AN IMPROVED CORROSION RESISTANCE OF MILD STEEL IN ACIDIC SOLUTION USING ALOE VERA EXTRACT

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ABSTRACT

Corrosion is a natural process and unfavourable occurrence when pipeline metals and alloys react with their surrounding environment, cause undesirable damage, and create harmful environment. This issue has resulted in substantial economic losses and posed significant safety concerns. In order to overcome these problems, typically, the industry employs the use of green inhibitors corrosion to safeguard metal surfaces from corrosive agents. However, commercial inhibitors pose a danger and toxic to both the environment and human health. Therefore, as a solution to those problem, green corrosion inhibitor has been found to be both effective and economically feasible, performing similarly to commercial inhibitors. This study aims to examine the efficacy of Aloe Vera extract as a green inhibitor of corrosion in mild steel in a 1M H_2SO_4 solution. Weight loss, Potentiodynamic polarization, Electrochemical Impedance Spectroscopy (EIS) and Scanning Electron Microscopy (SEM) studies were conducted in a 1M H_2SO_4 solution towards mild steel to analyse the effect of Aloe Vera as an effective corrosion inhibitor. It has been found that as the concentration of inhibitors increases, inhibitor efficiency also increases. Weight loss measurement has proven that the inhibition efficiency increased and reached to maximum values of 90.81 % after 8 h exposure time for 800 ppm concentration. Potentiodynamic polarization result also shown similar trend with weight loss where the corrosion rate is reduced with inhibitive efficiency with higher concentration of Aloe Vera content in the acidic solution. The result obtained from EIS shows one depressed capacitive loop where the capacitive loops diameter was bigger in presence of higher Aloe Vera content which suggested bigger imaginary film that protecting the surface. SEM analysis revealed a significant decrease in the roughness of mild steel surface after the addition of an inhibitor, which support the inhibitor efficiency of protecting the mild steel surface from the corrosive medium.

Keywords: Aloe Vera, H_2SO_4, corrosion inhibitor, weight loss, SEM, potentiondynamic polarization and EIS.

ABSTRAK

Hakisan ialah proses semula jadi dan kejadian yang tidak baik apabila logam saluran paip dan aloi bertindak balas dengan persekitaran sekelilingnya, menyebabkan kerosakan yang tidak diingini, dan mewujudkan persekitaran yang berbahaya. Isu ini telah mengakibatkan kerugian ekonomi yang besar dan menimbulkan kebimbangan keselamatan yang ketara. Untuk mengatasi masalah ini, lazimnya, industri menggunakan penggunaan kakisan perencat hijau untuk melindungi permukaan logam daripada agen menghakis. Walau bagaimanapun, perencat komersial menimbulkan bahaya dan toksik kepada alam sekitar dan kesihatan manusia. Oleh itu, sebagai penyelesaian kepada masalah tersebut, perencat kakisan hijau didapati berkesan dan boleh dilaksanakan dari segi ekonomi, berprestasi serupa dengan perencat komersial. Kajian ini bertujuan untuk mengkaji keberkesanan ekstrak Aloe Vera sebagai perencat kakisan hijau dalam keluli lembut dalam larutan 1M H_2SO_4. Kajian kehilangan berat, polarisasi Potensiodinamik, Spektroskopi Impedans Elektrokimia (EIS) dan Mikroskopi Elektron Pengimbasan (SEM) telah dijalankan dalam larutan 1M H_2SO_4 ke arah keluli lembut untuk menganalisis kesan Aloe Vera sebagai perencat kakisan yang berkesan. Telah didapati bahawa apabila kepekatan perencat meningkat, kecekapan perencat juga meningkat. Pengukuran penurunan berat badan telah membuktikan bahawa kecekapan perencatan meningkat dan mencapai nilai maksimum 90.81 % selepas masa pendedahan 8 jam untuk kepekatan 800 ppm. Hasil polarisasi potensiodinamik juga menunjukkan trend yang sama dengan penurunan berat badan di mana kadar kakisan dikurangkan dengan kecekapan menghalang dengan kepekatan kandungan Aloe Vera yang lebih tinggi dalam larutan berasid. Keputusan yang diperoleh daripada EIS menunjukkan satu gelung kapasitif tertekan di mana diameter gelung kapasitif lebih besar dengan kehadiran kandungan Aloe Vera yang lebih tinggi yang mencadangkan filem khayalan yang lebih besar yang melindungi permukaan. Analisis SEM mendedahkan penurunan ketara dalam kekasaran permukaan keluli lembut selepas penambahan perencat, yang menyokong kecekapan perencat melindungi permukaan keluli lembut daripada medium menghakis.

Kata kunci: Aloe Vera, H_2SO_4, perencat kakisan, penurunan berat badan, SEM, polarisasi potensidinamik dan EIS.

