Global Journal of Science Frontier Research: B
Chemistry
Volume 14 Issue 2 Version 1.0 Year 2014
Type : Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4626 & Print ISSN: 0975-5896

Aloe Vera used as Inhibitor for Corrosion Protection of Beverage Containing Stainless Steel

By Rajesh Kumar Singh & Vikas Kumar
J P University, India

Abstract- Beverage companies are used stainless steel in their manufacturing operations. Generally beverage companies make wine, beer and various types of soft drink. Their transportation and storage can be done in stainless steel containers. Beverage industries use different types of raw materials for the productions wine, beer and soft drink. They are acidic nature and their pH occur between5.5 to 6.5. Some preservatives are also added into these drinks for prevention of microorganism. These preservatives have acidic character. Wine, beer, soft drink and preservatives develop corrosion cell on the surface stainless steel thus corrosion reaction starts and harmful metal ions go into solution in this way these drinks contaminated. The contaminated drinks create several diseases. Corrosive effects are of remarkable consequence in beverage processing industry as wine, beer and soft drink contain corrosive substances, thereby causing significant impact on the degradation of constructional materials and the maintenance or replacement of products lost or contaminated as a result of corrosion reactions.

Keywords: aloevera, stainless steel, inhibitor, beverage, contaminated.

GJSFR-B Classification : FOR Code: 039999

ALOEVERA USEDASINHIBITORFORCORROSIONPROTECTION OFBEVERAGE CONTAININGSTAINLESSSTEEL

Aloe Vera used as Inhibitor for Corrosion Protection of Beverage Containing Stainless Steel

Rajesh Kumar Singh [α] & Vikas Kumar [σ]

Abstract- Beverage companies are used stainless steel in their manufacturing operations. Generally beverage companies make wine, beer and various types of soft drink. Their transportation and storage can be done in stainless steel containers. Beverage industries use different types of raw materials for the productions wine, beer and soft drink. They are acidic nature and their pH occur between5.5 to 6.5. Some preservatives are also added into these drinks for prevention of microorganism. These preservatives have acidic character. Wine, beer, soft drink and preservatives develop corrosion cell on the surface stainless steel thus corrosion reaction starts and harmful metal ions go into solution in this way these drinks contaminated. The contaminated drinks create several diseases. Corrosive effects are of remarkable consequence in beverage processing industry as wine, beer and soft drink contain corrosive substances, thereby causing significant impact on the degradation of constructional materials and the maintenance or replacement of products lost or contaminated as a result of corrosion reactions.

For this work aloevera was taken as inhibitor. Aloevera was found to inhibit the corrosion of stainless steel in beverage. Its inhibition activities studied at different concentrations, temperatures and different intervals of times. The inhibition efficiencies and surface coverage area of aloevera increased as the concentration and temperature of aloevera increased. Inhibitive and adsorption properties of aloevera for the corrosion of stainless steel were investigated using weight loss and potentiostic methods. Test coupons dipped into drinks and the corrosion rate was determined by weight loss method. The corrosion current density absence and presence of inhibitor was studied by Potentiostic polarization technique.

The surface adsorption studied with help of Arrhenius equation, heat of adsorption, free energy, enthalpy and entropy. These thermo dynamical Para meters results produced the adsorption of the inhibitor on the surface of stainless steel was found to be exothermic, spontaneous and followed the mechanism of physical adsorption. Also Langmuir and Temkin adsorption isotherm was found to be the best isotherm that described the adsorption characteristics of the inhibitor. The result revealed that the corrosiveness of stainless steel mainly function of acidity of beverage.

Keywords: aloevera, stainless steel, inhibitor, beverage, contaminated.

Author α : Assistant Professor, Department of Chemistry, Jagdam College, J P University, Chapra, India. e-mail: rks_jpujc@yahoo.co.in
Author σ : Research Scholar, Department of Chemistry, Jagdam College, Chapra, India.

I. Introduction

The material for most technical equipment are stainless steel which is selected because of its strength, ductility, weldability and it is amenable to heat treatment for varying mechanical properties. Metals and its alloys come in contact of acids during industrial processes which cause severe corrosion problems and economical losses. Beverage industry uses organic and inorganic substances for preservative purpose and they generate corrosive environment for constructional materials. These corrosive effects on different constructional materials in all phases of processing and packing of food which becomes basic need of life. Other factors affect the corrosion of metal like moist oxygen, oxide of nitrogen, oxide of sulphur, temperature, flow of liquid, pH and other factors all of which can alter the rate of corrosion.

