Study the corrosion of Carbon steel in 1M HCl using extract of Water hyacinth

Pinky Sisodia[1], Renu Singh[2] ,S. Khalid Hasan[3]

[1, 2]Department of Chemistry, Maharishi University of Information Technology, Lucknow
[3]Institute of Technology & Management, GIDA, Gorakhpur

Abstract. Water hyacinth, an invasive species that adversely affects habitant, bioregions and environment has been studied as corrosion inhibitor. Leaves of Water hyacinth in 1 M hydrochloric acid was tested as corrosion inhibitor on mild steel using potentiodynamic polarization technique. The corrosion inhibition efficiency of Water hyacinth extract varied with concentration of extract and immersion of time. The inhibition was found to increase with increase in concentration of the extract. The polarization behavior of mild steel revealed that maximum inhibition efficiency is 97.33 % and 89.93 % respectively in the 1000 and 200 ppm concentration of the inhibitor respectively. The results showed that the extract of the Water hyacinth served as a mixed type inhibitor.

Keywords: Green inhibitor, inhibition efficiency, Water hyacinth mild steel, potentiodynamic polarization.

1. Introduction:

Mild Steel suffers from corrosion which is a slow foe that should be accepted as unavoidable phenomenon. However, it causes serious problem in daily life and greatly affect economy. The survey of 2016 by National Association of Corrosion Engineers (NACE) estimated the global cost of corrosion as $2.5 trillion; equivalent to 3.4% of a country's Gross Domestic Product (GDP) [1]. That is why investigators are attracted towards the corrosion study and its control in recent years.

Mild Steel is the excellent materials used in structural and construction applications. It is well known ferrous alloy having outstanding combination of mechanical properties, ease of fabrication, excellent weldability, and low purchasing cost [2]. However, it has a low corrosion resistance especially in acidic environments [3]. Owing to its universal use in the design of vessels, storage devices and other industrial accessories used in food, petro-chemical and chemical plants where acidified solutions are frequently utilized, this has been a major cause of concern [4].

Corrosion control is the matter of concern from applications point of view and it has been reported that inhibitors are needed to be used which act as a barrier to reduce the aggressiveness of the environments against the corrosion attack [5, 6]. Owing to toxicity of chromate and organic inhibitors, green corrosion inhibitors that are environmentally safe and readily available has been a growing trend in the use of natural products such as essential oils as corrosion inhibitors for metals in acid cleaning processes [7]. Natural products obtained from plant containing alkaloids act as inhibitor. They are environmentally friendly and cheap. India is blessed with natural products. Herbs and shrubs are widely distributed in nature [8]. Organic compounds can be adsorbed on the metal surface, block the active sites on the surface and thereby reduce the corrosion rate. However, synergistic (and antagonistic) effects are often expected with these mixtures of compounds that may affect their inhibition efficiency. The extracts of many plants have been reported as excellent inhibitors for corrosion of steel in acidic solutions [9-12]. Many extracts of common plants have been found useful in this regard – plants such as Tithonia diversifolia [13], Jatropha curcas [14], Rice husk [15], Aquilaria crassna [16], Prunus cerasus [17], Moringa oleifera [18], Murraya koenigii [19] , Aloe vera [20,21] Artemesia vulgaris [22] and Pogostemo benghalensis [23, 24] have been investigated and efforts are still going on to search for more green inhibitor alternatives [25, 26]. This plant is abundant in all over India . Extract of this plant contains alkaloids, flavonoids, terperoids, saponins and tannins [27] and therefore, this study aims to study corrosion inhibition efficiency of bark extract of this plant for mild steel corrosion in acidic medium.

2. Materials and Method:

2.1. Preparation of Extract:

The Water hyacinth were collected from Gorakhpur up India and dried for 1 month in the shade. Then the dried barks were crushed into the powder form with the help of grinding machine. Water hyacinth was obtained by cold percolation followed by evaporation in dry state.

2.2. Inhibitor Solution:

1000 mL of 1M HCl was prepared and 1g of the extract was dissolved in it by using magnetic stirrer. Then the mixture was filtrated to remove undissolved extract. Thus, prepared solution was of 1000 ppm concentration. From the stock solution, solution of different concentrations 800, 600, 400 and 200 ppm were prepared using 1M HCl as a solvent by serial dilution.

2.3. Preparation of Mild Steel Sample:
The Mild Steel (MS) sample was collected from the local market of india. The MS samples were mechanically abraded with different grade of silicon carbide paper (100-2000 grit) and stored in a desiccator. Before the experiment, samples were sonicated in ethanol and dried.

