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Cigarette Butts Waste Extract - A Mild Steel Corrosion Inhibitor in Sulphuric Acid (Environmental Aspect)

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Abstract: Cigarette butt waste is one of the main causes of pollution. Every year, a massive number of cigarettes are released into the environment, endangering the health of both terrestrial and marine life as well as humans. To lessen environmental contamination, in-depth research is necessary regarding these environmental concerns. The current study aims to recycle cigarette butt wastes while also reducing the corrosion of mild steel (ASTM Gr 385) in H_2SO_4 solutions by employing the wastes as an inhibitor. Using adsorption isotherm models, thermodynamic parameters, and the weight loss method, inhibitor adsorption and corrosion inhibition were investigated at room temperature. Additionally, in line with other studies, an adsorbent and absorbent comparison was made. The acquired results show that as the concentration of the inhibitor increased, so did the values of inhibition efficiency ranged from 36.41to 93.71 %. The weight loss calculations showed that the corrosion rate of mild steel in H2SO4 media decreases with increasing the inhibitor concentration from 2.9766 to 0.1871 cm/yr. According to the thermodynamic characteristics, the adsorption was both physisorption and spontaneous. In contrast to earlier research, the adsorption was aggressive, and the Langmuir and Freundlich models fit the data the best. In general, mild steel materials can be efficiently protected against corrosion in H_2SO_4 solutions by using the CBWE inhibitor. As a result, a clean atmosphere and a possible corrective solution for the cigarette butts waste were given.

Keywords: (Adsorption, Cigarette butt, Environmental Pollution, Mild Steel Corrosion, Weight loss)

Introduction

Most Arab nations still have very high rates of adult male cigarette smokers, which makes the prevalence of cigarette smoking quite relevant. Although the percentages of smoking among students in certain Arab nations have changed recently, they are still worrying; in Libya, for instance, the rate is 28.3% [1].

The term "cigarette butt" describes the portion of the cigarette that remains after burning and smoking. It is mostly made up of tipping paper on the outside, fibre wraps wrapped in forming paper on the inside, and regular smoke particles that are caught in the process of burning and smoking [2]. The length of a cigarette butt is around thirty percent of its original length and is made up of four main parts: ash, paper, unburned tobacco, and filter material. Because each component of this solid waste contains a large amount of dangerous chemical compounds, it is regarded to be dangerous and highly polluting [3]. Furthermore, the primary raw material used to make the filter is cellulose acetate, which degrades slowly and can linger in the environment for a number of years [4]. In view of this, cigarette butt waste, when disposed of directly into the environment without any treatment, can cause negative impacts on terrestrial and aquatic ecosystems, landscapes, and public health. The landfilling and incineration methods have been tested for the disposal of cigarette butt waste generated in large urban centres and cities [5]. Waste from cigarette butts takes between one and twelve years to break down [6]. Worldwide, some six trillion cigarette butts are generated annually, and anywhere from one third to two thirds of these cigarette butts may end up in parks, waters, streets, and local communities [7]. Given the massive number of cigarette butts that are dumped, it is important to take seriously the compounds that may be toxic to humans and the environment. Numerous studies have confirmed the harmful effects of cigarettes, and the waste's hazardous effects on fishes and other aquatic species have previously been determined [8]. An efficient method for handling and disposing of this trash appears to be necessary, given the inefficiency of traditional disposal methods like landfilling and burning, which are impractical for cigarette butts [9]. The recovery of captured chemicals for the production of corrosion inhibitors or carrier protection, which reduces wastewater and hazardous waste, is one of the efficient methods for safely recycling cigarette butts using supercapacitors [10].

The deterioration of metal due to an attack by chemicals or reaction with ambient oxygen is known as corrosion. On the other hand, corrosion has a significant global economic impact. According to estimates, the financial burden of solving the issues brought on by the corrosion issues equals about 1% of the global GDP [11].

One important component used in the chemical industry is sulfuric acid (H_2SO_4). The production of fertilizers is its most prevalent application, but it is also crucial to the processes of mineral processing, oil refining, wastewater treatment, chemical synthesis, steel pickling, and other hydrometallurgical processes. Its wide range of uses include being an electrolyte in lead-acid batteries, an ingredient in household acidic drain cleaners, and a component of many cleaning products [12]. However, because of this acid's aggressiveness, metallic components used to build storage tanks and pipes are attacked. As a result, depending on the sulfuric acid concentration range, a variety of metallic substances are utilized to build tanks and pipes [13]. The peculiar characteristic of H_2SO_4 is that, at low to relatively high concentrations, it functions as a non-oxidizing acid; nevertheless, at very high concentrations, it becomes a strong oxidizing acid. In low concentrations of H_2SO_4, iron corrodes quickly, but in high quantities, it passivates by building a protective oxide layer [14]. Researchers have been very interested in sulfuric acid corrosion, particularly in the oil and gas sector, because of regulations governing the conversion of sulphur oxides and hydrogen sulphide (H2S) (Sox), which are created during the extraction and refining of oil, to sulfuric acid. These regulations have been put in place to lessen the detrimental impacts that the aforementioned gases that are released into the environment as a result of burning fuels have on global warming [15, 16].

A substance or component that shields the metal from corrosion deterioration at a very low concentration is known as a corrosion inhibitor. The metal surface is coated with a corrosion inhibitor, which lowers the corrosion velocity by creating a thin protective film [17]. Because of its many benefits, including affordability, excellent adaptability, ease of use, and economic efficiency, corrosion inhibitors are utilised extensively across a variety of industries [18]. It has often been noted that heteroatoms like N, S, or P are present in the chemical structure of an efficient corrosion inhibitor [19]. Boilers, pressure vessels, heat exchangers, pipelines, and other moderate-temperature service systems that require strong strength and ductility are applications for carbon steel. Cost, availability, and fabrication ease are important additional concerns. Near the upper carbon level, mild steels, or carbon steels with less than 0.25% carbon, have a slightly higher strength [20].

The sustainable recycle of hazardous, non-biodegradable solid waste into value-added commodities has drawn increased interest from researchers in recent years [21].

