

Potential of Weeds Extract As A Green Corrosion Inhibitor on Mild Steel: A Review

Abhinay Thakur¹, Ashish Kumar^{1*}

School of Chemical Engineering & Physical Sciences
Lovely Professional University, Phagwara, Punjab, India
Corresponding Author mail id: drashishchemlpu@gmail.com

Abstract

Corrosion is an uncontrollable and ever persisting process which affects the physical properties of metals and their alloys. Due to the toxic behavior of corrosion inhibitors containing substances like chromate inhibitors, there is increasing in demand for the utilization of eco-friendly and biodegradable inhibitors, which comes out to be green corrosion inhibitors. The present review article in accordance on green corrosion inhibitors, aims for illustrating the use of weeds extracts for metallic corrosion inhibition by examining the inhibiting properties of numerous weeds extract, especially for mild steel and its surface. The adsorption isotherm analysis, electrochemical studies, Monte Carlo simulations, temperature effect on inhibition efficiency and morphological examination to weeds extract adsorption behavior on mild steel and other metals have also been deliberated in detail. This review will further help in clearing the concept of adsorption behavior of weeds extract against metal corrosion.

Keywords: Corrosion inhibition; EIS; Green inhibitors; Weeds extract; Mild Steel.

1. Introduction

Mild steel which usually contain a very less quantity of carbon and is highly tensile in nature; due to its mechanical properties and budget friendly nature it is considered as an efficient tool in the industrial and construction plants such as building bridges, home decorum and automobile sectors etc. But, the use of mild steel up holds in a limit when the dissolution of mild steel arises when it comes in contact with acid due to processes alike acid pickling, etching industries and

also due to presence of corrosive gases like sulphur dioxide, hydrogen chloride, chlorine in the surrounding which in hand leads to the corrosion of mild steel which in results fails its physical and mechanical properties[1]. Corrosion implicates metal ions movement into the active anodic part of the solution and electrons transfer from metal to acceptor takes place at cathodic part which is less active, finally an ionic current in the solution and an electronic current in the metal are all required for corrosion to initiate. Presences of electron acceptor species like oxygen or hydrogen ions are required in cathodic process. In such manner corrosion effects mild steel in high rate and due to these all factors the maintenance and defense of mild steel from corrosion has become a topic of prior importance, especially to mitigate economic losses and environmental issues. Corrosion attenuates by suitable approaches which in side retard or completely stop the anodic or cathodic reactions or both and make it stifle.

Among the numerous methods for corrosion control, its prevention upto global level, the implementation of corrosion inhibitors is in demand[2]. A corrosion inhibitor terms to be a chemical compound that when introduce to the corrosive medium in very appropriate amount (usually up to 1 wt%) get adsorbed on the surface of metal and hence mitigates corrosion, thereby protects the metal by forming a thin defensive layer on its surfaces. The detailed activity of a corrosion inhibitor is evaluated by the investigations of data, records obtained from the % calculation of the corrosion rate relative to medium in presence and absence of corrosion inhibitor indulging an particular metal. Such corrosion rate can be evaluated by weight loss and hydrogen evolution studies.

Inhibitors function by adsorption of its molecules on metallic surface. They reduce the corrosion rate by:

- 1) Increasing / decreasing the anodic or cathodic reactions which are responsible for initiation of corrosion.
- 2) Minimizing the electrical resistance of the metal surface
- 3) Slowing down the reactants diffusion rate to the surface of the metal

Though many synthetic and commercially available compounds which shows satisfactory anticorrosive behavior when use as corrosion inhibitor for mild steel and several metals or their

alloys, most of them came out to be highly toxic to both human beings as well as surrounding[3]. The safety and environmental issues of these sorts of corrosion inhibitors emerges in industries and other sectors have become a global concern[4]. These inhibitors harming the environment may be able to cause temporary or permanent damage to human health and their organ viz., kidneys or liver or affects biological system of body. The toxicity may occur during the synthesis of compound or during its applications as corrosion inhibitor. Such factors like toxic behaviour have admired researchers to move toward the application of natural products like weeds extracts as corrosion inhibitor agents which are cost effective, eco-friendly and un hazardous in nature. In recent decade many substitute of these toxic commercially available inhibitors have been developed which are eco-friendly, as they range from minor class to major class of elements and compounds.