Chemists and corrosion specialists have developed various types' corrosion protections methods. Generally organic and inorganic[1-3] substances used as inhibitors. Several works have been done with help of organic and inorganic materials for the corrosion protection of metal by coating[4-6]. Oxides of metals and phosphate of metals used as inhibitors[7, 8]. Sulpha drugs[9, 10] applied for corrosion control of stainless steel in sugar industry. Aromatic amine, fused aromatic amine and hetero cyclic aromatic amine[11] worked as inhibitors in phosphate inhibitors. Cyclic amine used for corrosion inhibition of metal in pulp and paper industry[12]. Nano coatings of organic and inorganic materials on surface of metal could produced good inhibition properties and improve the life of material[13]. Several types of nano coating can be done on the surface of materials like nano composite thin film coating, thermal barrier coating, Top layer coating, nano structural change and conversion coating. Thiourea and its derivates worked as inhibitors in petroleum industry in various operational units like production, storage and transportation. Recently natural products applied for corrosion protection of metal in acidic medium and these inhibitors were ecofriendly for environment. Polymeric coating also applied in highly corrosive environment. Organic compounds having nitrogen, oxygen and sulphur behave like anticorrosive inhibitors[14]. Electron rich organic compounds have good inhibition capability against acid. The corrosion is controlled by the application of aliphatic and aromatic amines. It is also observed that primary, secondary, tertiary and quaternary amine is produced good inhibitive effect against acidic medium. Several workers used heterocyclic compounds as inhibitors which possessed nitrogen, oxygen and sulphur. Rubber, polymer and silicon are used as coating material for protection of metal. For this work aloevera used as inhibitors for corrosion of protection of stainless in beverage.

II. Methods and Methodology

The sheets of stainless steel metal of 0.1 cm thickness was mechanically cut into coupons of sizes of 5cm length by 3cm width, perforated with hole of same diameter centrally to allow the passage of thread. These coupons were surface prepared using emery paper, acetone and water. The tested coupons were dipped into 40ml solution of beverage drink in 100ml beakers. The coupons, exposure periods were 24hrs, 48hrs, 72hrs and 96hrs. Tests were performed at different concentrations 2ml, 4ml and 6ml aloevera and at different temperatures 20°C, 25°C, 30°C and 35°C and temperature were maintained constant by keeping the solutions in a thermostat. The average corrosion rates of the in various concentrations and temperatures were determined by using weight loss method. The corrosion current measured with Potentiostatic polarization by using an EG & G Princeton Applied Research Model 173 Potentiostate. A platinum electrode used as an auxiliary electrode and a calomel electrode used as reference electrode with stainless steel coupons.

III. Results and Discussion

The Corrosion rate of metal was calculated absence and presence aloevera by weight loss methods at different concentrations and temperatures with help of equation1.

$$K\ (\text{mmpy}) = 13.56\ W / D\ A\ t \qquad (1)$$

where W = weight loss of test coupon expressed in kg, A = Area of test coupon in square meter, D = Density of the material in kg. M^{-3}.
The inhibition efficiency of inhibitor was determined by using equation 2.

$$IE = (1- K / K_o)\ 100 \qquad (2)$$

where K is the corrosion rate with inhibitor and K_o is the corrosion rate without inhibitor.
The surface coverage area of inhibitor was measured by equation 3.

$$\theta = (1 - K / K_o) \qquad (3)$$

where θ = Surface area, K = Corrosion rate with inhibitor, K_o = corrosion rate without inhibitor.

The Inhibition of Aloevera studied at 2ml, 4ml and 6ml concentrations and temperatures mention that concentrations were20°C, 25°C, 30°C and 35°C. The rate of corrosion of stainless steel with and without inhibitor at different concentrations and temperatures were recorded in Table 1, Table 2 and Table 3. Investigation of results of Table 1, Table2 and Table3 it observed that without inhibitor corrosion rate is high and addition of inhibitor corrosion rate is reduced. The results of Table1, Table 2 and Table 3 and Figure1indicated that at lower concentration of inhibitor, the inhibition efficiency and surface coverage area values were smaller and higher concentration the inhibition efficiency and surface coverage area values were bigger.

The recorded values of the rate of corrosion at different temperatures without and with inhibitor in Table 1, Table 2 and Table3 and Figure 2 were depicted that the corrosion rate increased without inhibitor and decreased without inhibitor. These results observed that use inhibitor active at high temperature and produces good inhibition efficiency.

Table 1 : Inhibition of Aloevera with beverage at different temperatures and 2ml concentration.