In 2023, Yu. A. Mirgorod et. al., By extracting nicotine and related materials from tobacco waste, such as cigarette butts and cigarettes (inhibitor 1) and tobacco dust powder (inhibitor 2) during the manufacturing of tobacco, an inhibitor was created using an aqueous solution of benzoic acid. Investigations were conducted into the yield of nicotine during tobacco waste extraction and the efficacy of steel used for oil pipelines' inhibitory protection. To ascertain its efficiency, electrochemical and gravimetric techniques were used. Both in the presence and absence of the inhibitors, the polarization curves behaved in the same way. The inhibitors influence both anodic and cathodic reactions because they function as mixed-type inhibitors. The steel inhibitor protection efficacy ranged from 92% to 96%. There is a good agreement between the corrosion inhibition data produced using the weight loss approach and electrochemical studies [22].

In 2021, Caroline Agustina et. al., said that the goal of the research is to develop a corrosion inhibitor to reduce the expense of material replacement, maintenance, and overdesign in order to address the issue with cigarette butts. ASTM 36 steel is being used in this study's experiment. Steel Grid, an abrasive substance, was used to blast clean the material beforehand. The coating procedure using an epoxy coating and the removal of cigarette butts, that were subsequently submerged in a caustic solution—sea water from Kenjeran-constituted the second phase of this investigation. The weight loss method is used to test corrosion rates. The corrosion rate at 1% mixing was the highest, measuring 0.06251 cm/y, while the corrosion rate at 2% mixing was the lowest, measuring 0.035 cm/y. This study indicates nicotine can be applied to coatings as a cathodic protection agent [23].

In 2020, Ambrish Singh et. al., examined the potential of tobacco derived from abandoned cigarettes to reduce copper and zinc corrosion in synthetic saltwater through the use of electrochemical, weight loss, and surface characterisation techniques. The maximal inhibitory efficiencies for copper and zinc were found to be 96.8% and 98.2%, respectively. The best fit was discovered to be the Langmuir adsorption isotherm [24].

In 2018, Xunji Li et. al., discovered that at 90 °C, 15% (wt.%) hydrochloric acid was used to compare the corrosion-inhibitive effect of four metal chloride intensifiers ($CoCl_2$, $NiCl_2$, $CrCl_2$, and $CuCl_2$) in cigarette butt extracts. Results from scanning electron microscopy, weight loss, polarization, impedance, and electrochemical noise all indicate that CuCl2 intensifiers have the greatest inhibitory effect on corrosion, followed by $CrCl_2$, $NiCl_2$, and $CoCl_2$; cigarette butt extracts had the least inhibitory effect. With the addition of 5% (wt.%), the corrosion-inhibitive efficiency of $CuCl_2$ intensifiers can reach 94.2%, and all four metal chlorides perform their intense tasks [25].

In 2017, Yong Guo et. al., via weight loss, electrochemical measurements, and surface analysis, the inhibitory effect of tobacco rob water extract (TRE) on the corrosion of N80 steel in HCl solution was examined. According to the findings, nicotine and other substances containing C and O are mostly in charge of TRE's ability to suppress corrosion. Furthermore, 750 mg·L-1 of TRE in 1M HCl at 60 °C produces a maximal inhibitory efficiency of 91.5%. The Langmuir adsorption isotherm is followed by the adsorption behavior of TRE [26].

In 2016, Hefang Wang et. al., used potentio-dynamic polarization to study the effectiveness of tobacco root extract (TRE) in inhibiting Q235 corrosion in artificial saltwater. According to the experimental findings, TRE has good corrosion inhibition ability, and as TRE concentration increased, so did the inhibition efficiency. The results of the corrosion and scale inhibition showed that TRE might be used as a successful corrosion and scale inhibitor in artificial seawater [27].

In 2016, S. Vahidhabanu et. al., Chemical extracts from cigarette butt litter were separated using polar solvents and employed as corrosion inhibitors for J55 oil well tubular steel, which is used in gas production and acidization of oil wells. Using LC-MS and ASS, the chemical components found in the crude extracts were examined. The study included weight loss and electrochemical techniques to assess the inhibitory effects of 15% HCl solution at 30 °C and 105 °C on corrosion-prone J55 oil well tubular steel. The findings indicate that at 6% concentration, the maximum inhibitory efficiencies of 99% and 61% are attained at 30 °C and 105 °C, respectively. Thus, we created a hygienic atmosphere and offered a possible corrective option for the cigarette butts that were scattered [28].

The aim of this study is to investigate the absorption mechanism of the employed inhibitor and to ascertain the level at which cigarette butts may be utilized as an inhibitor of corrosion of mild steels in H_2SO_4 acidic medium solution. The following are the anticipated benefits of this research: Utilize leftover cigarette butts to cut down on the quantity of waste that is generated in order to safeguard carbon steel structural elements and equipment, particularly in H_2SO_4 tanks found in oil refineries and desalination facilities. This will lower the expense of equipment replacement and upkeep.

Materials and Experiments

The Mild Steel Specimens Preparation

Specimens of mild steel, or carbon steel, measuring 3.5 x 1.4 x 0.15 cm were made. They are governed by ASTM Gr. 285B code. To achieve a smooth (like mirror), mild steel surface, the samples' surfaces were polished using abrasive grit sheets (400, 800, 1000, 1500, and 2000). They were then elevated using distilled water and dried. Subsequently, they performed a one-minute ultrasonic cleaning with alcohol to eliminate any remaining polishing residue and any oil. The samples were stored in a plastic container with anti-humidity silica gel after being prepared, cleaned, and dried. Table 1 [29] lists the mechanical characteristics and chemical composition of mild steel specimens that were employed in the weight loss experiments. Following application, Figure 1 displays the weight loss test samples, before and after abrasive grit polishing.

Table 1. Mechanical Characteristics and Chemical Composition of Mild Steel Specimens.

Mechanical Properties			Chemical Composition			
T. S. MPa	Y. S. MPa	M. E. %	C %	Mn %	P %	S %
345 - 450	185	28	0.22	0.90	0.035	0.035

* T.S.= Tensile Strength, Y. S>=Yield Strength, M. E.= Maximum Elongation, MPa= Megapascal, C=Carbon, Mn=Manganese, P=Phosphor, and S=Sulphur.

Fig. 1 The Weight Loss Test Specimens, Before and After Abrasive Grit Polishing.

The Cigarette Butt Extract Preparation

Cigarette paper, tobacco, tipping paper, additives, and a filter constituent of a cigarette (Figure 2) [30]. The degradation of cigarette filters, which are mostly made of plasticized cellulose acetate fibres, produces microplastics that worsen environmental pollution. Numerous factors, including rain, abrasion, salt, temperature changes, and—most importantly—UV radiation, accelerate the decomposition of these plastics [31]. Figure 3 shows the Structure of Cellulose Acetate, used in the filter of a Cigarette Butt [31].

