STUDIA UNIVERSITATIS BABEŞ-BOLYAI, CHEMIA, LIV, 2, 2009

INVESTIGATION OF UNDERGROUND GAS PIPELINES CORROSION BY OPTICAL AND X-RAYS DIFFRACTION METHODS

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ABSTRACT. This work aims to determine the corrosion behavior of the buried gas pipelines (OLT 35 and OL 37 carbon steel) in salty and swampy soils by optical methods.

The aspect of the corroded surface and the nature of corrosion products were studied by metallographic microscopy and by X-ray diffraction. By analyzing the metallographic microscopy for OLT 35 corrosion in soils, one can observe that salty soil is more aggressive than swampy soils. The X-ray diffraction method shows that all types of soil contain the two phases of trivalent iron oxides, in beta and gamma hydrated form.

Keywords*: carbon steel, buried metallic pipelines, underground corrosion, surface analysis, X-ray diffraction, metallographic microscopy.*

INTRODUCTION

Underground metal structures are usually expected to have a long working life, often 50 to 100 years. Before such a network is put in place, the risk of corrosion and the need for corrosion protection measures should be estimated.

In principle, stainless steels should be in the passive state in soils, but the presence of water and aggressive chemical species such as chloride ions, sulfates and as well as various types of bacteria and stray current, can cause localized corrosion [1-4].

The soil is a corrosive environment that has special characteristics from one place to another because of the variable humidity, the different percent of dissolved salts, various pH, the presence of microorganisms, the variable quantity of oxygen and the presence of stray currents [5-7].

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The pH value of soil is determined by the contents of carbonic acid, minerals (and/or their leaching), organic or inorganic acids (e.g. produced by microbial activity), and by industrial wastes or acid rain. The pH value of soil moisture also affects the solubility of the corrosion products [8-10].

Since corrosion is associated with electrochemical reaction the soil resistivity is a broad indicator of its corrosivity. The soil resistivity is widely used and generally considered to be the dominant parameter in the absence of micro-biological activity [1,5].

The most important factor of corrosion is the duration of steel surface exposure to water (wetting phase) and the presence of corrosion-stimulating agents in the moist zone. If the duration of exposure and the environment are known, it is possible to estimate the corrosion rate.

Electrochemical and optical methods are well suited for the study of corrosion phenomena because they allow one to simulate the corrosive effect of the environment [11]. Low carbon steel OLT-35, has been undertaken for corrosion study in swampy and salty soils and compared to other carbon steel for general usage as OL-37.

Metallographic investigation and surface analysis were made in order to evaluate the type of the corrosive attack .

RESULTS AND DISCUSSION

The chemical composition of the studied steels is given in Table1.

Table1. The content of various elements in the alloys

Steel type	***Weight %***					
	C	Si	Mn	P	S	Fe
OLT-35	0.17	<0.35	<0.40	<0.05	<0.05	Up to 100 %
OL-37	0.22	0.07	0.56	0.055	0.055	Up to 100 %

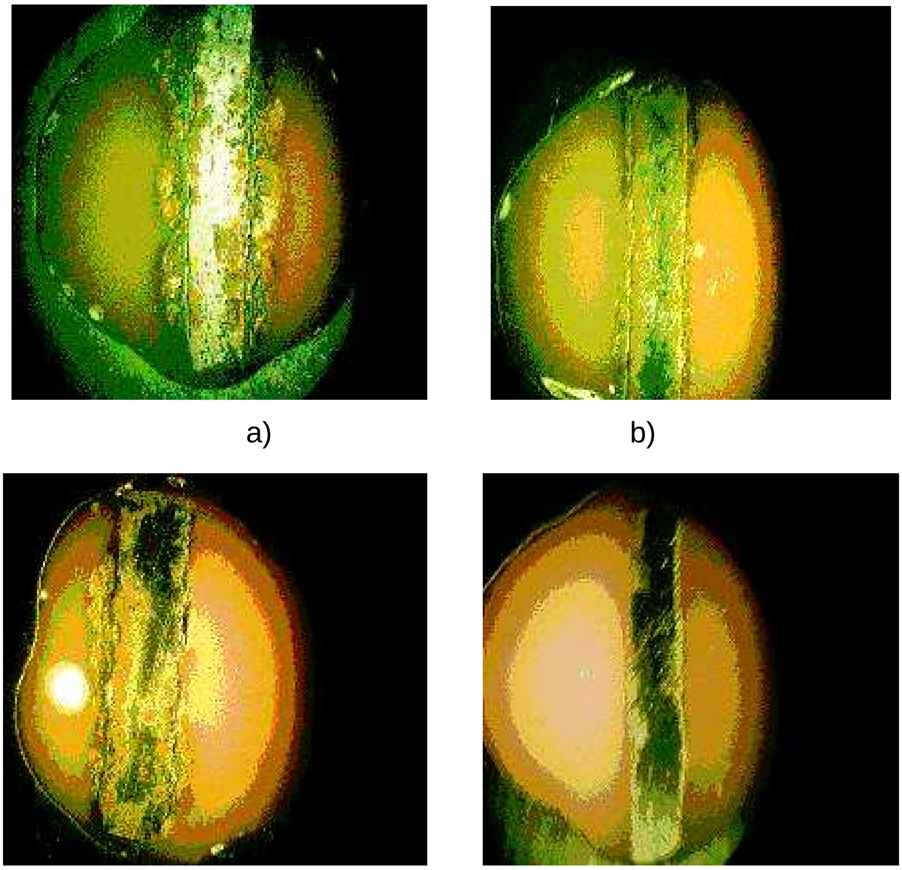
Some characteristics and the provenience of used soils are contained in table 2.

