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# Engineering behaviour of soil materials on the corrosion of mild steel

A.I.M. Ismail [a,*], A.M. El-Shamy [b]

[a] Geological Science Department, National Research Centre, Dokki, 12622, Cairo, Egypt
[b] Electrochemistry and Corrosion Laboratory, Department of Physical Chemistry, National Research Centre, Dokki, 12622, Cairo, Egypt

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ABSTRACT

Underground pipelines and steel structures are usually expected to have a long working life. The risk of corrosion should be estimated before installing such pipelines so this paper is aiming at the investigation of the surrounding and incorporating medium (soil filling materials).
Many problems related to soil application are due to the unfavorable interaction between water and soil. Underground corrosion is primarily influenced by the following factors: the presence of soil moisture, the supply of oxygen, the redox potential, the pH value, the soil resistivity, and also by microbial activity.
From engineering aspects an increase in soil water content has a number of disadvantages e.g. swelling, shrinkage and cohesion decreases which affect directly on the interaction of pipelines, causing deterioration of pipeline materials "corrosion" and also cause damage of infrastructure above this soil due to the occurrence of general and localized corrosion (pitting formation) which is present in different sites of steel structures. The presence of water is a prerequisite for the functioning of corrosion cells. Corrosion of mild steel is affected by grain size, swelling, shrinkage and clay mineral content. The finer soil particles, owing to the increase in swelling, shrinkage, and plasticity, are considered as corrosive medium for underground pipelines and steel structures. The clay mineral contents are also the main quality control to the mild steel corrosion for example montmorillonite and illite absorbed water more than kaolinite clay minerals so it is highly effective in the deterioration of metals.



## 1. Introduction

### 1.1. Corrosion overview

Underground metal structures are usually expected to have a long working life, often 50 to 100 years. Structures such as natural gas, crude oil pipelines and water mains are only some of the many structures reported to have been affected by soil corrosion around the world (Schaschle and Marsh, 1963; Starkey and Wight, 1983; Levlin, 1992). The fundamental cause of the deterioration of pipeline buried underground is soil corrosion (Norin, 1998). Control of corrosion is very expensive and the cost of corrosion is reported (Powell et al., 1988). Within two years (2004–2005), about 8 cases of failure along the pipelines route were reported (NAOC, 2005). Before such a structure is put in place the risk of corrosion and the need for corrosion protection measures should be estimated.

The position of the buried structure in relation to the groundwater table is of major importance for corrosion. Even in the soil above the groundwater table, there is water held by capillaries and pores. The finer the soil particles and pore size the more water is held (e.g. clay). Evaporation primarily influences the sodium sulfate and sodium chloride concentrations, whereas low percolation rate and accumulation of water lead to low redox potentials and higher concentrations of carbon dioxide. The water content, together with the oxygen and carbon dioxide contents, is a major corrosion-determining factor.

An increase in water content of soil is the main factor in the corrosion of mild steel. The change in water content of soil is the main factor in the corrosion of mild steel. The change in water content was influenced by the engineering characteristics of filling materials. So the study of the effect of clay content and the engineering properties of soil on the mild steel corrosion which constitute the most structures of pipelines in petroleum industry will be discussed in this context.

### 1.2. Geo-engineering overview

The type of filling materials comprises granular sand and gravel fill. This type of filling materials contains fine materials which close the pores between sand and gravel particles. Fines are clay and silt sized particles. Even a small amount of these particles will severely reduce the ability of the fill to transmit water but when the filling materials were compacted, the maximum dry density increases (Ismail, 2006, 2007). The increment of the dry density could decrease the transmission of water through the soil filling materials, which leads to the decrease in corrosion rate. The filling materials should not contain any material larger than 3 in. due to the larger the grain size (>3 in.), the greater transmission of water and thereby corrosion increases.

* Corresponding author.
*E-mail address:* ali_ismail_2000@yahoo.com (A.I.M. Ismail).

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**Fig. 1.** Location map of the area under study.