Fig. 2 The Constituent of a Cigarette.

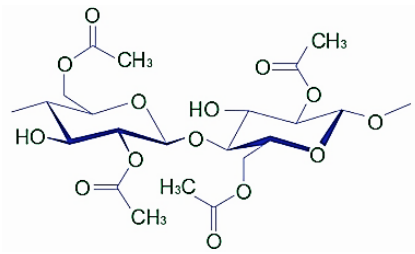

Fig.3 Structure of Cellulose Acetate, Used in the Filter of a Cigarette Butt.

The following is the procedure for creating corrosion inhibitors using extracts from cigarette butt water: Tobacco butt waste tobacco filler was pulverized into a fine powder (Figure 4). 100 millilitres of deionized water were used to soak five grammes of littered cigarette butts for a period of seven days. Each container was placed into an aluminium foil-covered shaker-conical flask and sealed with a paraffin strip. The sample of polar solvent was made. Following a period of seven days, the material was filtered through cellulose fibre filter paper and a vacuum pump to eliminate both suspended and solid particles. With a diameter of 9.0 cm, the filter paper had fine porosity, a particle retention of 1-4 micrometres, and a sluggish flow rate of 5 millilitres per minute. There were roughly 75–100 present. The headings and subheadings from introduction to Acknowledgement must be in 9 points, bold face, aligned left, don't underline any words in your paper, subheadings are numbered with 1, 2, 3 etc, delete and type).

The filter paper had a diameter of 9.0 cm, fine porosity, a slow flow rate of 5 milliliters per minute, and a particle retention of 1-4 micrometers. After soaking for seven days, there was around 75–100 mL of liquid left in the conical flask. Each sample's volume was determined by the sample itself. A rotary evaporator (Make: IKA) was used to extract the filtered material, which was then kept at room temperature in a glass vial. By using electrochemical and weight loss techniques, the cigarette butt extract was examined for corrosion inhibition [32]. Eight samples total—0.05, 0.10, 0.15, 0.20, 0.25, 0.30, and 0.35 g/L- were generated using different concentrations of cigarette butt extract in H_2SO_4 solution. The examples are displayed.

Fig. 4 Cigarette Butt Waste Powder Sample.

Fig. 5 Extraction Results of Inhibitor from Cigarette Butt Waste.

Experimental Results and Discussion

Weight Loss experiments

The following formula (1) [33] was used to determine the weight loss for the mild steel specimens submerged in H_2SO_4 solution along with and without CBWE:

$$\text{Corrosion Rate (C. R.)} = 87.6\ \frac{W_{loss}}{DAT}\ \text{(mm/yr)} \quad (1)$$

The specimen area (A) in this instance is 4.90 cm^2, the weight loss (W) is expressed in grammes, the metal density ($7.85 g/cm^3$) is expressed in hours, and T is the metal exposure period (24 hours). When mild steel is submerged in H_2SO_4, both with and without an inhibitor, Table 2 displays the weight loss results [33]: The inhibitor efficiency (I.E.%) for different CBEW concentrations in H2SO4 solution was calculated using formula 2 [34]:

$$\text{Inhibitor Efficiency (I. E.\%)} = \frac{W_i - W_o}{W_i}\ \text{x 100 \%} \quad (2)$$

where and stand for the mild steel specimen's weight loss in grammes before and after a corrosion test, respectively. The results for inhibitor efficiency (I.E.%) are listed in Table 2. Figure 6 shows the relationship between the inhibitor concentration I_{inh} and the rate at which a mild steel specimen corrodes C. R. in an H_2SO_4 solution with different inhibitor concentrations. Figure 7 shows the link between the log and the I.E.%. A homogeneous chemical film, which is most likely composed of a variety of antioxidant polyphenol molecules generated in combination with other film macromolecules such as fatty acids or pectin, is associated with the inhibitory activity [35].

According to Figure 6, it can be observed that the corrosion rate of the mild steel specimens in H_2SO_4 solution decreases with increasing of the cigarette butt waste extract concentration, the maximum obtained inhibitor efficiency was 96.32 at 0.35 g/L. This indicated that, the CBWE work effectively as corrosion inhibitor to protect a corrosion of mild steels in H_2SO_4 solutions. Figure 7 has the characteristic S-shape, indicating that CBWE forms a monolayer on the surface of mild steel [36].

Table 2. Weight Loss Experiments Data.

S. C.	W. B. I. G	W. A. I. g	W. L. W_{loss}, g	Area cm^2	C. R. cm/yr.	I_{inh} g/L	I. E. %
CBWE1	5.7624	5.7363	0.0261	4.9	2.9766	00	00.00
CBWE2	5.8016	5.7850	0.0166	4.9	1.8928	0.05	36.41
CBWE3	5.6996	5.6847	0.0113	4.9	1.2881	0.10	56.73
CBWE4	5.8529	5.8480	0.0049	4.9	0.5568	0.15	81.29
CBWE5	5.7738	5.7699	0.0039	4.9	0.4415	0.20	85.17
CBWE6	5.7582	5.7553	0.0028	4.9	0.3274	0.25	89.00
CBWE7	5.8275	5.8259	0.0016	4.9	0.1871	0.30	93.71

* S. C.= Specimen Code, W. B. I.= Weight Before Immersion, W. A. I.= Weight After Immersion. W. L.= W_{loss} = Weight Loss, C. R.= Corrosion Rate, I_{inh}= Inhibitor Concentration, I. E.= Inhibitor Efficiency, CBWE= Cigarette Butt Waste Extract.

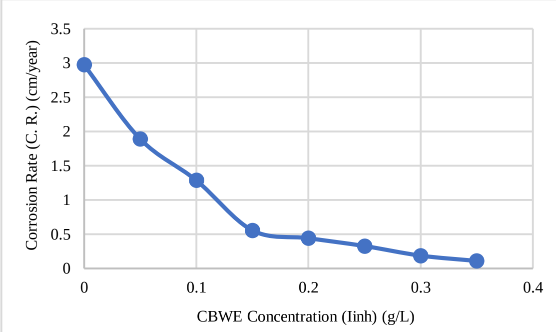

Fig. 6 Corrosion Rate (C. R.) Vs. Cigarette Butts Waste Extract (CBWE) Inhibitor Concentration.