2.4. Potentiodynamic Polarization:
Potentiodynamic polarization measurements were carried out. Open circuit potential (OCP) was measured for 30 minute at an interval of 2 minutes prior to potentiodynamic polarization of MS with and without inhibitor solutions. In this measurement, mild steel sample, carbon rod and saturated calomel electrode (SCE) were used as working electrode, counter electrode and reference electrode, respectively. The samples were subjected for cathodic and anodic polarization at a sweep rate of 1 mV/s. The potentiodynamic polarization was performed for the different concentrations of inhibitor solutions. From the polarization curves, Tafel slope, corrosion potential and corrosion current were calculated. The corrosion inhibition efficiency was calculated using the relation,

$$\text{Corrosion inhibition efficiency} = \frac{I_{corr} - I^{*}_{corr}}{I_{corr}} \times 100$$

where Icorr = corrosion current in absence of inhibitor; I*corr =corrosion current in the presence of inhibitor.

3. Results and Discussion:

3.1. Polarization of Mild Steel in 1M HCl and Plant Extract:
The potentiodynamic polarization of mild steel sample was performed in the presence and absence of the inhibitor solution in 1 M HCl solution. The polarization of mild steel sample was done in 1000 ppm inhibitor solution immersed for 24 hours and also immediately after the immersion (as immersed). Figure 3.1 compares the polarization behaviors of mild steel sample in 1M HCl and inhibitor solutions. From the figure it is seen that the cathodic current density decreased significantly than the anodic current density in the mild steel sample immersed for 24 hour in inhibitor solution, On the other hand, current density was decreased significantly in the mild steel sample immersed in inhibitor for 24 hours than the sample not immersed in the inhibitor solution. The decrease of current density in the case of as immersed sample shows that effect of time in adsorbing inhibitors molecules in the steel surface. After 24 h, the formation of protective layer on the mild steel surface can lead to the effective inhibition of steel corrosion. There was almost no change of corrosion potential with the addition of inhibitor solution. This is indicative of mixed type of inhibitor.

3.2. Effect of Concentration of Extract Solution:
The effect of concentration of the inhibitor solutions on mild steel corrosion was studied in 1M HCl solution and the results are presented in Figs. 3.2 and 3.3, respectively for the measurements just after immersion and after 24 h immersion in inhibitor solutions. The concentrations were varied from 1000 ppm to 200 ppm at 200 pm interval but results are plotted for only 1000, 600 and 200 ppm due to clarity. Figure 3.2 reveals that all the polarization curves have almost similar open circuit potentials (corrosion potential) and current density decreased on the addition of the extract. This action reflects the inhibition behavior of the extract on the mild steel.

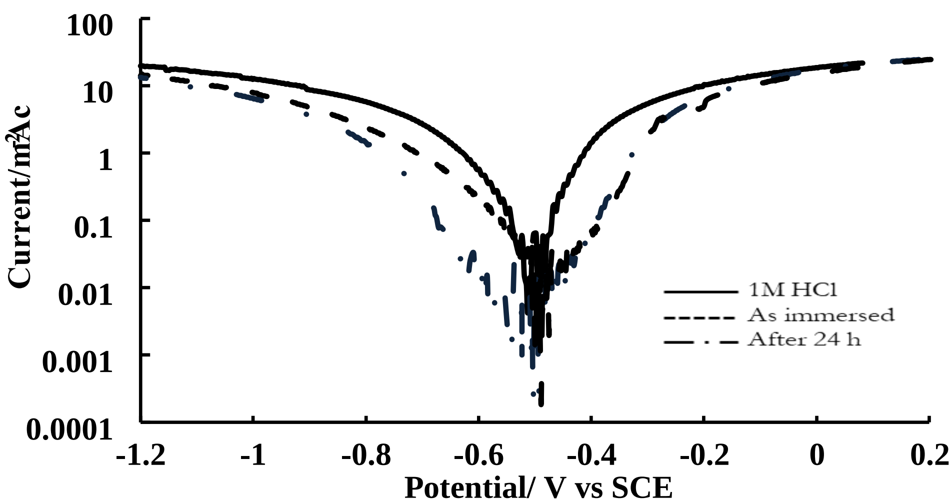

Fig. 3.1. Comparison of polarization behaviors of mild steel in 1M HCl and 1000 ppm Water hyacinth plant extracts at different immersion time.

