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An Investigation of the Influence of Corroded Galvanized Iron Pipeline Through Soil Properties

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ABSTRACT

This research aims to investigate the influence of soil engineering properties on the corrosion of current-buried galvanized iron pipes. Research has been done on the corrosion behavior of current steel pipelines in soil media that are utilized to transport fire systems. To investigate the effects of moisture content, pH, and chemical content on soil properties, soil samples have been brought into the laboratory. The findings showed that the contents and composition of the soil in the studied area varied significantly. The pipe was severely attacked by a soil medium that had a higher moisture content and a lower pH. Energy dispersive X-ray spectroscopy (EDS) and scanning electron microscopy (SEM) were used to determine the surface morphology and elemental distribution. The findings of the analysis indicated that these soil characteristics affected the steel pipe that was buried. Results from fieldwork indicated moisture content as the most influential factor in metal loss. The soil samples have high concentrations of silicon, iron, and aluminum oxides, according to the XRF results. The soil's pH value may decrease due to a higher aluminum oxide content. Iron oxide was identified as a dominant mineral by SEM-EDX testing, and it plays a significant role in the composition of corrosion products. Corrosion products would remain on the steel surface in soils, protecting the steel from further corrosion. This research identified that moisture content is the most significant governing factor on metal loss, while other soil properties have a strong to modest influence on corrosion growth. The findings of this investigation may help determine the mechanism of corrosion and forecast the service life of pipeline steel. The study's findings offer business owners numerous benefits, including the ability to assess corrosion failure at an early stage. Additionally, the study's data will be crucial for estimating a pipeline's remaining lifespan and determining when maintenance and replacement should be performed.

1. Introduction

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The word "corrosion," which refers to unpleasant processes, is derived from the Latin "corrosus," which means consumed to varying degrees [1]. As indicated by Table 1, seven failures at various locations in Johor, Malaysia, were reported as repeated failures within two years of service. This existing corroded pipe was made of 3 mm thick galvanized iron with a 2-4 mm thickness of bitumen coating as pipe insulation. These pipes were used to supply water for the fire extinguishing system around the building. They were buried at depths ranging from 1 to 2.5 meters. Figure 1 shows the corroded underground pipe that experienced external corrosion. Corrosion harms the environment and communities [2-3]. The kind and characteristics of the soil in which pipelines are buried have a significant impact on external corrosion [4-6].

Table 1

Reported failures of underground pipelines within two years that have been repaired.

| No | Work Order | Description | Area | Date |
|----|------------|---|--------------------------------|------------|
| 1 | CWO102672 | The hose reel underground pipe is leaking | Near hydrant Block A1 | 05/04/2018 |
| 2 | CWO103364 | The hose reel underground pipe is leaking | In front of cafeteria Block A1 | 03/07/2018 |
| 3 | CWO104923 | The hose reel underground pipe is leaking | Pump Room (Zone 2) | 18/12/2018 |
| 4 | CWO104925 | The hose reel underground pipe is leaking | Pump Room (Zone 1) | 18/12/2018 |
| 5 | CWO105698 | The hose reel underground pipe is leaking | Admin Block A1 (Zone 1) | 11/03/2019 |
| 6 | CWO105777 | The hose reel underground pipe is leaking | Walkway to cafeteria Block K | 11/03/2019 |
| 7 | CWO109536 | The hose reel underground pipe is leaking | Pump room | 04/10/2019 |

One of the main causes of the failure of many industrial facilities, including pipelines, concrete structures, bridges, etc., and the ensuing significant financial loss, has been identified as corrosion [7]. The behavior of a material during corrosion is determined by the environment it is exposed to, and the degree of corrosiveness of a material is determined by its environment. When discussing corrosion, it is critical to consider the interaction between a material and its surroundings. The varying nature of soil electrolytes causes a complex electrochemical process that corrodes steel pipelines in soil. The investigation of corrosion in carbon steel has become hazy due to the complexity of soil. According to definitions, soil is an environment that is porous, heterogeneous, and discontinuous and contains air, other gas phases, water, solid minerals, and organic materials. Soils vary widely in their corrosiveness due to their diverse compositions. Determining how soil can affect corrosion reactions requires an understanding of the physicochemical composition of soil. As illustrated in Figure 2, the main factors influencing the corrosion of underground pipes are soil moisture content, oxygen diffusion rate, redox potential, pH value of the surrounding environment, soil resistivity to current flow, and microbial activity. Despite extensive research into the pipeline

corrosion phenomenon, many questions about the specific role that soil plays in steel corrosion still need to be answered.