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LIST OF ABBREVIATIONS

Ag	-	Silver
AgCl	-	Silver Chloride
$C_6H_5COO^-$	-	Cyclopentadienyl carbonyl cobalt
CO_2	-	Carbon Dioxide
COOH	-	Carboxylic Acid
CrO_4^{2-}	-	Chromate
$CONH_2$	-	Amides
CR	-	Corrosion Rate
CIs	-	Corrosion Inhibitors
$COOC_2H_5$	-	Ethyl Ester
EDX	-	Energy Dispersive X-Ray Analysis
EN	-	Electrochemical Noise Analysis
Fe	-	Iron
Fe $(OH)_3$	-	Iron (III) Oxide-Hydroxide
FESEM	-	Field Emission Scanning Electron Microscopy
FTIR	-	Fourier-Transform Infrared Spectroscopy
GCIs	-	Green Corrosion Inhibitors
GC-MS	-	Gas Chromatography-Mass Spectrometry
HCL	-	Hydrochloric Acid
H_2	-	Hydrogen
Hz	-	Hertz
HNO_3	-	Nitric Acid
H_2O	-	Water
HO^-	-	Hydroxide
OH	-	Hydroxide
H_2SO_4	-	Sulfuric Acid
K	-	Kelvin
kHz	-	Kilo Hertz
LNG	-	Liquefied Natural Gas
LC-MS	-	Liquid Chromatography-Mass Spectrometry

Na_2MoO_4	-	Molybdate
Mm/y	-	Meli Meter Per Year
mV/s	-	Millivolt/ Second
N	-	Nitrogen
Na_2SO_3	-	Sodium Sulfite
$Na_2 SO_4$	-	Sodium Sulfate
NaCl	-	Sodium Chloride
N_2H_4	-	Hydrazine
NH_3		Ammonia
NH_2		Amino Radical
NO^{2-}		Nitrite Ion
O		Oxygen
P		Proline
PDP		Potentiodynamic Polarization
PH		Potential Of Hydrogen
PPM		Part Per Million
PO_4^{3-}		Phosphate
PO_3H_2		Phosphonic Acid
R-COOH		Carboxylic Acid
R-NH		N-Heptylpantothenamide
S		Sulfur
SCE		Saturated Calomel Electrode
µml		Microliter.
VCI		Volatile Corrosion Inhibitors
WLM		Weight Loss Method
XRD		X-Ray Diffraction

CHAPTER 1

INTRODUCTION

1.1 Overview

Natural gas considered to be the third source of fuel after crude oil and coal in terms of consumption. It is noticeable that there is growth in all energy sources but natural gas typically is increasing yearly and it reaches to 43% in 2018, due to it is properties. CO_2 emissions from natural gas consider to be the lowest comparing to crude oil and coal [1]. Natural gas can be transported in two ways - either as Liquefied Natural Gas (LNG) through vessels or ships, or in its gaseous state through pipelines.

Therefore, ensuring flow assurance in these pipelines is of utmost importance. However, it's important to note that any transportation system, including pipelines, can malfunction. Corrosion is widely recognized as a major issue in pipelines that transport wet gas. As a result, it can result in significant harm to the pipelines' structural integrity and result in gas leaks. This can subsequently contribute to both environmental contamination and pose safety risks. Furthermore, addressing this flow assurance problem through maintenance and repair would also require substantial economic resources [1].

Oil and gas industry face a significant challenge in the form of corrosion, as 50% of pipeline failures are attributed to this issue [2]. Corrosion arises from the fluid composition inside pipelines, consisting of acidic gases brine, organic acids including carbon dioxide and Hydrogen sulfide. When moist gas is transported via carbon steel pipes, these compounds' corrosive qualities damage the pipelines. The qualities of the fluid and material, as well as the ambient circumstances, have a significant impact on the degree and kind of corrosion [3]. Oil and gas industry

employ various methods to prevent corrosion, including cathodic protection, coatings, chemical treatment and design detailing [4].

However, design detailing involves the appropriate selection of pipeline material based on the environment in which it will be used in. Instead, cathodic protection is used to prevent corrosion on pipeline surfaces by altering their electrochemical state [5]. Coatings are typically used to safeguard pipelines from harsh environments, like seawater, which is abundant in chloride ions. Finally, chemical treatment involves adding either gas or liquid that can reduce the rate at which metals or alloy corrodes [6].

The focus of this thesis is on reducing corrosion through chemical treatment or modifying the environment. A barrier between the pipe surface and corrosive elements is provided by a commercial inhibitor, which is one of its features. Classifying corrosion inhibitors is not standardized. Four methods exist, including categorizing based on the impact of corrosion inhibitor (CI) on corrosion reactions. As an example, anodic inhibitors delay anodic reactions, while cathodic inhibitors slow down cathodic. Another approach is based on the type of metal it protects against corrosion, for instance, corrosion inhibitors (CIs) that protect carbon steel may not be effective for copper pipelines.

A third method is considering the dependency on environmental conditions, e.g., the presence of oxygen and free water can increase the corrosion rate. Lastly, it could also be grouped as organic and inorganic inhibitors [7]. Organic inhibitors reduce corrosion through adsorption, while inorganic inhibitors inhibit corrosion by reacting with either the cathodic or anodic aspect of the process [8]. The selection of an appropriate CI in the industry depends on factors such as the pipeline material, environmental conditions, and fluid properties flowing through the pipeline.