Inhibitor	Temp	20°C	25°C	30°C	35°C	C (ml)	logC
IH(0)	K_0	0.387	0.774	1.161	1.548	0.00	0.00
	$\log K_0$	-0.412	-0.111	-0.064	0.189		
IH(1)	K	0.301	0.512	0.713	0.965	2	-2.69
	logK	-0.521	-0.291	-0.147	-0.015		
	θ	0.22	0.34	0.39	0.38		
	(1- θ)	0.78	0.66	0.61	0.62		
	log(θ/1- θ)	-0.54	-0.28	-0.19	-0.21		
	(C/ θ)	-12.25	-7.91	-6.89	-7.07		
	log(C/ θ)	-0.602	-0.040	-0.051	-1.154		
	IE (%)	22	34	39	38		

Table 2 : Inhibition of Aloevera activities with beverage at different temperatures and 4ml concentration.

Inhibitor	Temp	20^0C	25^0C	30^0C	35^0C	C (Ml)	Logc
IH(0)	K_0	0.387	0.774	1.161	1.548	0.00	0.00
	$logK_0$	-0.412	-0.111	-0.064	0.189		
IH(1)	K	0.214	0.512	0.713	0.665	4	-2.39
	logK	-0.669	-0.430	-0.301	-0.177		
	θ	0.45	0.52	0.56	0.58		
	$(1-\theta)$	0.55	0.48	0.44	0.42		
	$\log(\theta/1-\theta)$	-0.09	-0.04	-0.10	-0.14		
	(C/θ)	-5.31	-4.59	-4.26	-4.12		
	$\log(C/\theta)$	-0.508	-0.229	-0.585	-0.920		
	IE (%)	45	52	56	58		

Table 3 : Inhibitor Aloevera activities with beverage at different temperatures and 6ml concentration.

Inhibitor	Temp	20^0C	25^0C	30^0C	35^0C	C (Ml)	Logc
IH(0)	K_0	0.387	0.774	1.161	1.548	0.00	0.00
	$logK_0$	-0.412	-0.111	-0.064	0.189		
IH(1)	K	0.195	0.201	0.319	0.413	6	-2.23
	logK	-0.709	-0.696	-0.496	-0.384		
	θ	0.49	0.74	0.72	0.73		
	$(1-\theta)$	0.51	0.26	0.28	0.27		
	$\log(\theta/1-\theta)$	-0.01	-0.28	-0.19	-0.21		
	(C/θ)	-4.55	-3.01	-3.09	-3.05		
	$\log(C/\theta)$	-0.259	-1.89	-1.04	-1.30		
	IE (%)	49	74	72	73		

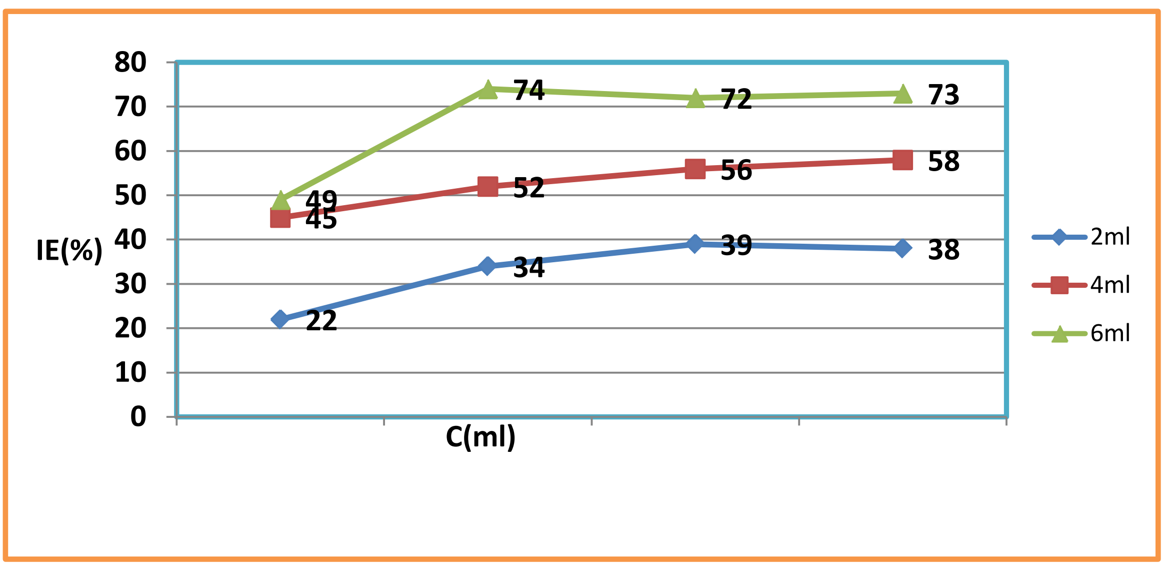

Figure 1 : Plot of IE(%) Vs. C(ml) for Stainless steel at different concentrations