The locations of the underground pipelines affect the soil's structure and chemical composition. Increased soil water content can result in cohesiveness loss, shrinkage, and swelling. Severe corrosion may occur at low elevations in poorly drained disturbed soils, such as clays and tidal marshes, because of soil shrinkage that produces a significant differential in air quality and salt buildup that raises electrical conductivity. Due to the development of both general and localized corrosion, these events cause infrastructure in the soil area to be damaged and buried pipeline materials to deteriorate [8]. Higher levels of corrosion may occur in soils with a pH range of 6–8, as opposed to soils with an alkaline pH [9]. Numerous researchers have conducted studies on the steel corrosion rate and how it interacts with soil parameters, as indicated in Table 2.



Fig. 1. Sample of corroded underground pipe

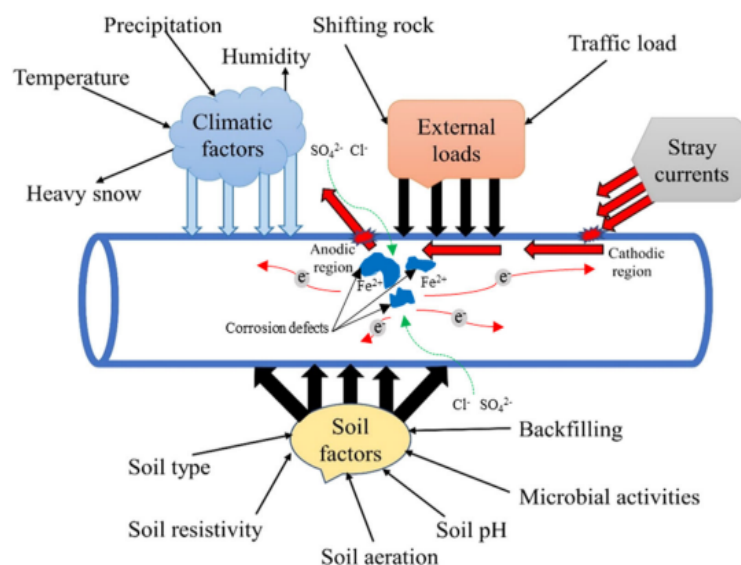


Fig. 2. Schematic of the buried water pipe and its environments

Table 2

A summary of the literature review on the factors that lead to soil corrosion.

