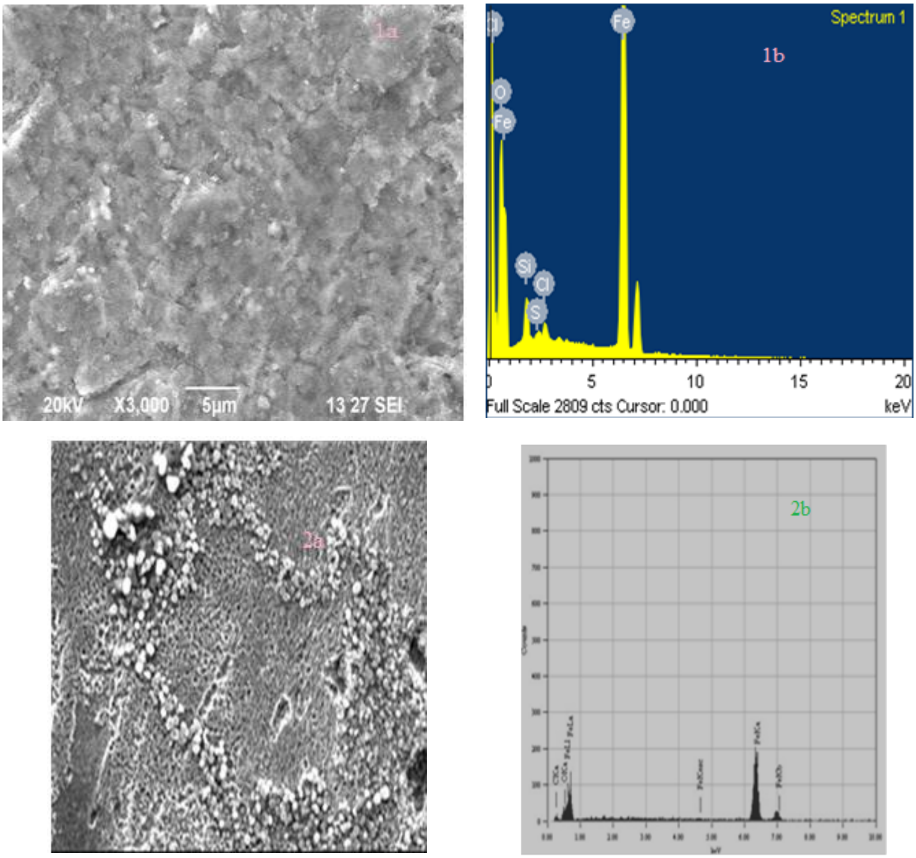
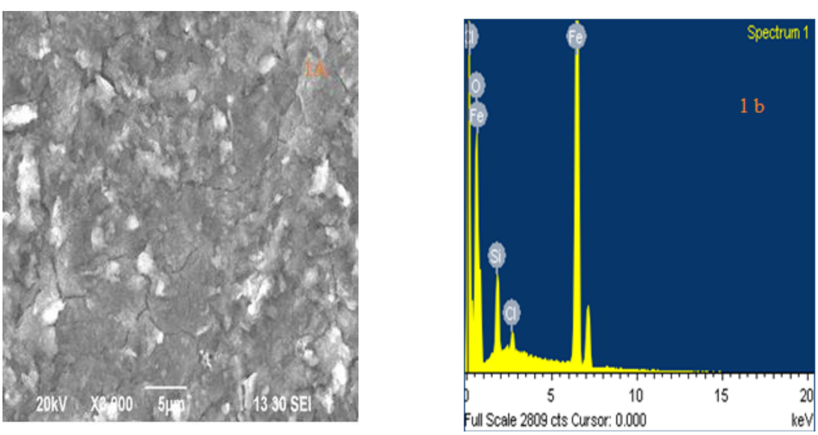


Fig. 78 SEM with EDAX image of MS in 1N HCl in presence of GSL plant (aqueous & alcoholic) 1a and 1b for aqeous and 2a & 2b for alcoholic extract (leaves) at optimum concentration of inhibitor



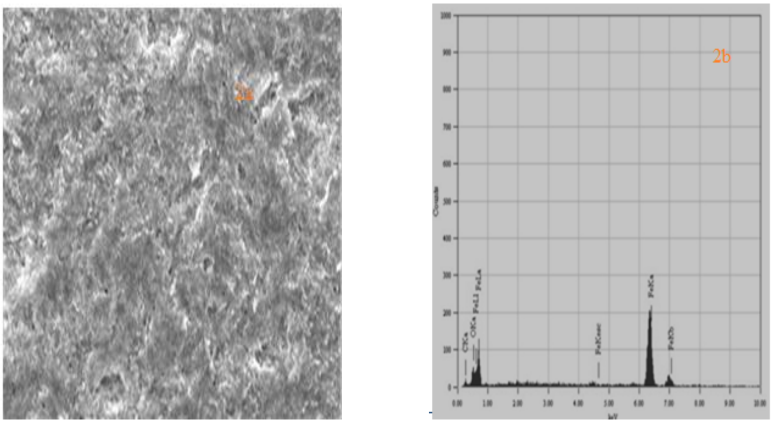


Fig. 79 SEM with EDAX image of MS in 1N HCl in presence of PD plant (aqueous & alcoholic) 1a and 1b for aqeous and 2a & 2b for alcoholic extract (leaves) at optimum concentration of inhibitor

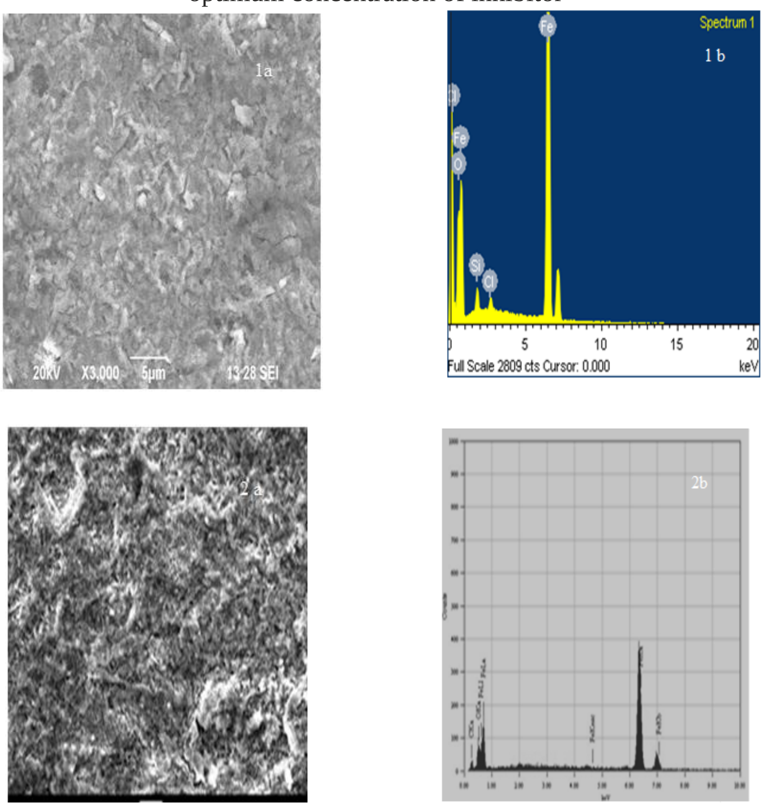


Fig. 80 SEM with EDAX image of MS in 1N HCl in presence of AL plant (aqueous & alcoholic) 1a and 1b for aqeous and 2a & 2b for alcoholic extract (leaves) at optimum concentration of inhibitor

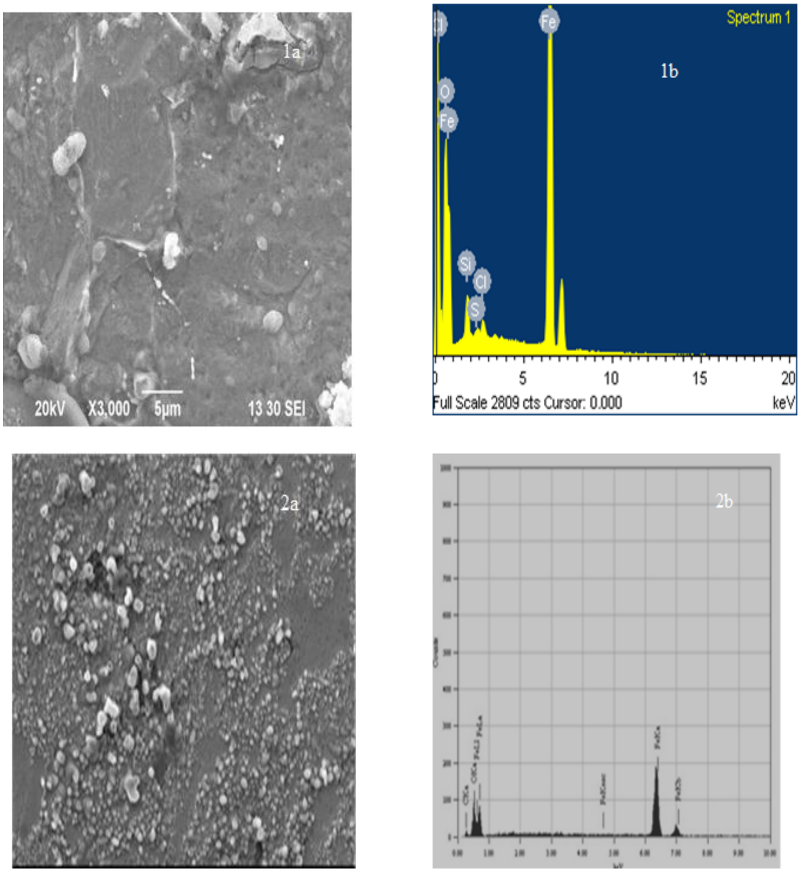
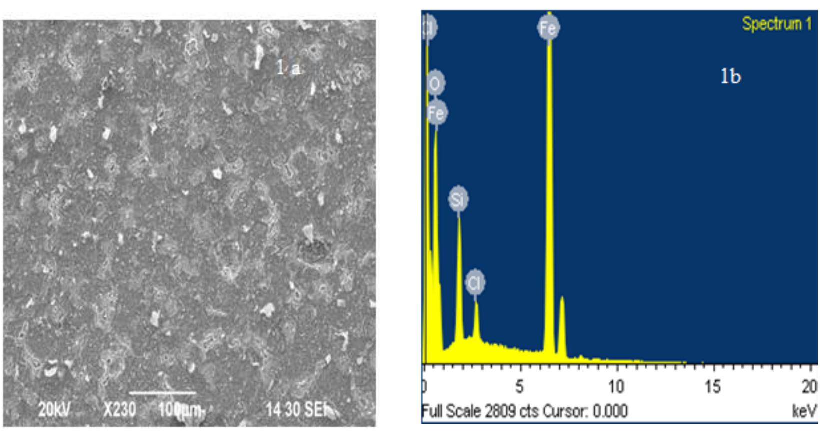


Fig. 81 SEM with EDAX image of MS in 1N HCl in presence of HI plant (aqueous & alcoholic) 1a and 1b for aqeous and 2a & 2b for alcoholic extract (leaves) at optimum concentration of inhibitor



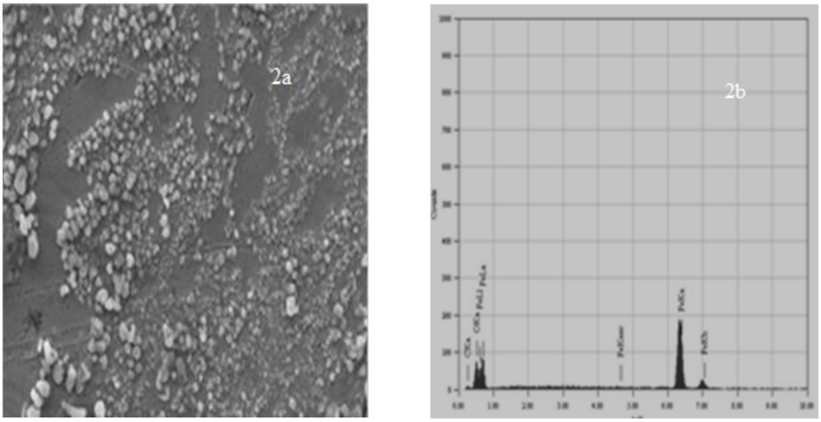


Fig. 82 SEM with EDAX image of MS in 1N HCl in presence of SS plant (aqueous & alcoholic) 1a and 1b for aqeous and 2a & 2b for alcoholic extract (leaves) at optimum concentration of inhibitor

5.7 Cyclic voltammetry measurement

Cyclic voltammetry experiments were carried out in conventional three electrode cell assembly. ***Figures 87 – 98*** shows the cyclic voltammograms of the mild steel specimens in HCl containing various concentrations of plant extracts. It showed that there are ***one anodic current peak and one cathodic peak in the blank solution***. The anodic dissolution of mild steel was occurred by reaction through which can find the first oxidation peak in the CV plots. Consequently, the second oxidation peak represents the process of mild steel to soluble Fe^{2+} by reaction. In reserve sweep, the corrosion product of mild steel can be partially reduced as described reaction. On the other hand the corrosion process would be restrained on a certain extent by the increase in film layer. Because of the competition of dissolution and adsorption of the film on mild steel, an anodic current humb appers in CV plots on the reverse sweep at about +1.4 V because the sweep rate is large enough the rate of the film dissolution is hardly compensated by the precipitation of corrosion products so that the anodic current hump becomes clear. Meanwhile, by increasing the inhibitor concentration the potential range of the second anodic peaks change to positive and the peaks gradually diminish. The result indicates that the plant extract is an effective inhibitor for mild steel.

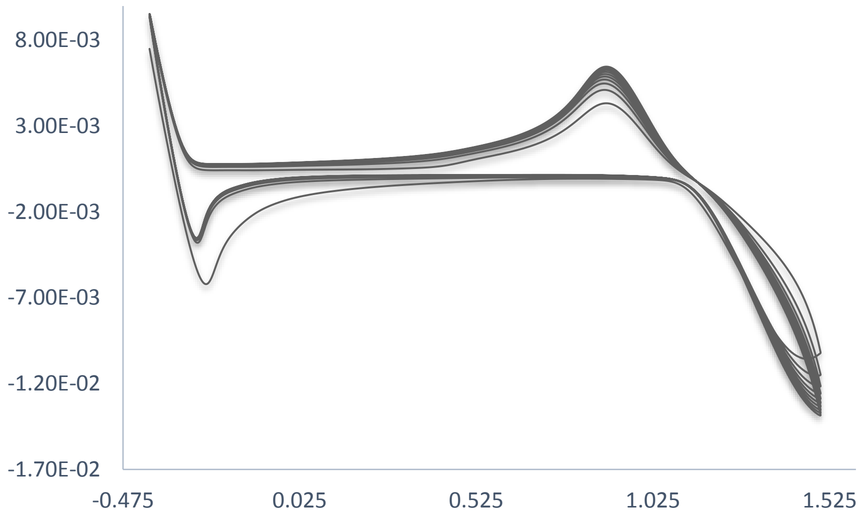


Fig. 83 Cyclic voltammetry of mild steel in 1N HCl in presence of ML plant (Leaves) aqueous extract at optimum concentration of inhibitor

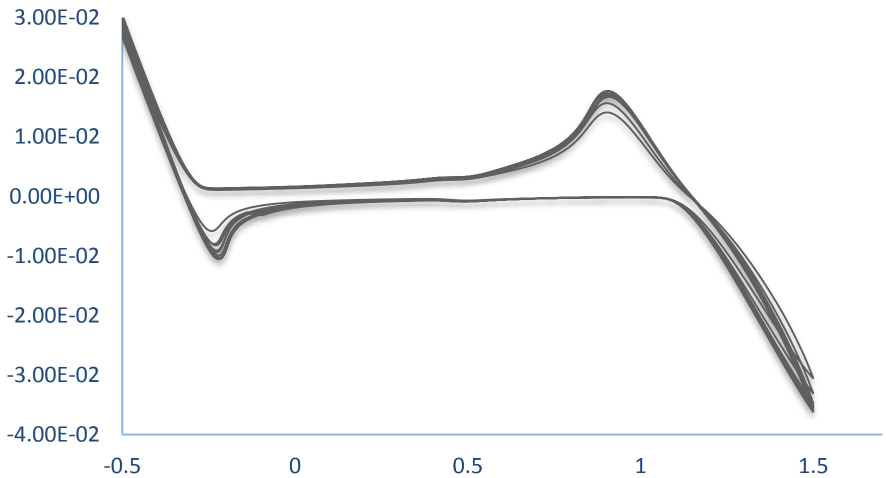


Fig. 84 Cyclic voltammetry of mild steel in 1N HCl in presence of ML plant (Leaves) alcoholic extract at optimum concentration of inhibitor

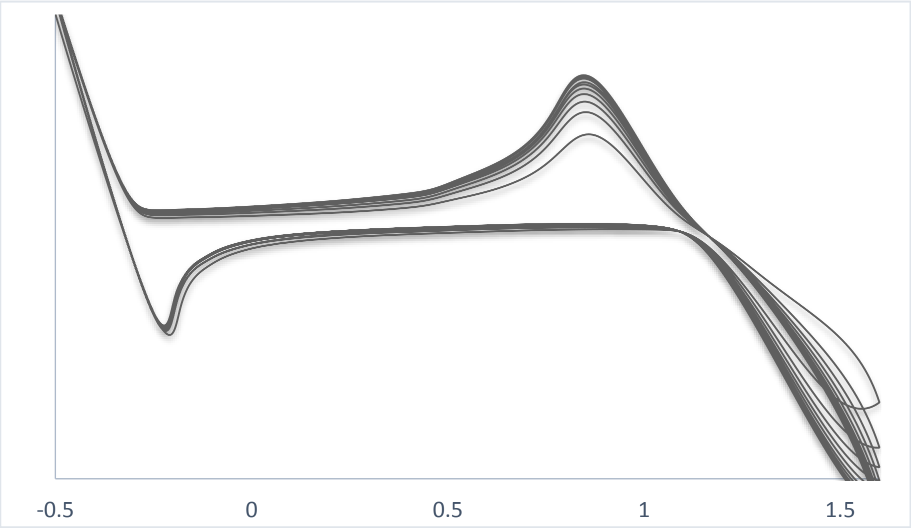


Fig. 85 Cyclic voltammetry of mild steel in 1N HCl in presence of GSL plant (Leaves) aqueous extract at optimum concentration of inhibitor

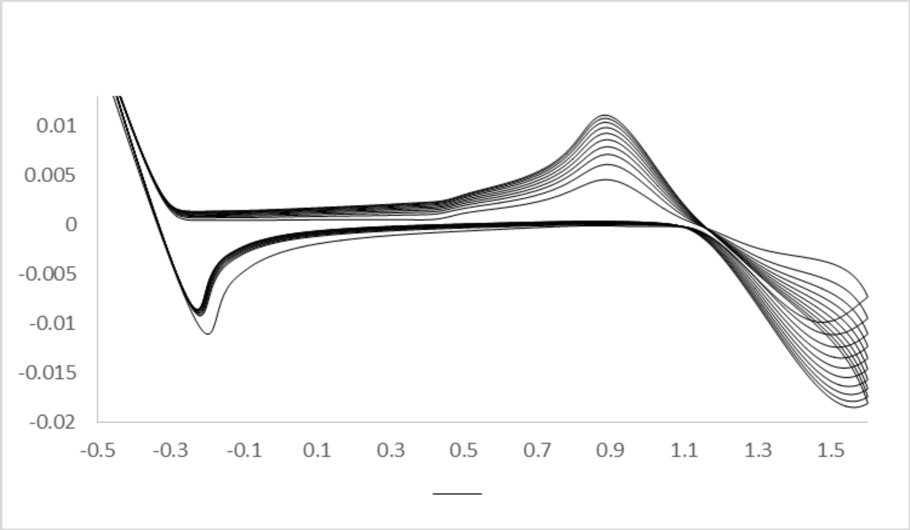


Fig. 86 Cyclic voltammetry of mild steel in 1N HCl in presence of GSL plant (Leaves) alcoholic extract at optimum concentration of inhibitor

