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# Corrosion Effect of X70 Pipeline External Surface Under Sedentary and Peat Soil Environment

**Nurul Izzah Mohamad NorDin[1], Zaidi Embong[1]***

[1]Faculty of Applied Sciences and Technology (FAST),
Universiti Tun Hussein Onn Malaysia (UTHM), Pagoh Campus, Km 1, Jalan Panchor, Pagoh, Muar, 84600, Muar, Johor, MALAYSIA

*Corresponding Author Designation

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**Abstract**: Soil characteristics and environmental conditions of surrounding both impact the corrosion of subterranean pipes, particularly on their external surface. Due to friable spots and corrosion prevention failure, corrosion of the external oil and gas pipeline might result in a catastrophic catastrophe in the oil refinery sectors, limiting pipeline performance under high pressure scenarios. In addition, this problem might cost the sector a lot of money, especially in terms of pipeline upkeep. The surface morphology study of this external pipeline was investigated using SEM-EDX in this work under two series of exposure in a week internal (7 and 14 days) in two type of soil species known as peat and sedentary soil. Both soil sample was chosen because their pH level is different. In this case, peat is more likely acidic compare to sedentary. SEM images revealed the production of dispersive corroded deposits form and tiny irregular porosity on the surface of X70 steel, while EDX proved the presence of Fe, O, and C elements associated with corrosion products. This phenomenon was primarily caused by intergranular corrosion throughout this pipeline, which led in the gradual induction of non-uniform and pitting corrosion products. The intergranular corrosion mainly contributed to this phenomenon along this pipeline and resulted in a progressive induction of non-uniform and pitting corrosion products.

**Keywords**: Corrosion, X70 Pipeline, External Surface, Peat Soil, Sedentary Soil, SEM-EDX

## 1. Introduction

Corrosion is one of the most dreadful events that engineers do not want to happen on the pipeline, especially when billions of dollars are at stake. Pipeline corrosion is intimately linked to a variety of environmental conditions Corrosion behavior of pipeline steel is heavily influenced by corrodents such as carbonates, chlorides, and sulfides [1]. Many businesses relied on pipelines to move their raw materials or finished goods from the point of origin to the point of treatment, and then to the end-users.Oil and gas industries, water treatment, and crude oil industries were among the businesses that employed pipelines extensively [2].

**Corresponding author :zaidi@uthm.edu.my*

Pipelines, being the most important part of the transportation role, must be kept in good working order at all times, and everything that could cause damage to these railways must be controlled immediately before an unintended accident occurs. According to a recent assessment, pipeline harms to the environment, whether human or natural, are extremely severe [3]. There were several human deaths and environmental damage that resulted in billions of dollars in losses. Due to the potential for future implications [4]as a result of a lack of information on pipeline conservation, a study into this issue will be conducted to determine the cause of buried pipeline damage caused by soil.

The data on pipeline accidents and their causes were compiled by the US Department of Transportation's Research and Special Programs Administration, Office of Pipeline Safety (RSPA/OPS) [4]. Pipeline damage can be caused by a variety of factors, including internal and external forces [5]. The inner force, such as the type of materials transported, the pressure inside the pipeline, and other factors, could produce a variety of damages to the pipes. Earth movement, high winds, strong rains and floods, temperature, lightning, excavation by the operator, fire or explosion outside the pipeline, rupture of the already damaged pipe, being struck by vehicles unrelated to excavation, and vandalism are all examples of outside force damage [6].

Excavation damage accounts for the majority of outside force damage to hazardous liquid pipelines and gas transmission pipelines, according to the statistics. This can happen if nearby excavation activity results in an unintentional punch on the pipeline. Excavation damage can range from causing damage to the pipe's external coating, which can lead to increased corrosion and the possibility of future failure, to cutting right into the line, exposing it, or, in certain situations, triggering massive catastrophic failure [4].

Due to this critical problem, it is necessary to study the interaction of soil particles and air particles with the external surface of oil and gas pipelines regarding surface corrosion morphology structure and roughness of X70 steel as an early-stage study of corrosion. Thus, Scanning Electron MicroscopyEnergy Dispersive X-ray Analysis (SEM-EDX) is chosen as an analytical method.

## 2. Methodology

The materials and methods section, otherwise known as methodology, describe all the necessary information that is required to obtain the results of the study.