| No | References | Research focus |
|----|--|---|
| 1. | A.I.M. Ismail, A.M. El-Sham, 2009 [8]. | The primary determinants of underground corrosion are soil moisture content, oxygen availability, redox potential, pH level, soil resistivity, and microbial activity. From an engineering perspective, adding more water to the soil has disadvantages, such as decreased cohesiveness, swelling, and shrinkage, all of which have an immediate impact on how pipelines interact with one another. This leads to corrosion, deterioration of pipeline materials, and damage to infrastructure above the soil because of both localized and general corrosion occurring at various locations of steel structures. |
| 2. | N. M. Noor et al [10] | The corrosion of X70 carbon steel coupons is the focus of this study, which examines the effects of three soil engineering properties: moisture content, clay content, and plasticity index. The findings indicate that a higher moisture content causes corrosion to develop more quickly. |
| 3. | J. Bhattarai, 2013 [11] | J. Bhattarai investigates the effects of different soil characteristics on the corrosiveness of soils on buried cast-iron and galvanized steel drinking water pipelines. These characteristics include moisture content, pH, resistivity, oxidation-reduction potential, and chloride and sulfate contents. The three properties of soil engineering are the plasticity index, clay content, and moisture content. |
| 4. | Wassim, 2018 [12] | The causes of buried pipe corrosion in soils are reviewed in this article. Some variables are temperature, microbial activity, dissolved oxygen, pH, moisture content, and soil resistivity. Furthermore, covered are the effects of manufacturing processes and comparing the corrosion resistance of mild steel, ductile iron, and cast-iron pipes. It was discovered that the rate at which pipes corrode increases with moisture contents up to the critical moisture value. |
| 5. | Ehssan A. Abdulameer et al, 2022 [13] | This work examines the effects of soil engineering features on buried mild steel coupon metal loss. The current study is focused on soil properties in AlKut City, which is close to the Tigris River. These characteristics include soil clay and moisture content. The qualitative assessment indicates that clay content has less effect on corrosion dynamics than soil moisture content. |
| 6. | Hongwei Liu et al, 2020 [14] | The findings show that steel corrosion is dependent on the thickness of the soil layer, with a maximum corrosion rate observed beneath a 5 mm layer of soil because of the competing influence of the soil layer's blocking effect and its capacity to retain moisture on the corrosion. Due to the increased water content of the soil, corrosion in thin soil layers accelerates as soil thickness increases. |
| 7. | Noor, E.A et al, 2014 [15] | The impact of soil moisture content on the corrosion behavior of X60 steel was examined at room temperature (29 ± 1 °C) in the soils of various Saudi Arabian cities. According to the data, X60 steel corrosion becomes under cathodic control as soil moisture content increases. Each measurement showed that, up to a critical moisture content of 10% weight percent, the corrosion rate of X60 increased with increasing moisture content in the investigated soils. Following that, the rate of corrosion began to decrease. |
| 8. | Gupta, S.K et al, 1979 [16] | A soil's corrosivity towards mild steel peaks when its moisture content reaches 65% of its water-holding capacity, a phenomenon known as "critical soil moisture content." When the moisture content of the soil is less than fifty percent of its water-holding capacity, mild steel corrosion in the soil only starts to become noticeable. |
| 9. | S. Suganya and R. | To comprehend how corrosion factors affect mild steel over the long term, a study on the corrosivity of mild steel in coastal areas was conducted. The rate of corrosion is influenced by the texture, moisture content, and chemical element of the soil. The |

| | | |
|-----|-----------------------------|---|
| | Jeyalakshmi, 2021 [17] | findings showed that coupons buried in soil experience a higher rate of corrosion due to moisture and chloride content. |
| 10. | Bin He, 2015 [18] | This study used electrochemical technology to examine the impact of soil particle size (0.1-0.25 mm, 0.6-1.0 mm) on the corrosion behavior of natural gas pipelines. According to the findings, pipeline steel's polarization resistance dropped as particle size decreased. |
| 11. | Freitas et al, 2012 [19] | The purpose of this study is to assess the API SL X52 steel's resistance to corrosion in soil from Brazil. Following Tafel analysis in both electrolytes, the steel surface displayed a corrosion product layer with a high iron and oxygen content. In an aqueous extract of soil, the corrosion product of iron oxides and hydroxides formed on the surface of API steel exhibits morphology with circular nodules. In the synthetic solution, localized corrosion with pits containing chlorides was seen on the surface of the API. |
| 12. | Wssim, 2016 [20] | The current study offers a new approach to investigating the variables affecting the external corrosion of underground metal pipes. When cast iron pipes were buried in natural soil, the technique effectively assessed the coupled effects of soil pH and moisture on the external corrosion behavior of the pipes. |
| 13. | Fernando, 2009 [21] | This study determines the impact of specific soil characteristics on metal corrosion. Investigations were conducted into the effects of soil acidity, oxygen availability, and chloride concentration. This study demonstrated that the behavior of metal samples buried in soils with varying degrees of aggression can be predicted by the characteristics of the soil. |
| 14. | Saupi et al, 2015 [22]-[25] | The mechanisms of corrosion in the soil environment are described in this paper. In water distribution systems, pipeline corrosion is a highly complex phenomenon that is influenced by nearly all physical, chemical, and biological factors. This work offers important variables that should be assessed to minimize corrosion issues. The soil environment contains several elements that play a major role in corrosion, including pH, oxygen, chloride, moisture, sulfates, and resistivity. |
| 15. | G Doyle, 2003 [26] | The interaction between the soil surrounding the pipeline and itself causes external corrosion. The aggressiveness of soil towards cast iron is affected by soil properties such as resistivity, pH, and the presence of sulfate-reducing bacteria. Soil resistivity has the largest effect on the observed maximum average pitting rate. Microbiological corrosion could be an aggravating factor since areas exhibiting increased levels of sulfide concentration were identified in soils that had originated from this district. |
| 16. | M Yan, 2014 [27] | Goethite, hematite, and other soil iron oxides are thought to be important in soil corrosion because they act as a cathodic depolarizer. To assess how Fe oxides affected the corrosion of pipeline steel in red clay soil, several experiments were carried out. The findings show that removing Fe oxides from the soil significantly reduces the corrosivity of the red clay soil. |