1.1.Green corrosion inhibitors

In this era of advanced science, researchers are finding new ways for the betterment of the existence of human being life in earth. The use of conventional corrosion inhibitors for several metals in various sectors is now comes in a limit because of enhancement in concept of “Green chemistry” in the science, engineering, technology field. “Green chemistry” is an area of chemistry and chemical engineering focusing on designing of environmental friendly products and processes that minimize/eliminate the use and generation of hazardous substances. Currently, the increasing ecological sensibility and strictness toward environment in the science field have motivated the scientists and researchers working in corrosion field towards the implementation of anticorrosion natural agents. Further, the use of natural corrosion inhibitors including plants, shrubs and weeds have gained adequate consideration towards a step on the way of green chemistry. But among of these all, weeds and their extracts have termed out to be a significant corrosion inhibitor among all other natural anticorrosion agents because of their cheap availability, non-toxic nature and the most prior that weeds are considered to be undesirable grown plant in a particular place, "a plant in the wrong place" like grows unwanted in farm fields, gardens, lawns, and parks which makes it just a waste and none of use. But use of such considerable waste thing as a corrosion inhibitor for metals with such high efficiency up to 98% is itself a novel work.

1.2. *Weeds extract as corrosion inhibitor*

Various phytochemicals and their extracts have gathered a demanding interest in the field of anticorrosion agents. The evaluation of weeds extracts and correlation in between their active constituents (having hetero atoms such as N,O,P and aromaticity in them) and the anticorrosion property on several metals and their alloys have gained a prophecy among all commercially usable inhibitors which act toxic and injuries for human health and environment. Listed weeds extract as corrosion inhibitor for mild steel etc. in table 1 contain active constituents such as Taraxacin, Meliantriol, Nimbin, Salanin, Valine etc. which are having heteroatoms such as O, N, S and π e⁻(s) and also aromatic ring in structure which plays an crucial role in determining the efficient inhibitor adsorption of corrosion inhibitor by getting adsorbed on the metal's surface[5].

In this review article, mainly focus is on weeds extracts for the corrosion inhibition of mild steel and other metals due to the following factors which are in advancement to the other commercially available corrosion inhibitors and organic compounds which are high toxic in nature:

- 1) Cost of the weeds extract as inhibitor are low as comparison to other commercially available inhibitors as weeds are considered to be waste plant which have no use and use of such waste (weed) as corrosion inhibitor is less cost effective and also novel work.
- 2) Toxicity of the weeds extracts as inhibitor are termed as zero which are safe for human beings, and other living species.
- 3) Weeds are available throughout the year, though this inhibitor becomes often cheap and economical.
- 4) Weeds and their extracts are environmental friendly.

Various weeds used as corrosion inhibitor and the several techniques used to investigate their corrosion inhibition efficiency and corrosion rate have been discussed in table 1.

Table 1. A list of weeds extracts as eco-friendly corrosion inhibitors is given below along with nature of metal, various techniques, electrolyte used and nature of adsorption of active constituent:

Weeds	Techniques used	Metal/ Electrolyte	Adsorption nature	Remark(s)	Ref(
Azadirachta indica	AZI, DFT, computational modeling,	Mild steel, aluminium/H ₂ SO ₄	Langmuir adsorption isotherm	Meliantriol, Nimbin, Salanin were the active constituents and 85% of inhibition efficiency was obtained	[6]
Epimedium grandiflorum	Gasometric technique, Linear Polarisation Test, Weight loss studies	Mild steel/ HCl	Langmuir, Freundlich adsorption isotherm	Lignans, phenol glycosides, flavonoids were the active constituents and 50% v/v extracts of inhibition efficiency was obtained	[7]
Jatropha Curcas	Gravimetric Method	Carbon steel/0.5M NaCl and 0.5M H ₂ SO ₄	Langmuir adsorption isotherm	92.1% of inhibition efficiency was obtained	[8]
Taraxacum officinal	Weight loss, thermometric, potentiodynamic polarization and electrochemical impedance spectroscopy	Stainless steel/ HCl	Langmuir adsorption	Taraxacinas active component and 88.8% of inhibition efficiency was obtained	[9]
Eichhornia Crassipes	Gasometric technique, Quantum Chemical Calculations	Mild Steel/ HCl	Mixed type adsorption	Methyl dioctyl phthalate, 1,2 Benzene dicarboxylic acid were the active component	[10]
Chromolaena	Weight loss,	Mild Steel/ 1M	Langmuir	Maximum efficiency of	[11]