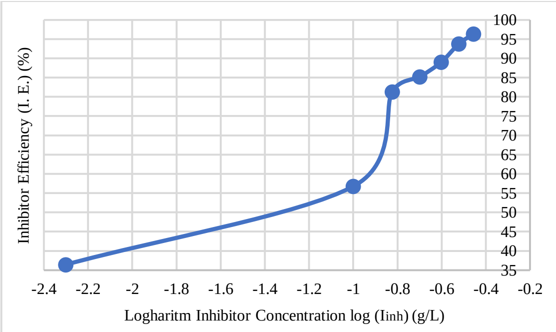

Fig. 7 Inhibitor Efficiency (I. E.) Vs. Cigarette Butts Waste Extract (CBWE) Inhibitor Concentration.

Thermodynamic Parameters

Understanding the thermodynamic parameters is a prerequisite to understanding the inhibitive process. The Gibb's free energy of adsorption $\Delta G°_{ads}$ was calculated using the following formula (3) to characterise the relationship between molecules that are absorbed and mild steel surfaces [37].

$$\Delta G°_{ads} = -\,2.303\ R\ T\ \log\,(55.5\ \text{x}\ K_{ads}) \quad (3)$$

The absolute temperature in Kelvin (298.15 K), the gas constant is ($8.314\ J\ K^{-1}\ mol^{-1}$), and the adsorption equilibrium constant in L/g are all represented in this equation by the values of T, R and K_{ads}. The free energy of adsorption $\Delta G°_{ads}$ can be found by computing the equilibrium constant (K_{ads}) of adsorption (formula 4) [37].

$$K_{ads} = \frac{(\frac{\theta}{1-\theta})}{I_{inh}} \quad (4)$$

Table 3 displays a thermodynamics parameter for the adsorption of cigar butt waste extract (CBWE) in H_2SO_4 solution. Generally speaking, electrostatic interactions (physisorption) between the inhibitor and a charged metal surface are indicated by $\Delta G°_{ads}$ magnitudes of approximately −20 kJ/mol-1 or less negative. Negative values of around -40 kJ/mol-1 or higher suggest charge sharing or transfer from organic species to the metal surface, forming a coordinate type of metal bond (chemisorptions). The current study's computed values of $\Delta G°_{ads}$ for mild steel at 298.15 K vary from - 10.269 to - 20.651 kJ/mol, indicating that physisorption adsorption is involved in the inhibitor molecules' adsorption on the metal surface [38]. Stronger inhibitor adsorption on the mild steel surface is indicated by greater K_{ads} values [39], the maximum K_{ads} was 74.7862 l/g.

Table 3. Adsorption and Thermodynamics Parameters for Adsorption of Cigarette Butts Extract on the Mild Steel Surface.

S. C.	S. C. (θ)	$\frac{Iin}{\theta}$	A. C. K_{ads}, L/g	A. E. $\Delta G°_{ads}$ kJ/mol
CBWE1	0.3641	0	11.4514	- 10.269
CBWE2	0.5673	0.088137	13.1107	- 16.335
CBWE3	0.8129	0.123016	28.9649	- 18.300
CBWE4	0.8517	0.176118	28.7155	- 18.274
CBWE5	0.8900	0.224719	32.3636	- 18.575
CBWE6	0.9371	0.26678	49.6608	- 19.631
CBWE7	0.9632	0.311462	74.7826	- 20.651

* S. C.= Specimen Code, S. C.= Surface Coverage, A. C.= Adsorption Constant. A. E.= Adsorption Energy.

Adsorption Isotherm Models

The adsorption of molecules of inhibitors in an aqueous solution can be conceptualized as a quasi-substitution process between organic compounds in the aqueous phase and water molecules at the electrode surface. The experimental results can be used to determine how surface inhibitor molecules interact with one another [40]. The Langmuir, Temkin, Freundlich Adejo Ekwenchi and El-Awady adsorption isotherms are the most frequently used in determining the mechanism of organo-electrochemical reactions. Each of these isotherms has the following general form: [39].

$$f(\theta, x) \exp(-2a\,\theta) = K_{ads}\, I_{inh} \quad (5)$$

where (a) is the molecular interactions parameter, (x) is the size ratio reflecting the entire number of molecules of water displace by a single molecule of an organic inhibitor, and is the value of equilibrium for the adsorption. In the isotherm's development, the physical representation and the assumptions that underlie it have a significant impact on the configuration factor, f (θ, x). Most people think that applying and keeping up a protective coating is the best technique to stop corrosion on metal surfaces [40]. To compute the surface coverage (θ), it was assumed that the inhibitor efficacy mostly stems from the adsorbed species' blocking effect, which resulted in an IE% = 100 [38]. The inhibitor adsorption mechanism on the steel surface was understood by mathematically fitting the coverage of the surface values into a variety of adsorption isotherms. The best-fitting isotherm was then found using the correlation coefficient (R^2) value [41]. In this study, the adsorption of CBWE on the surface of mild steel specimens was investigated using the Langmuir and Freundlich adsorption models.

Langmuir Adsorption Isotherm

The Langmuir adsorption isotherm is used to describe the equilibrium between adsorbate and adsorbent system, it's only applicable to homogeneous surfaces since it relies on a monolayer of the adsorbed adsorbate [42]. Langmuir's theory of monolayer formation relied on the unique binding interaction between discrete solid surface locations and adsorbate molecules. The original version of the image was derived from studies with hydrogen and other tiny molecules in the form of very low pressure, heated metal filaments. [43]. The adsorptive capabilities of different adsorbents are compared and quantified, and the gas-solid phase of adsorption is defined [44]. The expression for the relationship between the inhibitory concentration of a material and its surface coverage is the Langmuir isotherm, which has the formula (6): [45].

$$\frac{I_{inh}}{\theta} = \frac{1}{K_{ads}} + I_{inh} \qquad (6)$$

A linear relationship was obtained by plotting (I_{inh}/θ) vs. (I_{inh}), as Figure (8) illustrates. The kinetics approach is usually used in conjunction with a few assumptions to generate the Langmuir adsorption isotherm equation. When the adsorption isotherm is linear, the resulting curves are almost the same [46]. The kinetics approach is typically used to generate the Langmuir adsorption isotherm formula based on a few assumptions. Typically, these assumptions are not sufficiently supported by the mechanisms and methods used to compute the adsorption constants [47]. Table 4 displays the parameters of the Langmuir isotherm. According to the (R^2) finding (0.9875), the cigarette butt waste extract (CBWE) inhibitor match the Langmuir adsorption isotherm, as it is more than 0.9 and close from unity [48]. This suggests that it was improbable to use multilayer adsorption for the adsorption of both metal ions [48].