### 2.1 Sample site

At Parit Botak, Johor, the corrosion’s induction between the surface of an X70 steel sample and the corrosion medium sedentary and peat soil was done in two different exposure configurations. Exposing X70 steel samples in sedentary soil was the first sort of exposure configuration used. In the meantime, the sample was buried for up to 14 days in peat soil at a depth of 0.5 to 1 m in the second type configuration. This peat soil has a lower pH between 4.5 to 5.5 and a greater moisture content than sedentary soil which is between 400% to 500% [7]. As a result, a simple strategy was employed to create an acidic environment for the sample exposure process, in which acidic soil, such as peat, was used as the principal medium for the in-situ exposure operation. The samples were exposed for 7 and 14 days at different intervals.

### 2.2 Selection of material

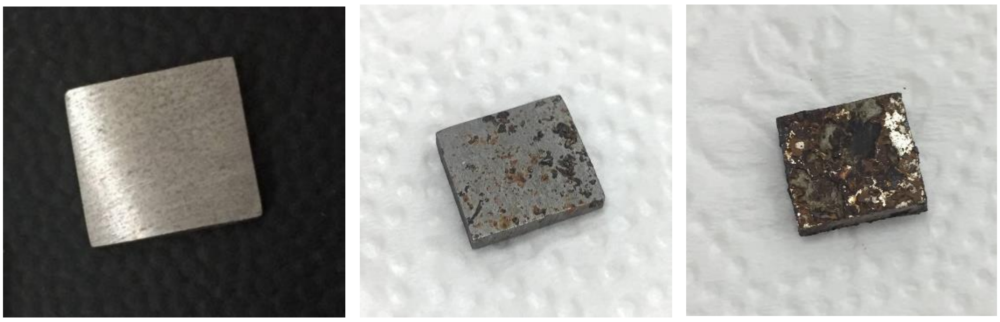
The X70 steel sheet utilized in this project was a common pipeline used in the oil and gas industry. This steel was sliced into smaller pieces with dimensions of 10 mm x 10 mm x 3 mm, and then it was polished with grit paper up to 800. Following that, the sample was washed with ethanol ($C_2H_5OH$) (Sigma-Aldrich) and dried at room temperature. Table 1 shows the chemical composition of X70 steel based on EDX analysis.

**Table 1: Chemical composition of the X70 steel (wt%)**

| Pipeline Steel | C | Mn | Si | P | Ni | Cu | Mo | Nb | Fe |
|---|---|---|---|---|---|---|---|---|---|
| X70 (wt%) | 0.17 | 0.64 | 0.28 | 0.12 | 0.71 | 0.25 | 0.12 | 0.87 | 96.42 |

### 2.3 Surface microstructural analysis

Following the exposure test, wipe the sample with a gentle brush as soon as possible to remove the dirt conglomerate before it hardens. Figure 1 depicts the appearance of pre- and post-exposure samples. The samples were then kept moist in a sealed desiccator before being sent to the laboratory for additional testing. At a magnification of 1000x, the SEM-EDX system (COXEM EM-30AX) was used to describe the elemental and morphological studies for the as-exposed sample surface.



a) b) c)

**Figure 1: Appearance of pre and postexposure samples; a) polished, b) exposed under sedentary, and c) exposed under peat soil**

## 3. Results and Discussion

The results and discussion section present data and analysis of the study. This section can be organized based on the stated objectives, the chronological timeline or any logical order as deemed appropriate.

### 3.1 Scanning electron microscopy and energy dispersive X-ray (SEM-EDX) analysis

SEM with Energy Dispersive X-Ray Analysis (EDX) is capable of delivering high-resolution images of the sample by focusing electron beams across the surface and detecting secondary or backscattered electron signals to analyze the sample's elemental identification and quantitative compositional information by focusing electron beams across the surface and detecting secondary or backscattered electron signals. As a result, the researchers utilized the SEM-EDX methodology on the samples to get a basic understanding of the textural qualities and morphology of the samples before using pyrolysis to determine the structural changes that occurred.

Figure 2 and 3 show the microscopy picture and the corresponding chemical analysis for the polished X70 steel pipeline by using SEM-EDX. The polished steel was consisted of iron, Fe (90.88%) as shown in Table 2.