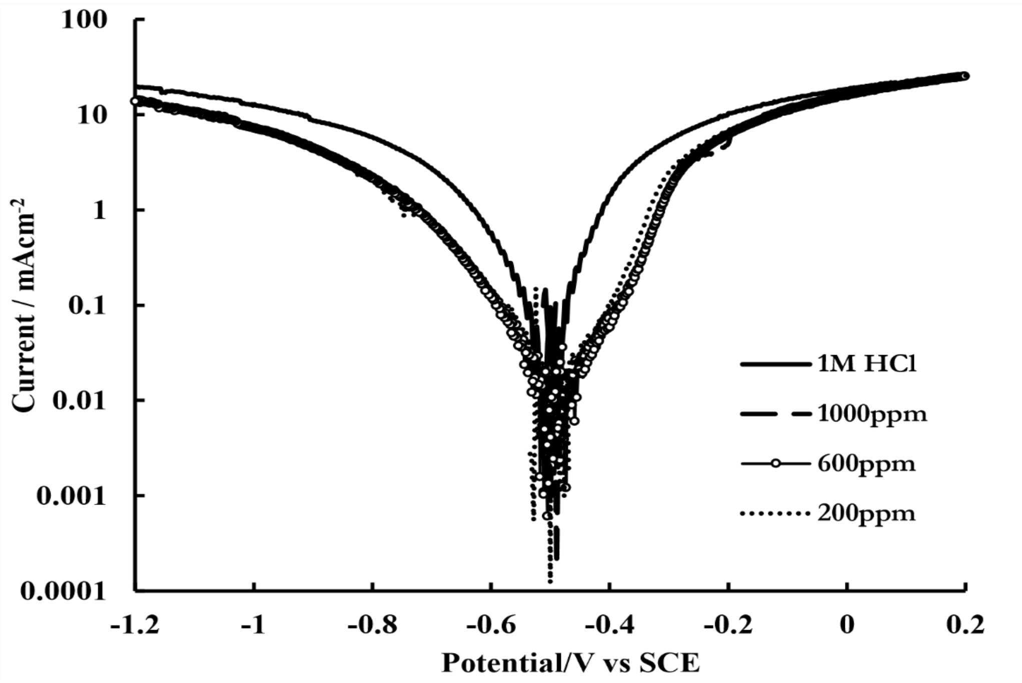

Fig. 3.2. Effect of concentration of Water hyacinth extract on the polarization behavior of mild steel in 1M HCl, when polarization was done immediately after immersion (OCP measurement).

Figure 3.3 illustrates the polarization curves of mild steel in the absence and presence of Water hyacinth extract of different concentrations (200, 600 and 1000 ppm) in 1M HCl, after immersion of mild steel sample for 24 hours. The results show similar trends of no shift of open circuit potential like in as immersed sample, which imply that inhibitor is of mixed type. On the other hand, it was clearly noticed that corrosion current density decreased more sharply with the increase in concentration of the inhibitors solution compared to as immersed sample. Therefore, it indicates the enhanced retardation of the corrosive reaction on the mild steel after long time immersion. In both cases, more than 600ppm concentration of inhibitor solution was effectively inhibiting the corrosion of mild steel. From the results, it can be concluded that the Water hyacinth extract acted as a good inhibitor for corrosion of mild steel when immersed in inhibitor solution for 24 hours.