Table 2. Some characteristics of used soils

Soil type	***Provenience***	***pH***	***Conductivity (mS)***
Normal (ordinary)	Cluj-Napoca rail station zone	6.5	0.6
Salty	Ocna Dej, salt mine zone	6.7	3.5
Marshy	Cluj-Napoca Intre Lacuri district	7.0	10.2

1. Metallographic microscopy

This method analyzes corroded surfaces, after smoothing and polishing. It allows the observation of the corrosion effects in the depth of the metallic wall. Two types of carbon steel samples, the OLT 35 and OL 37, were undertaken, were buried into aggressive soils for 36 months and analyzed after such exposure. From figure 1 can be observed both the oxide layers formed and the surfaces attacked by corrosion (macroscopic observation) of OLT 35 and OL 37 steels, in swampy and salty soil.

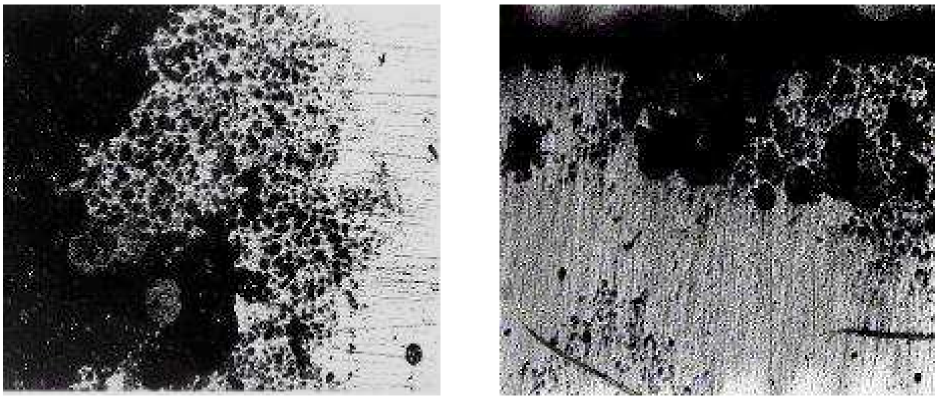


a) b)

c) d)

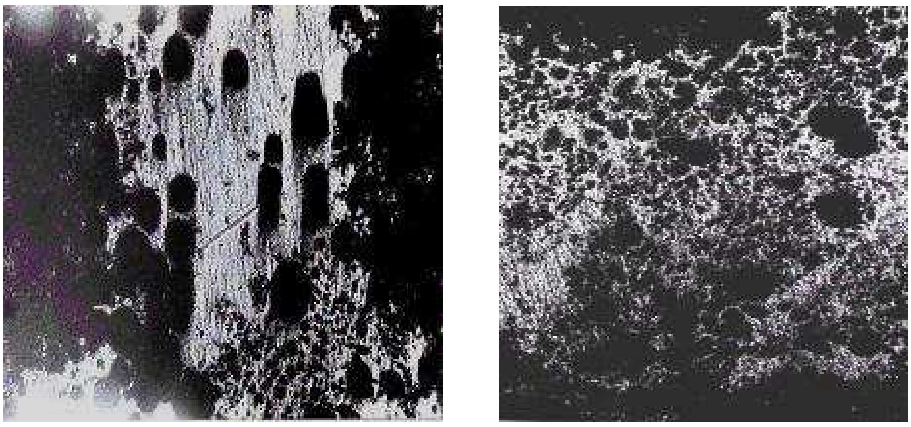
Figure 1. The aspect of samples surfaces comprised in resin after smoothing and polishing: OLT 35/swampy soil *ex situ* (a); OL 37/ swampy soil *ex situ* (b); OLT 35/salty soil *in situ* (c); OLT 35/salty soil *ex situ* (d). (X 63)