The objective of this research is to investigate current GI buried water pipeline failures and frequent corrosion. The characteristics of the soil surrounding the pipeline and the pipeline surface at the corrosion area were both investigated. The effect of environmental conditions was analyzed. Through microscopic analysis, the structure and composition of the product layer were evaluated. The findings of this investigation may help determine the mechanism of corrosion and forecast the service life of pipeline steel. The study's findings offer business owners numerous benefits, including the ability to assess corrosion failure at an early stage. Additionally, the study's data will be crucial for estimating a pipeline's remaining lifespan and determining when maintenance and replacement should be performed.

2. Methodology

The materials used for the study as well as the methods and techniques used are the main topics of this chapter. The analysis of corrosion morphologies will be done by scanning electron spectroscopy (SEM), and the investigation of corrosion products will be done by X-ray diffraction spectroscopy (XRD). By determining the composition, structure, and morphology of corrosion, these instruments have the potential to provide detailed information on corrosion products both internally and externally.

2.1 Corrosion product analysis

Energy dispersive X-ray spectroscopy (EDX) was used to analyze the corrosion products and to characterize the microstructure morphologies of the exposed surface of the existing corroded steel. As seen in Figure 3, spot analysis was used to determine the composition of the various surface features. After the corrosion products were eliminated, the morphology of the corrosion surface was also discovered.

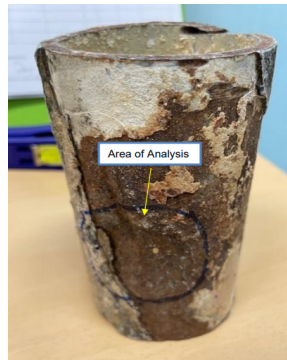


Fig. 3. Area of analysis of corroded GI pipe

2.2 Soil Sample

All soil samples were collected along the failed pipeline between 1 and 1.5 meters below ground level. Within less than twenty-four hours of being collected from the actual site, the soil samples were transported to the laboratory for analysis in an airtight polyvinyl bag. A 20-mesh sieve was used to filter the soil samples after they had been air-dried. ASTM G162-99 is the reference for the methods used to prepare the soil medium. The results are shown in Table 3.

2.3 Determination of moisture content

This was carried out in compliance with ASTM D2216. The 20g of the soil sample was weighed into a moisture can and placed in an oven at 1050°C for 24hrs. After the sample was taken out, the weight was measured consistently. The percentage of mass lost to water was used to compute the moisture content.

2.4 Determination of soil pH

This was carried out in compliance with ASTM G51-18. Soil pH meters were taken straight out of the ground and used to measure the acidity or alkalinity of the soil. This meter measures the activity of hydrogen ions, which is represented by the potential for hydrogen, or "pH." Ensure that any rocks

or stones are removed from the topsoil. Before taking the measurement, the topsoil is cleared from rocks or stones and excavated to a depth of about 5 cm. For each area, three measurements were made to get an exact average.

2.5 Soil chemical analysis

In this study, Rigaku Supermini 200 Wavelength Dispersive X-Ray Fluorescence Spectrometer (WDXRF) techniques were used together to characterize the soil samples. The major element of soil composition was determined by using an X-ray fluorescence Spectrometer (WDXRF). About 5g of soil powder samples were directly scanned to get the data.

3. Results

The findings and relevant results and discussion about the involvement of the soil properties and corrosion products of the current corroded underground steel pipelines are being further analyzed as detailed below.