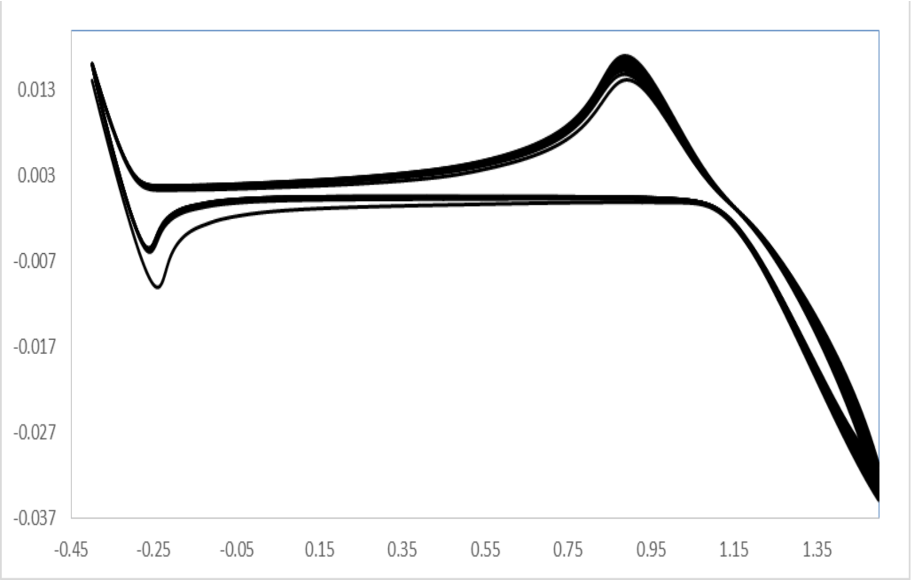


Fig. 87 Cyclic voltammetry of mild steel in 1N HCl in presence of PD plant (Leaves) aqueous extract at optimum concentration of inhibitor

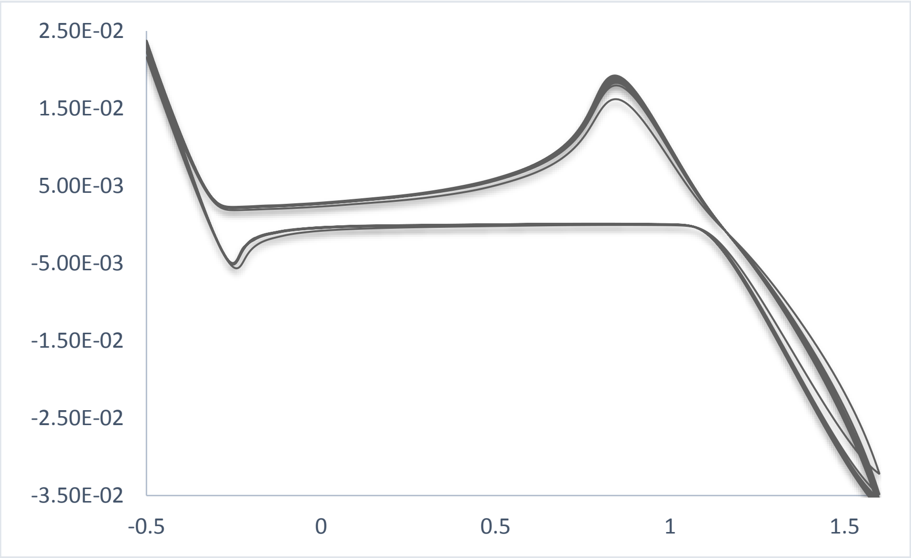


Fig. 88 Cyclic voltammetry of mild steel in 1N HCl in presence of PD plant (Leaves) alcoholic extract at optimum concentration of inhibitor

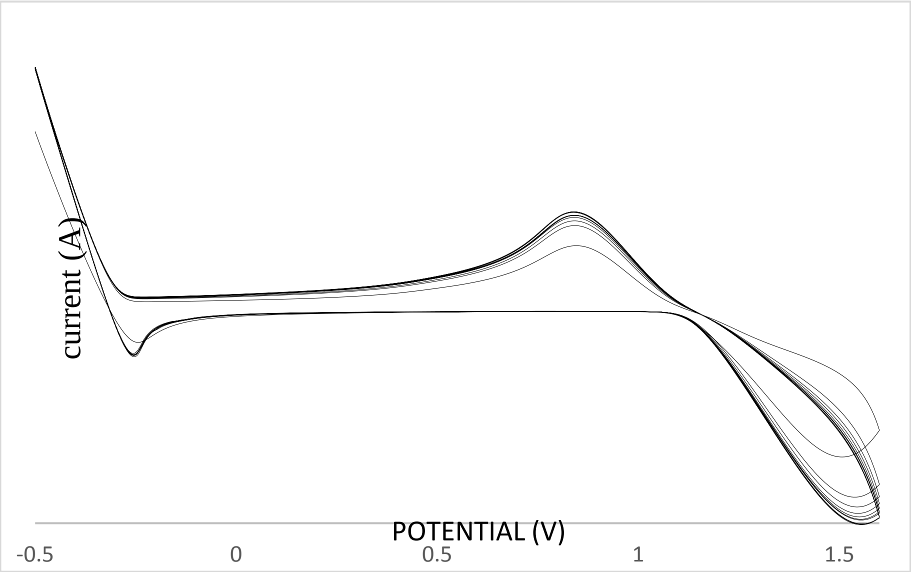


Fig. 89 Cyclic voltammetry of mild steel in 1N HCl in presence of AL plant (Leaves) aqueous extract at optimum concentration of inhibitor

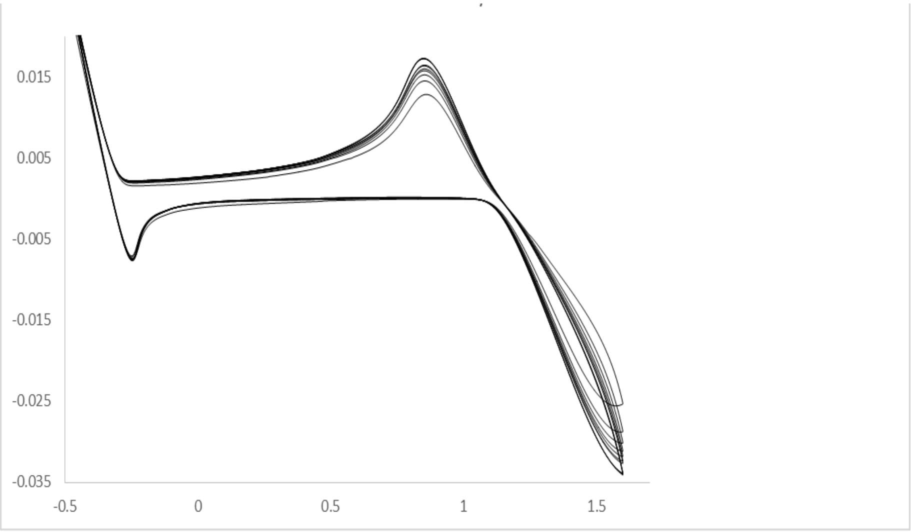


Fig. 90 Cyclic voltammetry of mild steel in 1N HCl in presence of AL plant (Leaves) alcoholic extract at optimum concentration of inhibitor

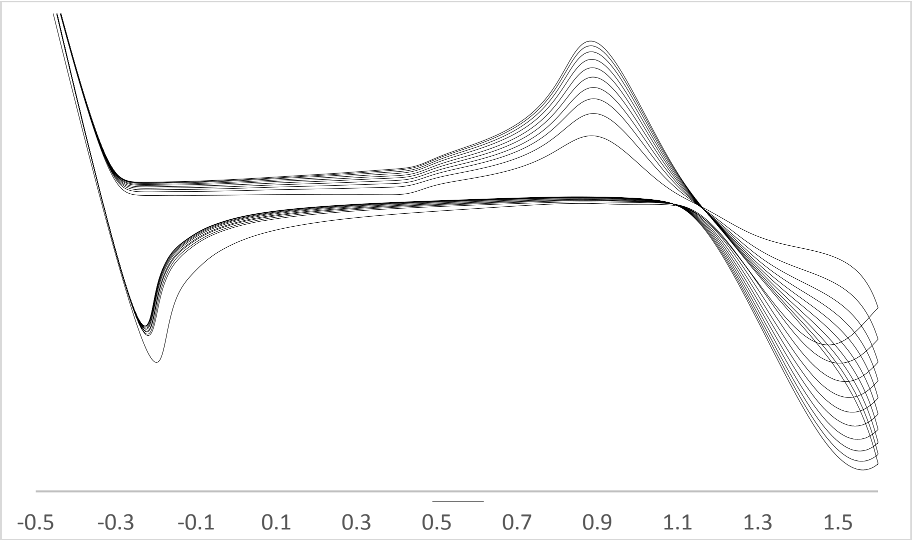


Fig. 91 Cyclic voltammetry of mild steel in 1N HCl in presence of HI plant (Leaves) aqueous extract at optimum concentration of inhibitor

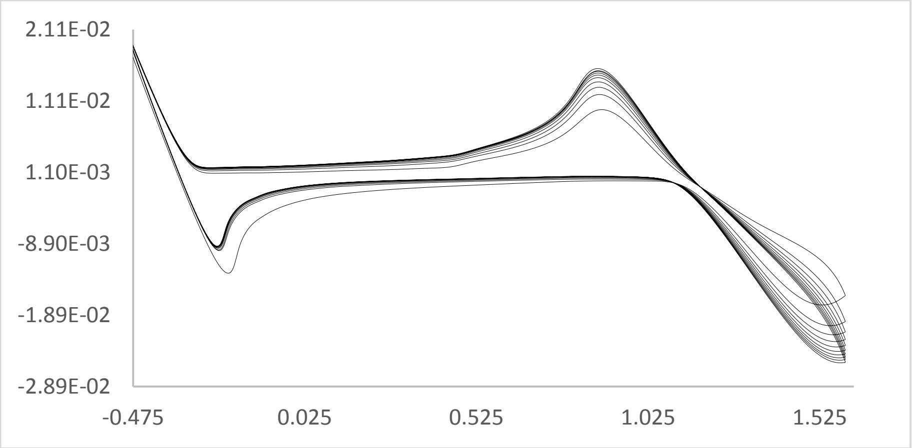


Fig. 92 Cyclic voltammetry of mild steel in 1N HCl in presence of HI plant (Leaves) alcoholic extract at optimum concentration of inhibitor

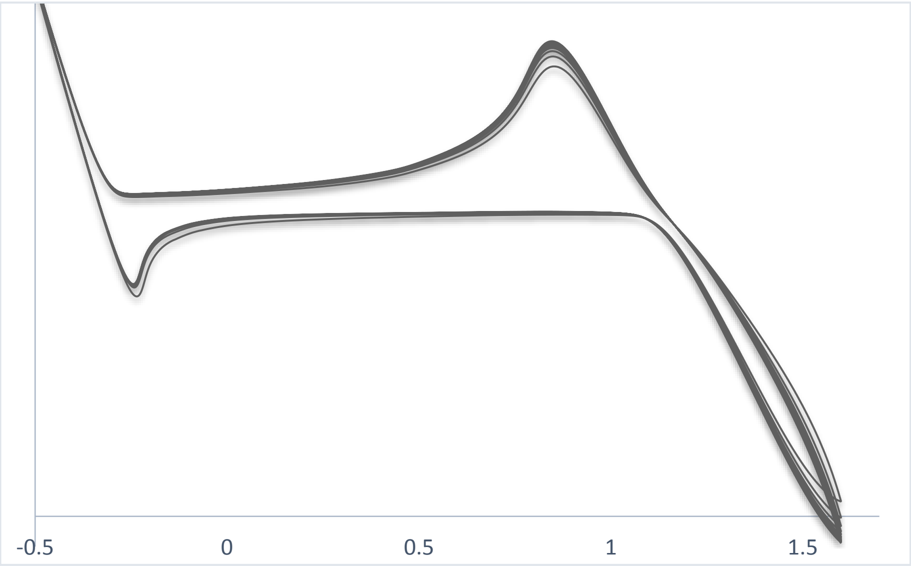


Fig. 93 Cyclic voltammetry of mild steel in 1N HCl in presence of SS plant (Leaves) aqueous extract at optimum concentration of inhibitor

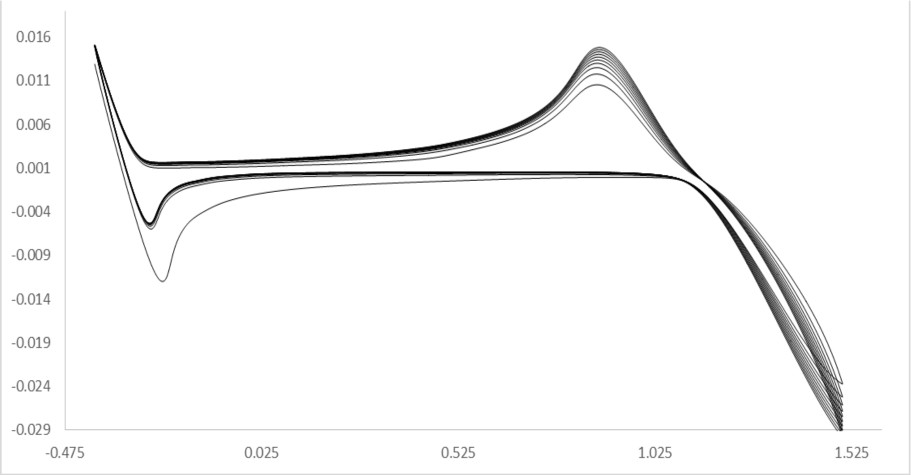


Fig. 94 Cyclic voltammetry of mild steel in 1N HCl in presence of SS plant (Leaves) alcoholic extract at optimum concentration of inhibitor

5.8 Effect of immersion time

Mass loss analysis is one of the easiest and frequently used methods of determining corrosion in metal. In this methods the polished rectangular of mild steel were weighed accurately, fully and separately immersed in 100 ml of 1N HCl in a beaker at room temperature. The inhibition efficiency of plants (aqueous and alcoholic) extract on mild steel as a function of time was presented in ***Tables 28 - 39***. It is revealed that the presences of phytochemical constituent in the plant extract are found to be ***bigger molecules to cover a larger surface area on adsorption.*** Hence more adsorption takes place on the mild steel surface, the IE increases with an increase in immersion time and inhibitive properties of all the plants extract are fairly good for studied situation.

The influence of duration of immersion and the IE of ***ML*** (aqueous and alcoholic extracts) is given in ***Table 28 and 34.*** From the table it is clear that when the immersion period increases the inhibition efficiency decreases and the corrosion rate increases. The inhibition efficiency was found to decrease at longer immersion time, was due to an increase in cathodic or hydrogen evolution kinetics or decreasing strength of adsorption (shifting adsorption – desorption equilibrium towards desorption) This shows that the protective film formed on the metal surface, was broken by the corrosive environment and the film was dissolved.

Weight loss measurement was performed in 1N HCl in the presence and absence of **GSL** extract **(**both extract) at room temperature for different immersion period from 1-12 h and 3 days, the data is listed in ***Table 29 and 35.*** The data clearly clarify that the inhibition efficiency increase and after 3 days it decreases. Increase in IE from 1-12 h, showed that the strong adsorption of constituent present in the plant extract on the surface of mild steel giving it a protective layer. Immersion for a longer period (3 days) leads to desorption of plants constituents.

The inhibition efficiency is found to increase from 1-12 hours in 1N HCl medium in the presence of ***PD*** extract (both extracts) at room temperature; the data are listed in ***Table 30 and 36***. The increase of IE up to 12 h reflect the strong adsorption of phytoconstitutens present in the extract onto MS surface, resulting in a more protective layer formed at the steel/acid solution interface. After 3 days, the IE decrease with increasing immersion time in the acid environment. This decrease may be due to the absence of the inactive layer on the MS surface with increasing immersion time.

Table 31 and 37 gives the values of IE obtained in 1N HCl in the presence and absence of both ***AL*** extracts. The IE increases with increase in concentration of the inhibitor irrespective of the time of immersion. Maximum IE was observed from the table at 12 h of immersion time. Long-time of immersion (3 days), the IE decreases in the acid environment.

Table 32 and 38 shows the corrosion parameters of MS in acid solution containing various concentration of ***HI*** plant of both extract. It is revealed that the mass loss significantly enhanced with increase of exposure time in inhibitor free solution. However, it was slowly declined with rise in immersion time (3 days). This is mainly due to the presence of phytochemical compounds.

In order to assess the stability of adsorbed inhibitor film at MS - acid solution interface with time, mass loss measurements were performed in both extract of ***SS*** plants. From the ***Table 33 and 39*** it was noticed that a maximum IE was observed for 12 h of immersion periods. Immersion studies reveal that as the time of immersion increased from 1-12 h the IE also increased. After 3 days there is slightly declined in the IE, this may be explained that decrease (desorption) in inhibition for long periods of immersion can be attributed to the depletion of available inhibitor molecules in the solution due to chelate formation between steel and the inhibitor ligands.

Initially inhibitor efficiency increase from 1 to 12 hours and then there is a decline in inhibitor effect at 3 days. This behavior may be attributed due to the increase in corrosion loss with increase in the time of immersion may be ascribed to change occurring in the inhibitor and built up of metal salts in solution. Many researcher points out rather strongly the fact that the rate increases in active surface area as the metal attached. Nevertheless it was a decrease in the inhibition efficiency with further exposure time, showing that the inhibition was brought about by the physical absorption of the reactive constituents of the solution extract to the test metal's surface. Thus with increase ***in exposure time, the interfacial bond between the extracts active molecular constituents (due to contamination) and weakened, thereby decreasing the inhibition efficiency***.

In discussing corrosion inhibition by surface – active organic compounds, various factors are taken into consideration including the number and types of adsorbing group and their electron structure. The selected six plant extract under investigation contains different organic substance with proven corrosion inhibiting capabilities such as alkaloids and terpiniods are shown in ***Fig. 21-26.*** It is very difficult to assign the observed inhibiting effect to a particular constituent. The net adsorption of the organic compounds on the corroding steel surface creates a barrier that isolates the metal from the corrodent. IE increases with an increase in the metal surface fraction occupied by the organic matter.