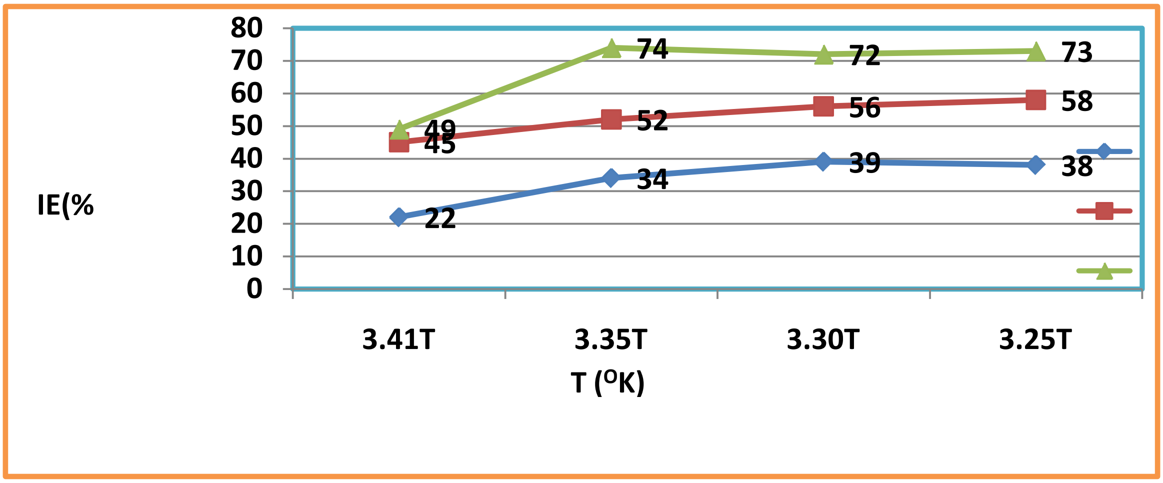

Figure 2 : Plot of IE (%) Vs. T (^{0}K) for Stainless steel at different temperatures

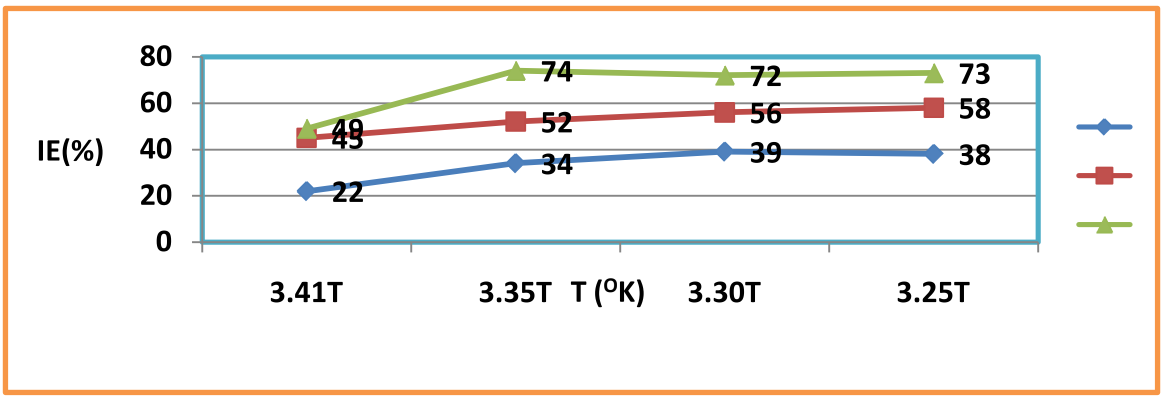

Figure 3 : Plot of IE (%) Vs. T (^{0}K) for Stainless steel at different temperatures

Activation energy was determined with help of Arrhenius equation 4

$$d/dt(\log K) = E_a / R T^2 \qquad (4)$$

where T is temperature in Kelvin and E_a is the activation energy of the reaction.

The values of activation energies were recorded in Table4, Table5 and Table6 absence and presence inhibitor by use of the plot between log K Vs. 1/T in Figure 3. It observed that without inhibitor activation energies decreased and with inhibitor activation energies increased. It indicated that physical adsorption occurred on the surface metal.