3.1 Elemental composition of soil

The percentage of minerals in samples 1 and 2 of soil are displayed in Table 3. Based on this table, silicon dioxide, SiO₂ (quartz), and aluminum oxide, Al₂O₃ are the two most common clay minerals. These soil samples also contained iron oxide or Fe₂O₃. Because of their low percentages, sulfate and chloride do not contribute to corrosion.

Table 3
 Chemical composition analysis results of Soil 1 and Soil 2

| No | Composition | Weight percent, % | |
|----|---|-------------------|--------|
| | | Soil 1 | Soil 2 |
| 1 | Sodium Oxide, Na ₂ O | 0.08 | 0.1 |
| 2 | Aluminium Oxide, Al ₂ O ₃ | 38.2 | 37.9 |
| 3 | Silicon Dioxide, SiO ₂ | 45.9 | 46.1 |
| 4 | Sulfur Trioxide, SO ₃ | 0.13 | 0.1 |
| 5 | Chlorine, Cl | 0.01 | 0.01 |
| 6 | Potassium Oxide, K ₂ O | 0.84 | 0.49 |
| 7 | Calcium Oxide, CaO | 0.21 | 0.05 |
| 8 | Titanium Dioxide, TiO ₂ | 0.18 | 0.15 |
| 9 | Iron (III) Oxide, Fe ₂ O ₃ | 2.46 | 3 |
| 10 | Gallium (III) Oxide, Ga ₂ O ₃ | 0.01 | 0.01 |
| 11 | Arsenic Trioxide, As ₂ O ₃ | 0.01 | 0.01 |
| 12 | Rubidium Oxide, Rb ₂ O | 0.01 | 0.01 |
| 13 | Yttrium (III) Oxide, Y ₂ O ₃ | 0.07 | 0.01 |
| 14 | Zirconium Dioxide, ZrO ₂ | 0.04 | 0.05 |
| 15 | Niobium Pentoxide, Nb ₂ O ₅ | ND | 0.02 |
| 16 | Magnesium Oxide, MgO | ND | ND |
| 17 | Zinc Oxide, ZnO | ND | ND |
| | Loss On Ignition (LOI) | 11.9 | 11 |

3.2 Corrosion Product Analysis using SEM EDX

After two years in the soil, the sample surface developed a single layer of corrosion products. As seen in Figure 4 - Figure 6, there were some cracks and voids spread on the surface of the pipe. The percentage of chemical compositions of Area 1 and Area 2 are listed in Table 4. The primary elements contained in the corrosion products are oxygen, O, and iron, Fe with a trace amount of carbon, C. It is reasonable to speculate that the corrosion products are composed of iron oxide, Fe. Iron oxyhydroxides, goethite (α -FeOOH), akaganeite (β -FeOOH), magnetite/maghemite, and lepidocrocite (γ -FeOOH) are frequently found as corrosion products formed on carbon steel which later transform to goethite [28].

Table 4
EDS analysis results of GI Pipe

| No. | Composition | Weight Percent, % | |
|-----|---------------|-------------------|--------|
| | | Area 1 | Area 2 |
| 1 | Carbon, C | 4.98 | 4.2 |
| 2 | Oxygen, O | 38.36 | 38.51 |
| 3 | Sodium, Na | 0.5 | 0.39 |
| 4 | Aluminium, Al | 1.97 | 1.68 |
| 5 | Silicon, Si | 1.79 | 1.5 |
| 6 | Sulphur, S | 0.2 | 0.23 |
| 7 | Potassium, K | 0.51 | 0.48 |
| 8 | Iron, Fe | 51.05 | 52.15 |
| 9 | Copper, Cu | 0.23 | 0.27 |
| 10 | Zinc, Zn | 0.41 | 0.58 |

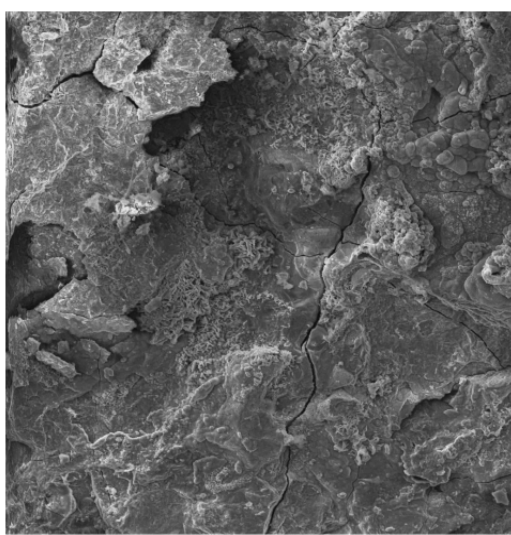


Fig. 4. SEM micrograph of GI Pipe at 200x magnification.