Table 28 Inhibition efficiency of aqueous extract of ML plants at various immersion time

Parts of Madhuca Longifolia plant	**Conc. of the extract (v/v)**	**Inhibition efficiency (%)**						
		1h	**3h**	**5h**	**7h**	**9h**	**12h**	**3days**
Madhuca Longifolia **leaves**	Blank	*	*	*	*	*	*	*
	5	59.78	64.83	72.54	76.54	90.86	85.02	55.90
	10	62.00	70.29	76.05	80.96	84.00	90.72	50.78
	15	68.75	75.09	82.19	85.42	90.69	96.25	43.09
	20	92.31	95.14	96.57	96.88	94.30	99.04	43.03
Madhuca Longifolia **barks**	5	10.31	60.29	74.93	85.02	88.78	89.13	59.04
	10	35.81	66.59	80.88	90.29	89.88	92.78	49.42
	15	44.05	78.06	88.19	95.75	95.02	97.92	41.66
	20	63.18	92.83	95.03	97.79	97.73	98.12	40.75

(Continued)

Table 28 (Continued)

Madhuca Longifolia **fruits**	5	31.81	41.24	56.24	74.11	84.29	88.76	32.09
	10	36.95	55.85	86.60	76.32	86.89	92.05	22.74
	15	59.84	88.55	92.97	86.68	90.38	94.15	22.56
	20	84.17	90.29	94.10	94.98	95.49	96.69	22.47
Madhuca Longifolia **seed peels**	5	31.75	45.03	51.33	74.86	80.81	92.01	63.04
	10	40.21	66.24	65.89	81.98	92.37	95.69	53.48
	15	75.88	78.38	74.51	89.79	94.15	96.21	44.90
	20	89.02	89.01	90.56	94.98	96.03	97.14	43.21

Table 29 Inhibition efficiency of aqueous extract of GSL plants at various immersion time

Parts of *GS*L plant	**Conc. of the extract (v/v)**	**Inhibition efficiency (%)**						
		1h	**3h**	**5h**	**7h**	**9h**	**12h**	**3 days**
Gloriosa Superba Linn **leaves**	Blank	-	-	-	-	-	-	-
	5	16.10	32.13	46.36	56.72	73.36	84.28	56.78
	10	36.56	48.38	62.72	71.39	79.93	88.36	44.20
	15	49.57	60.39	66.36	82.18	89.03	90.71	40.09
	20	65.35	72.12	80.18	87.73	90.24	96.39	38.78
Gloriosa Superba Linn **stems**	5	31.45	39.37	53.27	60.17	72.97	80.72	65.29
	10	43.13	56.75	67.38	72.52	78.17	81.21	53.90
	15	52.24	60.09	69.20	74.08	80.26	82.82	41.87
	20	69.30	74.14	86.16	89.32	94.15	96.27	23.90
Gloriosa SuperbaLinn **flowers**	5	53.15	62.29	65.29	74.19	85.89	91.09	44.20
	10	66.29	69.71	74.40	75.69	89.13	92.59	38.67
	15	74.86	79.46	82.34	89.17	90.73	94.57	30.48
	20	94.95	80.25	88.90	89.99	94.65	96.23	26.17
Gloriosa Superba Linn **tubers**	5	32.29	60.73	76.16	78.28	90.49	94.99	39.12
	10	53.28	84.65	84.96	87.34	91.64	96.05	35.33
	15	69.75	85.48	88.59	88.90	93.37	96.35	27.07
	20	72.58	86.53	90.27	91.90	94.10	96.89	19.39

Table 30 Inhibition efficiency of aqueous extract of PD plants at various immersion time

Parts of Pithecellobium Dulce plant	**Conc. of the extract (v/v)**	**Inhibition efficiency (%)**						
		1h	**3h**	**5h**	**7h**	**9h**	**12h**	**3 days**
Pithecellobium Dulce **leaves**	Blank	-	-	-	-	-	-	-
	5	46.17	50.23	74.66	74.88	82.56	89.96	53.20
	10	57.55	59.28	79.00	82.79	89.76	92.32	48.67
	15	70.90	72.94	80.28	84.65	90.54	93.93	40.30
	20	81.58	82.62	87.93	88.84	93.28	96.45	33.78

Table 30 (Continued)

Pithecellobium Dulce **barks**	5	42.76	74.18	81.32	78.09	90.87	94.22	47.89
	10	48.19	76.57	85.87	88.78	94.45	95.13	39.63
	15	63.23	78.32	87.69	89.09	95.04	95.49	33.09
	20	74.02	83.98	93.96	94.67	96.36	96.20	24.97
Pithecellobium Dulce **fruits**	5	37.34	59.53	64.17	71.35	70.87	80.83	49.38
	10	43.06	64.78	73.96	75.78	83.33	89.76	47.90
	15	59.06	73.96	74.09	79.89	88.52	91.89	38.94
	20	70.45	74.76	79.74	83.54	90.23	96.98	28.67
Pithecellobium Dulce **seeds**	5	49.65	78.20	78.04	70.87	85.78	90.23	38.94
	10	57.96	82.59	81.76	84.89	87.32	93.18	29.07
	15	77.09	84.22	86.90	87.45	93.89	94.87	20.78
	20	86.91	89.93	89.07	93.57	94.71	96.99	20.78

Table 31 Inhibition efficiency of aqueous extract of AL plants at various immersion time

Parts of Alangium Lamarckiii Plant	**Conc. of the extract (v/v)**	**Inhibition efficiency (%)**						
		1h	**3h**	**5h**	**7h**	**9h**	**12h**	**3 days**
Alangium lamarckiii ***Leaves***	5	57.98	59.48	64.56	72.39	84.22	70.56	53.89
	10	65.39	69.59	70.54	66.76	70.14	78.72	46.92
	15	74.95	81.36	77.16	77.96	82.49	87.95	38.04
	20	83.16	92.16	84.15	80.37	93.76	98.19	38.01
Alangium Lamarckiii ***barks***	5	70.11	70.30	60.53	76.46	65.78	72.12	47.90
	10	74.08	85.19	77.28	83.12	66.28	83.38	39.87
	15	79.35	91.06	86.19	87.22	77.92	92.02	28.65
	20	91.93	93.83	95.05	90.09	89.78	96.91	28.13
Alangium Lamarckiii ***Fruits***	5	70.81	78.90	72.44	74.21	80.89	75.02	40.73
	10	76.15	86.16	77.63	76.78	89.28	79.53	36.29
	15	87.34	94.56	84.60	82.59	94.19	88.98	28.18
	20	94.21	97.89	92.19	93.65	95.66	97.16	28.14
Alangium Lamarckiii ***Seeds***	5	68.10	70.93	72.65	75.78	76.87	79.21	38.20
	10	79.98	84.24	85.33	86.98	82.96	83.56	34.68
	15	88.98	89.94	89.89	87.48	89.08	91.33	28.30
	20	95.62	96.37	97.25	93.09	94.54	98.60	27.89

Table 32 Inhibition efficiency of aqueous extract of HI plants at various immersion time

Parts of ***Holoptelea Integrifolia*** plant	Conc. of the extract (v/v)	Inhibition Efficiency (%)						
		1h	3h	5h	7h	9h	12h	3 days
Holoptelea Integrifolia **leaves**	Blank	-	-	-	-	-	-	-
	5	24.10	51.13	36.79	54.89	59.72	65.56	46.20
	10	44.43	60.29	58.14	66.70	69.16	78.72	38.17
	15	57.50	72.33	66.76	77.36	85.29	96.95	34.09
	20	66.29	80.45	83.15	89.37	90.87	98.13	26.33
Holoptelea Integrifolia **barks**	5	30.31	44.90	50.43	56.16	65.78	69.62	39.29
	10	45.08	56.19	67.88	77.72	69.18	84.70	30.15
	15	58.85	68.94	74.19	82.45	87.22	93.22	26.99
	20	64.93	82.63	85.52	90.09	92.78	94.18	26.99
Holoptelea Integrifolia **flowers**	5	52.81	58.90	56.40	50.51	53.89	48.09	37.89
	10	65.25	70.60	69.13	66.48	67.34	69.33	33.08
	15	72.34	74.16	79.40	80.57	77.19	88.89	24.11
	20	79.21	81.09	89.29	93.17	95.80	97.16	24.08
Holoptelea Integrifolia **seeds**	5	38.06	44.81	50.23	58.98	66.71	69.11	36.18
	10	46.68	50.54	55.33	64.02	78.06	89.36	27.49
	15	67.34	73.73	76.41	78.12	89.45	93.38	22.80
	20	72.62	79.34	81.05	82.05	92.50	97.72	22.80

Table 33 Inhibition efficiency of aqueous extract of SS plants at various immersion time

Parts of Schreabera swietenioids plant	Conc. of the extract (v/v)	Inhibition efficiency (%)						
		1h	3h	5h	7h	9h	12h	3 days
Schreabera swietenioids **leaves**	Blank	-	-	-	-	-	-	-
	5	16.34	40.37	56.16	54.32	45.56	82.90	43.89
	10	65.78	60.57	72.12	60.44	68.27	86.27	36.98
	15	71.50	83.12	77.98	83.95	84.23	88.55	28.67
	20	74.98	90.44	95.16	91.30	94.02	93.90	18.55
Schreabera swietenioids **barks**	5	39.22	56.83	60.03	66.23	75.06	81.04	45.22
	10	53.50	65.24	63.90	78.07	84.56	85.38	48.99
	15	60.28	76.23	73.70	83.88	89.02	90.34	39.66
	20	73.31	89.34	89.03	90.67	92.11	93.02	32.87
Schreabera swietenioids **fruits**	5	27.90	59.09	84.05	80.64	77.55	85.73	35.15
	10	54.17	70.06	86.72	87.09	84.03	92.11	30.44
	15	68.83	79.81	92.45	88.24	90.04	92.87	24.48
	20	74.36	88.73	94.89	92.58	93.75	94.09	20.78

(Continued)

Table 33 (Continued)

Schreabera swietenioids **seeds**	5	37.89	40.19	67.70	82.33	88.24	80.36	27.90
	10	59.20	58.83	84.69	85.07	91.27	88.97	24.88
	15	68.06	69.90	89.91	91.38	92.60	89.34	26.90
	20	82.38	80.74	93.47	92.65	93.04	94.45	26.89

Table 34 Inhibition efficiency of alcoholic extract of ML plants at various immersion time

Parts of Madhuca Longifolia plant	**Conc. of the extract (v/v)**	**Inhibition efficiency (%)**						
		1h	**3h**	**5h**	**7h**	**9h**	**12h**	**3 days**
Madhuca longifolia **leaves**	Blank	*	*	*	*	*	*	*
	5	52.21	65.12	69.14	71.67	70.06	74.89	50.39
	10	59.01	74.21	72.30	80.23	80.21	86.71	48.30
	15	64.72	81.61	79.95	84.09	89.45	93.01	48.28
	20	89.32	86.73	89.32	92.09	91.79	93.98	48.28
Madhuca longifolia **bark**	5	39.16	44.87	59.21	69.92	69.09	70.32	37.29
	10	42.09	50.32	64.72	77.32	74.89	75.22	35.90
	15	56.32	67.34	75.02	88.05	92.90	86.32	34.91
	20	64.72	88.96	90.18	89.09	93.01	94.17	34.90
Madhuca longifolia **fruits**	5	60.71	72.43	66.24	79.38	64.34	86.54	42.78
	10	77.02	87.94	75.95	81.12	72.71	93.09	40.29
	15	78.97	93.35	84.94	82.34	86.36	94.38	39.40
	20	89.98	94.41	94.92	90.28	95.25	96.49	39.37
Madhuca longifolia **seeds peel**	5	66.21	45.35	59.29	52.32	66.14	74.96	47.90
	10	76.11	60.62	73.13	69.19	78.22	88.12	46.38
	15	78.09	77.30	75.52	80.34	84.19	89.90	46.38
	20	89.98	89.12	88.19	92.36	95.25	96.32	46.30

Table 35 Inhibition efficiency of alcoholic extract of GSL plants at various immersion time

Parts of Gloriosa Superba Linn plant	**Conc. of the extract (v/v)**	**Inhibition efficiency (%)**						
		1h	**3h**	**5h**	**7h**	**9h**	**12h**	**3 days**
Gloriosa Superba linn **leaves**	Blank	-	-	-	-	-	-	-
	5	27.09	40.35	54.32	63.79	66.76	71.53	47.90
	10	29.34	47.67	60.79	66.67	68.10	78.10	46.78
	15	40.35	55.89	64.09	75.77	77.96	80.72	45.87
	20	53.49	66.21	73.51	81.89	80.78	93.92	45.87

(Continued)

Table 35 (Continued)

Gloriosa Superba linn **stems**	5	23.56	35.90	49.57	75.86	76.36	79.06	58.00
	10	27.89	41.43	62.12	78.03	80.84	89.72	57.35
	15	38.07	49.67	64.75	79.56	88.90	94.17	55.90
	20	53.25	59.72	70.09	89.90	93.05	96.75	55.90
Gloriosa Superba linn **flowers**	5	40.54	50.23	61.23	76.98	88.45	89.39	47.89
	10	53.90	59.46	66.44	78.54	89.04	90.07	40.55
	15	63.72	69.03	70.96	87.02	91.90	93.56	33.90
	20	80.43	88.34	89.37	94.76	92.09	97.49	33.89
Gloriosa Superba linn **tubers**	5	49.34	58.38	60.11	71.34	79.56	88.88	41.20
	10	56.90	70.17	72.54	76.09	84.00	89.45	37.39
	15	66.75	72.64	78.96	85.23	88.73	90.92	28.90
	20	88.80	89.97	96.37	97.17	97.43	97.52	28.87

Table 36 Inhibition efficiency of alcoholic extract of PD plants at various immersion time

Parts of Pithecellobium Dulce plant	**Conc. of the extract (v/v)**	**Inhibition efficiency (%)**						
		1h	**3h**	**5h**	**7h**	**9h**	**12h**	**3 days**
Pithecellobium Dulce **leaves**	Blank	-	-	-	-	-	-	-
	5	40.23	79.66	80.91	79.50	70.12	52.16	50.23
	10	78.10	82.81	86.60	76.76	80.14	73.17	49.90
	15	85.04	85.96	90.46	87.96	90.93	85.12	47.92
	20	94.18	88.14	94.91	90.37	91.80	94.23	34.84
Pithecellobium Dulce **barks**	5	70.31	79.12	40.30	24.27	85.78	16.36	49.30
	10	85.95	80.12	58.12	59.17	58.82	36.27	41.28
	15	93.37	94.12	74.10	84.12	69.27	95.73	38.96
	20	95.21	96.01	88.12	95.16	91.32	46.98	28.90
Pithecellobium Dulce **fruits**	5	19.29	43.12	41.25	71.18	69.70	89.45	42.89
	10	29.54	52.59	62.70	72.19	72.18	35.21	35.67
	15	47.70	63.61	66.75	82.95	84.80	70.12	26.59
	20	79.12	74.05	79.69	85.80	85.50	79.18	26.59
Pithecellobium Dulce **seeds**	5	56.76	26.61	50.49	33.74	63.87	84.27	36.99
	10	74.16	44.50	61.50	42.76	78.69	79.12	30.87
	15	74.96	56.17	75.19	58.43	90.81	80.12	30.87
	20	82.16	80.17	82.18	86.66	94.72	95.14	29.45

Table 37 Inhibition efficiency of alcoholic extract of AL plants at various immersion time

Parts of Alangium lamarckiii Plant	**Conc. of the extract (v/v)**	**Inhibition efficiency (%)**						
		1h	**3h**	**5h**	**7h**	**9h**	**12h**	**3days**
Alangium lamarckiii **Leaves**	Blank	-	-	-	-	-	-	-
	5	68.10	71.53	66.76	64..39	54.32	45.56	38.90
	10	78.22	80.25	78.54	76.76	60.12	68.72	33.12
	15	87.50	89.99	86.16	87.96	82.49	86.95	24.87
	20	90.2	92.16	93.15	90.37	91.30	94.10	24.70
Alangium lamarckiii **Barks**	5	70.31	74.90	80.33	86.16	85.78	90.12	37.12
	10	75.08	86.59	87.88	87.72	86.88	94.78	36.49
	15	78.85	88.90	89.19	89.15	87.22	95.92	35.22
	20	84.93	92.03	93.05	94.09	90.78	96.91	35.20
Alangium lamarckiii **Fruits**	5	72.81	78.90	76.14	74.21	83.89	78.90	47.21
	10	75.95	80.16	85.33	76.78	87.28	89.13	37.29
	15	78.84	84.56	87.60	82.59	87.99	92.98	37.10
	20	93.21	91.89	92.69	90.17	93.89	94.16	37.10
Alangium lamarckiii **Seeds**	5	78.90	74.93	80.23	83.78	86.87	89.21	44.23
	10	86.98	80.54	85.33	84.98	88.96	90.56	40.21
	15	87.98	83.44	86.59	88.98	89.18	92.21	40.21
	20	92.62	90.34	94.25	92.09	91.54	94.60	40.20

Table 38 Inhibition efficiency of alcoholic extract of HI plants at various immersion time

Parts of *Holoptelea Integrifolia* plant	**Conc. of the extract (v/v)**	**Inhibition Efficiency (%)**						
		1h	**3h**	**5h**	**7h**	**9h**	**12h**	**3 days**
Holoptelea Integrifolia **leaves**	Blank	-	-	-	-	-	-	-
	5	63.12	67.33	73.98	79.29	82.90	84.42	46.28
	10	66.27	70.29	76.09	85.67	89.34	90.89	40.12
	15	68.76	79.30	83.81	86.90	90.95	93.67	40.12
	20	78.34	82.10	88.54	90.06	94.23	96.22	39.99
Holoptelea Integrifolia **barks**	5	20.13	34.67	46.90	62.10	78.01	89.99	52.95
	10	54.80	65.40	76.99	78.28	88.90	91.90	50.67
	15	68.23	76.33	80.18	88.22	91.47	94.93	50.60
	20	70.21	79.89	83.05	90.98	93.78	95.22	50.60
Holoptelea Integrifolia **flowers**	5	52.19	60.57	73.89	76.31	84.20	89.09	48.29
	10	62.90	74.65	79.67	84.22	89.37	92.11	42.18
	15	66.29	79.56	84.95	86.07	92.16	93.87	42.18
	20	79.54	80.19	88.38	90.65	93.84	95.90	40.70

(Continued)

Table 38 (Continued)

Holoptelea Integrifolia **seeds**	5	58.38	61.11	67.25	81.83	89.30	93.28	51.38
	10	67.89	70.25	80.12	84.74	93.95	94.76	49.97
	15	79.34	80.90	88.19	92.11	94.36	96.98	38.77
	20	82.34	84.35	90.34	93.29	96.84	97.95	30.28

Table 39 Inhibition efficiency of alcoholic extract of SS plants at various immersion time

Parts of Schreabera swietenioids plant	**Conc. of the extract (v/v)**	**Inhibition efficiency (%)**						
		1h	**3h**	**5h**	**7h**	**9h**	**12h**	**3 days**
Schreabera swietenioids **leaves**	Blank	-	-	-	-	-	-	-
	5	33.08	38.11	44.24	48.28	50.78	64.37	49.73
	10	59.67	48.34	57.57	69.78	68.24	72.89	45.29
	15	62.66	64.93	65.23	73.90	75.10	88.42	45.29
	20	67.88	69.43	71.45	77.64	88.43	93.12	45.29
Schreabera swietenioids **barks**	5	59.92	60.76	65.23	70.26	71.94	89.90	51.90
	10	66.72	64.06	77.12	81.34	83.73	92.48	47.21
	15	78.82	65.27	80.34	87.79	90.45	94.79	47.19
	20	88.71	88.23	89.90	90.28	93.21	97.72	45.89
Schreabera swietenioids **fruits**	5	59.43	64.65	66.10	67.29	70.19	88.23	38.11
	10	65.03	77.35	83.04	85.12	87.34	90.06	35.90
	15	71.28	88.90	89.72	89.99	88.90	91.66	35.90
	20	75.87	90.24	94.18	95.29	93.90	93.02	35.78
Schreabera swietenioids **seeds**	5	70.92	72.10	77.21	79.05	90.28	92.65	49.18
	10	73.47	74.29	87.79	89.74	92.22	93.38	42.11
	15	76.89	80.78	89.34	92.18	96.07	94.99	40.84
	20	80.22	89.30	91.78	94.29	97.31	97.92	40.84

5.9. Effect of temperature

Temperature is one of the main factors like to modify the behavior of materials in a corrosion medium. The adsorption of organic compounds on the corroding system by physical or chemical adsorption was described by studying the effect of temperature.