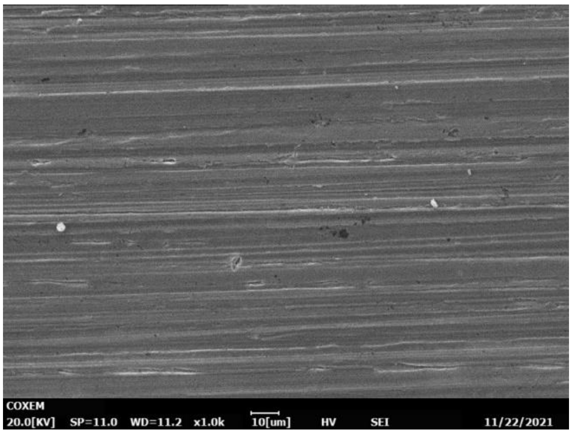



**Fig. 2: Polished of X70 steel pipeline**

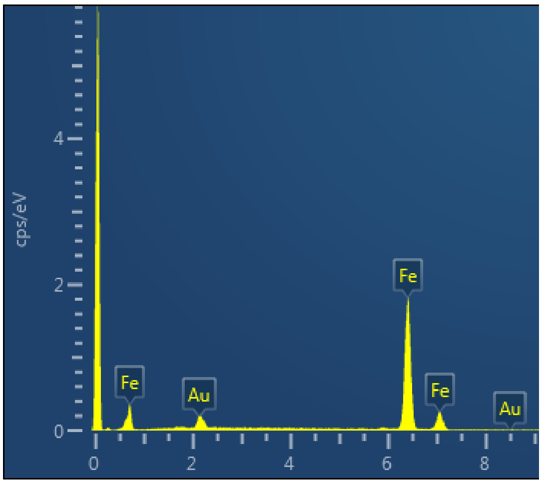



**Fig. 3: SEM micrographs obtained on polished APL X70 steel pipeline**

**Table 2: Element composition of X70 steel pipeline**

| Element | wt(%) |
|---|---|
| **Fe** | 90.88 |
| **Au** | 9.12 |

Figure 4(a&b) shows the surface morphology pictures and EDX peak of components of corrosion products generated on X70 steel exposed to peat soil. The photos show the remarkable change of surface morphologies after 7 and 14 days of exposure. The micrograph of an X70 steel sample exposed to peat soil for 7 days demonstrates the production of brittle corrosion products and globular cotton-ball-shaped goethite (a-FeOOH) molecular structure, as shown in Figure 4a [8]. After 14 days of exposure, Figure 4b shows denser oxide layers free of fractures and globular cotton ball-shaped corrosion products. Finally, the surface degradation in these peat soil conditions was particularly aggressive, as evidenced by the globular cotton-ball shaped and dendrites structure on the samples. When the corrosion product composition transforms into a new product after being exposed for a lengthy period of time (e.g lepidocrocite transforms into goethite), evidence can be provided [9]. As a result, issues such as pitting corrosion on the X70 steel's external surface may arise, lowering the performance of surface physical attributes that indicate surface deterioration [10].

The primary constituents, such as Fe, O, and H, are also responsible for the ongoing expansion of the corrosion product layer on the exterior X70 pipeline's surface. In this situation, the electrochemical reaction of iron ions, $Fe^{2+}$, discharged from the anodic to the cathodic zone, while hydrogen ions, H+

(acidic soil) from the soil that infiltrates into soil cavities is the major ingredient that causes corrosion in-situ [11]. Moisture, which works as an electrolyte, also plays an important role. The electrolyte might be poor conductivity water, causing the metal to corrode more quickly. EDX analysis, as shown in Table 3, backed up this assertion. The steel corrosion products under peat soil exposure after 7 and 14 days are indicated by the compositions from two separate locations of I and ii, as shown in Fig. 4. The corrosion products' elemental compositions were Fe (40.847%) and O (31.19%), with trace amounts of C, Ca, and Si. The elements Ca and Si were thought to have come from the earth. At the soil particle to metal surface contact region, a dominant chemical reaction such as chemisorb and physisorbed may have occurred, resulting in corrosion products constituted of FeOOH, $Fe_3O_4$, and $Fe_2O_3$ [12].