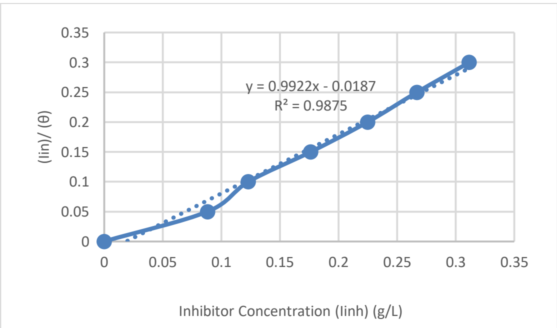

Fig. 7 Langmuir Isotherm for Adsorption of Cigarette Butts Extract (CBWE) on the Mild Steel Surface.

Freundlich Adsorption Isotherm

The second option for figuring out the absorbent solution's adsorption potential is the Freundlich adsorption isotherm model. It's typically a better option than the Langmuir model. In contrast to the Langmuir model, the Freundlich adsorption isotherm model can also be applied to multilayer adsorption [49]. This isotherm model is characterized by the absorbates forming a monomolecular layer on the absorbent's surface [50]. The variation of the molecules' surfaces is expressed by the Freundlich model [51]. The Freundlich isotherm is the consequence of formula (7) [52]:

$$\log \theta + \log K_{ads} + n \log I_{inh} \qquad (7)$$

where n is the interaction's parameter. The parameters of the Freundlich isotherm are shown in Table 4. Additionally, a linear relationship is shown in Figure 8's shows plot of log (θ) vs. log (I_{inh}) [49]. where n is the interaction's parameter. The parameters of the Freundlich isotherm are shown in Table 4. The graph of log (θ) against log (I_{inh}) in Figure 8 also shows a linear relationship, and its (R^2) value is 0.9301, which is higher than 0.9 and closer to unity than the Langmuir model. As a result, the inhibitor of cigarette butt waste extract (CBWE) fits better into the Freundlich model and indicates that the inhibitor's adsorption on a mild steel surface is appropriate.

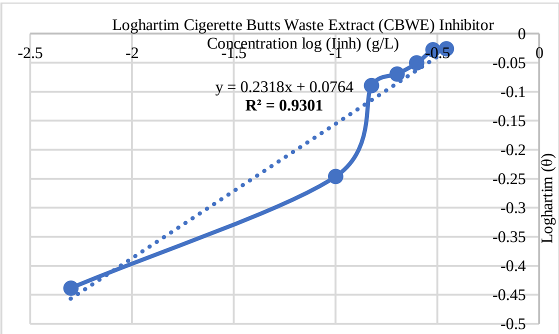

Fig. 8 Freundlich Isotherm for Adsorption of Cigarette Butts Extract (CBWE) on the Mild Steel Surface.

Comparison of Various Adsorbent Materials

The comparison of the maximum inhibitor efficiency and isotherm adsorption correlation coefficient R^2 of the mild steel material with that of various adsorbents (other materials) in H_2SO_4 using cigarette butt waste extract (CBWE) as an inhibitor is given in Table 4.

In comparison to the other values in the table, the value of the cigarette butt waste extract (CBWS) corrosion inhibition efficiency is deemed fair, based on the results. The greatest correlation coefficient achieved in this study is less than the other values in the table, indicating that the inhibitor employed is less adsorptive. This is related to the correlation coefficient's value regarding its capacity to adsorb on the surface.

Table 4. Comparison of Inhibitor Efficiency and Correlation Coefficient R^2 of (CBWE) with Various Adsorbents.

Adsorbent	Max. I. E. %	Isotherm Model	R^2	Ref.
Carbon Steel in HCl	94.20	Langmuir	0.990	[53]
Copper & Zinc in Sea Water	Cu 96.80 Zn 98.20	Langmuir	0.998 0.996	[54]
Oil Pipeline Steel in benzoic acid	96.00	-	-	[22]
Copper Chloride Metal in HCl	94.20	-	-	[25]
N80 Steel in HCl	91.50	-	-	[26]
J55 Oil Well Tubular Steel in Acidization Gas	99.00	-	-	[28]

* Max. I. E.= Maximum Inhibitor Efficiency, Ref. = Reference.

Comparison of Cigarette Butt Waste Extract (CBWE) with Various Absorbent Materials in Corrosion of Mild Steels in H_2SO_4 Solution

The comparison of the maximum inhibitor efficiency and isotherm adsorption correlation coefficient R^2 of the cigarette but waste extract (CBWE) inhibition of Mild steel corrosion in H_2SO_4 solution with that of various absorbents is given in Table 5. Figures 9 and 10 shows inhibitor efficiency and correlation coefficient comparison of various absorbents, respectively. It is evident from that the CBWE inhibitor has a higher efficiency value than the values of the other inhibitors. While the inhibitor's adsorption on the surface is slightly less than that of the inhibitors listed in the table, it is still regarded as somewhat acceptable. The highest correlation coefficient in the present investigation is less than most results, indicating that the inhibitor's efficiency is relatively high.

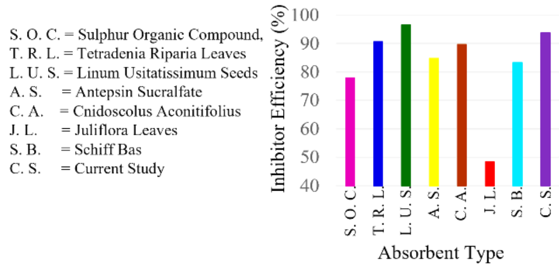

Fig. 9 Comparison of Inhibitor Efficiency of Various Absorbents.

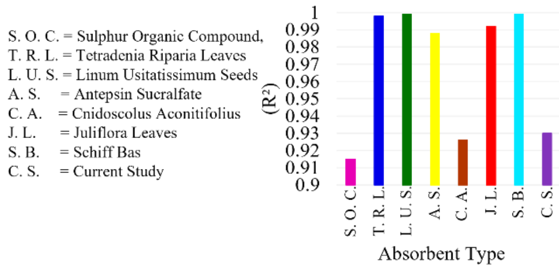

Fig. 10 Comparison of correlation factor (R^2) of Various Absorbents.

Table 5. Comparison of Inhibitor Efficiency and Correlation Coefficient R^2 of (CBWE) with Various Absorbents.