Table 4 : Thermo dynamical parameters for Aloevera at different temperatures

Thermodynamical Parameters	20^0C	25^0C	30^0C	35^0C
$E_{a(0)}$	26.87	7.11	4.04	11.75
E_a	33.98	18 .64	9.27	1.18
Q_{ads}	-35.81	-18.45	-12.24	-4.05
ΔG	-38.37	-21.14	-14.93	-6.72
ΔH	-68.75	-52.22	-41.98	-32.75
ΔS	-40.32	-31.17	-25.44	-20.15

Table 5 : Thermo dynamical parameters for Aloevera at different temperatures

Thermodynamical Parameters	20^0C	25^0C	30^0C	35^0C
$E_{a(0)}$	26.87	7.11	4.04	11.75
E_a	43.64	27 .55	19.01	12.18
Q_{ads}	-5.67	-2.17	-6.56	-8.70
ΔG	-8.06	-4.56	-8.95	-11.09
ΔH	-78.29	-61.20	-51.63	-43.89
ΔS	-45.91	-36.53	-31.29	-27.01

Table. 6 : Thermodynamical parameters for Aloevera at different temperatures

Thermodynamical Parameters	20^{0}C	25^{0}C	30^{0}C	35^{0}C
$E_{a(0)}$	26.87	7.11	4.04	11.75
E_a	46.25	44 .60	31.31	23.87
Q_{ads}	-1.10	-29.09	-25.88	-26.79
ΔG	-3.33	-31.32	-28.11	-29.02
ΔH	-80.88	-78.18	-63.76	-55.75
ΔS	-47.43	-46.67	-38.64	-34.25

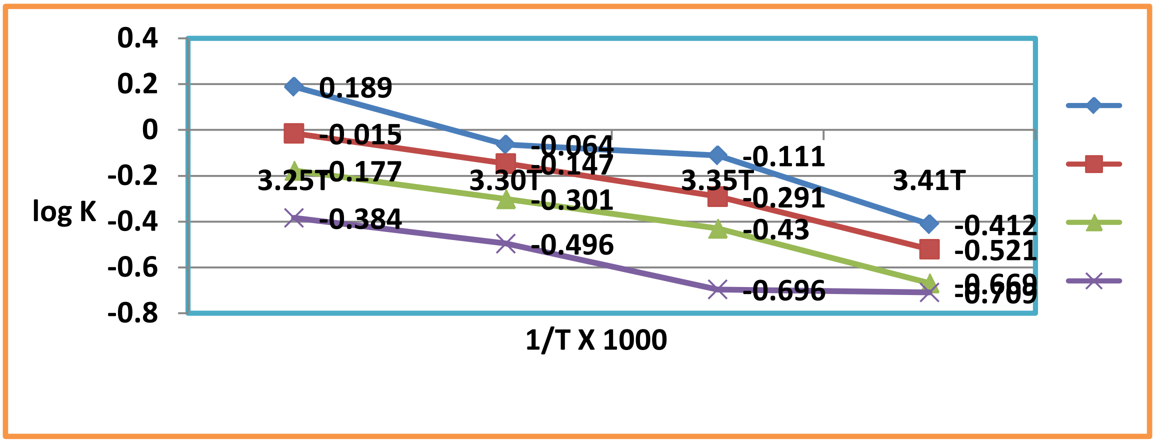

Figure 4 : Plot of log K Vs. 1/T for Stainless steel at different temperatures

The heat of adsorption was calculated by equation 5 with help of plot between log (^{θ}/1- ^{θ}) vs. 1/T in Figure 4 and it values recorded in Table 4, Table 5 and Table 6.

$$\log (θ/ 1\text{-}θ) = \log (A .C) - (Q_{ads}/ R T) \quad (5)$$

where T is temperature in Kelvin and Q_{ads} heat of adsorption

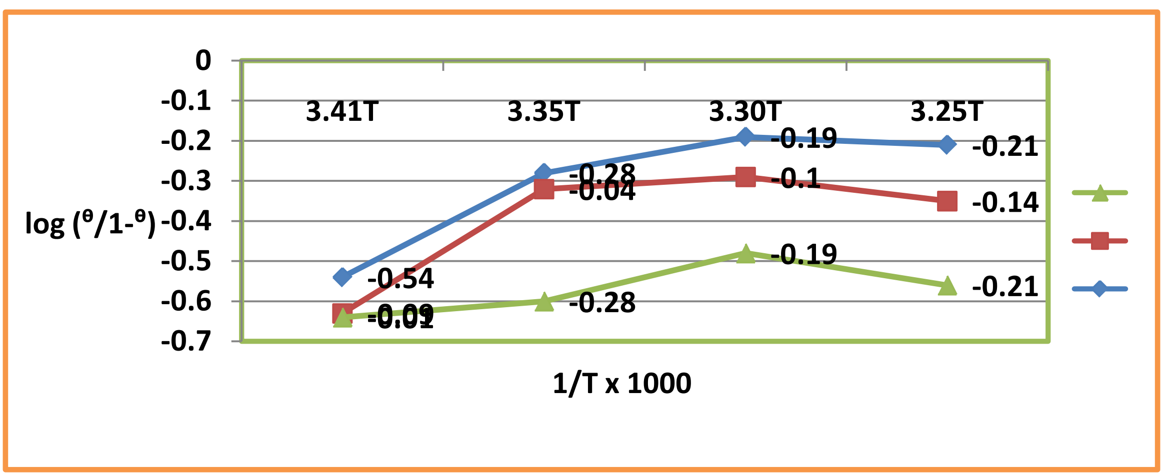

Figure 5 : Plot of log (^{θ}/1-^{θ}) Vs. 1/T for Stainless steel of different temperatures