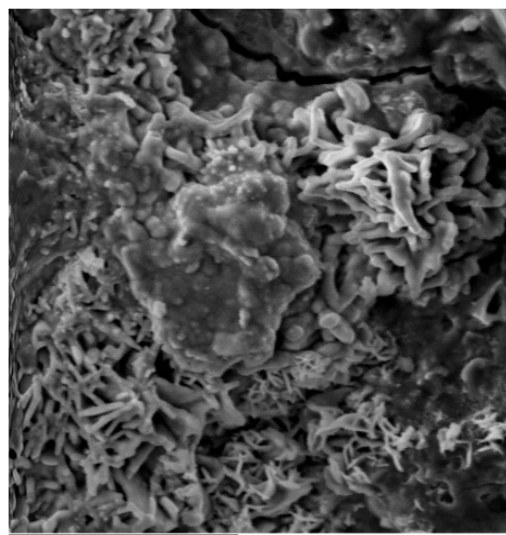


Fig. 5. SEM micrograph of GI Pipe at 1000x magnification.

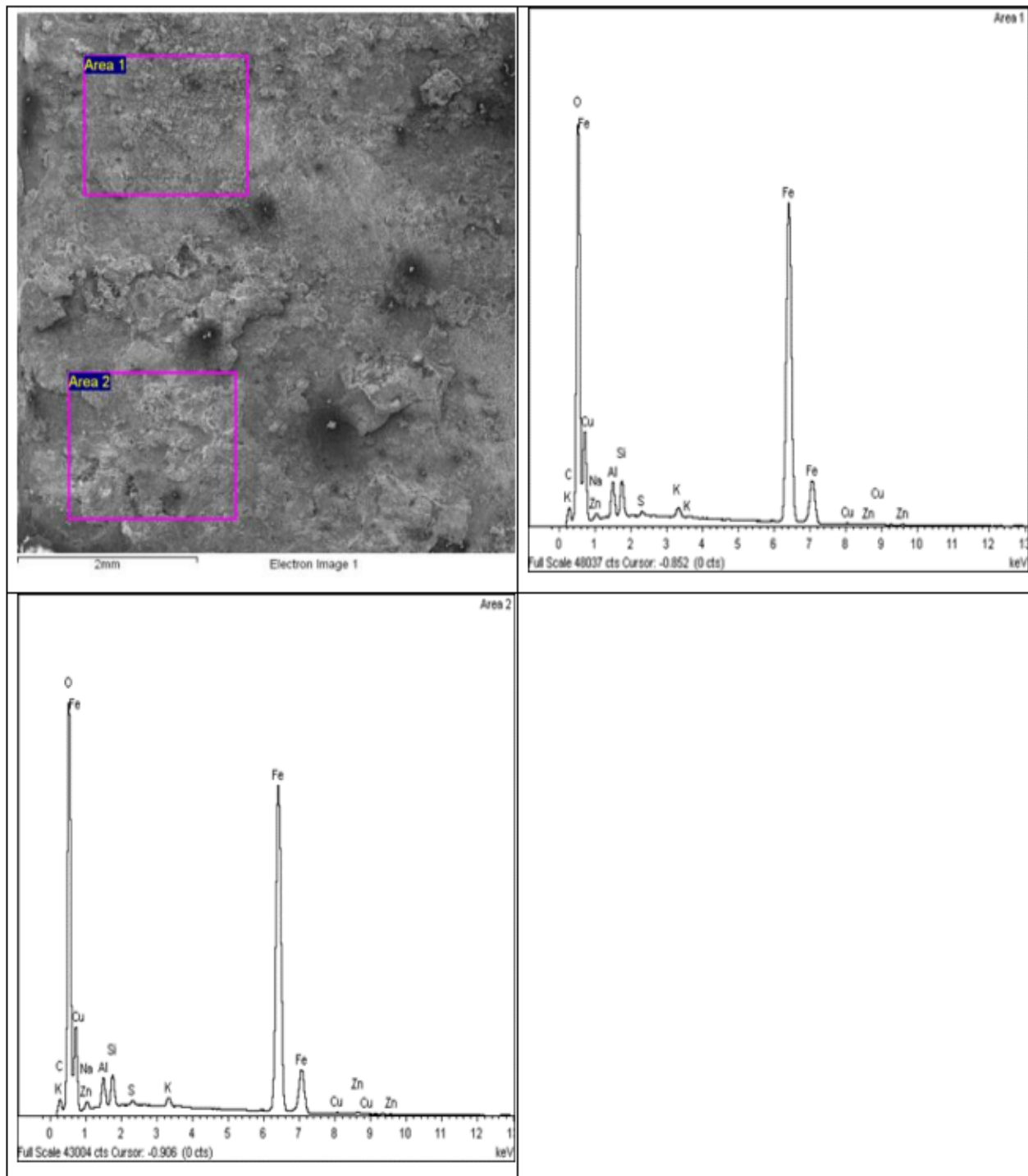


Fig. 6. SEM micrograph and EDS spectra of GI Pipe

3.3 Moisture content

The moisture content of the soil sample is tested according to the BS1377: Part 2:1990 standard. The percentage of moisture content of this soil sample is between 50% - 60% as we can see in Table 5. According to several previous studies, corrosion significantly increased when the moisture content surpassed 50% of the water-holding capacity and decreased as the capacity (saturation) approached 100%. When soil moisture content surpasses 50% of its holding capacity, it is critical for the corrosion of steel [8,16]. Corrosion is regarded to occur in an aqueous environment

such as this due to the presence of high moisture content. Yahaya *et.al.* (2011) also states that water will enter and flow through soil particles governed by soil physical properties including pore and capillary spaces at various zones in the soil profile [28]. The rate of corrosion progressively rises as the soil's moisture content rises. The results of this testing indicate that soil with an excessive amount of moisture will encourage underground pipe corrosion.

Table 5

Moisture content in tested soil samples

| Number of tests | Sample 1 | Sample 2 |
|------------------|----------|----------|
| Moisture content | 52.55 | 58.6 |

3.4 Soil pH