The effect of temperature on the corrosion inhibition properties of all plant (both extract) was studied by exposing the mild steel in 1 N HCl containing 5, 10, 15, 20 v/v of the selected six plant (both extract) in the temperature range of 303-323 K and the data obtained are presented in ***Tables 40 - 45.*** The data obtained suggest that the plant extract get observed on the metal surface in both extracts studied, corrosion rate increased with increase in temperature (corrosion of metal is generally accompanied with evolution of H_2 gas) in acid solution. However, in temperature variation the ***inhibition efficiency decreases with increase of temperature*** indicates that the inhibitor film which formed on the metal surface is ***less protective in nature at higher temperature*** because of desorption (de-shielded) of inhibitor molecules from the metal surface. The result indicates that the adsorption of main active phytochemical constituents present in the inhibitors shields the metal surface at room temperature. This observation has been explained to be due to reduction in stability of adsorbed film at high temperature as temperature increases, Gibbs free energy and enthalpy rise to a higher value, so that some of the chemical bonds joining the molecules onto metallic surface are impaired and film stability reduced. This indicates that adsorption of selected six plants (both extract) extract is spontaneous and occurs via physical adsorption.

The decrease in IE with rise in temperature, as illustrated in ***Table 40***, suggests that the possible desorption of some of the adsorbed inhibitor from the metal surface at high temperature. From this occurrence, it can be said that the decrease in IE with increase in temperature could be traceable to the fact that, at lower temperature, inhibitor molecules have the tendency to adsorb themselves on the steel surface. So, at lower temperature, the inhibitor has the tendency to establish stronger interaction to the surface of the mild steel than at high temperature. Also the adsorption of the ***ML*** plant (both extract) onto the mild steel surface at lower temperature prevents the breakdown of the passive film, hence higher corrosion resistance of mild steel.

To evaluate the adsorption of ***GSL*** in both extract in HCl acid media, mass loss data were investigated in the range of 303-323 K and the results are depicted in ***Table 41***. Further rise in temperature, decreases the IE at higher concentration. This observation established the effectiveness of GSL extract in reducing corrosion of mild steel in the temperature range of 313K. It results that the lower IE at high temperature.

Weight loss measurement was carried out over range of 303-323 K in the presence and absence of ***PD*** plant (both extract) for an immersion period of 1h, to evaluate the stability of the adsorbed film on the mild steel. The results obtained are listen in ***Table 42.*** The IE increase up to 313 K and thereafter decrease. Also, with increased desorption of inhibitor at high temperature, more surface area of mild steel come in contact with acid environment, resulting in decrease in IE with increase in temperature.

Weight loss experiment was carried out at different temperature in the presence and absence of ***AL*** plant (both extract) to evaluate the stability of the adsorbed film on the mild steel plates. The results obtained are shown in ***Table 43.*** At elevated temperature, the rate of dissolution of mild steel increases as time lag between adsorption and desorption decrease and hence the inhibition efficiency decreases. Metal surface remaining exposed to acid environment for a longer period increase the rate of corrosion and thus decreases the IE.

Weight loss studies were carried out at three different temperatures in presence and absence of ***HI*** plant (both extract) and the inhibition efficiency values calculated are presented in ***Table 44.*** From the table, it is noted that the IE increases steadily with increasing concentration of the inhibitor. The IE decrease with increasing temperature, though it is not so significant. The data represents the dependence of inhibitor concentration for improved protection.

Temperature change of the system involving mild steel in HCl acid solution is a function of time in the absence and presence of different concentration of ***SS*** plants (both extract) and the IE values calculated are presented in ***Table 45.*** Addition of the inhibitor caused a decreased in the high temperature and an increase in the time required reaching it. The effectiveness of the ***SS*** plant extract is attributable to the presence of pi electron in aromatic ring and lone pair of electron on the nitrogen and oxygen atom. This indicates that adsorption of SS plants (both extract) is spontaneous and occurs via physical adsorption.

Table 40 The percentage inhibition efficiency of ML plants (both extracts) at various temperatures

Aqueous extract					**Alcoholic extract**			
Parts of Madhuca Longifolia plant	**Conc. of the extract (v/v)**	**IE (%)**			**Conc. of the extract (v/v)**	**IE (%)**		
		303K	**313K**	**323K**		**303K**	**313K**	**323K**
Madhuca Longifolia **leaves**	Blank	*	*	*	Blank	*	*	*
	5	44.10	46.20	40.70	5	50.64	45.15	46.66
	10	57.60	58.60	44.80	10	68.83	52.72	43.01
	15	62.20	62.80	32.20	15	69.22	57.27	30.95
	20	63.10	57.30	26.10	20	70.90	66.36	38.88
Madhuca Longifolia **barks**	5	47.40	43.10	48.61	5	45.90	38.39	33.80
	10	51.50	49.40	35.71	10	52.45	36.79	28.33
	15	56.20	51.60	20.15	15	68.85	32.83	26.87
	20	64.30	59.15	16.18	20	71.80	28.82	22.95
Madhuca Longifolia **fruits**	5	44.35	41.85	31.00	5	24.92	39.96	6.34
	10	48.69	53.97	49.59	10	38.20	52.15	26.98
	15	54.55	57.60	54.84	15	44.04	63.67	32.06
	20	59.10	60.10	56.50	20	70.59	67.21	55.55
Madhuca Longifolia **seed peels**	5	53.84	43.47	34.59	5	25.97	20.25	27.63
	10	66.43	59.56	46.76	10	55.32	42.02	35.78
	15	74.40	69.56	57.42	15	74.41	58.48	45.00
	20	80.41	73.69	60.12	20	82.20	76.87	62.10

Table 41 The percentage inhibition efficiency of GSL plants (both extracts) at various temperatures.

Aqueous extract of GSL plants					Alcoholic extract of GSL plants			
Parts of *Gloriosa Superba Linn* (GSL) plant	**Conc. of the extract (v/v)**	**IE (%)**			**Conc. of the extract (v/v)**	**IE (%)**		
		303K	**313K**	**323K**		**303K**	**313K**	**323K**
Gloriosa Superba Linn **Leaves**	Blank	-	-	-	Blank	-	-	-
	5	34.13	39.12	26.76	5	39.48	40.24	36.48
	10	57.60	50.67	42.54	10	59.59	57.54	41.36
	15	62.28	57.95	50.16	15	71.36	63.74	48.04
	20	76.65	62.12	53.15	20	81.02	77.22	53.66
Gloriosa Superba Linn **Stems**	5	66.66	65.50	64.55	5	65.71	56.58	49.58
	10	71.11	69.40	68.54	10	73.89	62.24	54.86
	15	81.48	75.97	74.76	15	77.48	74.41	47.24
	20	82.22	79.05	77.79	20	80.45	77.13	45.50
Gloriosa Superba Linn **Flowers**	5	44.35	49.85	51.67	5	66.12	59.90	47.41
	10	48.69	53.97	59.59	10	67.90	61.55	60.55
	15	54.55	57.64	60.29	15	73.65	66.86	66.27
	20	68.76	61.48	65.65	20	74.97	72.12	69.80
Gloriosa Superba Linn **Tubers**	5	47.40	12.15	26.81	5	39.25	50.29	40.02
	10	50.37	59.13	34.37	10	64.48	60.73	54.82
	15	60.01	68.17	58.36	15	71.49	66.69	58.18
	20	71.10	74.70	69.03	20	77.59	74.78	63.10

Table 42 The percentage inhibition efficiency of PD plants (both extracts) at various temperatures.

Aqueous extract of PD plants					Alcoholic extract of PD plants			
Parts of Pithecellobium Dulce plant	**Conc. of the extract (v/v)**	**IE (%)**			**Conc. of the extract (v/v)**	**IE (%)**		
		303K	**313K**	**323K**		**303K**	**313K**	**323K**
Pithecellobium Dulce **leaves**	Blank	-	-	-	Blank	-	-	-
	5	57.01	64.00	32.10	5	17.56	15.94	19.67
	10	62.50	71.00	37.08	10	59.45	40.56	36.04
	15	79.10	77.79	59.14	15	60.81	46.57	37.26
	20	84.64	81.16	61.00	20	73.24	51.30	48.52
Pithecellobium Dulce **barks**	5	72.67	69.26	65.36	5	17.24	38.80	16.17
	10	83.44	78.48	72.18	10	31.03	70.14	30.29
	15	87.65	82.19	79.21	15	70.68	72.08	36.17
	20	88.04	86.79	81.76	20	81.03	78.58	42.35

(Continued)

Table 42 (Continued)

Pithecellobium Dulce **fruits**	5	40.52	46.18	82.10	5	20.83	34.24	18.66
	10	52.64	55.72	46.89	10	58.33	64.38	53.33
	15	62.18	61.47	58.91	15	75.00	78.08	69.33
	20	72.10	71.36	62.38	20	84.72	81.78	70.66
Pithecellobium Dulce **seeds**	5	30.24	39.34	35.21	5	21.40	35.33	24.69
	10	48.72	49.15	40.84	10	39.43	40.00	46.91
	15	60.11	59.53	52.59	15	60.56	66.66	61.60
	20	70.27	68.21	66.39	20	84.50	78.00	65.18

Table 43 The percentage inhibition efficiency of AL plants (both extracts) at various temperatures.

Parts of Alangium lamarckiii plant	**Conc. of the extract (v/v)**	**Aqueous extract IE (%)**			**Conc. of the extract (v/v)**	**Alcoholic extract IE (%)**		
		303K	**313K**	**323K**		**303K**	**313K**	**323K**
Alangium lamarckii leaves	Blank	*	*	*	Blank	*	*	*
	5	59.48	40.24	26.48	5	53.16	26.38	14.06
	10	61.59	57.54	35.36	10	69.62	34.72	44.06
	15	69.36	63.74	68.04	15	72.15	77.77	65.00
	20	89.02	87.22	73.66	20	86.07	78.88	70.50
Alangium lamarckiii barks	5	65.71	56.58	59.58	5	22.97	23.61	32.53
	10	73.89	62.24	64.86	10	43.24	27.77	63.85
	15	77.48	74.41	69.24	15	60.81	73.61	69.13
	20	80.45	77.13	70.50	20	89.18	78.88	70.36
Alangium lamarckiii fruits	5	46.12	59.90	47.41	5	30.12	25.97	44.26
	10	67.90	61.55	60.55	10	60.12	51.20	51.02
	15	73.65	66.86	66.31	15	78.01	64.56	63.56
	20	74.97	72.12	69.80	20	86.48	81.23	73.41
Alangium lamarckiii seeds	5	39.25	50.29	40.02	5	35.23	32.15	23.09
	10	64.48	60.73	54.82	10	44.52	39.54	40.56
	15	71.49	66.69	60.18	15	66.03	58.90	56.81
	20	77.59	74.78	70.10	20	80.83	76.65	69.31

Table 44 The percentage inhibition efficiency of HI plants (both extracts) at various temperatures.

Aqueous extract of HI plants					**Alcoholic extract of HI plants**			
Parts of *Holoptelea Integrifolia* plant	**Conc. of the extract (v/v)**	**IE (%)**			**Conc. of the extract (v/v)**	**IE (%)**		
		303 K	**313 K**	**323 K**		**303 K**	**313 K**	**323 K**
	Blank	-	-	-	Blank	-	-	-
Holoptelea	5	22.18	18.12	17.23	5	74.35	10.00	48.46

Integrifolia **leaves**	10	41.06	30.42	25.69	10	89.74	50.90	50.38
	15	58.60	38.41	32.71	15	92.30	61.90	65.38
	20	69.51	52.20	46.22	20	92.30	78.18	68.84
Holoptelea Integrifolia **barks**	5	38.24	32.18	29.10	5	43.18	48.27	45.16
	10	56.42	40.36	32.32	10	65.90	51.72	34.51
	15	68.25	50.22	43.98	15	79.54	68.96	50.96
	20	69.16	70.33	51.71	20	84.09	79.31	67.41
Holoptelea Integrifolia **flowers**	5	18.56	15.14	10.21	5	58.92	38.09	30.43
	10	21.96	19.32	17.54	10	62.50	52.38	36.95
	15	25.97	21.73	19.06	15	73.21	57.14	63.04
	20	29.43	28.81	22.19	20	85.71	80.95	72.60
Holoptelea Integrifolia **seeds**	5	38.33	34.08	28.69	5	38.46	48.00	36.81
	10	54.02	49.25	43.46	10	69.23	68.00	59.09
	15	74.02	51.12	46.46	15	73.09	74.00	70.45
	20	85.56	60.53	52.67	20	84.23	79.00	69.72

Table 45 The percentage inhibition efficiency of SS plants (both extracts) at various temperatures.

Parts of Schreabera swietenioids plant	**Conc. of the extract (v/v)**	**IE (%)**			**Conc. of the extract (v/v)**	**IE (%)**		
		303K	**313K**	**323K**		**303K**	**313K**	**323K**
Schreabera swietenioids **leaves**	Blank	-	-	-	Blank	*	*	*
	5	74.49	70.63	64.00	5	13.75	40.24	21.91
	10	85.15	77.40	71.50	10	27.50	71.95	56.16
	15	89.15	80.16	76.50	15	76.25	78.04	62.19
	20	91.13	82.04	80.00	20	85.00	89.02	78.04
Schreabera swietenioids **barks**	5	47.10	44.00	42.00	5	16.25	42.66	44.04
	10	62.50	56.50	47.88	10	40.00	58.66	53.80
	15	76.48	70.60	67.83	15	78.75	69.33	59.76
	20	80.28	77.50	75.66	20	81.25	74.00	62.14
Schreabera swietenioids **fruits**	5	57.20	45.59	33.05	5	34.11	10.95	18.05
	10	71.16	60.06	56.07	10	57.64	46.57	50.00
	15	75.13	62.30	59.72	15	65.88	54.38	69.16
	20	77.16	69.16	64.82	20	71.76	73.56	70.27
Schreabera swietenioids **seeds**	5	34.74	31.57	38.21	5	26.38	34.21	26.38
	10	42.25	36.31	39.67	10	61.11	59.21	38.88
	15	57.31	47.89	44.45	15	65.27	72.36	62.50
	20	61.43	53.68	54.45	20	70.27	74.58	71.22

5.10 Adsorption isotherm

The primary step in the action of inhibitors in acid solution is generally agreed to be adsorption on the MS surface. In order to clarify the nature of adsorption, temperature dependence of corrosion rates in uninhibited and inhibited solution, weight loss measurement were carried out in the temperature range 303 – 323 K. The information on the collaboration between inhibitor molecules (organic adsorbate) and mild steel surface can be provided by adsorption isotherm. In order to obtain the isotherm, the fractional surfaces coverage (θ) as a function of inhibitor concentration must be obtained. Recent researches have looked into action of the adsorption from a purely mechanistic kinetic point of view.

It is well established that the first step in corrosion inhibition of metal and alloys is the adsorption of organic inhibitor molecules at the metal/solution interface. The extent of adsorption on many factors, such as the nature of metal, conditions of metal surface, the chemical structure of the inhibitors and nature of its functional groups, pH and type of corrosion medium and temperature. So it is necessary to determine empirically which isotherm fits best to the adsorption of inhibitor on the steel surface. Several adsorption isotherm viz., ***Frumkin, Hasley, Langmuir, Temkin, Freundlich, flory-Huggins*** were tested and the adsorption isotherm was found to provide the best description of the behaviour of this inhibitor. The mass loss measurements are tested graphically for fitting three isotherms like ***Hasley, Langmuir and Temkin.*** Attempts were made to fit surface coverage values determined from weight loss measurements into different adsorption isotherms models ***figures 94-129.*** The alcoholic and aqueous data plot showed ***[see Fig. 94-129]*** a straight line with regression coefficient almost equal to 1. The adsorption indicating major components (heterocyclic), compounds usually contains polar function with hetero atom such as ***N, S, O, and P and have double or triple bond or aromatic ring*** have more active sites (electron donor and possibility of centre of adsorption) in the all plants is strongly adsorbed on the metal surface by mutual attraction of the molecules. The adsorption studied suggested that all the six plants (both extract) obeyed the following adsorption isotherm:

Langmuir isotherm: The plots of log (θ/1-θ) vs log C yield a straight line, where C is the inhibitor concentration, proving that the inhibition is due to the adsorption of the active compounds onto the metal surface and obeys the ***Langmuir isotherm [Figures 95, 98.,].*** From the results obtained, it is significant to note that these plots are linear with slopes equal to unity, which indicates a strong adherence of the adsorption data to the assumptions confirming Langmuir adsorption isotherm.

Temkin isotherm: The plots of θ against log C as shown in figures ***[see 97, 100]*** gave a linear relationship indicating that the adsorption of the compounds on the mild steel surface from acid followed Temkin adsorption isotherm, supporting the hypothesis that corrosion inhibition by these compounds results from adsorption on the metal surface. The applicability of Temkin's adsorption isotherm verifies the assumption of monolayer adsorption on a uniform, homogeneous metal surface with an interaction in the adsorption layer.

Hasley isotherm: the plots of log θ against ln C as shown **[96, 99.,]** in linear lines comfirm that obeys Hasley isotherm. In the action mechanism of inhibitor in acid media the first step is adsorption on the metal surface. The formation of donor-acceptor surface complexes between pi-electron of inhibitor and the vacant d-orbital of metal was postulated in most of the inhibition studies. These isotherms are very important in determining the mechanism of ***Organo-electrochemical reaction*** and it provides important clues to the nature of the ***metal-inhibitor interaction***. The metal/solution interface is due to the formation of either ***electrostatic or covalent bonding between the adsorbates and the metal surface atom***. Good correlation between plant water and alcoholic soluble constituent and suggest ***physical adsorption mechanism*** was obtained.

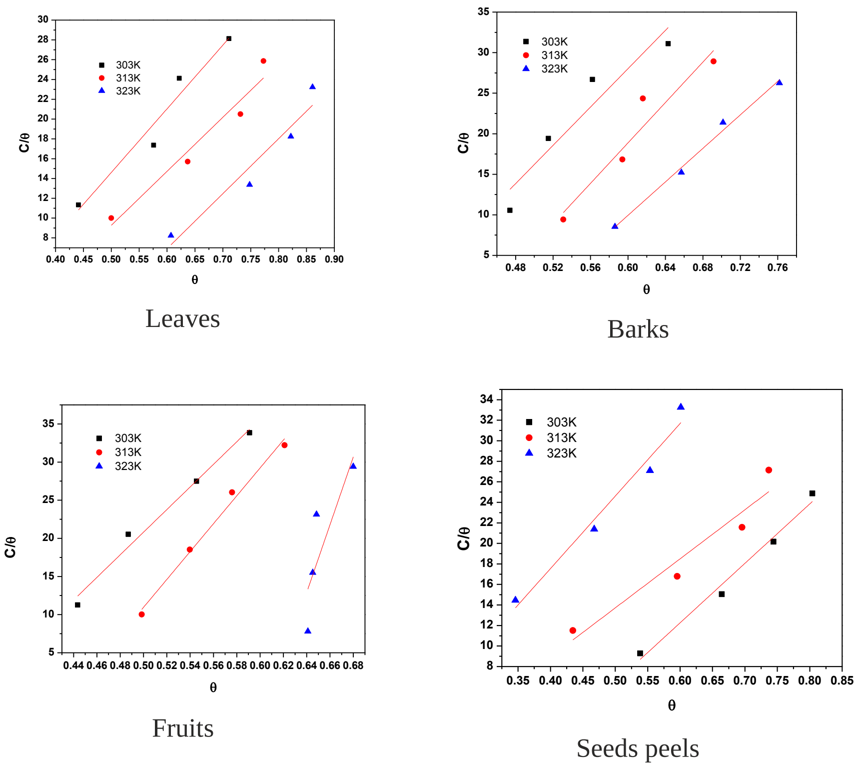
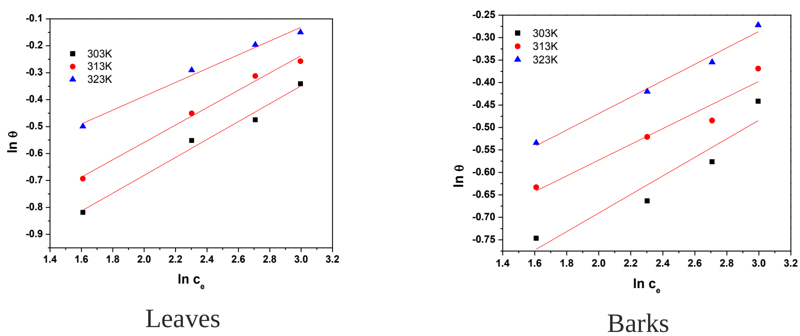
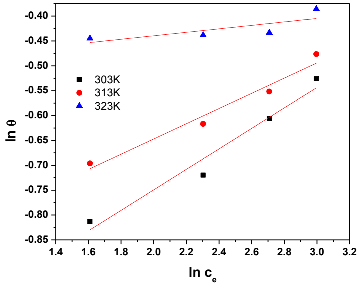
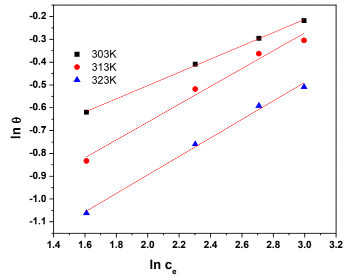


Fig. 95 Langumir adsorption isotherm plot for mild steel in 1N HCl containing different concentration of ML plant aqueous extracts (a) leaves (b) barks (c) fruits and (d) seeds peels.