The metallographic microscopy is presented in figures 2 and 3 and the main observations are summarized in table 3.



a) b)

Figure 2. Micrographs of the corroded surface in swampy soil *ex situ* :
OLT 35 (a) and OL 37 (b). (X 63)



a) b)

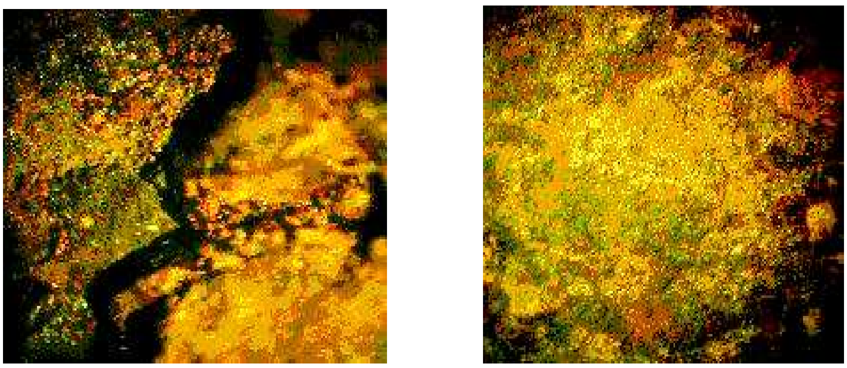
Figure 3. Micrographs of the corroded surface of the OLT 35 in salty soil:
in situ (a) and *ex situ* (b) (X 63)

Table 3. Observations noticed on the metallographic microscope

Steel type	Aggressive environment	Observations
OLT 35	***Salty soil*** *in situ*	- the thickness of the corrosion products layers is between 0.2 mm and 2.6 mm; - localized corrosion; - the most aggressive environment analyzed, on both sides of the sample, most of the surfaces are attacked by corrosion in the plagues form;
	Salty soil *ex situ*	- the thickness of the steel layers is approximately 0.2 mm; - the generalized corrosion, removed by smoothing, reveals localized attacks
	Swampy soil *ex situ*	- the thickness of the corrosion products layers is between 0.1 and 2.5 mm - localized corrosion; unlike the salty soil in which the pitting were of large and medium sizes, part of them are united in plagues; - the aggressivity of this type of soil is lower then that of the salty soil;
OL 37	***Swampy soil*** *ex situ*	- the thickness of the corrosion products layers is between 0.2 and 0.6 mm - localized corrosion with pitting of medium dimensions forming plagues;

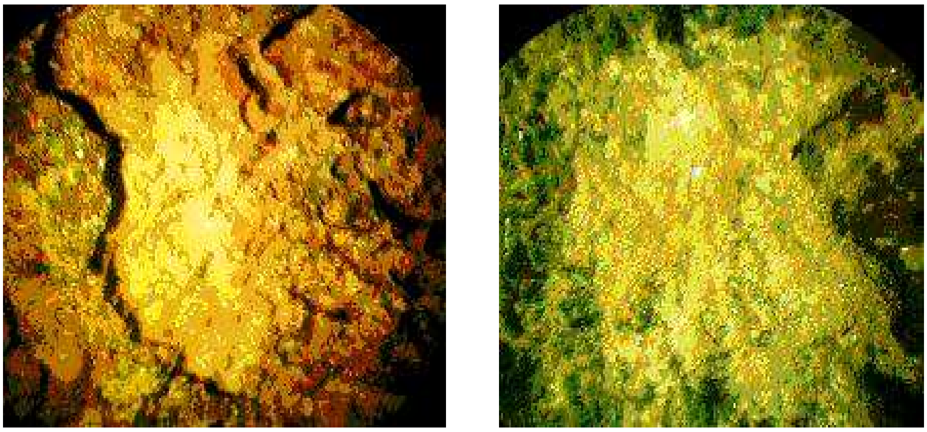
2. Optical microscopy

This investigation aims to analyze the corrosion products structures formed at the interface soil/metal. The method allows getting a sight in the depth of the corrosion products layers. The representative images of the corrosion products formed during the exposure are presented in figures 4 and 5. The characteristics of the corrosion products are presented in the table 4.