There are several CIs available to combat corrosion. Many CIs have been developed and demonstrated to be effective, depending on their chemical composition and environmental conditions. Despite extensive evidence of the

efficacy of CIs in controlling corrosion in wet gas pipelines, conventional inhibitors have a known adverse impact on the environment.

The operation of corrosion inhibitors does not result in complete consumption during the effort to mitigate corrosion. Unused portions of CIs will inevitably be released into the environment as aqueous waste [9]. Thus, CIs can have a direct impact on living organisms since they possess some degree of toxic nature. Commercial organic inhibitors in particular have been discovered to be extremely harmful to both people and the environment [10]. Additionally, the high amount required for adequate efficiency makes some commercial inhibitors costly.

Therefore, investing in research for alternative, environmentally friendly and cost-effective methods to formulate corrosion inhibitors is of utmost importance. Extensive studies have been conducted to develop green CIs that perform as well as, if not better than, conventional inhibitors. Plants are commonly used as green inhibitors due to their environmental safety and abundant, low-cost availability [11]. As its name suggests, as its name suggests, green CIs are composed of biodegradable, non-heavy metal compounds that are naturally compatible.

Plant extracts are one of the most common materials used as green corrosion inhibitors. There are various other materials that can serve this purpose as well [12]. plant extracts such as flour, papaya, and aloe vera have been found to effectively inhibit corrosion in acidic environments. Numerous studies have been carried out to demonstrate their effectiveness as corrosion inhibitors.

Green inhibitors are sources of naturally occurring compounds, and those extract plants have some complex molecular structure beside having different physical, biological and chemical properties. Nowadays, these green inhibitors are widely, naturally occurring and especially valued for their availability, affordability, and good environmental effects. however, naturally occurring and especially valued for their availability, affordability, and good environmental effects

This study aims to examine the effectiveness of Aloe Vera leaf extracts as a green corrosion inhibitor on mild steel in a solution of 1M sulfuric acid. The parameters that were measured from this study are weight loss measurements, corrosion rate efficiency of the Aloe Vera leaves extracts to protect the mild steel specimens in the test solution, the impact of immersion time, efficiency vs exposure time, and efficiency vs corrosion rate, Potentiodynamic Polarization (PDP), and Electrochemical Impedance Spectroscopy, are also used to support findings from weight loss measurement. Scanning Electron Microscopy is used to analyse the surface analysis on the metal surface.

1.2 Problem Statement

Corrosion inhibitors are a viable solution for preventing the harmful corrosion of mild steel, particularly in acidic environments. This can prevent the need for costly total replacements. Inhibitors often contain organic and inorganic compounds with polar groups, such as nitrogen, sulfur, and oxygen hetero-atoms. Upon being adsorbed onto the metal surface, these inhibitors obstruct the active sites of corrosion. Despite their effectiveness, the production of many organic and inorganic inhibitors can be challenging in certain countries, and some of these compounds can pose significant risks to both human health and the environment due to their high toxicity.

The necessity for environmentally friendly alternatives has prompted numerous researchers to explore various new compounds that are biodegradable. As a result, the utilization of natural substances, including plant extracts (phytochemicals), as corrosion inhibitors for metals in acidic solutions has emerged as a contemporary approach towards achieving sustainable development. The extracts from natural sources, such Aloe Vera, show remarkable promise as an exceptional green inhibitor for mild steel corrosion mitigation. Few researches have been published so far on the use of Aloe Vera as a green inhibitor. So, the focus of this study is on determining how well aloe Vera extracts prevent corrosion of mild

steel in a variety of acid solutions concentration when used under ambient circumstances.

1.3 Research Objectives

The following are objective of this research: -

1) To assess the effectiveness of aloe vera extract as a corrosion inhibitor for mild steel in 1M H_2SO_4, utilizing electrochemical measurements and weight loss.
2) To examine the surface morphology of the sample after being exposed to the test solution, both with and without the inhibitor, utilizing Scanning Electron Microscopy (SEM).

1.4 Scope of Study

The followings are the scope of this research:

i. The inhibitor solutions are formulated within the concentration range of 500-800 ppm.
ii. The evaluation of the corrosion test will involve the use of weight loss measurement, Potentiodynamic Polarization, and Electrochemical Impedance Spectroscopy.
iii. Surface morphology will be limited for the Scanning Electron Microscopy test.

1.5 Significances and Original Contributions of this Study

This project's importance is in its capacity to tackle one of the most critical issues related to corrosion, thereby presenting significant benefits to both scientific research and various industries. This research's significance lies in its focus on investigating the impact of utilizing new Aloe Vera extracts as a green inhibitor, which offers substantial advantages in reducing pollution and environmental toxicity when compared to other corrosion protection approaches. Additionally, this study may serve as a gateway for future research into developing new compositions of green inhibitor materials suitable for oil and gas applications.

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