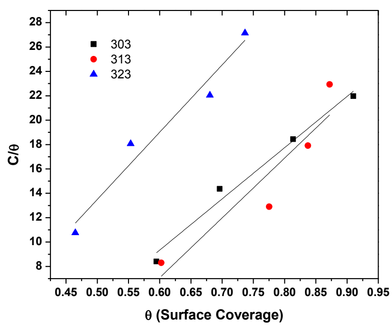


Fruits

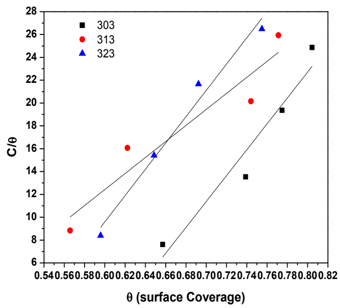


Seeds peel

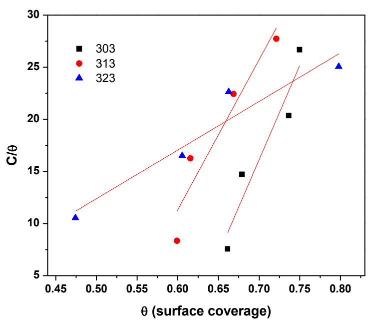
Fig. 96 Hasley adsorption isotherm plot for mild steel in 1N HCl containing different concentration of ML plant aqueous extracts (a) leaves (b) barks (c) fruits and (d) seeds peels.



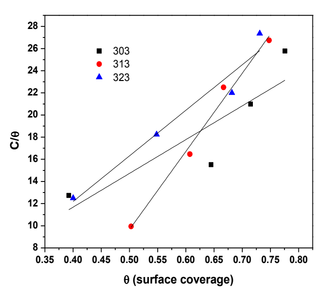
Leaves



Bark

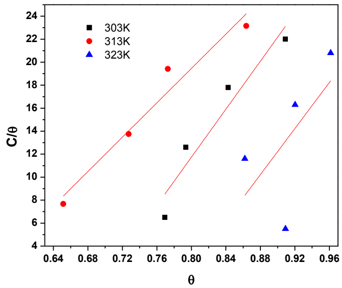


Fruits

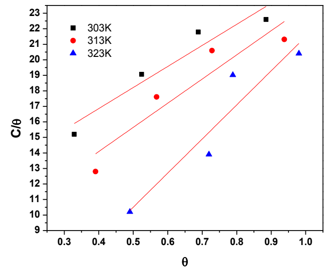


Seeds peels

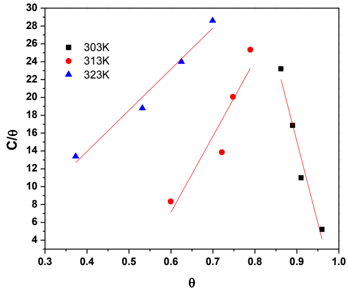
Fig. 97 Temkin adsorption isotherm plot for mild steel in 1N HCl containing different concentration of ML plant aqueous extracts (a) leaves (b) barks (c) fruits and (d) seeds peels.



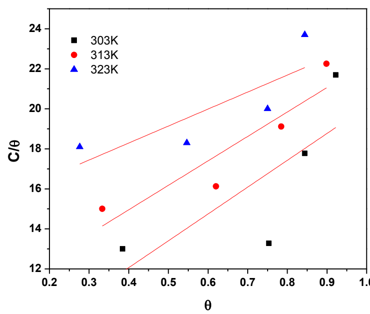
Leaves



Barks

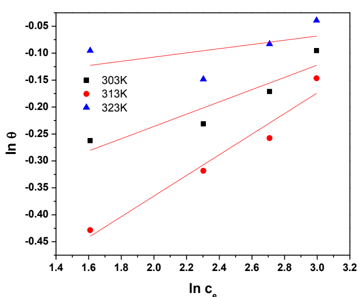


Fruits

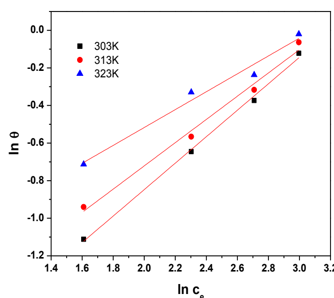


Seeds peels

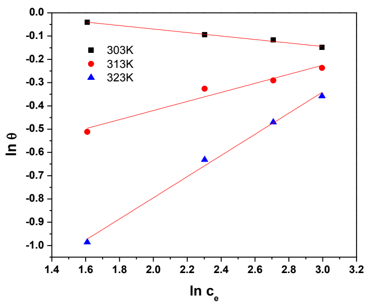
Fig. 98 Langumir adsorption isotherm plot for mild steel in 1N HCl containing different concentration of ML plant alcoholic extracts (a) leaves (b) barks (c) fruits and (d) seeds peels.



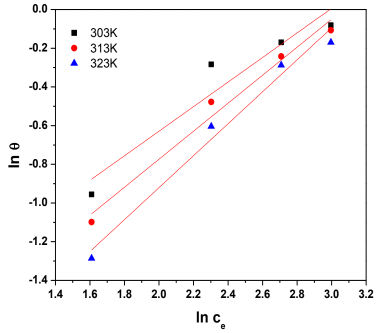
Leaves



Barks

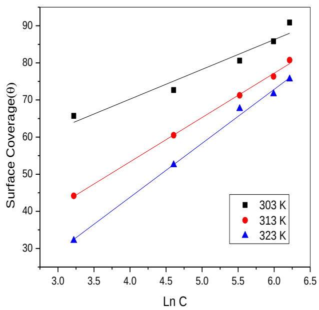


Fruit

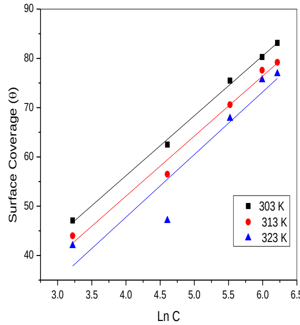


Seeds peels

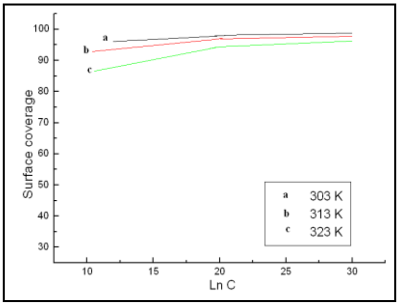
Fig. 99 Hasley adsorption isotherm plot for mild steel in 1N HCl containing different concentration of ML plant alcoholic extracts (a) leaves (b) barks (c) fruits and (d) seeds peels.



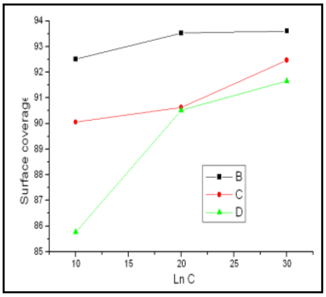
Leaves



Barks

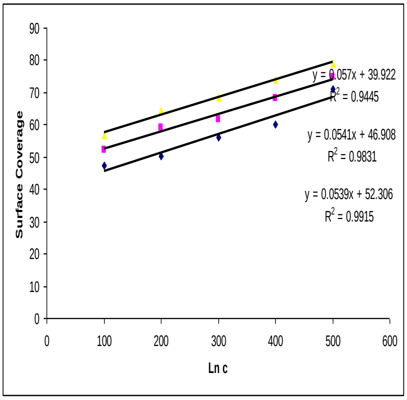


Fruits

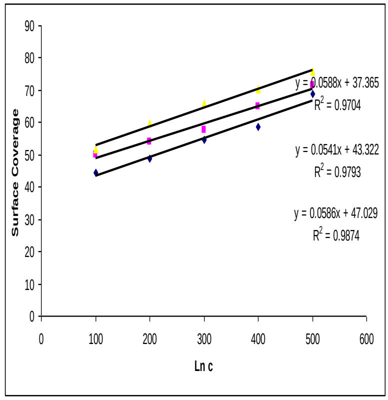


Seeds peels

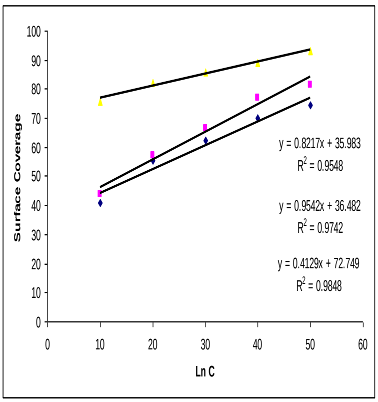
Fig. 100 Temkin adsorption isotherm plot for mild steel in 1N HCl containing different concentration of ML plant alcoholic extracts (a) leaves (b) barks (c) fruits and (d) seeds peels.



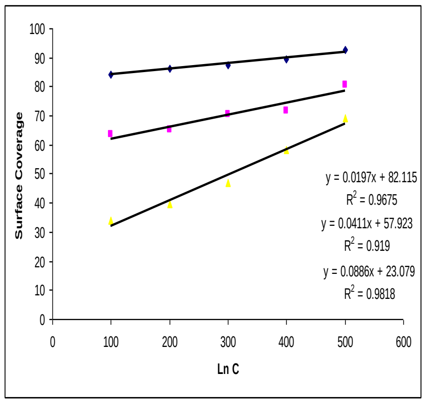
Leaves



Stems

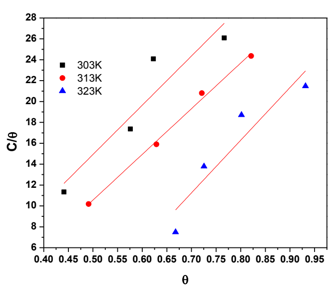


Flowers

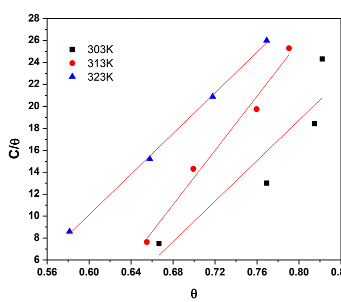


Tubers

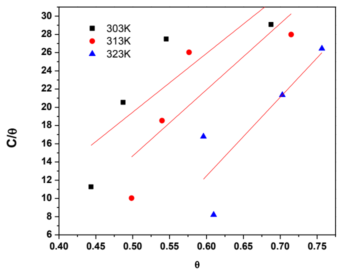
Fig. 101 Temkin adsorption isotherm plot for mild steel in 1N HCl containing different concentration of Gloriosa superba linn plant aqueous extracts (a) leaves (b) stems (c) flowers and (d) tubers.



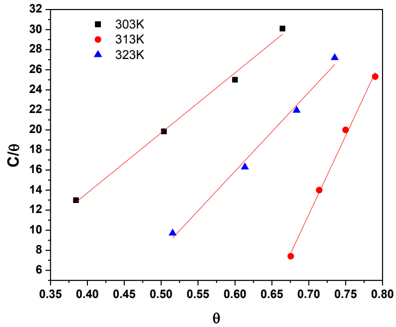
Leaves



Stem

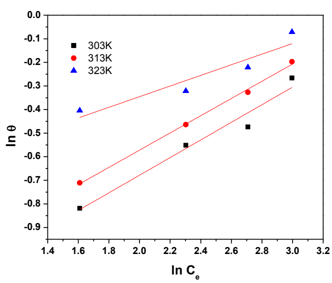


Flower

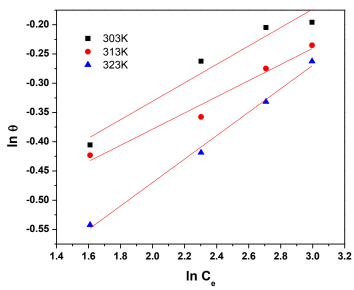


Tuber

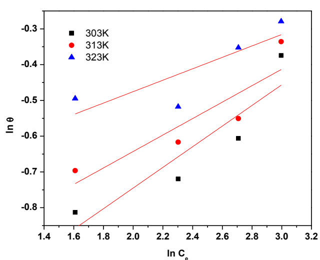
Fig. 102 Langmuir adsorption isotherm plot for mild steel in 1N HCl containing different concentration of Gloriosa superba linn plant aqueous extracts (a) leaves (b) stems (c) flowers and (d) tubers.



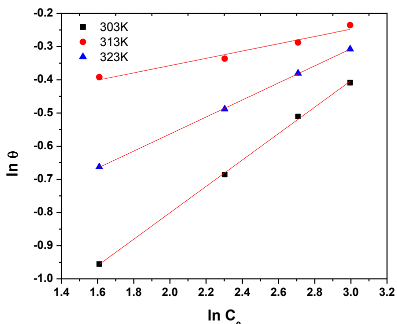
Leaves



Stem

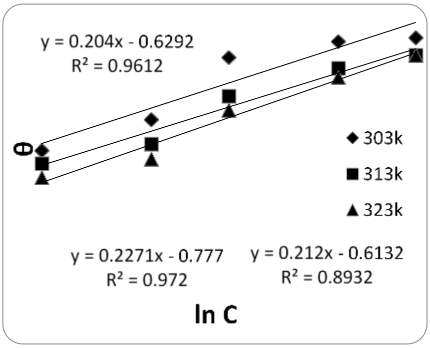


Flowers

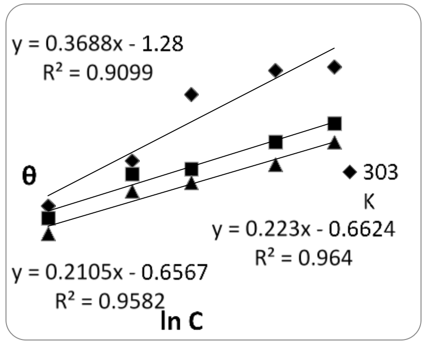


Tubers

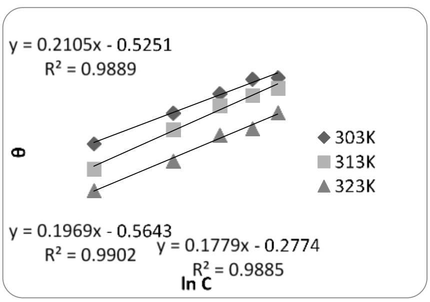
Fig. 103 Hasley adsorption isotherm plot for mild steel in 1N HCl containing different concentration of Gloriosa superba linn plant aqueous extracts (a) leaves (b) stems (c) flowers and (d) tubers.



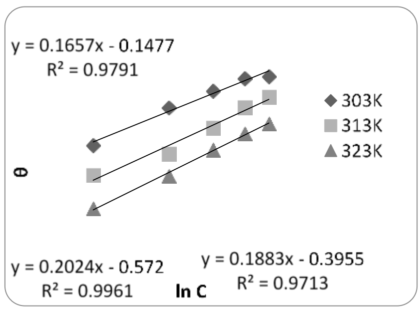
Leaves



Stems

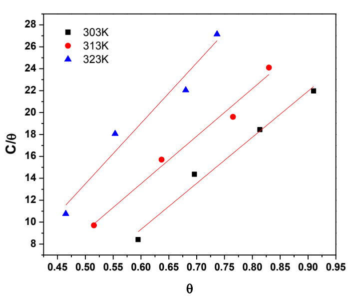


Flowers

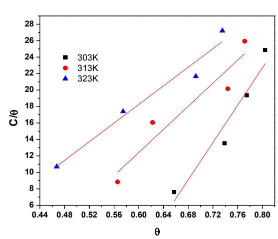


Tubers

Fig. 104 Temkin adsorption isotherm plot for mild steel in 1N HCl containing different concentration of Gloriosa superba linn plant alcoholic extracts (a) leaves (b) stems (c) flowers and (d) tubers.



Leaves



Stems

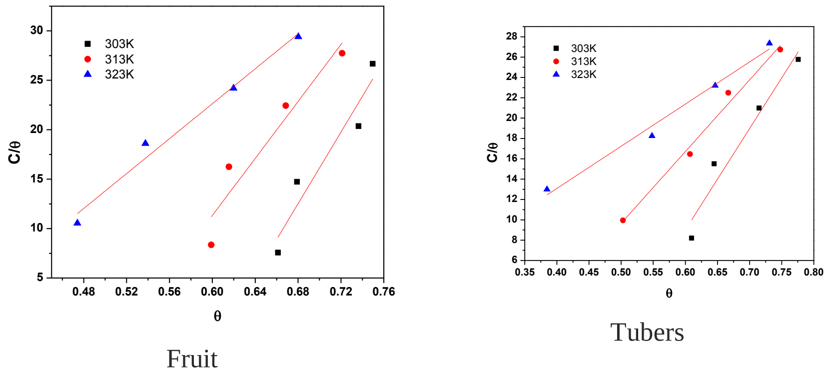


Fig. 105 Langmuir adsorption isotherm plot for mild steel in 1N HCl containing different concentration of Gloriosa superba linn plant alcoholic extracts (a) leaves (b) stems (c) flowers and (d) tubers.