a) b)

Figure 4. The structure of the corrosion products formed in salty soil *in situ* on: OLT 35(a) and OL 37 steels(b) (X 50).



a) b)

Figure 5. The structure of the corrosion products formed in swampy soil *in situ* on : OLT 35 (a) and OL 37 steels (b) (X 50).

Table 4. The characteristics of the corrosion products formed on steels in different aggressive soils

Steel / electrolyte	***Characteristics of the formed corrosion products***
OLT 35 pipe / salty soil *in situ*	- porous product cakes of orange and red- brown colour, voluminous, quite thick, adherent, alternating with formations of different forms and thin layers; - it is observed the appearance of shiny formations, of black color; it does not appear in cases of other types of soil. The corrosion products contain, Fe_3O_4 or iron sulfides: FeS, FeS_2
OL 37 blade / salty soil *in situ*	- product cakes less porous, of red -brown color, less voluminous, more present on the edges of the sample, without conglomerates, smaller thicknesses then in the pipes case;
OLT 35 pipe / swampy soil *in situ*	- product cakes situated in the centre of the sample, red -brown color, smaller thickness then the one form the salty soil, bigger in the centre of the sample, with conglomerates of smaller dimensions on the edges, with smaller inclusions of black color (possible Fe_3O_4, FeS, FeS_2) on the edges of the sample; - the products are thinner then the ones in salty soil *in situ* and thicker than those *ex situ;*

3. X-rays diffraction

This study aims to make a qualitative and semi-quantitative phase analyses of the corrosion products. The diffractogramms of the corrosion products resulted form the corrosion of OLT 35/salty soil and OLT 35/swampy soil are presented in figures 6 and 7. The compounds identified in each type of soils are presented in table 5.

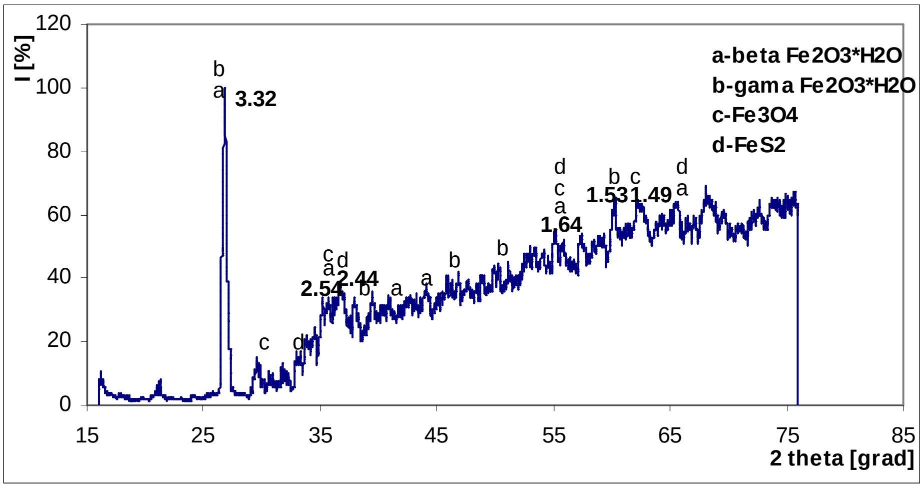


Figure 6. The diffractogramm obtained for the corrosion products from OLT 35/salty soil