The heat of adsorption found to be negative so it indicated that adsorption occurred on the metal surface. The values of heat of adsorption were shown that inhibitor was bounded with metal by physical adsorption. The plot between log (^{θ}/1- ^{θ}) vs. log C found to be straight line in figure 5 which indicated Langmuir adsorption isotherm. It was a sign of adsorption. Temkin equation of isotherm for adsorption expressed as:

$$\log (C/ {}^θ) = \log C – \log K \quad (6)$$

Where C is concentration of inhibitor, θ is surface coverage area and K be constant. The values of log (C/ ^{θ}) were mentioned in Table1, Table 2 and Table 3. The plot against log (C/ ^{θ}) vs. log C exhibited a straight line in figure 6 which indicates sign of adsorption.

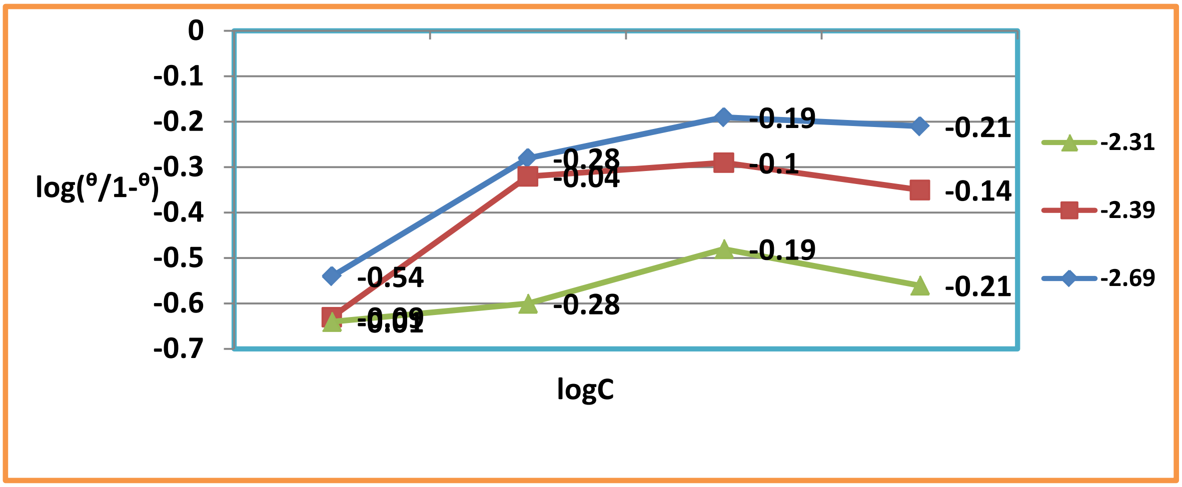

Figure 6 : Plot of log (θ/1-θ) Vs. log C for Stainless steel at different concentrations