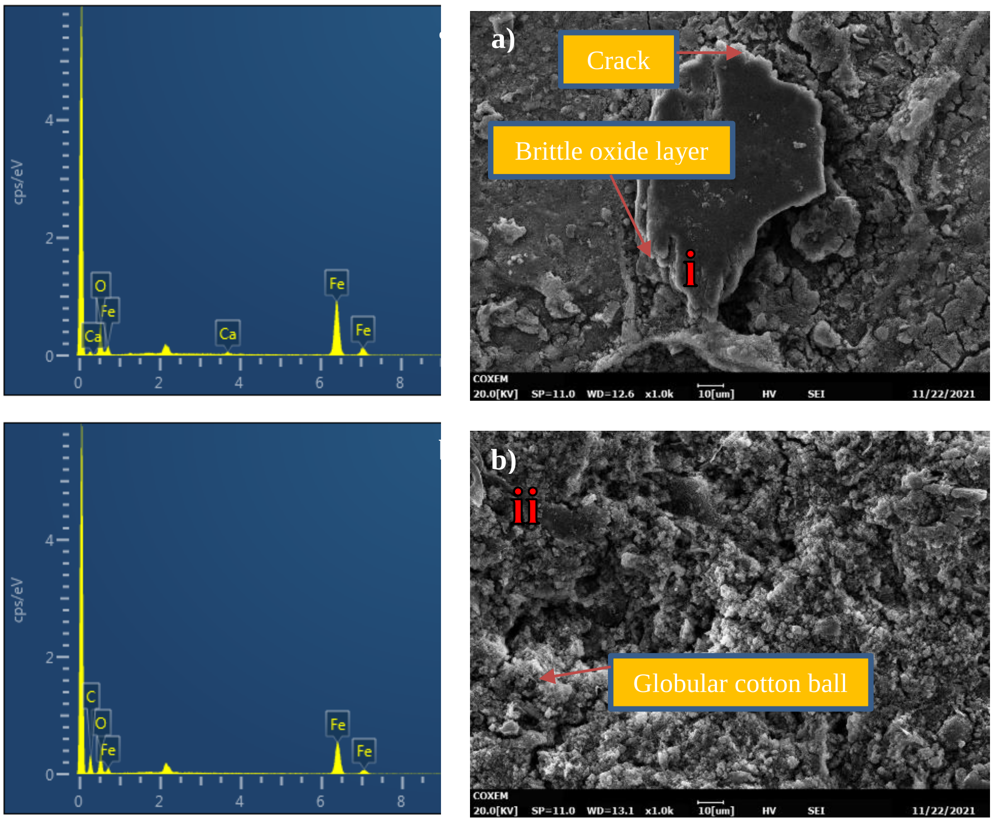



**Figure 4: SEM micrographs obtained on APL X70 steel pipeline in peat soil a) for 7 days and b) for 14 days**

**Table 3: Element composition of corrosion products for determined by EDX**

| Element | i (wt%) | ii (wt%) | Average (wt%) |
|---|---|---|---|
| **Fe** | 53.16 | 27.77 | 40.47 |
| **O** | 26.09 | 36.08 | 31.09 |
| **Ca** | 1.86 | 0.18 | 1.02 |
| **C** | 17.32 | 16.77 | 17.05 |
| **Si** | 1.57 | 18.11 | 9.84 |

The EDX peaks of elements and surface morphology of the X70 steel surface degradation under sedentary soil for 7 and 14 days are shown in Fig. 5(a & b). Sandy grains corrosion products were formed within 7 days of the first sedentary soil exposure, as shown in Fig. 4.8a. The results show that the oxide layer's early phase on these samples resulted in sandy grain corrosion products on the sample surfaces. Lepidocrocite (a-FeOOH) may be linked to the sandy grain morphology [13]. Finally, when the steel samples were exposed to sedentary soil for 14 days, the metal surface was gradually coated with hard and thick corrosion products, resulting in considerable agglomeration (Fig. 5b). Table 4 shows that corrosion products are mostly related with considerable amounts of Fe (65.53%) and O (25.57%), with minor amounts of C (6.82%) and Si (1.89%). As a result, when the X70 sample was exposed to the ambient environment, rain, which contains a corrosion promoter, $H^+$, played an important role in the development of corrosion. As a result, rainfall will deposit a thick oxide coating on the exposed surface consisting of metal ions, $Fe^{2+}$, and oxygen ions, $O_2$ layers [14].