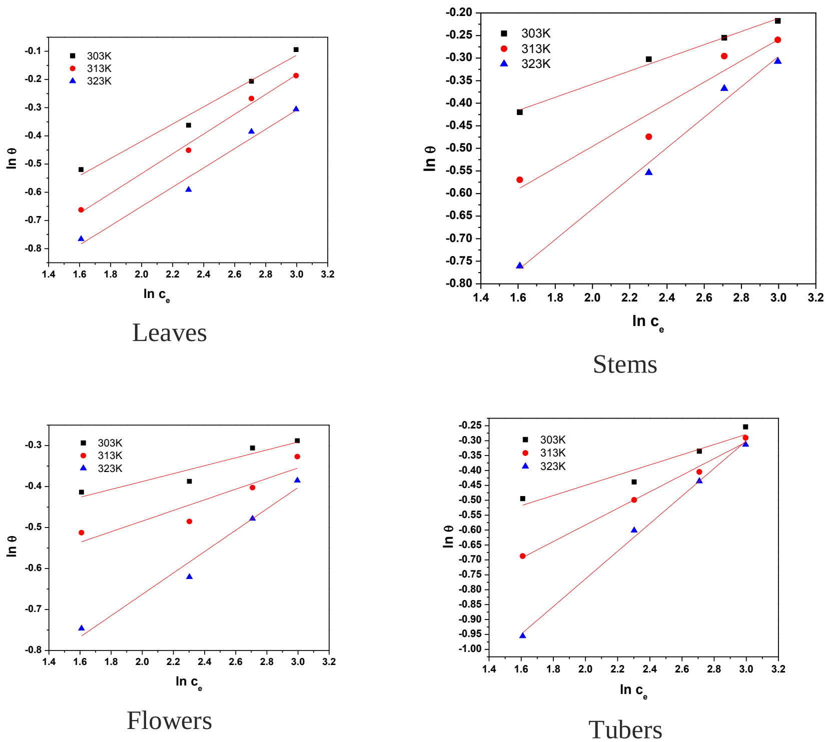


Fig. 106 Hasley adsorption isotherm plot for mild steel in 1N HCl containing different concentration of Gloriosa superba linn plant alcoholic extracts (a) leaves (b) stems (c) flowers and (d) tubers.

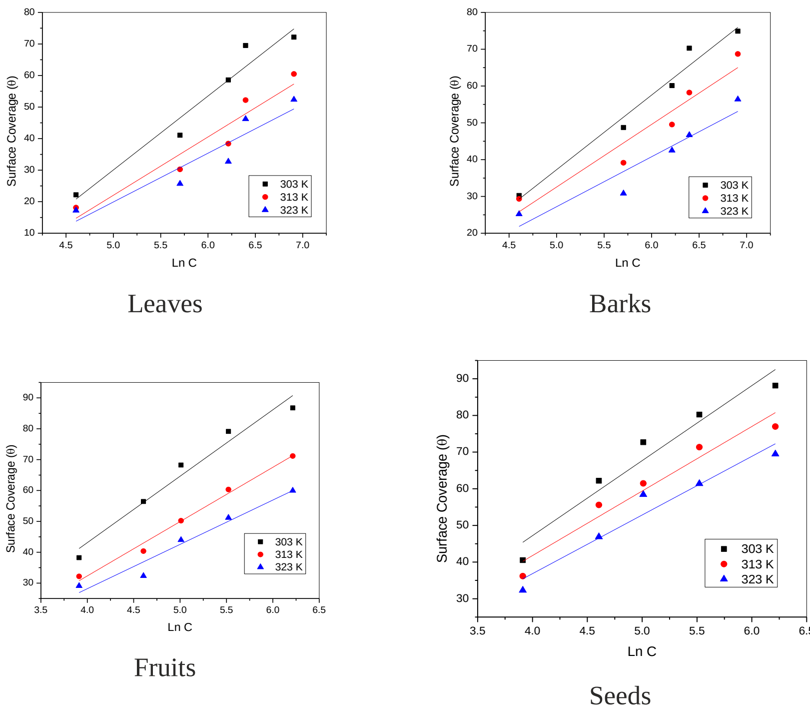
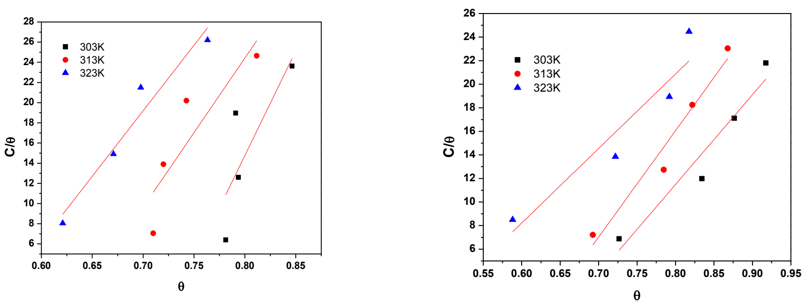
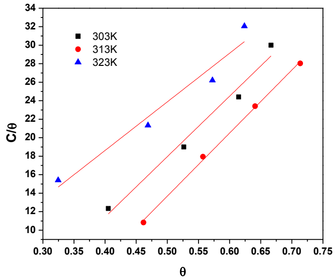


Fig. 107 Temkin adsorption isotherm plot for mild steel in 1N HCl containing different concentration of PD plant aqueous extracts (a) leaves (b) barks (c) fruits and (d) seeds.

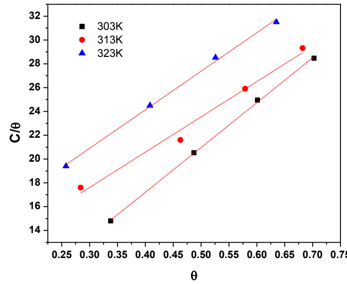


Leaves

Barks

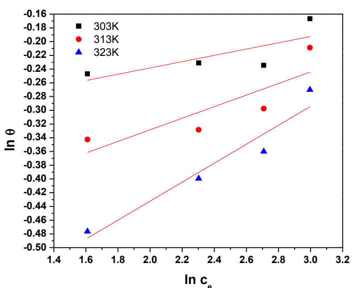


Fruits

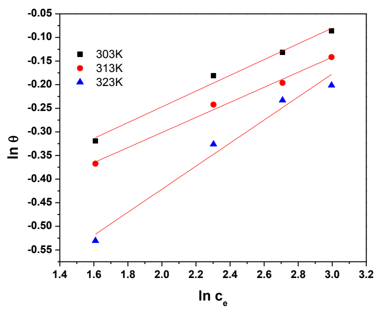


Seeds

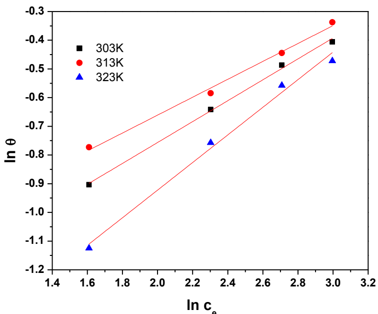
Fig. 108 Langmuir adsorption isotherm plot for mild steel in 1N HCl containing different concentration of PD plant aqueous extracts (a) leaves (b) barks (c) fruits and (d) seeds.



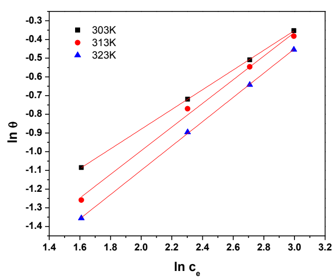
Leaves



Barks

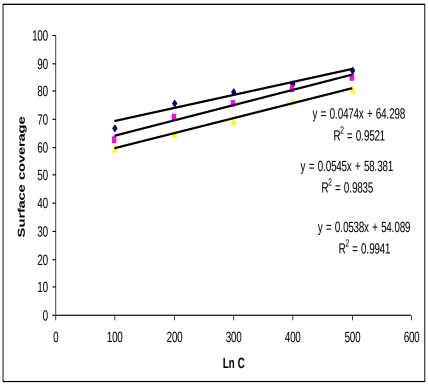


Fruits

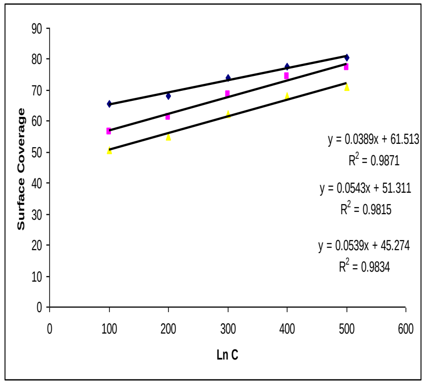


Seeds

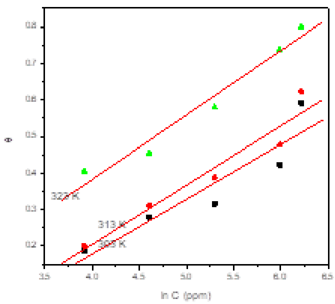
Fig. 109 Hasley adsorption isotherm plot for mild steel in 1N HCl containing different concentration of PD plant aqueous extracts (a) leaves (b) barks (c) fruits and (d) seeds.



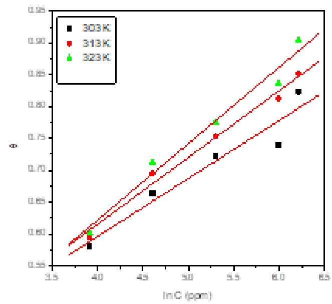
Leaves



Barks

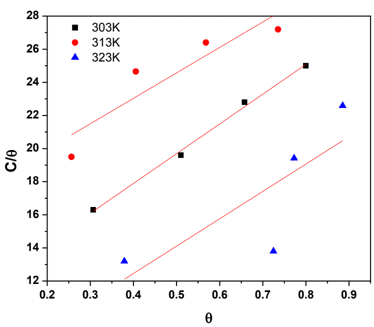


Fruits

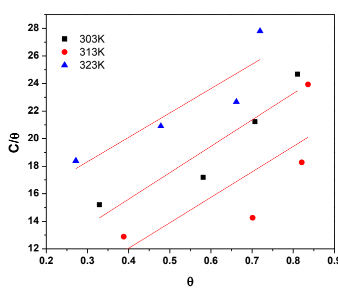


Seeds

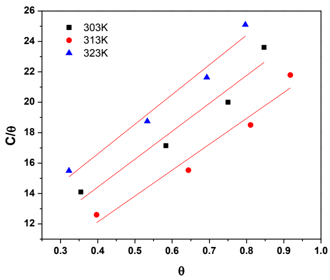
Fig. 110 Temkin adsorption isotherm plot for mild steel in 1N HCl containing different concentration of PD plant alcoholic extracts (a) leaves (b) barks (c) fruits and (d) seeds.



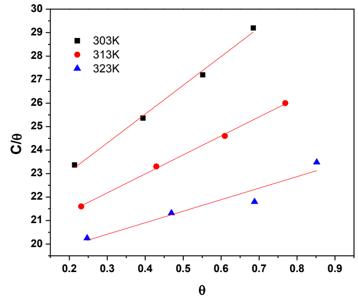
Leaves



Barks

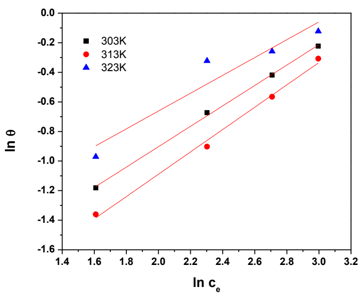


Fruits

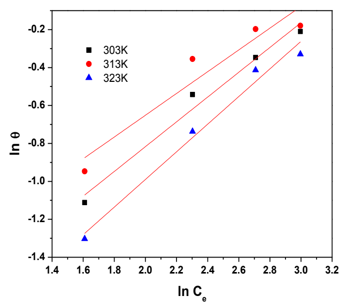


Seeds

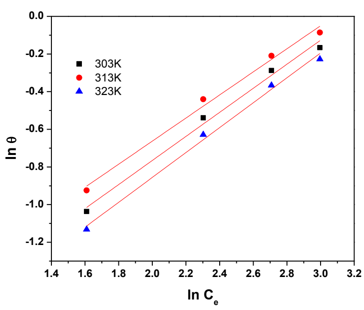
Fig. 111 Langmuir adsorption isotherm plot for mild steel in 1N HCl containing different concentration of PD plant alcoholic extracts (a) leaves (b) barks (c) fruits and (d) seeds.



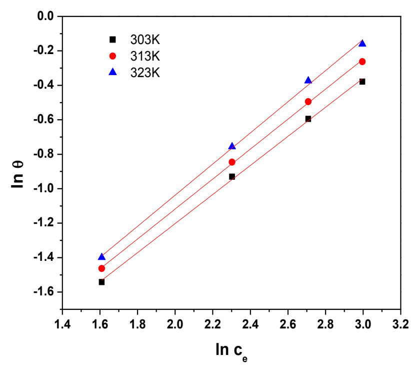
Leaves



Barks



Fruits



Seeds

Fig. 112 Hasley adsorption isotherm plot for mild steel in 1N HCl containing different concentration of PD plant alcoholic extracts (a) leaves (b) barks (c) fruits and (d) seeds.

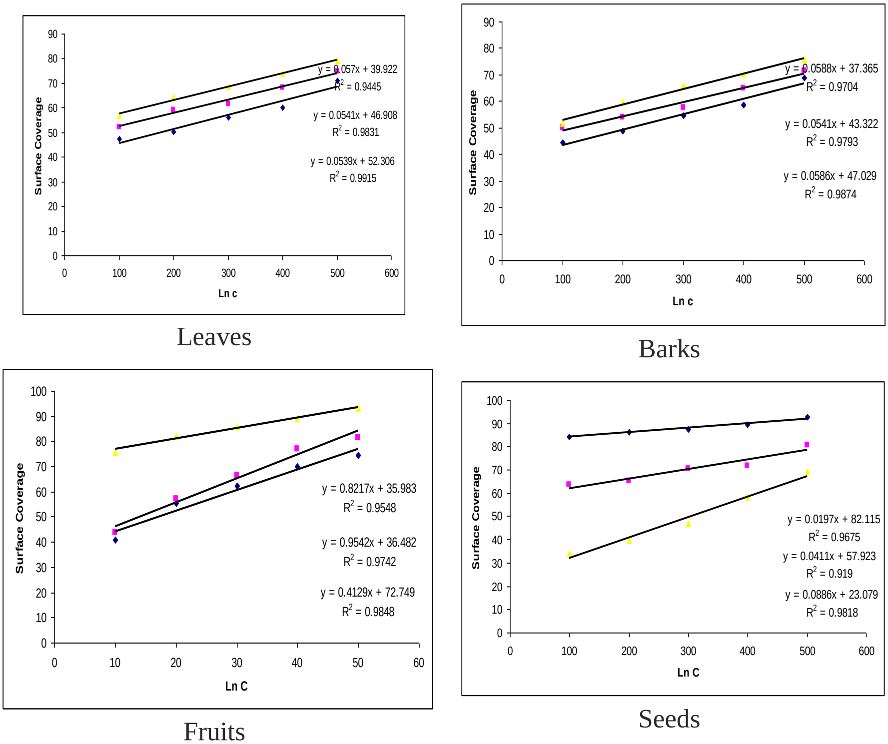
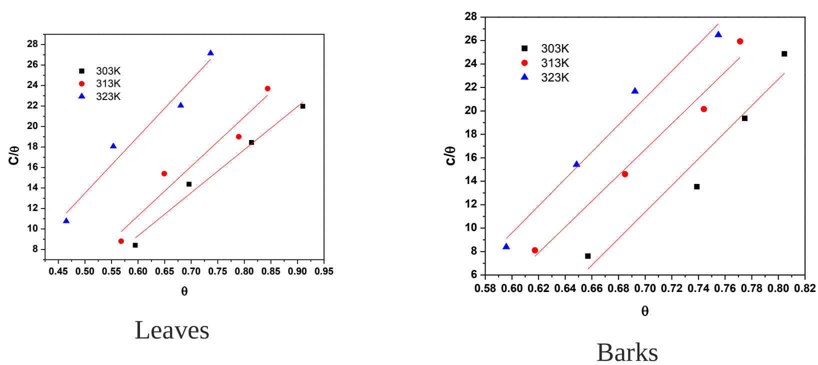
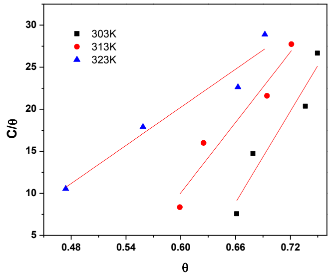
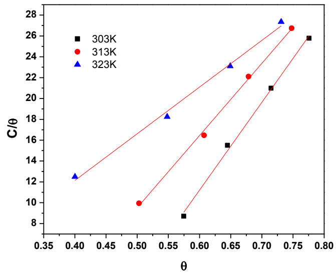


Fig. 113 Temkin adsorption isotherm plot for mild steel in 1N HCl containing different concentration of Alangium lamarckiii plant aqueous extracts (a) leaves (b) barks (c) fruits and (d) seeds.



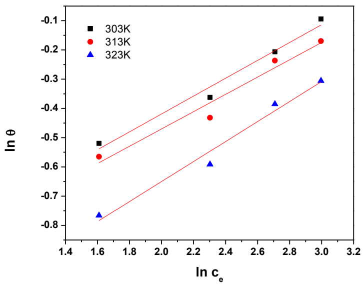


Fruits

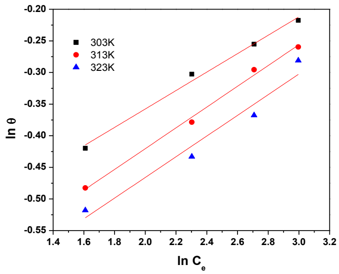


Seeds

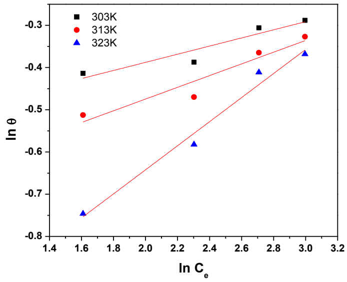
Fig. 114 Langmuir adsorption isotherm plot for mild steel in 1N HCl containing different concentration of Alangium lamarckiii plant aqueous extracts (a) leaves (b) barks (c) fruits and (d) seeds.



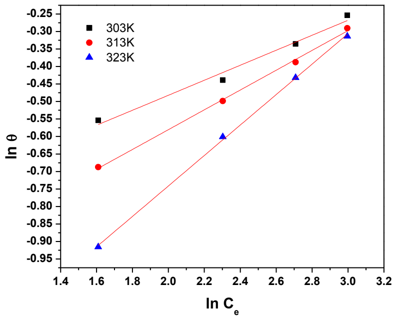
Leaves



Barks



Fruits



Seeds

Fig. 115 Hasley adsorption isotherm plot for mild steel in 1N HCl containing different concentration of Alangium lamarckiii plant aqueous extracts (a) leaves (b) barks (c) fruits and (d) seeds.