odorata	potentiodynamic polarization methods and scanning electron microscopy	NaCl	adsorption isotherm	99.83 % was achieved	
Galinsoga parviflora	Weight loss, potentiodynamic polarization curves and electrochemical impedance spectroscopy	Mild Steel/ 1M HCl	Langmuir, Freundlich and Temkin adsorption isotherms	Maximum efficiency of 90% at 6% V/V of the inhibitor was achieved	[12]
Bidens biternata	Quantum Chemical Analysis (QCA), spectroscopic (UV-Visible Spectroscopy) and surface morphological studies (SEM)	AA6063 (aluminium alloy)/HCl	Langmuir's adsorption	Maritimetin, Quercetin and Kaempferol were the active constituents and Maximum efficiency of 88.09 % was achieved	[13]
Malvasylvestris	GC-MS, EIS, SEM	Carbon steel/ 1M HCl	Mixed sort of adsorption	91% of maximum efficiency achieved	[14]
Tephrosia Purpuria	Mass loss method	Iron/ 1N HCl	Langmuir adsorption isotherm	Maximum efficiency of 90% was achieved	[15]
Dathura stromonium	Mass loss method, Activation parameters	Mild steel /H ₂ SO ₄	Tempkin adsorption isotherm	Maximum efficiency of 84% was achieved	[16]
Trichodesma indicum	Weight loss method at various temperatures	C38 Steel/ 1MHCl	-	Maximum efficiency of 94.5% was achieved	[17]
Erigeron floribundus	Gasometric method, Thermodynamic and adsorption	Mild steel/ 2M HCl	Langmuir adsorption isotherm	Inhibition efficiency increased as concentration of the	[18]

	parameters Some			inhibitorincreased	
Commelina Benghalensis	Gravimetric method	Mild Steel/ 1M HCl	Mixed type adsorption	Alkaloids, Flavonoids, Tannins, Saponins were the active constituents	[19]
Euphorbia hirta	Gravimetric technique and corrosion rates	Aluminium / HCl and NaOH	Langmuir and Temkin adsorption isotherm	Triterpenoids, Alkaloids, Tannins, Glycosides, Sterols were the active constituents	[20]
Abutilon indicum	Potentiodynamic polarisation technique, Electrochemical impedance spectroscopy	Mild steel/ 1 M HCl and 0.5 M H ₂ SO ₄	Mixed type adsorption	Valine, Quercetin-3-o-β- glucopyranoside were the active constituents and 95% of efficiency was obtained	[21]
Portulaca oleracea	Weight Loss Measurement	Mild steel /H ₂ SO ₄	Langmuir, Freundlich, Temkin, Flory- Huggins adsorption isotherms	>80% of inhibition efficiency was obtained	[22]
Parthenium hysterophorus	Weight loss and thermometric technique	Mild steel /1.5 N H ₂ SO ₄	Langmuir adsorption isotherm	Sequiterepene lactone was the active constituent and >80% of inhibition efficiency was obtained	[16]
Dialum guineense Extracts	Gravimetric technique, Adsorption Isotherms	Aluminium alloy (AA8011)/ HCl	Langmuir's adsorption	Physisorption phenomenonwasobserved	[23]
Sida acuta	Weight Loss Measurement	Al-Cu-Mg alloy/0.5 M HCl	Langmuir adsorption isotherm	>93.63% of inhibition efficiency obtained	[24]

Siam weed	Weight loss techniques, Tafel extrapolation, scanning electron microscopy and energy dispersive microscopy (SEM-EDS)	Mild steel/1 M HCl	Langmuir and Freundlich adsorption isotherm	Maximum efficiency of 83% was achieved	[25]
Ageratum Conyzoides	Weight loss measurement, EIS and galvanostatic polarisation techniques	SX 316 steel/ HCl	Langmuir adsorption isotherm	Chromone and 5,6,8,3',4',5' – hexamethoxyflavone were the active constituents and Maximum efficiency of 94.39 – 99.15 % was achieved	[26]
Heliotropium Indicum	Weight loss measurement	Aluminium/2.5M H ₂ SO ₄	Langmuir adsorption isotherm	Helindicine and lycopsamine were the active constituents and	[27]
Morinda tinctoria	Weight loss, colorimetric and electrochemical techniques	Carbon steel/0.5 M H ₂ SO ₄	Langmuir, Freundlich adsorption isotherms	Corrosion inhibition efficiency increases with increase in concentration of inhibitor	[28]