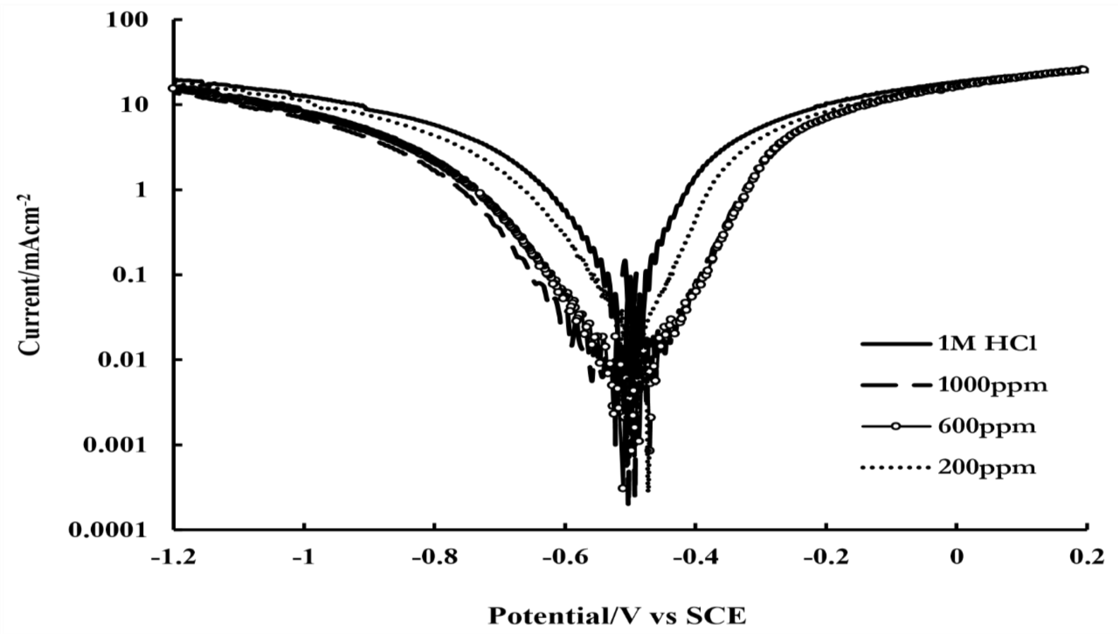

Fig. 3.3. Effect of concentration of Water hyacinth extract on the polarization behavior of mild steel in 1M HCl when polarization was done after the MS was immersed in inhibitors solution for 24 hours.

3.3. Effect of Concentration on Inhibition Efficiency:

Inhibition efficiency effect was studied at various concentration of Water hyacinth extract in order to know how the concentration of inhibitor affects the inhibitor efficiency of plant extract. The inhibition efficiency was calculated from the data obtained from potentiodynamic polarization of Fig. 3.2 and 3.3 and plotted against different concentration of inhibitor solution as shown in Fig.4.

From Fig. 3.4, it can be revealed that the inhibition efficiency of the extract on the mild steel increases with increase in the concentration of the extract. It is due to increase in the fraction of the surface covered by the adsorbed molecule with increase in concentration of extract As it can be seen that inhibition efficiency increases gradually up to 600 ppm, further increase in extract concentration did not cause any significant change in the performance of the extract. This can be due to the complete adsorption of inhibitor component onto the mild steel surface. Therefore, it can be explained that inhibitor is more effective when the MS sample is exposed above 600 ppm inhibitor solution for 24 hour. The maximum inhibition efficiency was found to be 97.33% at 1000 ppm concentration of the plant extract. However, the IE is above 90% when the inhibition efficiency was calculated for the mild steel immersed for 24 hour and it did not show any significant increase in inhibition efficiency with increase in concentration of inhibitor solution. It is due to the complete surface coverage of MS by inhibitor.

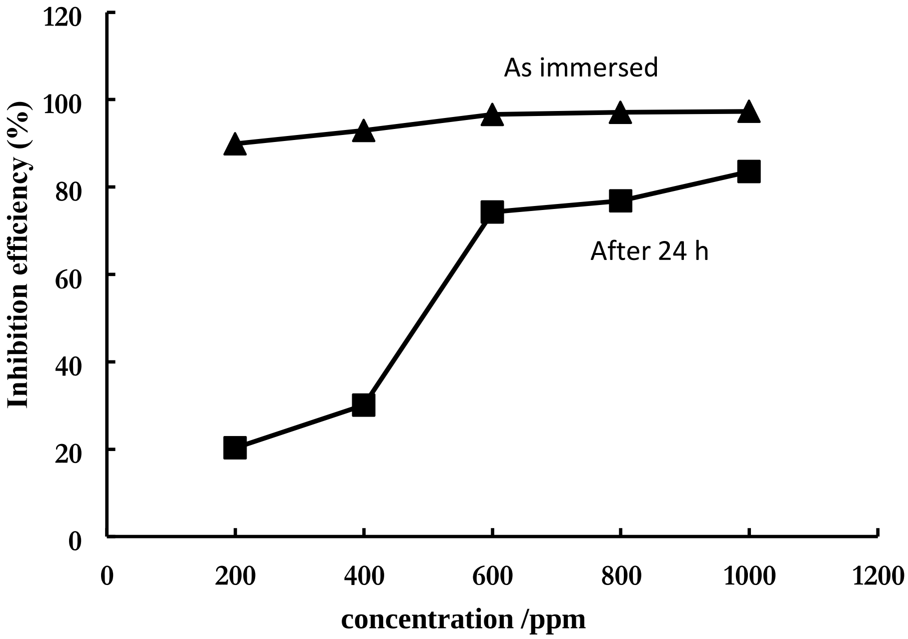

Fig. 3.4. Variation of inhibition efficiency of extract of Water hyacinth on mild steel in 1M HCl after immersion for 24 hour and immediately after immersion.