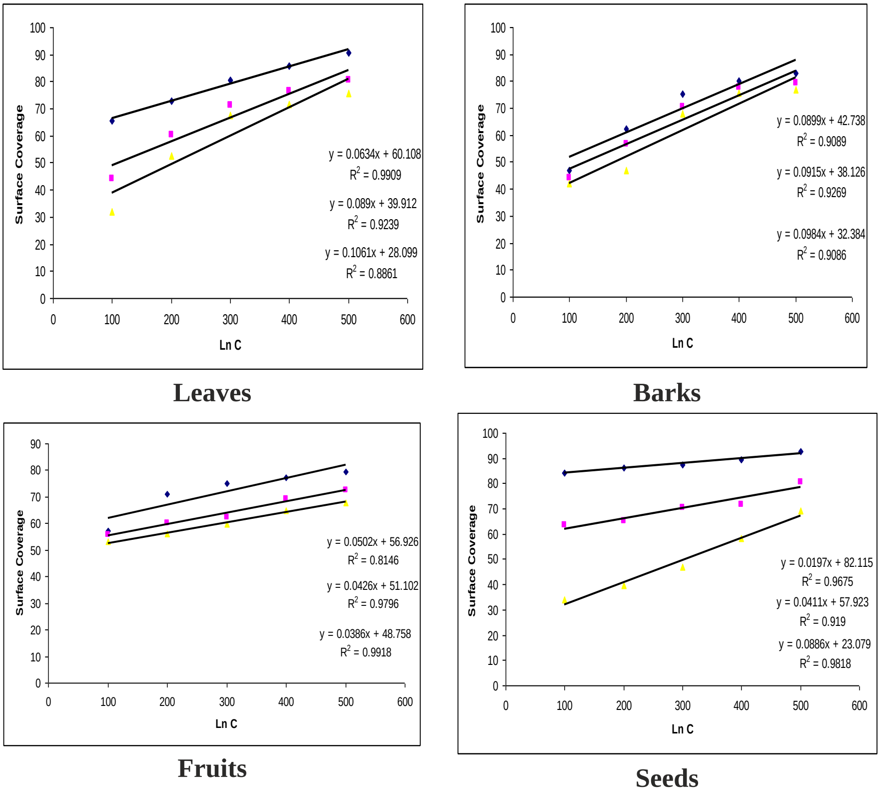
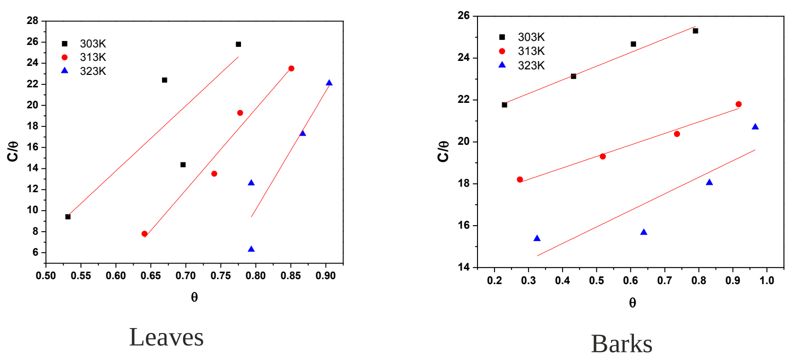
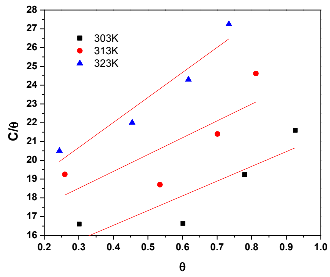
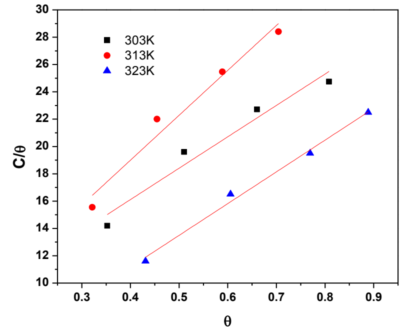


Fig. 116 Temkin adsorption isotherm plot for mild steel in 1N HCl containing different concentration of Alangium lamarckiii plant alcoholic extracts (a) leaves (b) barks (c) fruits and (d) seeds.



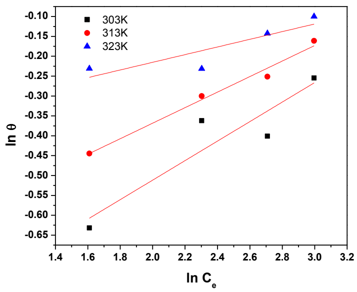


Fruits

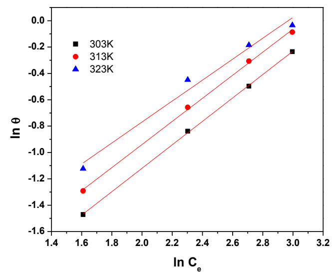


Seeds

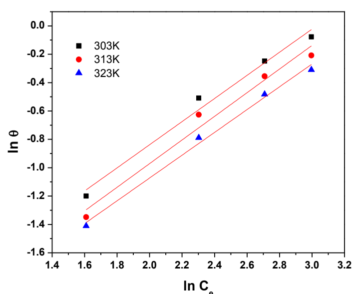
Fig. 117 Langmuir adsorption isotherm plot for mild steel in 1N HCl containing different concentration of Alangium lamarckiii plant alcoholic extracts (a) leaves (b) barks (c) fruits and (d) seeds.



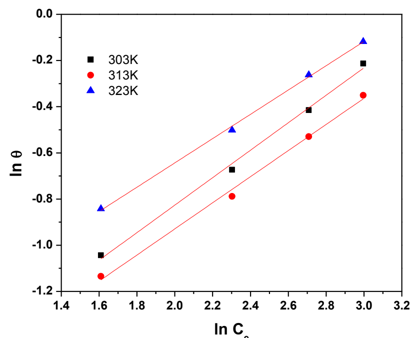
Leaves



Barks



Fruits



Seeds

Fig. 118 Hasley adsorption isotherm plot for mild steel in 1N HCl containing different concentration of Alangium lamarckiii plant alcoholic extracts (a) leaves (b) barks (c) fruits and (d) seeds.

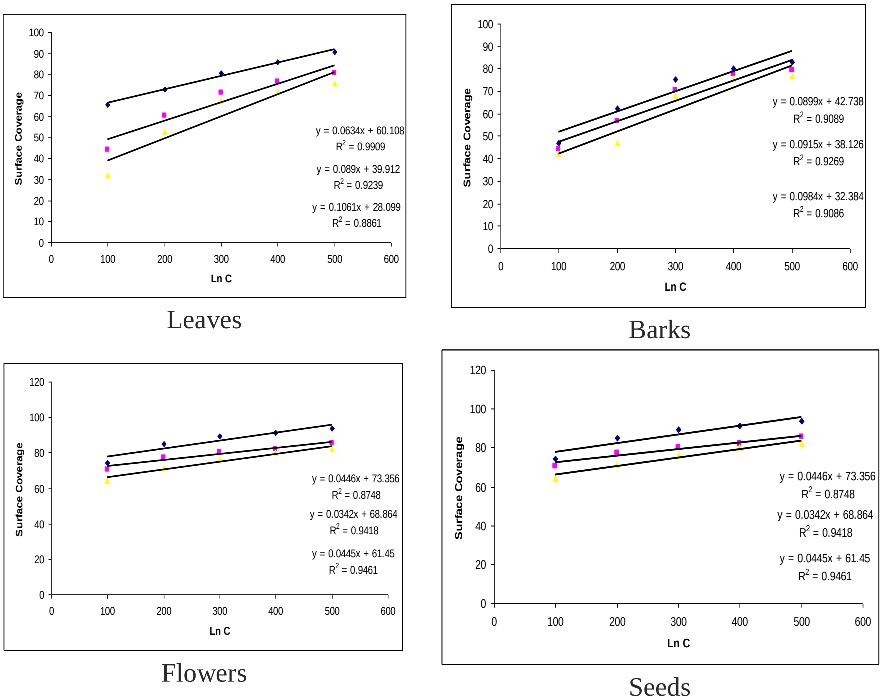
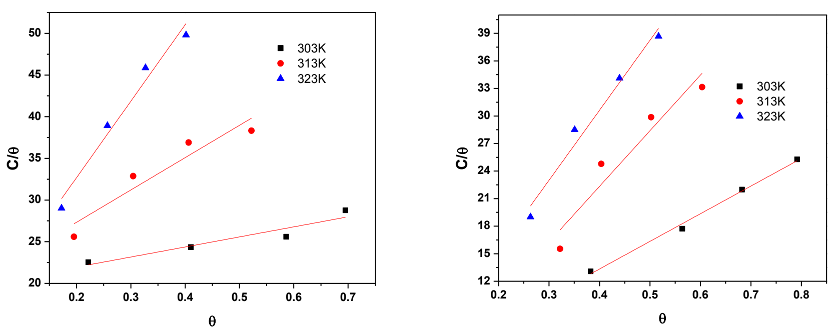
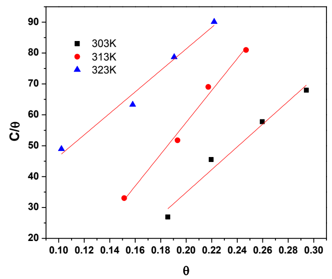


Fig. 119 Temkin adsorption isotherm plot for mild steel in 1N HCl containing different concentration of HI plant aqueous extracts (a) leaves (b) barks (c) flowers and (d) seeds.

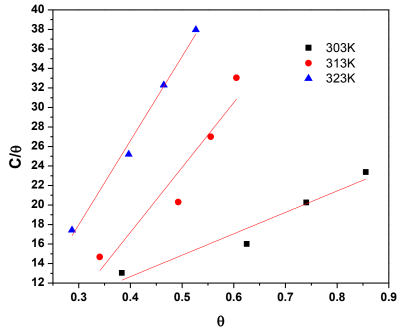


Leaves

Barks

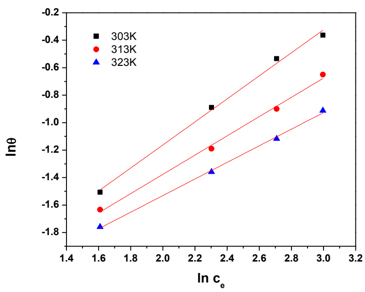


Flowers

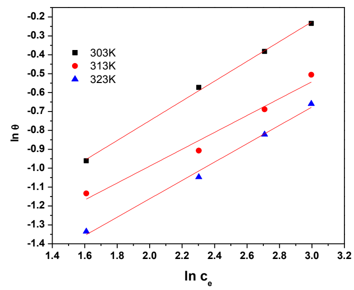


Seeds

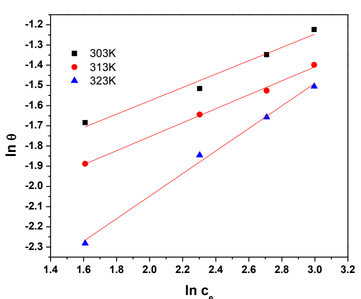
Fig. 120 Langumir adsorption isotherm plot for mild steel in 1N HCl containing different concentration of HI plant aqueous extracts (a) leaves (b) barks (c) flowers and (d) seeds.



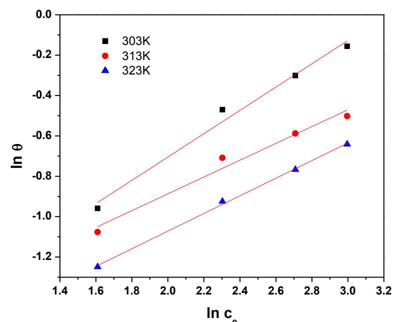
Leaves



Barks

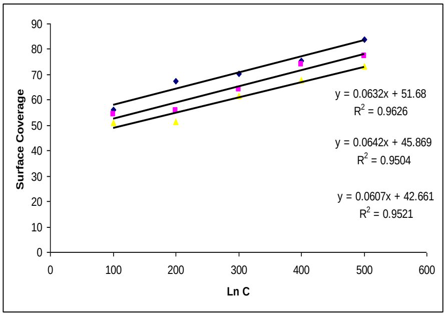


Flowers

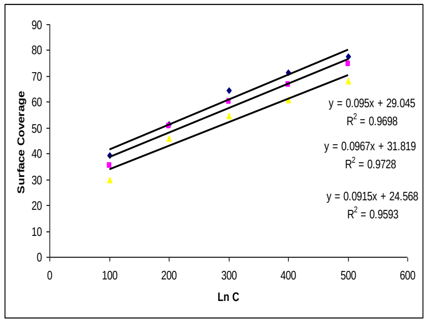


Seeds

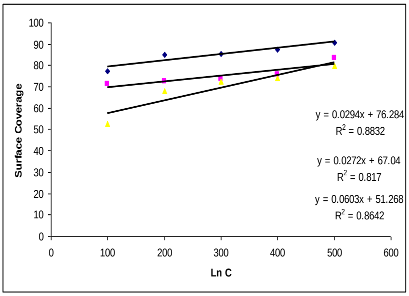
Fig. 121 Hasley adsorption isotherm plot for mild steel in 1N HCl containing different concentration of HI plant aqueous extracts (a) leaves (b) barks (c) flowers and (d) seeds.



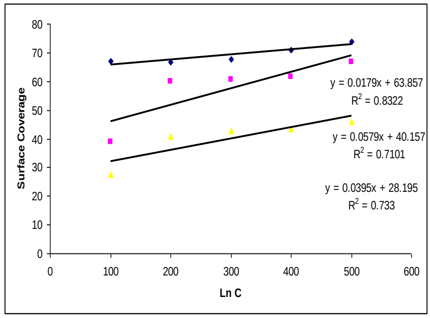
Leaves



Barks

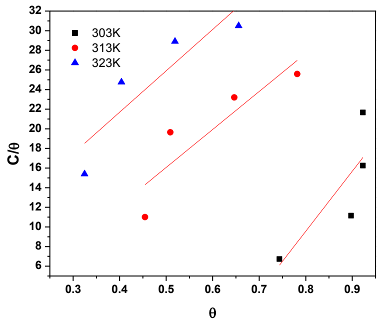


Flowers

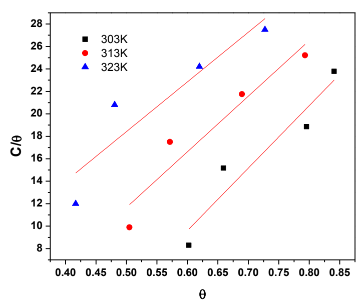


Seeds

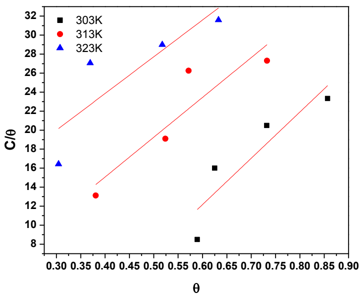
Fig. 122 Temkin adsorption isotherm plot for mild steel in 1N HCl containing different concentration of HI plant alcoholic extracts (a) leaves (b) barks (c) flowers and (d) seeds.



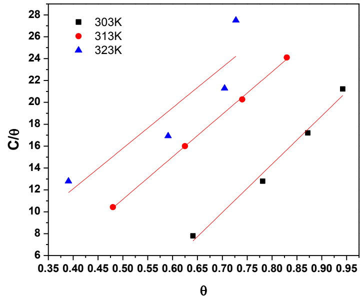
Leaves



Barks

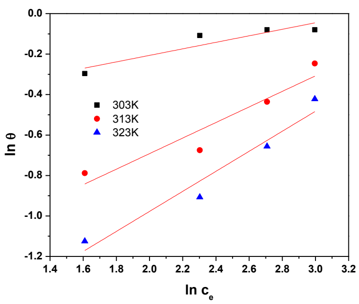


Flower

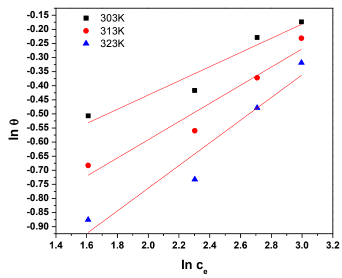


Seeds

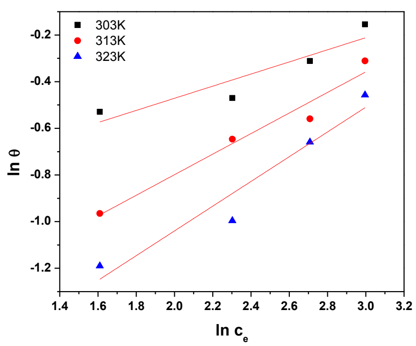
Fig. 123 Langumir adsorption isotherm plot for mild steel in 1N HCl containing different concentration of HI plant alcoholic extracts (a) leaves (b) barks (c) flowers and (d) seeds.



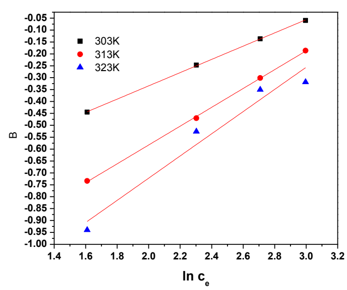
Leaves



Barks

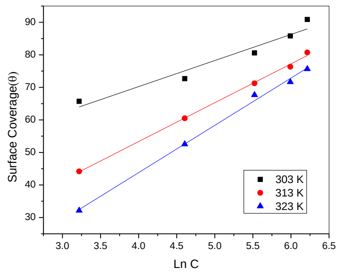


Flowers

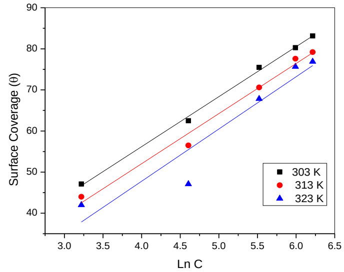


Seeds

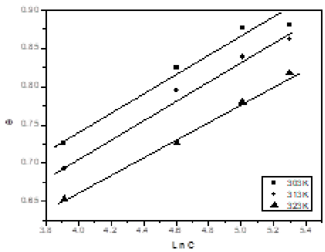
Fig. 124 Hasley adsorption isotherm plot for mild steel in 1N HCl containing different concentration of HI plant alcoholic extracts (a) leaves (b) barks (c) flowers and (d) seeds.



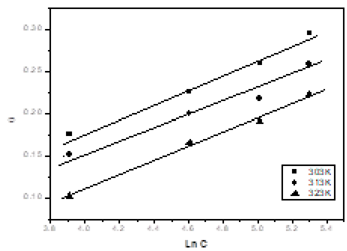
Leaves



Barks

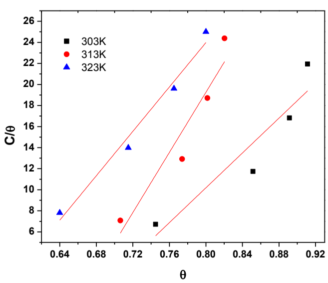


Fruits

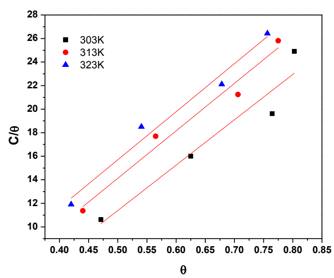


Seeds

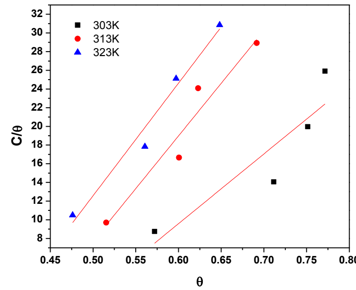
Fig. 125 Temkin adsorption isotherm plot for mild steel in 1N HCl containing different concentration of SS plant aqueous extracts (a) leaves (b) barks (c) fruits and (d) seeds.



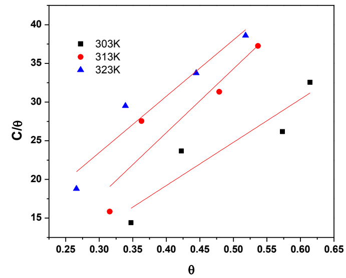
Leaves



Barks

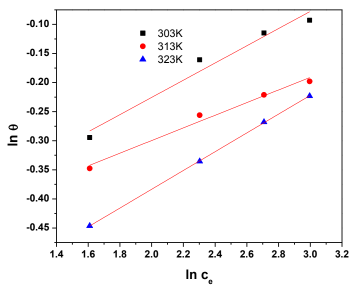


Fruits

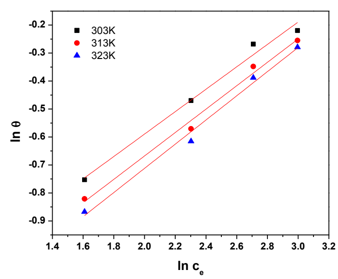


Seeds

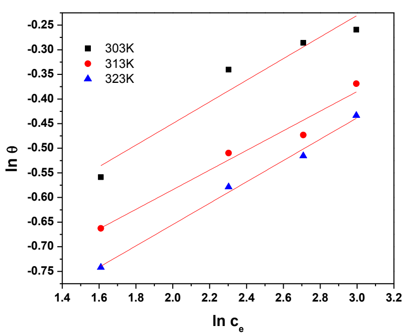
Fig. 126 Langumir adsorption isotherm plot for mild steel in 1N HCl containing different concentration of SS plant aqueous extracts (a) leaves (b) barks (c) fruits and (d) seeds.