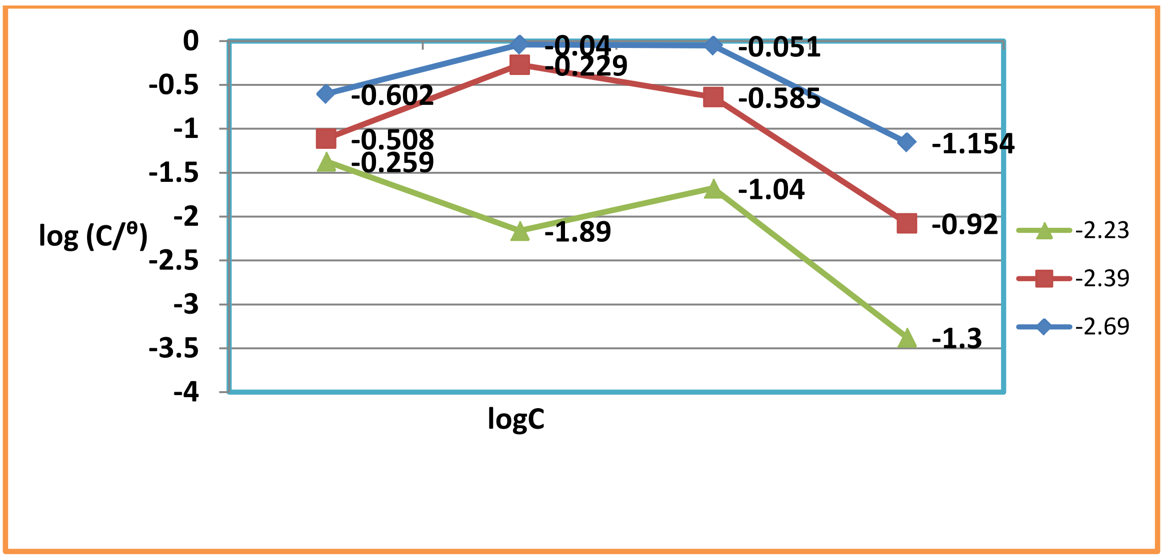

Figure 7 : Plot of log (C/θ) Vs. log C for Stainless steel at different concentrations

Free energy was determined by equation 7 and it values recorded in Table 4, Table 5 and Table 6 at different concentrations.

$$\Delta G = -2.303RT\ [\log C - \log(\theta/1-\theta) + 1.72] \qquad (7)$$

Free energy results show that use inhibitor produces an exothermic reaction so it indicates sign of adsorption.

The energy of enthalpy and entropy were determined by transition state equation 8 and it values mentioned in Table 2.

$$K = RT/Nh \log(\Delta S^{\#}/R) \times \log(-\Delta H^{\#}/RT) \qquad (8)$$

Where N is Avogadro's constant, h is Planck's constant, $\Delta S^{\#}$ is the change of entropy activation and $\Delta H^{\#}$ is the change of enthalpy activation.

Enthalpy and entropy values are mentioned in Table 4, Table 5 and Table 6 which are found to be negative, it exhibited an exothermic reaction. The negative values of entropy indicated that inhibitors stable on surface adsorption of metal.

The corrosion current density determined absence and presence of inhibitor with help of equation 9 and values recorded in Table 7.

$$\Delta E/\Delta I = \beta_a \beta c/2.303 I_{corr}\ (\beta_a + \beta_c \qquad (9)$$

where $\Delta E/\Delta I$ is the slope which linear polarization resistance (Rp), β_a and β_c are anodic and cathodic Tafel slope respectively and I_{corr} is the corrosion current density in mA/cm^2.

Looks the results of Table 7, it was noticed that corrosion current increases without inhibitor and its values reduced after addition of inhibitor.

The metal penetration rate (mmpy) is determined by

$$C.R\ (mmpy) = 0.1288 I_{corr}\ (mA/cm^2) \times Eq.Wt\ (g)/\rho\ (g/cm^3) \qquad (9)$$

where I_{corr} is the corrosion current density ρ is specimen density and Eq. Wt is specimen equivalent weight.

Figure 7 indicates that Tafel graph has plotted between electrode potential and current density and absence and presence of inhibitors. Anodic potential, current density and corrosion rate increased without inhibitors but addition of inhibitors these values decreased and inhibition efficiency increased.

Table 7 : Potentiostatic Polarization values of Aloevera with different Concentrations at 30°C.

Inhibitor	ΔE	ΔI	Ba	Bc	Icorr	K(Mmpy)	IE (%)	C(MI)
IH(0)	-800	350	250	230	28.81	0.875	0.00	0
IH (1)	-475	190	115	135	10.78	0.327	62.62	2
	-465	175	100	125	9.10	0.276	68.45	4
	-450	160	50	115	7.80	0.237	72.91	6