Clay and silt soil filling materials could be used as filling materials particularly when compacted in a proctor device (DIN (18123), 1998).

This paper is aiming at the study of the effect of clay content and the engineering properties of soil under investigation (Fig. 1) on the mild steel corrosion (Fig. 2) which constitute the most structures of pipelines in petroleum industry and sewerage as well as potable water pipelines.

On the other hand there are three aspects that agree with the requirements of construction engineering and chemists (corrosion) as follows:

1. Accept the site materials as it is and design to standard sufficient to meet the restriction imposed by its existing quality.
2. Remove the site materials and replace it with a superior material.
3. Alter the properties of the existing soil so as to create new materials capable of better meeting the requirements of the task in hand (Bell, 1976; Denis et al., 1991; Bell, 1994; Rogers and Glendinning, 1997).

In this study, the engineering characteristics of the derived soil materials and their effect on the mild steel corrosion will be discussed to recommend one of the three decisions, namely, whether to accept the soil as filling materials as it is or to remove it or to improve its engineering properties by adding foreign materials in appreciable amounts.

The area of filling materials was described by El-Shahat et al. (1999) as a late Quaternary evolution of the north-eastern Nile Delta and classified stratigraphically into basal unit (late Pleistocene) and upper unit of Holocene age. The basal unit is composed of shallow marine transgress sands with stiff mud remnant. The upper unit of the area under study (Fig. 1) belongs to the Holocene age and is dominated by mud facies of alluvial plain and lagoon environments of Neonile sediments (Said, 1981).

In the filling process, the contractor should meet with the engineer on the site to review procedures and to agree the fill material to be used. All stumps and large boulders should be removed. If necessary, the top soil should be stripped and the area plowed or scarified. Prior to the placement of the fill, the bottom surface of the excavation shall be scarified. Fill material should be stockpiled at the edge of the excavation until a suitable base of select material has been spread over the entire exposed area. Fill should not be placed during periods of heavy rains, snow storms or freezing temperatures. If water is present at the bottom of the excavation following a period of rain, the excavation shall be dewatered as necessary. The engineer should inspect the prepared site and set grade stakes before "select fill" is placed. The excavation for the placement of "select fill" shall extend to a minimum of 5 ft laterally in all directions beyond the outer perimeter of the leaching system and to a depth to make contact with naturally occurring pervious material. Representative sample (made up of a composite taken from numerous locations in the fill section) may be taken from the in-place fill. The sample should be tested for compliance with the grain size distribution and engineering properties (swelling, shrinkage and plasticity). If it appears that the fill may not be sufficiently compacted, an engineering compaction test may be required to decrease the permeability and the infiltration of water.

## 2. Materials and methods

### 2.1. Weight loss measurements

The weight loss measurements are performed with mild steel coupons, each having the dimensions of $10\times1.5\times0.2$ cm. The steel coupons were polished with different degrees of emery papers from the rough to the finest degrees, and then washed with distilled water and degreased by acetone before immersion in water. At the end of the experiment (about 5 days), the specimens were visually inspected, cleaned and weighed. The cleaning process should remove all corrosion products from the specimens with a minimum removal of sound metal. This has been achieved by washing the coupons with running tap water and scrubbing with bristle brush. Then the coupons were chemically cleaned in inhibited 15% HCl solution. From the average value of the weight loss in the absence ($W_{free}$) and presence of additives ($W_{inh.}$), the inhibition efficiency of the inhibitor is calculated according to:

$$\text{Inhibition Efficiency, \%} = \{(W_{free} - W_{inh.})/W_{free}\} \times 100.$$

### 2.2. Soil texture

The major classification in identifying the type of soil is the grain size distribution test as determined according to DIN, 18123 (1998) and BS, 1377 (1975). Both wet sieving and sedimentation analysis were used to get a full particle distribution analysis of the samples under investigation (Table 1).

As shown in Table 1, the studied soil materials comprise of 53% silt, 43% clay and 4% sand giving rise to classify such soil as clayey silt type.

**Fig. 2.** Soil consistency and its effect on mild steel corrosion.