Absorbent	Max. I. E. %	Isotherm Model	R^2	Ref.
Sulphur Organic Compound	77.86	Langmuir	0.915	[55]
Tetradenia Riparia Leaves	90.60	Langmuir	0.998	[56]
Linum Usitatissimum Seeds	96.50	Langmuir	0.999	[57]
Antepsin Sucralfate	84.75	Frumkin	0.988	[58]
Cnidoscolus Aconitifolius	89.60	Langmuir	0.926	[59]
Juliflora Leaves	48.34	Freundlich	0.992	[60]

Schiff Bas MMP	83.20	Langmuir	0.999	[61]

* MMP=2[4MethoxyPhenyl)Imino]Methyl}Phenol

Conclusion

This study examined the impact of utilizing different CBWE inhibitor concentrations (0.05, 0.1, 0.15, 0.20, 0.25, 0.30, and 0.35 g/L) on mild steel corrosion in an electrolyte solution containing 1 M of H_2SO_4.

The following findings were reached after performing weight loss studies and calculating the adsorption variables:

(1) Increasing the concentration of CBWE inhibitor lowers the rate of mild steel corrosion in H2SO4 solution.

(2) At a concentration of 0.35 g/L of CBWE, the maximum inhibition efficiencies were 93.71%.

(3) According to Freundlich's adsorption model, the CBWE inhibitor adsorbs.

(4) The adsorption process' spontaneity and physisorption are demonstrated by the K_{ads} and $\Delta G°_{ads}$ values.

(5) The current study's findings were found to be in line with and compatible with those of earlier investigations.

(6) Finally, Recycling cigarette butt waste will prevent environmental pollution and also reduce the corrosive problem occurring with mild steel in H_2SO_4.

References

[1] Shafey O., (2007), Global Epidemiology and Health Hazards of Tobacco Use: Arab World Patterns. Ethnicity Dis. 2 17:13. https://www.researchgate.net/publication/264999646

[2] Abou-Faddan H. H. and Ahmed S. M., (2012), Knowledge, Attitude and Practice Study on Smoking Among Male Students in Al-Jabal Al-Gharbi University, Gharian–Libya. Journal of American Science, 8 (11). http://www.jofamericanscience.org.

[3] Meenakshi Thakur, et. al., (2024), Study on the Awareness of Cigarette Butt as a Potential Environmental Hazard, Journal of Research Square. DOI: https://doi.org/10.21203/rs.3.rs-3745229/v1.

[4] Torkashvand J., et. al., (2020), Littered Cigarette Butt as A Well-Known Hazardous Waste: A Comprehensive Systematic Review. Journal of Hazard Mater., 383: e121242, DOI: 10.1016/j.jhazmat.2019.121242. https://doi.org/10.1016/j.jhazmat.2019.121242.

[5] Puls J., et. al., (2011), Degradation of Cellulose Acetate-Based Materials: A Review. J Polym Environ, Vol. 19, pp 152–165, DOI 10.1007/s10924-010-025. https://doi.org/10.1007/s10924-010-0258-0.

[6] Mohajerani A., et. al., (2016), A Practical Proposal for Solving the World's Cigarette Butt Problem: Recycling in Fred Clay Bricks. Waste Manag, 52: pp 228–244. https://doi.org/10.1016/j.wasman.2016.03.012.

[7] Adedapo A., et. al., (2016), Cardiotoxicity Study of the Aqueous Extract of Corn Silk in Rats. Macedonian Veterinary Review, 39 (1), pp 4-49, DOI: 10.1515/macvetrev-2015-0065.

[8] World Health Organization Tobacco and Its Environmental Impact: An Overview. [(accessed on 3 May 2019)];2017 Available online: https://www.who.int/tobacco/publications/environmental-impact-overview/en/

[9] Dobaradaran, S., et. al., (2019), Cigarette Butts: An Overlooked Source of PAHs in the Environment, Environ. Pollut., 249: pp 932-939, DOI: 10.1016/j.envpol.2019.03.097.

[10] Yuan, Y., et. al., (2006), Optimization of a Medium for Enhancing Nicotine Biodegradation by Ochrobactrum Intermedium DN2. Journal of Applied Microbiology, Vol. 101(3), pp 691-697. DOI: 10.1111/j.1365-2672.2006.02929.x.

[11] Torkashvand, J. and Farzadkia, M., (2019), A Systematic Review on Cigarette Butt Management as a Hazardous Waste and Prevalent Litter: Control and Recycling. Environ. Sci. Pollut. Res. 26 (12): 11618-11630, DOI: 10.1007/s11356-019-04250-

[12] O. S. I. Fayomi, et. al., Economic Impact of Corrosion in Oil Sectors and Prevention: An Overview. Journal of Physics: Conference Series, 1378 (2019) 022037. https://doi.org/10.1088/17426596/1378/2/022037.

[13] H. Müller, (2000), Sulfuric Acid and Sulfur Trioxide., in: Ullmann's Encycl. Ind. Chem., Wiley-VCH Verlag GmbH & Co. KGaA, Weinheim, Germany, pp 1–71. DOi:10.1002/14356007.a25_569.

[14] Z. Panossian, et. al., (2012), Corrosion of Carbon Steel Pipes and Tanks by Concentrated Sulfuric Acid: A Review, Corros. Sci. 58 (2012) 1–11. DOI: 10.1016/j.corsci.2012.01.025.

[15] G. W. P. Rengstorff, et. al., Friction and Wear of Iron in Sulfuric Acid, Natl. Aeronaut. Sp. Adm. (1984), pp 1–19.

[16] M. Ferhat, et. al., (2014), Corrosion Behaviour of Fe-C Alloys in a Sulfuric Medium, J. Mater. Environ. Sci. 5, ISSN: 2028-2508, pp1059–1068.

[17] M. Valladares-Cisneros, et.al., (2015), Naturally Cleaned Surfaces and Controls the Corrosion of Metallic Materials. Inventio, 11, ISSN: 2007-1760, pp 37-41.

[18] F. Ravazzolo, and J. Vespignani, (2020), World Steel Production: A New Monthly Indicator of Global Real Economic Activity. Canadian Journal of Economics, 53, pp 743-766. https://doi.org/10.1111/caje.12442.