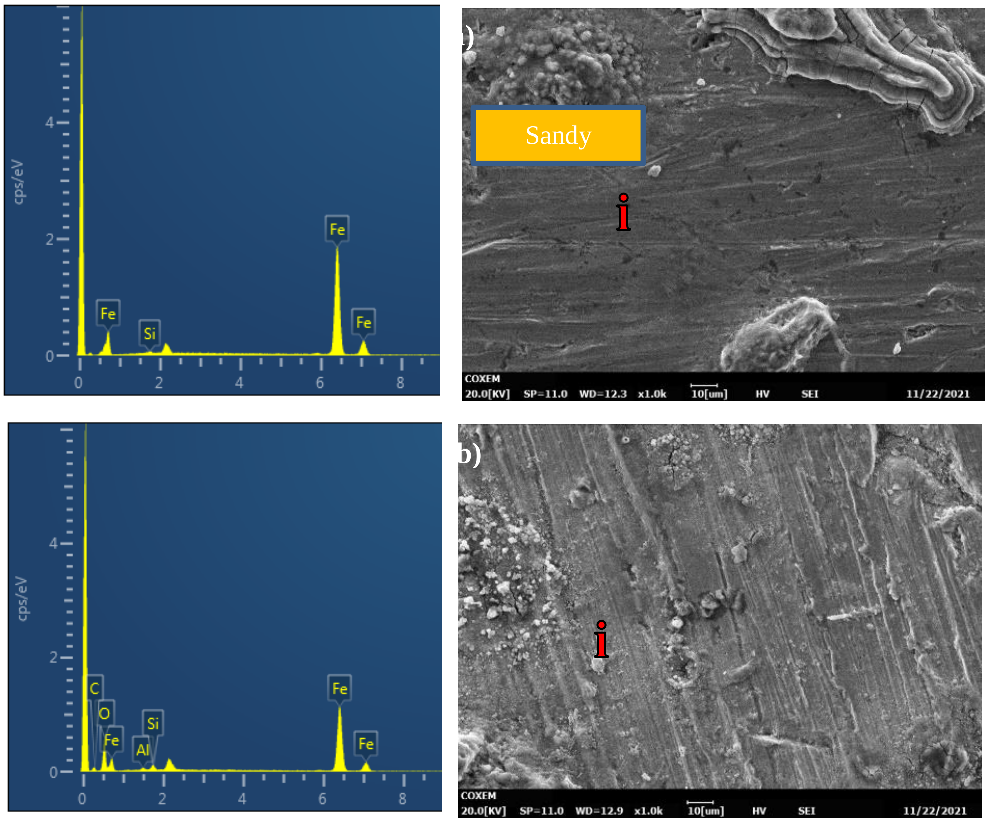



**Figure 5: SEM micrographs obtained on APL X70 pipeline steel in sedentary soil a) for 7 days and b) for 14 days**

**Table 4: Element composition of corrosion products under sedentary soil for determined by EDX**

| Element | iii (wt%) | iv (wt%) | Average (wt%) |
|---|---|---|---|
| **Fe** | 68.44 | 62.62 | 65.53 |
| **O** | 26.04 | 25.10 | 25.57 |
| **C** | 3.77 | 9.87 | 6.82 |
| **Si** | 1.36 | 2.41 | 1.89 |

In Malaysia, peat soil is generally found in coastal areas and hillside areas, such as Kuantan, Pontian, Batu Pahat, Pekan and Perak. Peat soils have high porosity, acidity and moisture content, which may impact the surface deteriorations on the pipeline exterior surface when exposed to a peat environment. Thus, suitable assessments need to be performed before installing an oil and gas pipeline in peat soils due to their natural properties. Peat soils contain higher hydrogen ions ($H^+$) concentrations, so these specific soils are acidic. The low pH for the peat is a strong signal or indicator that the oxidation reaction of iron, Fe in the X70 pipeline is accelerating at a high rate.

## 4. Conclusion

From this report, several conclusions can be summarized that Sedentary and peat soil particle may induce the corrosion on the most X70 steel pipeline surface. When X70 steel pipeline exposed to sedentary and peat soil for 7 to 14 days, the heterogeneous corrosion products generated on the exterior steel surface of this X70 grow progressively severe. The creation of corrosion products may be seen in the SEM data, which show the formation of a thicker, brittle, porous layer as well as the fracture surface. The corrosion product's principal element makeup, according to EDX analysis, is Fe and O, with trace quantities of Si, C, and Ca. The morphology of the surface was dominated by sandy grain as a lepidocrocite (a-FeOOH). Cotton-ball-shaped goethite (a-FeOOH) was discovered early in the exposure era and grew more prevalent afterwards. Under sedentary and peat soil, SEM-EDX investigations have been confirmed to characterize the distinct surface corrosion morphologies for varied exposure time periods. In comparison data, X70 sheets of steel are severely eroded in peat soil than sedentary soil.

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