4. Conclusion:

In this study, the corrosion inhibition efficiency of the Water hyacinth extract was studied using potentiodynamic polarization measurement in 1M HCl solution. Potentiodynamic polarization analysis of mild steel samples in presence and absence of inhibitor showed that the corrosion current density decreased significantly in the presence of inhibitor solution. It was further revealed that the efficiency was increased, when the sample was immersed for 24 hours than that of immediately immersed one. Inhibition efficiency increased with increasing the concentration of inhibitor in both the cases but the optimum efficiency of was found to be 97.33% in the sample immersed for 24 hours in 1000 ppm concentration of inhibitor solution.

References:

[1] G. Koch, J. Varney, N. Thompson, O. Moghissi, M. Gould, and J. Payer, "International measures of prevention, application, and economics of corrosion technologies study," NACE International, 2016.

[2] A. S. Yaro, A. A. Khadom, and R. K. Wael, "Apricot juice as green corrosion inhibitor of mild steel inphosphoric acid," *Alexandria Eng. J.*, vol. 52, no. 1, pp. 129–135, 2013.

[3] A. K. Satapathy, G. Gunasekaran, S. C. Sahoo, K. Amit, and P. V. Rodrigues, "Corrosion inhibition by Justicia gendarussa plant extract in hydrochloric acid solution," *Corros. Sci.*, vol. 51, pp. 2848–2856, 2009.

[4] Z. Ahmad, *Principles of Corrosion Engineering and Corrosion Control*, 1st ed. UK: Butterworth-Heinemann (Elsevier imprint), 2006.

[5] F. Eghbali, M. H. Moayed, A. Davoodi, and N. Ebrahimi, "Critical pitting temperature (CPT) assessment of 2205 duplex stainless steel in 0.1 M NaCl at various molybdate concentrations," *Corros. Sci.*, vol. 53, no. 1, pp. 513-522, 2011.

[6] A. S. Fouda and A. S. Ellithy, "Inhibition effect of 4-phenylthiazole derivatives on corrosion of 304L stainless steel in HCl solution," *Corros. Sci.*, vol. 51, no. 4, pp. 868-845, 2009.

[7] A. V. Fokin, M. V. Pospelov, E. S. Churshukov, L. P. Maiko, A. Sergeikin, Y. N. Shekhter, and T. I. Belova, "Influence of structure of hydrophobic fragments of oil-soluble corrosion inhibitors on their protective properties," *Chem. Tech. Fuels Oils.*, vol. 22, no. 2, pp. 62-65, 1986.

[8] D. S. Rawal, J. Sijapati, N. Rana, P. Rana, A. Giri, and S. Shrestha, "Some high value medicinal plants of Khumbu region Nepal," *Nepal Journal of Science and Technology*, vol. 10, pp. 73-82, 2009.