[19] C. Verma, et. al., (2016), 2, 4 - Diamino - 5-(Phenylthio)-5H-Chromeno [2, 3-B] Pyridine-3-Carbonitriles as Green and Effective Corrosion Inhibitors: Gravimetric, Electrochemical, Surface Morphology and Theoretical Studies. RSC Adv., 6, 53933. https://doi.org/10.1039/c6ra04900a

[20] P. Flenner, Carbon Steel Handbook. EPRI, Palo Alto, CA, (2007), 1014670, p 1-1, 2-8, A-4, and B-3.

[21] Li L., Jia C., et. al, (2020), Utilization of Cigarette Butt Waste as Functional Carbon Precursor For Supercapacitors and Adsorbents, J. Cleaner Production 256, 120326. DOI: 10.1016/j.jclepro.2020.120326.

[22] Yu. A. Mirgorod, et. al., (2023), Acid Corrosion Inhibitor from Tobacco Waste for Steel of Oil Pipes, Journal of Surface Engineering and Applied Electrochemistry, Vol. 59, pp 85–89, DOI: 10.3103/S1068375523010106.

[23] Caroline Agustina, e t. al., (2021), Effect of Cigarette Butts Extraction on the Corrosion Rate of ASTM A36 for Jacket Platform, In Proceedings of the 7th International Seminar on Ocean and Coastal Engineering, Environmental and Natural Disaster Management (ISOCEEN 2019), pp 225-230, ISBN: 978-989-758-516-6. DOI: 10.5220/0010132102250230.

[24] Ambrish Singh, et. al., (2020), Tobacco Extracted from the Discarded Cigarettes as an Inhibitor of Copper and Zinc Corrosion in an ASTM Standard D1141-98(2013) Artificial Seawater Solution, Journal of Material Research and Technology, Vol. 9(3): pp 5161–5173. https://doi.org/10.1016/j.jmrt.2020.03.033.

[25] Li, X., et. al., (2018). Cigarette Butts Water Extracts as Corrosion Inhibitor in Oil Field Acidizing Fracture Using Different Metal Chlorides Intensifiers. In: Han, Y. (eds) Advances in Materials Processing. CMC 2017. Lecture Notes in Mechanical Engineering. Springer, Singapore. https://doi.org/10.1007/978-981-13-0107-0_110.

[26] Yong Guo, et. al., (2017), Tobacco Rob Extract as Green Corrosion Inhibitor for N80 Steel in HCl Solution, International Journal of Electrochemical Science, Vol. 12, Issue: 2, pp 1401-1420, DOI: 10.20964/2017.02.25.

[27] Hefang Wang, et. al., (2016), A Natural Extract of Tobacco Rob as Scale and Corrosion Inhibitor in Artificial Seawater, ELSEVIER: Desalination, Vol. 398, pp 198-207. https://doi.org/10.1016/j.desal.2016.07.035

[28] S. Vahidhabanu, et. al., (2016), Study of Cigarette Butts Extract as Corrosive Inhibiting Agent in J55 Steel Material, : International Journal of Research in Engineering and Technology (IJRET), eISSN: 2319-1163, pISSN: 2321-7308, DOI: 10.15623/ijret.2014.0301077.

[29] P. Flenner, Carbon Steel Handbook. EPRI, Palo Alto, CA, The Electric Power Research Institute (EPRI), California 94303-0813, USA (2007), 1014670.

[30] Aron Pazzaglia and Beatrice Castellani, (2023), Policy, Social, Operational and Technological Factors Affecting Cigarette Butt Recycling, Not Peer-Reviewed, DOI: 10.20944/preprints202307.0317.v1.

[31] Mušič Branka, (2024), Invited, Lecture/ Research: Weathering Effects on Cellulose Acetate Microplastics from Discarded Cigarette Butts, pp 168-234.

[32] S. Vahidhabanu, et. al., (2014), Study of Cigarette Butts Extract as Corrosive Inhibiting Agent in J55 Steel Material, International Journal of Research in Engineering and Technology, eISSN: 2319-1163 pISSN: 2321-7308. DOI:10.15623/ijret.2014.0301077, 2014.

[33] Osoh E. A., et. al., (2019), Corrosion Inhibitory Properties of La 0.5 Ca 0.5 MnO3-Gold Nanoparticles in 1 M HCl, Department of Chemistry, Covenant University, Ota, Ogun State, Nigeria, 13th Joint Conference on Chemistry (13th JCC), IOP Conf. Series: Materials Science and Engineering, 509 (2019) 012039, DOI:10.1088/1757-899X/509/1/012039.

[34] Nath A. K., et. al., (2011), Purification and Characterization of a Novel Inhibitor from Poinciana pulcherrima Seeds with Activity towards Pest Digestive Enzymes, 75-81 ©2012 Global Science Books, http://www.globalsciencebooks.info/Online/GSBOnline/images/2012/FPSB_6(SI1)/FPSB_6(SI1)75-81o.pdf.

[35] Aghzzaf A. A., et, al., (2019), Pomegranate Peels Crude Extract as a Corrosion Inhibitor of Mild Steel in HCl Medium: Passivation and hydrophobic Effect, Materials and Corrosion, 1–7, WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim, www.matcorr.com.

[36] S. A. Soliman and M. Y. Mourad, (1993), The Inhibitive Action of Sodium Castor Sulphonate Towards the Corrosion of Aluminium in Hydrochloric Acid, Qatar Univ. Sci. J., Vol. 13 (2): pp 190- 193, DOI: 0793132-0003-fulltext.pdf.

[37] Osoh E. A., et. al., (2019), Corrosion Inhibitory Properties of La 0.5 Ca 0.5 MnO3-Gold Nanoparticles in 1 M HCl, 509, 012039, DOTi:10.1088/1757-899X/509/1/012039.

[38] Li X., Deng S. and Fu H. (2011). Inhibition by Tetradecylpyridinium Bromide of the Corrosion of Aluminium in Hydrochloric Acid solution, Journal of Corrosion Science, Vol. 53, Issue 4, pp 1529-1536, https://doi.org/10.1016/j.corsci.

[39] B. Anand and S. Chitra, (2020), Adsorption Studies on the Inhibition of the Corrosion of Mild Steel in 2 M NaCl by Tetracycline and Neomycin Trisulphate Drugs, Communication in Physical Sciences, Vol. 5(1): pp 1- 6.

[40] Chuan Lai, et. al., (2017). Adsorption and Corrosion Inhibition of Mild Steel in Hydrochloric Acid Solution by S-Allyl-O, O0-Dialkyldithiophosphates, Journal of Science Direct: Results in Physics, Vol. 7, 2017, Pages 3434-3443. https://doi.org/10.1016/j.rinp.2017.09.012

[41] Singh A., Singh V. K. and Quraishi M. A. (2013). Inhibition of Mild Steel Corrosion in HCl Solution Using Pipali (Piper longum) Fruit

Extract, Arabian Journal for Science and Engineering, 38, pages 85–97.