2. Factor influencing corrosion inhibition by Plant Extracts.

2.1. Nature of the metal and inhibitor.

The adsorbing behavior of inhibitor on the metal's surfaces determined by various factors such as metal's nature, chemical structure and substituent's nature present in inhibitor, solution temperature and concentration[29].

2.2. Corrosive Media.

The research usually done in acidic media such as sulphuric acid, hydrochloric acid and sometimes in basic medium such as NaCl as corrosive media[30].

2.3. Increasing Inhibitor's Concentration and Temperature effects.

As per the investigation of corrosion inhibition efficiency of inhibitor and corrosion rate determination, it was observed that Inhibition efficiency significantly increases on increasing the inhibitor concentration[31]. Whereas on other hand, on increasing temperature, inhibition efficiency decreases simultaneously in most cases.

3. Methods for Studying Adsorption mechanism and Inhibition Efficiency.

Mostly, the gravimetric, gasometric methods were used to measure inhibition efficiency. Although various potential method such as Potentiodynamic polarization, electrochemical impedance spectroscopy, UV , FT-IR and surface studies were also helpful in analyzing inhibitor's type and its adsorption mechanism. Tafel polarization, thermometric methods were also examined in few cases. Langmuir isotherm model was followed by various inhibitors as explaining the adsorption mechanism of plant extracts on mild steel surfaces. Some of the methods which have been used for studying inhibition efficiency are discussed below:

3.1 Gravimetric technique.

This technique includes the use of metal coupons with dimensions of $2 \times 2 \text{ cm}^2$ (height $\times$ breadth) for weight loss analysis. Before experiment, the metal coupons degreased by different grade of emery papers and laterly cleaned with distilled water and acetone and dried for further use[32]. The inhibitors were used at various concentrations and the temperature range was set for the appropriate analysis of weight loss method. The metal coupons were weigh down before and after being immersed in acidic and inhibitor solution. It was observed that inhibition efficiency directly varies with the inhibitor concentration. Inhibition efficiency was calculated from the eqn. 1[33].

$$\eta \% = \left[\frac{(W_o - W_i)}{W_o} \right] \times 100 \text{ -----1}$$

Here η %, W_o , W_i terms for inhibitions efficiency, initial weight and final weight.

3.2 Electrochemical impedance spectroscopy.

This technique determines the various electrochemical parameters such as double layer capacitance, frequency, charge transfer resistance etc, which further used to analyze corrosion inhibition efficiency of inhibitors and obtain insight details in the corrosion mechanism. Corrosion potential (E_{corr}) were used to measure EIS under various frequencies. An electrical equivalent circuit system with the charge transfer resistance (R_{ct} value) was employed to get EIS values. The different parameters obtained from EIS study affirm the formation of defensive layer on metal's surface. IE % is calculated by the eqn.2[34]:

$$IE\% = \frac{R_{ct(I)} - R_{ct(o)}}{R_{ct(I)}} \times 100 \text{ -----2}$$

Where $R_{ct(0)}$ depicts metal's charge resistance transfer without inhibitor

$R_{ct(I)}$ depicts metal's charge resistance transfer with inhibitor.

3.3 Computational studies.

Computation studies like Quantum chemical calculation explains the bond between inhibition efficiency and electronic/molecular structure of corrosion inhibitor. It deals with the semi empirical quantum calculations of the inhibitor. The various electronic parameters and structures derived by computational methodologies and theoretical calculations of quantum chemistry. The activity of inhibitor molecules were defined by the distribution of the frontier orbital i.e. HOMO and LUMO. The reactivity of an inhibitor molecule depends by energy gap $E_H - E_L$. Mainly, ΔE higher value depicts low reactivity and higher stability, whereas lower values of ΔE depicts higher reactivity of molecule.