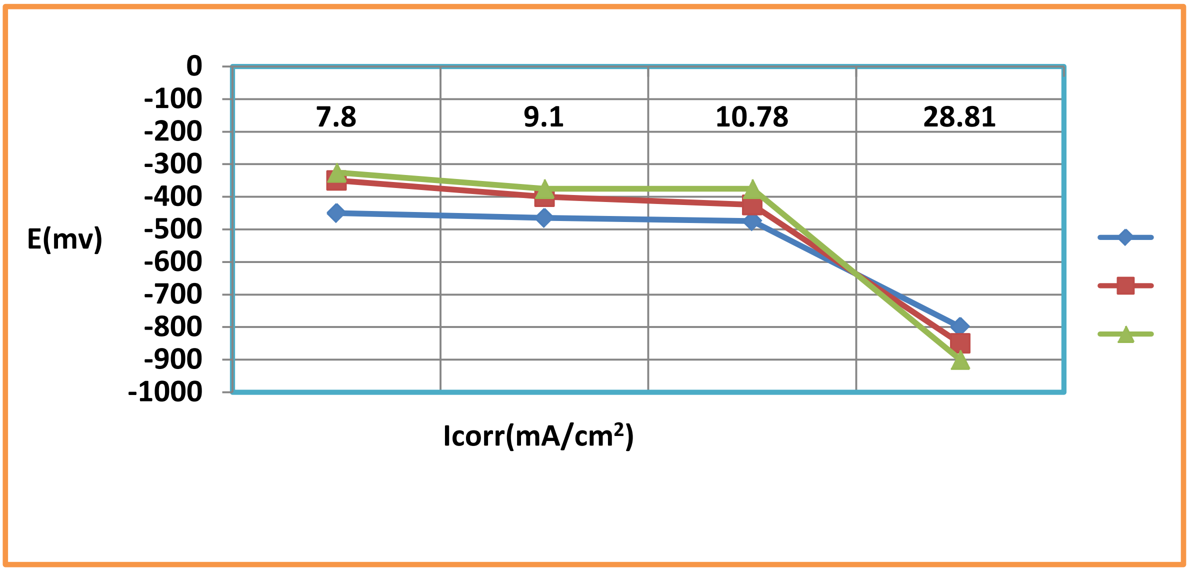

Figure 8 : Plot of E (mV) Vs. Icorr(mA/cm^2) for Stainlees steel at different concentrations

IV. Conclusion

Aloevera is a medicinal natural plant. It is eco friendly and it has no any side effect. Due to this character it is used as inhibitor in milk solution for protection of stainless steel. Its inhibition efficiency is low at lower concentration and its inhibition efficiency is high at higher concentration. The inhibition efficiency lies between 22 to 73% at different concentrations. It also produces good inhibitive effect at different temperatures. The results of activation energy, heat of adsorption, free energy, enthalpy and entropy show that aloevera bonded with metal surface physical adsorption. Potentiostatic polarization study results indicate that corrosion current decrease after addition of inhibitor.

V. Acknowledgement

The author is thankful to the Department of chemistry, Jagdam College, Chapra, Bihar, the Department of applied Chemistry Indian school of Mines, Dhanbad for providing laboratory facilities and UGC for financial support.

References Références Referencias

1. Holm, George E (1928) Chemistry and the Dairy Industry, Ind. Eng. Chem. 20 1312.
2. Lewis M.S (1931), Iron and Copper in the Treatment of Anemia in Children, J. Am. Med. Assn. 96 1135.
3. Abiola O.K, Oforka N.C and Ebenso, E.E, (2004) "The Inhibition of Mild steel Corrosion in an Acidic Medium by Fruit Juice of Citrus Paradisi", J. of Corrosion Science and Technology 1, 75-78.
4. Mobin M (2008). Electrochemical studies on the corrosion behavior of carbon steel in presence of Cu and Ni, Portugaliae Electrochemical Acta 26 (5) 449-457.
5. Singh R K (2010). The corrosion protection of stainless steel in phosphate industry, Journal of Metallurgy and Materials Science, 52(2)173-180.
6. Alam J, U Riaz and Ahmad S (2009). High performance corrosion resistant polyaniline /alkyd eco friendly coating, Current Applied Physics, 9 80-86.
7. Wang X, Liu X and Feng M (2008). Fabrication of hollow Fe3O4-polyaniline spheres with sulfonated polystyrene templates, Materials Chemistry and Physics, 112 (2) 319-321.
8. Brodinov J, J Stejskal and A Kalendov (2007). Investigation of ferrites properties with polya- niline layer in anticorrosive coating, J Physics and Chemistry of Solids 68 (5-6)1091-1095.

9. Alam J, Riaz U, S M Ashraf and S Ahmad (2008). Corrosion-protective performance of nanopolyaniline/ferrite dispersed alkyd coating, Journal Coating Technology and Research 5 123-128.
10. Kalendova A I, Sapurina J, Stejskal and D Vesely (2008). Anticorrosion properties of polyaniline-coated pigments in organic coating, Corrosion Science 50 (2) 3549-3560.
11. Nmai C K (2004) Multi-functional organic corrosion inhibitor, Cement and Concrete Composites 26 (3) 199-208.
12. Singh R K (2011) Gram production hampered by corrosive pollutants Journal Chemtracks, 13 (2) 341-344.
13. Singh R K (2009) Corrosion protection of stainless steel in oil well recovery, Material Science Research India, 6 (2) 457-466.
14. Singh R K (2009) Comparative study of the corrosion inhibition of mild steel and stainless steel by use of thiourea derivatives in 20% HCl solution, Journal of Metallurgy and Materials Science, 51(3)225-232.