As a guide, the pH of the soil is measured using BS ISO 10390:2005. With an average pH of 4.5 to 4.7, the soil sample belonged to the acidic medium, according to Table 6's pH test results. A previous study by Shabangu *et al.* (2015) found that soil has an acidic pH range of 1 to 6 and an alkaline pH range of 8 to 14 [30]. As a result, the pH measurement of this soil sample demonstrated that it is more acidic and extremely corrosive to the underground pipeline, a condition caused by an increase in hydrogen ion concentration. Rust, also known as hydrated iron (III) oxide, was produced during the oxidation process of metal pipes due to higher concentrations of hydrogen ions [31].

Table 6

The pH values for the tested soil samples

| Area of test | Sample 1 | Sample 2 |
|--------------|----------|----------|
| pH reading | 4.5 | 4.7 |

4. Discussion

The primary factors that lead to damage to the exterior pipe surface are high moisture contents, low pH levels, and soil elements [32–33]. The surface of underground water pipes develops external corrosion scales because of electrochemical reactions between the pipe materials and the soil. The subsurface is determined by the product's design, the proportionality of chemical compositions, and the manufacturing process, particularly as it relates to the formation of defects. The outer surface is determined by the type of coating and materials used. Because the minerals in soil vary so much, different places have different types and compositions of soil by nature. Underground water pipes are affected by external soil corrosion, which can result in various losses for public health, the economy, and water treatment costs.