3.4 Surface studies.

To perform the morphological analysis SEM and AFM were used. In the SEM analysis, metal coupon were immersed in acidic solution showing some cavities, holes and damaged surface which results due to corrosion but these defects observedless in the SEM analysis of metal coupon immersed along with inhibitor solution, which revealed the occurrence of a defensive film on surface of mild steel which incorporates in better corrosion inhibition.

AFM (Atomic force microscopy) used to study 3-D topography of mild steel surface on a scale from angstroms to 100 microns[35]. AFM revealed the average roughness values of cleaned metal, metal dipped in acidic solution and metal dipped in inhibitor solution. Rough values came out to be less in the case of metal immersed in inhibitor solution which revealed that inhibitor forms a vigilant thin layer on metal's surface which in results inhibits corrosion.

4. Conclusion

The research work by many reputed researchers proclaimed over some past decades on corrosion inhibition of mild steel and its alloys in numerous acidic solution such as 0.5 M HCl and 1M H₂SO₄ solutions, using a varieties of weeds extracts are presented in this review article. A diverse range of different organic solvents such as ethanol, methanol or some time distilled water for aqueous extract were accessed to obtained the extracts of weeds parts such like stems, leaves, roots etc. Rarely the phytochemical investigation was also reported on extracts and effects are made in pinpoint direction to investigate the presence of active components which are further responsible for corrosion inhibition of mild steel and its alloys in acidic medium. It was still so amazed to go through reports and literature review where in an extent of 99.83% inhibition efficiency was achieved. We concluded that use of weeds extract as corrosion inhibitor for metals should be carried out plus also on other corrosive nature environments like H₂S, CO₂ which adversely affects the metals in the gas and oil industries. From the various reports discussed it has been clear that natural compounds such as weeds extract emerge out to be an excellent corrosion inhibitors in the upcoming era of science due to their non-toxic nature,

potentially biodegradability and easy availability and this paradigm will create such class of chemicals to be used as corrosion inhibitor which will be non-hazardous to human beings and its surrounding and will also contribute its excellency in the prevention of loss due to the effects of corrosion on global level. Literature briefly discussed and affirmed that era of green corrosion inhibitors has significantly begun.

5. Future outlook

The application of weeds extracts as a corrosion inhibitor for mild steel and its further alloys is majorly recommended for future researches related to the corrosion inhibition of other metals such as copper, tin, stainless steel, aluminium etc. in this area. There are not so many reports in the literature on the use of weeds extracts as corrosion inhibitor for metals as discussed above and such further work in the corrosion field using weeds which are environmental friendly and least cost effective as anticorrosion product will be useful to understand the inhibition effects and use of such waste considered weeds in such good manner at the global research level.

References

- [1] A. Singh, T. Pramanik, A. Kumar, and M. Gupta, "Phenobarbital: A new and effective corrosion inhibitor for mild steel in 1 M HCl Solution," *Asian J. Chem.*, vol. 25, no. 17, pp. 9808–9812, 2013.
- [2] S. Bashir, G. Singh, and A. Kumar, "An Investigation on Mitigation of Corrosion of Aluminium by *Origanum Vulgare* in Acidic Medium," *Prot. Met. Phys. Chem. Surfaces*, vol. 54, no. 1, pp. 148–152, 2018.
- [3] S. Bashir, G. Singh, and A. Kumar, "Shatavari (*Asparagus Racemosus*) as green corrosion inhibitor of aluminium in acidic medium," *J. Mater. Environ. Sci.*, vol. 8, no. 12, pp. 4284–4291, 2017.
- [4] A. Singh, A. Kumar, and T. Pramanik, "A Theoretical Approach to the Study of Some Plant Extracts as Green Corrosion Inhibitor for Mild Steel in HCl Solution," pp. 1–7, 2013.
- [5] A. Kumar and S. Bashir, "Ethambutol: A new and effective corrosion inhibitor of mild steel in acidic medium," *Russ. J. Appl. Chem.*, vol. 89, no. 7, pp. 1158–1163, 2016.
- [6] S. K. Sharma, A. Peter, and I. B. Obot, "Potential of *Azadirachta indica* as a green