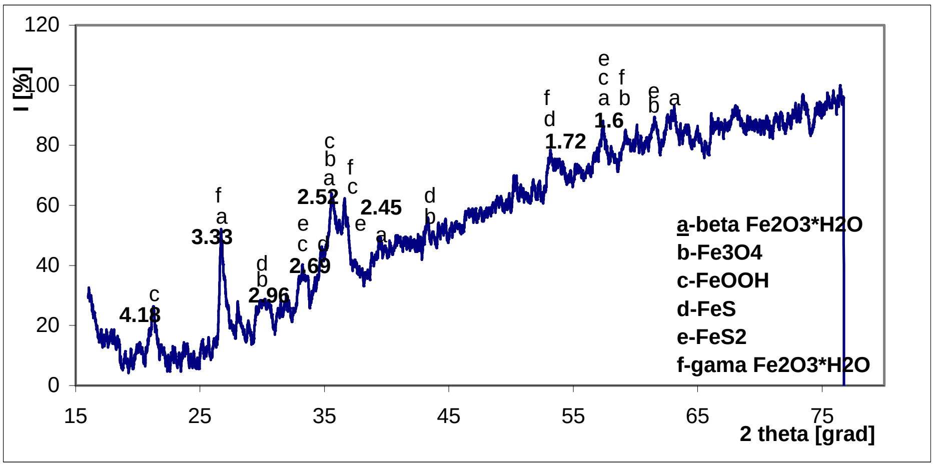


Figure 7. The diffractogramm obtained for the corrosion products from OLT 35/swampy soil.

The higher aggressiveness of swampy soil is confirmed by the various types of corrosion products. It can be observed that some of them are common for all types of soils: β-Fe_2O_3*H_2O; γ-Fe_2O_3*H_2O;

Table 5. The phase's component of the corrosion products.

OLT 35/ salty soil		***OLT 35/ swampy soil***	
Identified phases	*Mass composition %*	*Identified phases*	*Mass composition %*
β-Fe_2O_3*H_2O	43.03	β-Fe_2O_3*H_2O	22.9
γ-Fe_2O_3*H_2O	43.03	γ-Fe_2O_3*H_2O	22.9
Fe_3O_4	8.19	FeOOH	19.1
FeS_2	5.73	Fe_3O_4	19.1
		FeS	7.1
		FeS_2	8.74

CONCLUSIONS

The most aggressive non sterilized soil for OLT 35 carbon steel is the swampy soil, followed by the salty soil and normal soils. This fact is confirmed by the higher localized attack of the metallic surface, which is covered by corrosion defects (pitting and plague type with higher depth and diameters). The OLT 35 carbon steel is more affected as compared to OL 37 carbon steel in swampy soil. This test shows that in swampy soils, this material is not very useful to make pipes.

For selection purposes, it is recommended to consider corrosion resistance of buried stainless steels according to soil resisitivity and pH. Specific stainless steel grade must be carefully selected according to soil conditions.

By the determinations through diffraction with X-rays, it was put in evidence that all types of soil contain the two phases of trivalent iron rust, in beta and gamma form hydrated with one water molecule. The swampy soil contains two phases of sulfides that confirms the increased aggressivity by high chemical and bacteriological charge. After analyzing the products of corrosion, in the case of the steel OLT 35, in salty soil, the thickness of the corrosion products layers is higher than in the case of the OL 37 steel, which confirms that OLT 35 is more sensitive to corrosion in salty environments than OL 37.

Taking into consideration the relative high corrosion susceptibility in such aggressive environments, the OLT 35 carbon steel pipeline buried in soils should therefore be coated and cathodically protected.

EXPERIMENTAL SECTION

1. Metallographic microscopy

For performing the metallographic microscopy, a microscope of Neophot 21 type, made by Carl Zeiss Jena (GDR) has been used, with incorporated camera. In this case the determinations have been realized at a magnification of 63 times. For this purpose, the samples have been processed by smoothing with metallographic paper of different granulations and by polishing with felt impregnated in alumina suspension

2. Optical microscopy

A Carl Zeiss Jena binocular microscope, which works by reflection has been used. Unlike the metallographic microscopy, in which it could be analyzed only metallographic slides, in this case any kind of samples can be analyzed The determinations have been performed on the samples taken out from the aggressive environments both in pipe form and in blade form, without smoothing or polishing.

3. Analysis of corrosion products by X-rays diffraction

The phases analysis has been performed by an X-rays diffractometer of DRON 3 type (made in USSR).

The corrosion products samples were powder. The phases were identified by comparing with both American (ASTM) and Russian standards. The angles of the maximum diffraction and their intensity were measured on the diffractogramms. Relative intensities, I/I_1 and the interplanes distance, d were computed by means of Bragg relation.

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