[42] Al-Aoh H. A., et. al., (2012). Isotherm and Kinetic Studies of 4-Nitrophenol Adsorption by NaOH-Modified Palm Oil Fuel Ash. Journal of Purity, Utility Reaction and Environment, Vol.1 (2): pp 104-120, ISSN: 2232-1179.

[43] Swenson H. and Stadie N. S. (2019). Supporting Information for: Langmuir's Theory of Adsorption: a Centennial Review1-3, MT, 59717, USA. DOI:10.1021/acs.langmuir.9b00154.

[44] Elmorsi T. M. (2011). Equilibrium Isotherms and Kinetic Studies of Removal of Methylene Blue Dye by Adsorption onto Miswak Leaves as a Natural Adsorbent, Journal of Environmental Protection, 2(6), 817–827.

[45] Iroha N. B. and James A. O. (2018). Assessment of Performance of Velvet Tamarind-Furfural Resin as Corrosion Inhibitor for Mild Steel in Acidic Solution. Journal of Chemical Society of Nigeria, Vol.43 (3), pp 510-517.

[46] Budhiary K. and Sumantri I. (2021). Langmuir and Freundlich Isotherm Adsorption Using Activated Charcoal from Banana Peel to Reduce Total Suspended Solid (Tss) Levels in Tofu Industry Liquid Waste, International Conference on Chemical and Material Engineering (ICCME), IOP Conf. Series: Materials Science and Engineering 1053- 012113, DOI:10.1088/1757-899X/1053/1/012113.

[47] Heraldy P. E., Hidayat Y. and Firdaus M. (2016). The Langmuir Isotherm Adsorption Equation, Conf. Series: Materials Science and Engineering 107 (2016) 012067 DOI:10.1088/1757-899X/107/1/012067.

[48] Attaso Khamwichit, et. al., (2022), Adsorption Kinetics and Isotherms of Binary Metal Ion Aqueous Solution Using Untreated Venus Shell, Journal of Heliyon, Vol. 8, Issue 6, e09610. https://doi.org/10.1016/j.heliyon.2022.e09610

[49] Al-Ghouti, M. A. and Da'ana, D. A. (2020) 'Guidelines for the Use and Interpretation of Adsorption Isotherm Models: A Review', Journal of hazardous materials, Vol. 393, 122383. https://doi.org/10.1016/j.jhazmat.2020.122383

[50] Singh, A. K., (2016), Nanoparticle Ecotoxicology, Engineered Nanoparticles. Boston: Academic Press, pp 343–450, DOI: 10.1016/B978-0-12-801406-6.00008-X.

[51] Gast A. P. and Adamson A. W., (1997), Physical Chemistry of Surfaces, 6th Edition | Wiley, Wiley.com. Available at: https://www.wiley.com/

[52] Ebenso, E. E., et. Al., (2008), Addy Inhibitive Properties and Adsorption Behaviour of Ethanol Extract of Guinensis as A Green Corrosion Inhibitor For Mild Steel In Piper H_2SO_4,. African Journal of Pure and Applied Chemistry, 11; pp 107-115, ISSN: 1996 – 0840.

[53] A. S. Fouda, et. al., (2014), Tobacco Plant Extracts as Save Corrosion Inhibitor for Carbon Steel in Hydrochloric Acid Solutions, International Journal of Advanced Research, Vol. 2, ISSN 2320-5407, Issue 3, 817-832.

[54] Ambrish Singh, et. al., (2020), Tobacco Extracted from the Discarded Cigarettes as an Inhibitor of Copper and Zinc Corrosion in an ASTM Standard D1141-98(2013) Artificial Seawater Solution, J Mater. Res. Technol., 2 020; 9(3): pp 5161–5173. https://doi.org/10.1016/j.jmrt.2020.03.033

[55] Mohammed S. Suliman, Mohammed A. Al-Madani and El-Fitouri K. Ahmied, (2019), The Inhibition of Mild Steel Corrosion by Sulphur Containing Organic Compound, Journal of Pure Applied Sciences (JOPAS), ISSN: 2521-9200, Vol. 18, No. 2, pp 59-6.

[56] Alinanuswe Mwakalesi, (2023), Corrosion Inhibition of Mild Steel in Sulphuric Acid Solution with Tetradenia riparia Leaves Aqueous Extract: Kinetics and Thermodynamics, Biointerface Research in Applied Chemistry, Vol. 13, Issue 1, 2023, 32, DOI: 10.33263/BRIAC131.032.

[57] Hassan Elgahawi, et. al., (2017), Inhibition of Mild Steel Corrosion in Sulfuric Acid Solution Using Extraction of Linum Usitatissimum Seeds, 17, the International Conference on Aerospace Sciences & Aviation Technology, Paper: ASAT-17-050-CA – April 11 - 13, 2017.

[58] B. C. Udeh, et. al., (2021), Deployment of Antepsin (Sucralfate) as Corrosion Inhibitor of Mild Steel in H_2SO_4 Medium: Chemical and Electrochemical Studies, World News of Natural Sciences, EISSN 2543-5426, WNOFNS, Vol. 37, pp 117-134.

[59] Ugi B. U., et. al., (2016), Sulphuric Acid Corrosion of Mild Steel in Leave Extracts of Cnidoscolus aconitifolius Plant, Chemical and Process Engineering Research, ISSN: 2224-7467 (Paper) ISSN: 2225-0913 (Online), Vol.46. www.iiste.org

[60] Safiyya Abubakar Minjibir and Magaji Ladan, (2023), Corrosion Inhibition Potential of Prosopis Juliflora Leaves Extract on Mild Steel in H_2SO_4 Solutions, Advanced Journal of Chemistry-Section A, Vol. 6, Issue 3, pp 311-323. https://doi.org/10.22034/ajca.2023.398774.1372

[61] K. Senthil Murugana and T. Mohanapriya, (2024), Antimicrobial and corrosion inhibition activity of Schiff base in mild steel of HCl and H_2SO_4 acidic solutions, Journal of Optoelectronic and Biomedical Materials, Vol. 16, No. 1, pp 1 – 16, DOI: https://doi.org/10.15251/JOBM.2024.161.1.