- corrosion inhibitor against mild steel, aluminum, and tin: a review,” *J. Anal. Sci. Technol.*, vol. 6, no. 1, 2015.
- [7] A. Olanrewaju, A. K. Oluseyi, B. V. Ayomide, A. O. Theresa, and A. S. Oluwakayode, “Corrosion inhibitive properties of *Epimedium grandiflorum* on mild steel in HCl acidic media,” *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 509, no. 1, 2019.
- [8] J. Omotoybo and D. Olorunba, “Corrosion Inhibition of Pulverized *Jatropha Curcas* Leaves on Medium Carbon Steel in 0.5 M H₂SO₄ and NaCl Environments Steel in Sodium Chloride Solution,” *Int. J. Sci. Technol.*, vol. 2, no. 7, pp. 510–514, 2013.
- [9] B. U. Ugi and T. O. Magu, “Phytochemical constituents of *Taraxacum officinale* leaves as eco-friendly and nontoxic organic inhibitors for stainless steel corrosion in 0.2 M HCl acid medium,” *Int. J. Chem. Sci.*, no. January 2019, 2018.
- [10] S. B. Ulaeto, U. J. Ekpe, M. a Chidiebere, and E. E. Oguzie, “Corrosion Inhibition of Mild Steel in Hydrochloric Acid by Acid Extracts of *Eichhornia Crassipes*,” *Int. J. Mater. Chem.*, vol. 2, no. 4, pp. 158–164, 2012.
- [11] M. M. Muzaki, F. O. Nwosu, and S. O. Amusa, “Mild steel corrosion inhibition in a NaCl solution by lignin extract of *chromolaena odorata*,” *Port. Electrochim. Acta*, vol. 37, no. 6, pp. 359–372, 2019.
- [12] P. Divya, R. Saratha, and S. V Priya, “Chemical Science Review and Letters Impediment Effect of *Galinsoga parviflora* (Quick Weed) on Mild Steel Corrosion in 1 M HCl,” *Chem Sci Rev Lett*, vol. 5, no. 18, pp. 115–126, 2016.
- [13] G. Choudhary, A. Sharma, R. K. Bangar, and A. Sharma, “Eco-friendly Inhibition by Weed (*Bidens biternata*) Extract towards Acid Corrosion of AA6063 INTRODUCTION :,” vol. 2, no. 12, pp. 112–119, 2015.
- [14] R. Salahandish, A. Ghaffarinejad, and A. Moradpour, “*Malvasylvestris* Flower Extracts as Green Corrosion Inhibitor for Carbon Steel in HCl Solution ,” vol. 110, pp. 97–110, 2016.
- [15] A. K. Sakerwal and V. K. Swami, “CORROSION INHIBITION OF IRON BY HYDROCHLORIC ACID SOLUTION BY *TEPHROSIA PURPURIA* PLANT,” vol. 8, no. 4, pp. 2046–2054, 2010.
- [16] A. Begum, “Evaluation of plants and weeds extract on the corrosion inhibition of mild steel in sulphuric acid,” *E-Journal Chem.*, vol. 8, no. SUPPL. 1, pp. 488–495, 2011.
- [17] S. A. Mangai and S. Ravi, “Comparative corrosion inhibition effect of imidazole