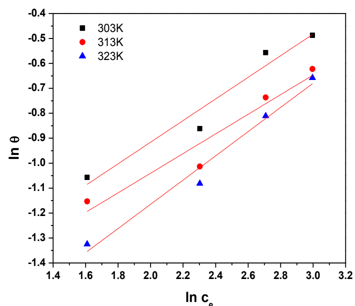
Leaves



Barks



Fruits



Seeds

Fig. 127 Hasley adsorption isotherm plot for mild steel in 1N HCl containing different concentration of SS plant aqueous extracts (a) leaves (b) barks (c) fruits and (d) seeds.

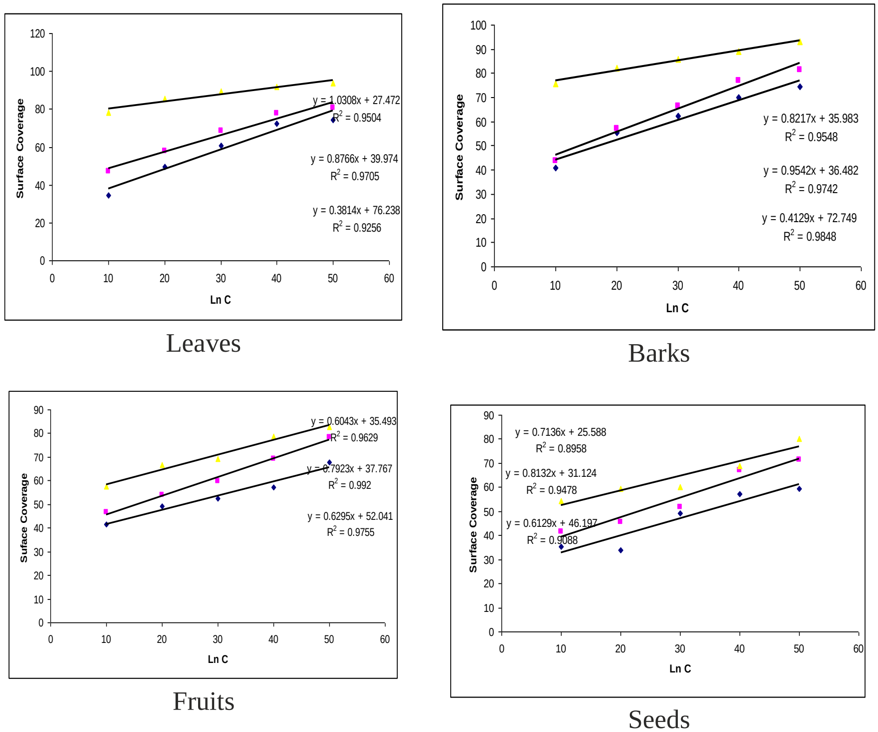
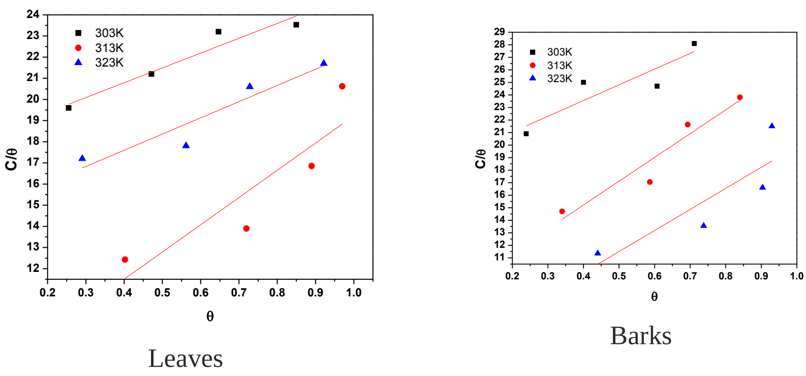
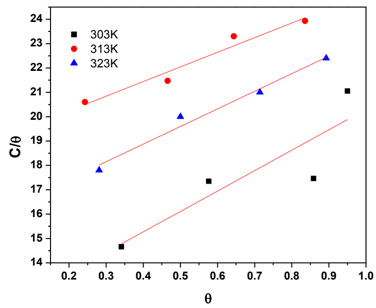


Fig. 128 Temkin adsorption isotherm plot for mild steel in 1N HCl containing different concentration of SS plant alcoholic extracts (a) leaves (b) barks (c) fruits and (d) seeds.





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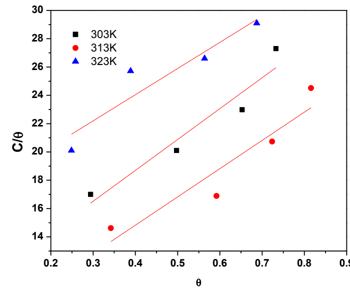
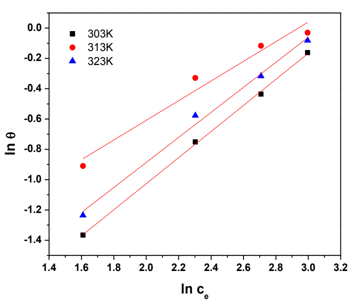
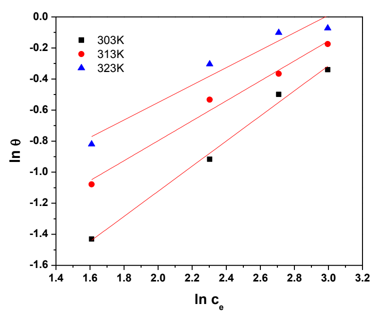


Seeds

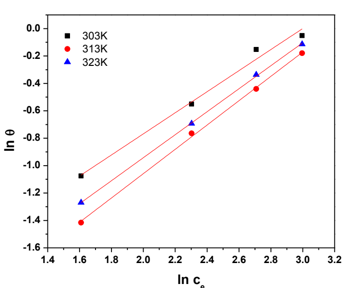
Fig. 129 Langumir adsorption isotherm plot for mild steel in 1N HCl containing different concentration of SS plant alcoholic extracts (a) leaves (b) barks (c) fruits and (d) seeds.



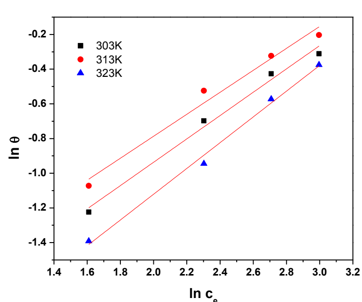
Leaves



Barks



Fruits



Seeds

Fig. 130 Hasley adsorption isotherm plot for mild steel in 1N HCl containing different concentration of SS plant alcoholic extracts (a) leaves (b) barks (c) fruits and (d) seeds.

5.11 Thermodynamic considerations

From the temperature study results, thermodynamic parameters such as ***Ea, ΔH, ΔS*** and **ΔG** were calculated. Values of ***Ea, ΔH, ΔS,*** **ΔG** were obtained at different temperature of ML leaves of both extract is presented in ***Tables 46 - 47***. The activation parameters play an important role in understanding the inhibitive mechanism of the inhibitor. The activation energies (Ea) for the corrosion of mild steel in the absence and presence of different concentration of the plants extracts were calculated by using Arrhenius-type equation.

$$\ln R_c = \ln A - \frac{Ea}{RT}$$

Where Ea is the activation energy, R is universal gas constant, A is the Arrhenius pre-exponential factor, T is absolute temperature and R_c is corrosion rate. The values of Ea were evaluated from the slope of the plots of R_c versus 1/T (not shown) and it is given in ***Tables 46 - 47.*** The enthalpy of activation (ΔH*) and the entropy of activation (ΔS*) for the corrosion of mild steel in 1N HCl solution was estimated using the transition state equation.

$$Rc = KT/h \exp(\Delta S/R) \exp(-\Delta H/RT)$$

Where K is the Boltzmann constant, h is the Plank constant, A is Arrhenius pre-exponential factor, T is the absolute temperature and R_c is corrosion rate.

$$Ea_{(ads)} = Ea_{(system)} - Ea_{(blank)}$$

$Ea_{(blank)}$ is the apparent activation energy in the absence of the inhibitor, $Ea_{(system)}$ is the apparent activation energy in the presence of the inhibitor and $Ea_{(ads)}$ is the apparent activation energy of adsorption.

The data in ***Tables 46 - 47*** indicates that the addition of plant extract leads to increase in Ea and (ΔH*) to values greater than that of the free solution. The average difference values of (Ea - ΔH*) is 2.69 KJ/mol which is approximately equal to the value of RT (i.e. 8.314 x 326.5 = 2.71) KJ/mol at the average temperature studied. This result agrees that the corrosion process is uni-molecular reaction defined by the perfect gas equation given by

$$Ea - \Delta H^* = RT$$

Positive values of enthalpies ΔH* reflect endothermic nature of mild steel dissolution. The presence of inhibitor increases ΔH* and the reaction becomes more endothermic when compared to blank. Large and positive values of entropies showed that the activated complex in the rate determining step represents a dissociation step meaning that an increase in disordering takes place on going from reactants to the activated complex. A negative value for ΔS also indicates spontaneity of the adsorption process, the increase of ΔS (**-62.90 to -35.76 and -116.89 to -97.94**) with increasing inhibitor concentration, reveals that an increase in disordering takes place on going from reactant to the activated complex. However physical adsorption was the major contributor while chemisorption only slightly contributed to the adsorption mechanism judging from the decrease in percentage of inhibition efficiency with increase in temperature. Chemisorbed molecules protect anodic areas and reduce the inherent reactivity of the metal at the sites where they are attached. The values of **ΔG** up to ***-20 KJ/mol*** are consistent with electrostatic interaction between charged molecules and a charged metal and the process indicates physical adsorption, while those more negative than ***-40 KJ/mol*** involves charge sharing or transfer from the inhibitor molecules to the metal surface to form a co-ordinate type of bond that indicates chemical adsorption. According to the data of **ΔG** obtained (**-8.782 to -11.794 and -15.77 to -10.79 *KJ/mol***) in the present study indicates that the adsorption mechanism of plant extract on mild steel is simply physisorption, thus inhibitor protection is through film formation providing an unbreakable (***see SEM Fig. 75 - 86***) barrier against aggressive ions, the electrolyte and the adsorbed layer is more stable one. The values of **ΔG** do not show a gradual increase or decrease with change in inhibitor concentration. This might be due to the fact that the adsorption of the phytoconstituents is dependent not only on concentration but also on other factor like presence of others constituents, electronic and steric interaction of the inhibitor constituents among themselves as well as with the others constituents present in the corrosive media, etc. The data clearly clarifies that the values of Ea increase with increasing the concentration of plant extract, while the decrease in the value of A (Arrhenius pre-exponential factor) indicates that the higher values of Ea and the lower value of A lead to a reduction in the corrosion rate. The results can be explained by this behavior that the size ratio and equals the number of adsorbed water molecules replaced by an inhibitor (adsorption) molecules.

Table 46 Thermodynamic parameters for adsorption of ML plant (aqueous extract) on mild steel in acid solution at various Temperatures.

Adsorption isotherm	**Temperature**	**Slope**	**K**	**R^2**	**Ea**	**ΔG**	**ΔH**	**ΔS**
Langumir	303	0.8239	0.6049	0.9928	10.127	-8.782	7.819	-62.90
	313	0.8378	0.7827	0.9943	18.945	-10.387	6.186	-37.26
	323	0.8290	0.6638	0.9921	21.489	-11.794	16.326	-35.76

Table 47 Thermodynamic parameters for adsorption of ML plant (alcoholic extract) on mild steel in acid solution at various Temperatures.

Adsorption isotherm	**Temperature**	**Slope**	**K**	**R^2**	**Ea**	**ΔG**	**ΔH**	**ΔS**
Langumir	303	0.6039	0.89	0.99	24.67	-15.77	53.38	-116.89
	313	0.8993	0.93	0.99	46.98	-15.26	60.72	-103.67
	323	0.8097	0.78	0.99	49.90	-10.79	62.43	-97.94

5.12 Mechanism of corrosion inhibition

The possible mechanism of inhibition can be described on the center of adsorption method and the structure of the components present in the all plant extracts. The leading constituent of all plant extracts whose structures are given ***[Figures 21-26]*** having multiple bonds ***(pi or double aromatic ring)*** through which they get adsorbed on the metal surface. The compounds have to ***block the vigorous corrosion positions*** on the MS surface and hence the adsorption is occurred by the bonding of the free electron of the inhibitors (through electron transfer from the adsorbed species to the ***vacant electron orbital of low energy in the metal to form a co-ordinate type link***) with the metal.

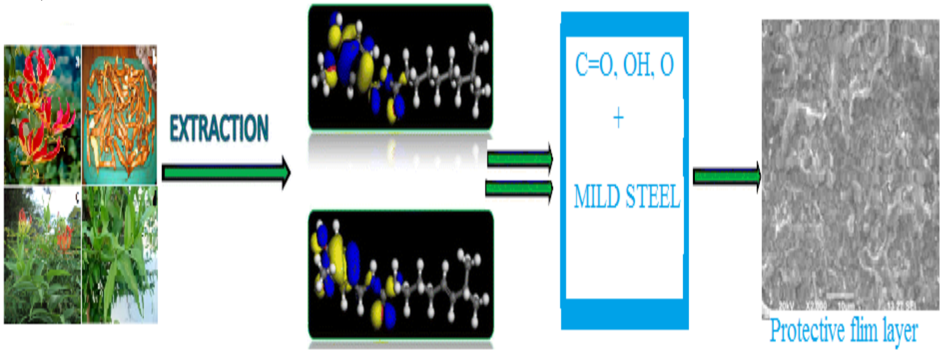


Fig. 131 Phytochemical constituent involve in corrosion mechanism

Phytochemical analysis showed the presence of [***Table 4-9***] ***glycosides, flavonoids, saponins, steroids, phenols, tannins,*** *and* ***alkaloids*** with the heteroatoms like ***N, S, O*** etc. Above organic fragments grows adsorbed (iron has co-ordinate affinity towards heteroatom) on the metal surface developing a protecting film and difference in inhibitory properties of inhibitor is closely related to the difference in molecular structure. The inhibitive effect of the natural plants extract were attributed by FTIR spectra [***see Figures 27-38]*** that the functional ***hydroxyl groups, carbonyl groups and oxygen*** within the inhibitor macromolecules could make bridge between the mild steel, as a results the corrosion rate was decreased. Moreover, the presence of lone-pair of electrons on the oxygen atoms of the hydroxyl groups of the inhibitor may enhance the interaction between the inhibitor and positives sites formed on mild steel surface.

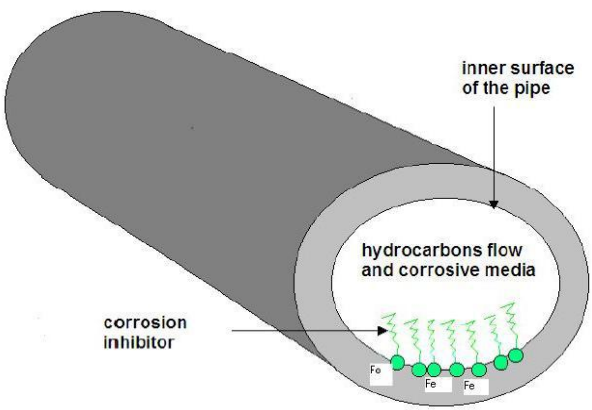


Fig. 132 Representation of a corrosion inhibitor adsorbed into metal surface

The inhibition efficiency depends on many factors including the ***number of adsorption centers, mode of interactions with metal surfaces, molecular size*** *and*

structure. From all the above facts, it is confirmed that the investigated selected plants ((i) electrostatic interaction between the charged molecules and the charged metal (ii) interaction of unshared electron pairs in the molecules with the metal (iii) interaction of pi electron with the metal (iv) combination of type) obey a ***combination type*** mechanism [1]. Adsorption of negatively charged species is facilitated if the metal surface is positively charged. Positively charged species can also protect the positively charged metal surface acting with a negatively charged intermediate, such as acid anion adsorbed on the mild steel surface. Better corrosion inhibition properties exhibited by the plant extracts give new alternative way for the sustainability of green or eco-friendly material applications.

5.13 Conclusion

The effect of various concentrations of green extracts, namely, Gloriosa Superba Linn (GSL), Madhuca longifolia (ML), Alangium lamarckiii (AL), Holoptelea integrifolia (HI), Pithecellobium dulce (PD) and Schreabera swietenioids (SS) plant's extracts on the corrosion of mild steel in 1N HCl has been studied. The

following conclusions can be made based on the results obtained.

- ❖ Based on the literature survey, during the corrosion reaction the metal loses its useful properties. As a result, chemical or electrochemical reaction takes place with the environment.
- ❖ The studies on various extracts of six different plants showed promising corrosion inhibition properties for mild steel in 1N HCl media.
- ❖ The weight loss data showed that the inhibition efficiency of all these green inhibitors increase with the increase in the concentration of the extract and inhibit the corrosion of mild steel.
- ❖ Corrosion rate reduced with increase in concentration of inhibitor and increased with raise in acid concentration.
- ❖ Potentiodynamic polarization studies revealed that the extracts act through mixed mode of inhibition.
- ❖ The Nyquist diagrams obtained in impedance method revealed that charge-transfer process mainly controls the corrosion of mild steel.
- ❖ The mechanism involved in this study is the phytochemical constituents present in both (aqueous and alcoholic) the plant extracts that have adsorbed on the mild steel surface forming a protective thin film layer and hence the anti-corrosive behavior.
- ❖ Phytochemical constituents in both the extracts play a very vital role in the inhibiting action.
- ❖ The SEM morphology of the adsorbed protective film on the mild steel has confirmed the high performance of inhibitive effect of the plant extracts.
- ❖ Organic molecules present in the extract were also found responsible for the performance of the inhibitor which was well supported by FTIR studies.
- ❖ The Temperature studies showed that when the temperature increases,

the inhibition efficiency decreases. Therefore, the isotherm observed is the Temkin, Langumir, Hasley adsorption isotherm.

- ❖ The reduction of corrosion inhibition efficiencies by increasing the temperature, may be due to thermal degradation of its organic content especially degradation of plant extracts.
- ❖ The adsorption study results revealed that the nature of all the studied inhibitors showed that the adsorption is of physisorption and no chemisorption occur between the inhibitor molecules and the metal surface.
- ❖ The natural of plant extracts were identified as very good inhibitors because of the presence of heteroatoms and unsaturated bond that cause effective adsorption process leading to the formation of an insoluble protective surface film which suppresses the metal dissolution reaction.
- ❖ Results obtained in weight loss method were very much in good agreement with the electrochemical methods (Potentiodynamic polarization and impedance method).
- ❖ All the studied plant extracts exhibit various biological and pharmacological activities approximately such as 97 % antiviral, antibacterial, antifungal etc., but 98 % serve as anticorrosion activity.
- ❖ Comparing the inhibition efficiency of the plant extract, the aqueous extract showed higher inhibition than that of the alcoholic extract in 1N HCl medium.
- ❖ Among the six plant extracts studied, the maximum inhibition efficiency was found in Alangium lamarckiii leavess which showed 99.79 % inhibition efficiency at 15 v/v concentration of the extract.

This investigation gave an overview on material science in relation with a background of physical and chemical science and the nature of the metal have been studied. For further conclusion of corrosion rate the same work can be carried out in microorganism mediated corrosion.

References

[1] M. Lebrini, F. Robert and C. Roos, Int. J. Electrochem. Sci., 6 , 847-859, 2011.