[9] A. Bouyanzer, B. Hammouti, and L. Majidi, "Pennyroyal oil from Mentha pulegium as corrosion inhibitor for steel in 1 M HCl," *Material Letters*, vol. 60, no. 23, pp. 2840-2843, 2006.
[10] M. Manssouri, M. Znini, A. Ansari, A. Bouyanzer, Z. Faska, and L. Majidi, "Odorized and deodorized aqueous extracts of Ammodaucus leucotrichus fruits as green inhibitor for C38 steel in hydrochloric acid solution," *Der Pharma Chemica*, vol. 6, no. 6, pp. 331-345, 2014.
[11] M. Znini, J. Paolini, L. Majidi, J. M. Desjobert, J. Costa, N. Lahhit, and A. Bouyanzer, "Evaluation of the inhibitive effect of essential oil of Lavandula multifida L., on the corrosion behavior of C38 steel in 0.5 MH_2SO_4 medium," *Res. Chem. Intermed.*, vol. 38, no. 2, pp. 669-683, 2012.
[12] G. Cristofari, M. Znini, L. Majidi, A. Bouyanzer, S. S. Al-Deyab, J. Paolini, B. Hammouti, and J. Costa, "Chemical composition and anti-corrosive activity of Pulicaria mauritanica essential oil against the corrosion of mild steel in 0.5 M H_2SO_4," *Int. J. Electrochem. Sci.*, vol. 6, pp. 6699-6717, 2011.
[13] K. K. Alaneme and S. J. Olusegun, "Corrosion inhibition performance of lignin extract of sun flower (Tithonia diversifolia) on medium carbon low alloy steel immersed in H_2SO_4 solution," *Leonardo J. Sci.*, vol. 20, no. 11, pp. 59–70, 2012.
[14] S. J. Olusegun, B. A. Adeiza, K. I. Ikeke, and M. O. Bodunrin, "Jatropha Curcas leaves extract as corrosion inhibitor for mild steel in 1 M hydrochloric acid," *J. Emerging Trends Eng. Appl. Sci.*, vol. 4, no. 1, pp. 138- 143, 2013.
[15] K. K. Alaneme, Y. S. Daramola, S. J. Olusegun, and A. S. Afolabi, "Corrosion inhibition and adsorption characteristics of rice husk extracts on mild steel immersed in 1 M H_2SO_4 and HCl solutions," *Int. J. Electrochem. Sci.*, vol. 10, pp. 3553–3567, 2015.
[16] L. Y. S. Helen, A. A. Rahim, B. Saad, M. I. Saleh, and P. Bothi Raja, "Aquilaria crassna leaves extracts— A green corrosion inhibitor for mild steel in 1 M HCl medium," *Int. J. Electrochem. Sci.*, vol. 9, pp. 830– 846, 2014.
[17] H. Ashassi-Sorkhabi and D. Seifzadeh, "The inhibition of steel corrosion in hydrochloric acid solution by juice of Prunus cerasus," *Int. J. Electrochem. Sci.*, vol. 1, pp. 92–98, 2006.
[18] A. Singh, I. Ahamad, D. K. Yadav, V. K. Singh, and M. A. Quraishi, "The effect of environmentally benign fruit extract of shahjan (Moringa oleifera) on the corrosion of mild steel in hydrochloric acid solution," *Chem. Eng. Commun.*, vol. 199, no.1, pp. 63–77, 2012.
[19] K. S. Beenakumari, "Inhibitory effects of Murraya koenigii (curry leaf) leaf extract on the corrosion of mild steel in 1 M HCl," *Green Chem. Lett. Rev.*, vol. 4, no. 2, pp. 117–120, 2011.
[20] O. K. Abiola and A. O. James "The effects of Aloe vera extract on corrosion and kinetics of corrosion process of zinc in HCl solution," *Corros. Sci.*, vol. 52, no. 2, pp. 661–664, 2010.
[21] M. Mehdipour, B. Ramezanzadeh, and S. Y. Arman, "Electrochemical noise investigation of Aloe plant extract as green inhibitor on the corrosion of stainless steel in 1 M H_2SO_4," *J. Ind. Eng. Chem.*, vol. 21, pp. 318–327, 2015.
[22] N. Karki, Y. Chaudhary, and A. P. Yadav, "Thermodynamic adsorption and corrosion innhibition study of mild steel by Artemisia vulgaris extract from methanol as green corrosion inhibitor in acid medium," *J. Nepal Chem. Soc.*, vol. 39, 2018.
[23] P. C. Lama, Y. Chaudhary, N. Karki, and A. P. Yadav, "Study of the corrosion inhibition behavior of Pogostemo benghalensis (Rudilo) for mild steel in acidic medium by Potentiodynamic method," *J. Nepal Chem. Soc.*, vol. 34, 2016.
[24] Y. Chaudhary, N. Karki, and A. P. Yadav, "Study of the corrosion inhibition behavior of Pogostemo benghalensis (Rudilo) for mild steel in acidic medium by weight loss method," *J. Nepal Chem. Soc.*, vol. 35, 2016.
[25] G. Ji, S. Anjum, S. Sundaram, and R. Singh, "Musa paradisica peel extract as green corrosion inhibitor for mild steel in HCl solution," *Corros. Sci.*, vol. 90, pp. 107–117, 2015.
[26] P. Mourya, S. Banerjee, and M. M. Singh, "Corrosion inhibition of mild steel in acidic solution by Tagetes erecta (Marigold flower) extract as a green inhibitor," *Corros. Sci.*, vol. 85, pp. 352–363, 2014.
[27] J. T. Salada, L. M. Balala, and E. A. Vasquez, "Phytochemical and antibacterial studies of *Lantana camara* L. leaf fraction and essential oil," *Int. J. of Scientific and Res. Pub.*, vol. 5, no. 3, pp. 1-5, Mar. 2015.