Table 4 presents the findings of the soil media analysis, which indicate that soil 1 and soil 2 have slightly lower pH values, 4.5 and 4.7. A major risk of corrosion to common building materials like steel, cast iron, and zinc coatings is increased acidity in the soil. Acidic soil will quicken the concurrent chemical process of corrosion when the soil reaches a particular state, such as a higher soil moisture content. It has been discovered that soils that contain between 50% and 60% of their maximum water-holding capacity are corrosive to carbon steel [34]. This is known as the "Critical Soil

Moisture Content." In addition to facilitating the transportation of oxygen and other liquid components, this high moisture content may hasten the corrosion of buried coupons. Corrosiveness tends to increase and resistivity tends to decrease with increasing soil moisture content [29]. Table 3 demonstrates the high iron oxide content of the soil samples. Because iron oxides are present, the soil's surface charge varies with pH. Inherent characteristics of clay minerals, especially iron oxides in the soil, should be considered as an important factor for understanding the corrosivity of iron oxide and the environment.

An electrochemical process is responsible for soil metallic corrosion. Steel's surface reacts with soil to form an oxide consisting of Fe_2O_3 , $\text{Fe}(\text{OH})_2$, and $\text{Fe}(\text{OH})_3$ [35–36]. Iron oxide was discovered to be a dominant mineral through SEM-EDX testing in Figures 4–6 and Table 4, and it is an important component of corrosion products. Corrosion products would remain on the steel surface in soils, protecting the steel from further corrosion [37]. Numerous studies have noted that iron oxide formation is more likely to occur in environments that are more reduced due to limited oxygen supply [38–39]. The amount of dissolved oxygen in the samples gradually decreased when they were buried in the soil. Fe^{2+} and electrons generated by the anodic reaction can transfer through the Fe_3O_4 layer and go on reducing FeOOH to Fe_3O_4 . When steel is exposed in a dry soil environment, the FeOOH transforms to Fe_2O_3 in the way as a dehydration reaction. Furthermore, since oxygen acts as the cathodic depolarizer in aerobic soils, the rate of oxygen diffusion towards the steel surface is low in clay soils, which would significantly affect corrosion [40].

5. Conclusion

The primary objective of the study was to determine the corrosion behavior of underground galvanized iron pipes that had leaked and corroded after about two years of use. This study indicates that the properties of the soil play a major role in the rate of corrosion of underground pipes. It was found that the moisture content of the soil sample has a bigger impact. The moisture content of the soil is one of the primary factors influencing corrosion because it provides an ideal medium for the oxidation of iron particles in underground pipes to produce rust particles. The accelerated oxidation of metal pipes in acidic soil is caused by the high concentration of hydrogen ions in the soil. This process preserves the electrobalance of ions in the soil and speeds up the corrosion of underground pipes. The soil samples have high concentrations of silicon oxide (46.1%, 37.9%) and aluminum oxide (45.9%, 38.2%), according to the XRF results. A higher concentration of aluminum oxide may cause the pH of the soil to drop. Soil samples also contain iron oxide, Fe, one of the elements that can cause corrosion. Iron oxide interacts with water to speed up the deterioration of underground pipes, which contributes to the corrosion process. Following the experiment, corrosion of these underground pipelines becomes more harmful when it happens in the presence of acid. Uniform corrosion was formed from a uniform reduction in pipe thickness surrounding buried pipes. This type of corrosion damage occurs rapidly and is caused by the corrosion product magnetite, Fe_3O_4 . Localized corrosion which is referred to as "pitting corrosion" causes the metal surface to develop a tiny hole or cavity. The pitting corrosion product was created when iron, oxygen, and moisture or water were combined. Galvanic corrosion is formed between the coating material and the outer metallic surface. It can also occur in dissimilar metallic alloying elements due to the difference in electrode potentials between the two materials [40-41].

6. Suggestions for Future Work

This study focuses on measuring certain parameters to estimate the corrosivity of current steel pipes in soil. The pipeline failure observed in the study area may have been caused by the highly

corrosive soil samples that were tested. The characteristics of the soil are the main cause of the corroded pipes in this situation. It is important to examine the relationship between the clay structure and water content simultaneously. Further research is required to understand how soil pH, microbial load, and moisture content affect underground steel corrosion. In addition, certain parties must be aware of the pH, moisture content, and type of soil before beginning any pipe installation work. The purpose of this is to develop effective corrosion protection strategies using coatings or other protections, as well as to propose an efficient pipe type that is appropriate for use in that area.

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