- compounds and of trichodesma indicum (Linn) R. Br. on C38 Steel in 1 M HCl medium,” *J. Chem.*, vol. 2013, pp. 1–5, 2013.
- [18] F. E. Abeng and V. D. Idim, “Green corrosion inhibitor for mild steel in 2 M HCl solution : Flavonoid extract of *Erigeron floribundus*,” vol. 98, no. April, pp. 89–99, 2018.
- [19] S. Laryea, S. A. Agyepong, R. Leiringer, and W. Hughes, *Stakeholder Perception of Risks and Risk Factors in Infrastructural Projects: The Case of the Niger Delta.*, vol. 2, no. 1. 2012.
- [20] L. Nnanna and I. Anozie, “Comparative study of corrosion inhibition of aluminium alloy of type AA3003 in acidic and alkaline media by *Euphorbia hirta* extract,” *African J. ...*, vol. 5, no. August, pp. 265–271, 2011.
- [21] R. Saratha and R. Meenakshi, “Evaluation of *Abutilon indicum* as mild steel corrosion inhibitor in 1 M HCl and 0.5 M H₂SO₄ by Electrochemical Techniques,” *Asian J. Chem.*, vol. 25, no. 3, pp. 1415–1419, 2013.
- [22] S. O. Adejo, M. M. Ekwenchi, P. O. Olatunde, and E. F. Agbajeola, “Adsorption characteristics of ethanol root extract of *Portulaca oleracea* as eco-friendly inhibitor of corrosion of mild steel in H₂SO₄medium,” *IOSR J. Appl. Chem.*, vol. 7, no. 4, pp. 55–60, 2014.
- [23] I. U. Anozie, C. S. Akoma, and L. a Nnanna, “Corrosion Inhibition of Aluminium Alloy in Acidic Medium by *Euphorbia hirta* and *Dialum guineense* Extracts,” *Int. J. Pure Appl. Sci. Technol.*, vol. 6, no. 2, pp. 79–88, 2011.
- [24] F. A. Ayeni *et al.*, “Investigation of <i>Sida acuta</i> (Wire Weed) Plant Extract as Corrosion Inhibitor for Aluminium-Copper-Magnesium Alloy in Acidic Medium,” *J. Miner. Mater. Charact. Eng.*, vol. 02, no. 04, pp. 286–291, 2014.
- [25] S. J. Olusegun, E. A. Okoronkwo, A. E. Okotete, and O. A. AJAYI, “Gravimetric and electrochemical studies of corrosion inhibition potential of acid and ethanol extract of siam weed on mild steel,” *Leonardo J. Sci.*, no. 29, pp. 25–42, 2016.
- [26] O. O. Adeyemi, O. O. Olubomehin, and R. O. Bello, “Investigation of *Ageratum Conyzoides* Aqueous Extract as Inhibitor for Hydrochloric Acid Corrosion of SX 316 Steel,” *Acad. J. Sci. Eng.*, vol. 8, no. 1, pp. 20–32, 2017.
- [27] J. Sharma and K. Sharma, “Corrosion Inhibitory Effects of Extracts of *Heliotropium Indicum* on Aluminum in Sulphuric Acid Medium,” vol. 2, pp. 20–29, 2015.

- [28] K. Krishnaveni, J. Ravichandran, and A. Selvaraj, "Inhibition of mild steel corrosion by Morinda tinctoria leaves extract in sulphuric acid medium," *Ionics (Kiel)*, vol. 20, no. 1, pp. 115–126, 2014.
- [29] A. Singh, N. Soni, Y. Deyuan, and A. Kumar, "A combined electrochemical and theoretical analysis of environmentally benign polymer for corrosion protection of N80 steel in sweet corrosive environment," *Results Phys.*, vol. 13, p. 102116, Jun. 2019.
- [30] V. S. and A. K. Pooja Dhaundiyal, Sumayah Bashir, "AN INVESTIGATION ON MITIGATION OF CORROSION OF MILDSTEEL BY ORIGANUM VULGARE IN ACIDIC MEDIUM," *J. Chem. Inf. Model.*, vol. 33, no. 1, pp. 159–168, 2019.
- [31] S. Bashir, V. Sharma, H. Lgaz, I.-M. Chung, A. Singh, and A. Kumar, "The inhibition action of analgin on the corrosion of mild steel in acidic medium: A combined theoretical and experimental approach," *J. Mol. Liq.*, vol. 263, 2018.
- [32] S. Bashir *et al.*, "Electrochemical Behavior and Computational Analysis of Phenylephrine for Corrosion Inhibition of Aluminum in Acidic Medium," *Metall. Mater. Trans. A*, Nov. 2018.
- [33] K. A. Sharma V, Kumar S, Bashir S, Ghelichkhah Z, Obot IB, "Use of Sapindus (reetha) as corrosion inhibitor of aluminium in acidic medium," vol. 5, no. 7, p. 076510, 2018.
- [34] S. Bashir, H. Lgaz, I. I. I. M. Chung, and A. Kumar, "Potential of Venlafaxine in the inhibition of mild steel corrosion in HCl: insights from experimental and computational studies," *Chem. Pap.*, vol. 73, no. 9, pp. 2255–2264, Apr. 2019.
- [35] S. Bashir, A. Thakur, H. Lgaz, I.-M. Chung, and A. Kumar, "Computational and experimental studies on Phenylephrine as anti-corrosion substance of mild steel in acidic medium," *J. Mol. Liq.*, vol. 293, 2019.