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CORROSION RATES BASED ON THE PHYSICAL PROPERTIES OF SOIL AT NAGAPATTINAM DISTRICT

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ABSTRACT

Experiments were conducted to investigate the correlation of soil properties towards metal loss of API 5L X42 carbon steel coupons, with emphasis on soil pH and resistivity. A total of four pieces of X42 coupons was placed in four different soil samples gotten from four different villages within the Nagapattinam Delta region for 2400 hours, to study the influence of soil properties towards metal loss via weight loss method. The soil coupons were buried in the soil samples placed in a plastic container, allowed to corrode naturally and then retrieved every 240 hours. The influence of soil pH value and resistivity were evaluated using the weight loss method to evaluate the corrosion rate on coupons in the different soil samples. Results showed that both parameters had an influence on buried steel, but soil resistivity had a dominating influence compared to soil pH.

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INTRODUCTION

This study is the outgrowth of continuing interest throughout the oil industry, especially in the oil rich part of Nagapattinam District in a bid to reducing the incidence of oil spillages caused by corrosion. This involves identifying the key processes and environmental conditions which mostly influences the equipment deterioration rate. Once identified, a strategy is established to routinely monitor these key processes and environmental parameters and maintain them within prescribed limits to control corrosion or material deterioration to acceptable levels (Jeremiah Emeka Mbamalu, 2004). In the absence of an efficient monitoring system, the dynamic progress of corrosion may cause the pipeline to leak or rupture, and a pipeline failure can cause grave human, environmental and financial losses. The word corrosion is derived from the Latin *corrosus* which means eaten away or consumed by degrees; an unpleasant word for an unpleasant process. As such, when corrosion is being discussed, it is important to think of a combination of a material and an environment. The corrosion behavior of a material cannot be described unless the environment in which the material is to be exposed is appropriately identified. Similarly, the corrosivity or aggressiveness of an environment cannot be described unless the material that is to be exposed to that environment is also identified. Summarily therefore, the corrosion behavior of the material depends on the environment to which it is subjected, and the corrosivity of an environment depends on the material exposed to that environment.

Soil which is the electrolyte is a complex environmental material which has made the study of corrosion in carbon steel vague. However, understanding the physicochemical composition of soil is a key to unravelling how a soil can influence the corrosion reaction. It has become expedient that operators should examine every particular site to explain the corrosion mechanisms models resulting from the steel interaction with the soil environment which depends on several factors such as soil type, moisture content, soil resistivity soil pH, oxidation – reduction potential and microbial load.

MATERIALS AND METHODS

This study employed a quantitative analysis method to determining the corrosion rate based on weight loss method. This involved exposing the sample coupons to the test medium (soil) and measuring the loss of weight of the material as a function of time. The measurements of the specimens were taken during exposure and after removal according to ASTM G162-99.

Description

Steel Sample: API 5L X42 was the specimen chosen for this investigation (Anyanwu *et al*.,2014). The API 5L X42 steel pipe segment used for this research work was obtained from Corrosion Monitoring Services (CMS), India.

Soil Sample

Four different villages were chosen and soil collected from each villages. All soil samples were taken from the depth of at least one (1) meter from the ground level. All of which were collected from four different sites along the Nagapattinam Delta region of Tamilnadu, India. The Napattinam Delta region is located at an elevation of 10 meters (32 ft) above sea level with latitude of 10°45′50″ N and within longitude of 79°50′40″ E. The soil samples were taken to the laboratory for analysis in an air tight polyvinyl bag less than 24 hours after collection from actual site.

contained and their proportions in the sample were revealed on the digital processor attached to the spectrometer. The results as shown in Table 1 below

Specimen preparation of soil sample the procedures followed in preparing the soil medium is referred to ASTM G162-99. Since the soil samples were collected from four different sites along the Nagapattinam Delta region of Tamilnadu, India the soils were first packaged in polyvinyl bags and transferred from its actual site to a laboratory for determination of its chemical properties. The results are shown in the Table-2 below.

Geo-Engineering and Chemical Analysis of Soil Samples Test procedure

Determination of moisture content

This was performed according to ASTM D2216. 20g of the soil sample was weighed into a moisture can and placed in an oven (MRC DNO-50, India) at 1050[°C] for 24hrs. The sample was removed and weighed until constant weight was observed. The moisture content was calculated as the percentage of mass of water loss.

Soil Classification-Sieve Analysis (Soil Texture)

The test was conducted according to ASTM D422 (Anyanwu Samuel Ikechukwu et al., 2014).

Table 1. Chemical composition of API 5L X42 carbon steel (wt %)

C	Mn	P	S	Si
0.34	2.56	0.048	0.0215	0.4375

Table 2. Chemical Analysis of Experimental Soils

Parameters	Nagapattinam	Mayiladuthurai	Velankanni	Thiruvarur
pH	7.66	7.52	7.68	7.42
Redox Potential [mV]	147.8	142.8	140.5	148.6
Temperature [°C]	29.30	28.90	29.20	28.80
Soil Resistivity [Ω cm]	7013.77	6878.89	6973.50	6984.88
Chloride [mg/kg]	36.23	41.10	28.33	36.60
Sulphate [mg/kg]	11.10	12.45	9.87	13.99

Table 3. Mechanical and Physical Analysis of Experimental Soil

Village	% Sand	% Silt	% Clay	% Moisture	% Porosity	Permeability [cm/sec]
Nagapattinam	61.5	23.9	14.6	10.26	68	1.7
Mayiladuthurai	60.1	29.2	10.7	21.05	58	0.9
Velankanni	59.2	17.6	14.2	11.27	65	1.5
Thiruvarur	58.8	21.3	19.9	10.41	70	1.2

Specimen Preparation of Steel Sample

The steel pipe segment was sectioned (cut) into coupons of 3mm X 25 mm X 75mm using a hacksaw. The cutting process was chosen so as not to alter the microstructure of the sample (Anyanwu, 2015). To prevent inconsistent coating protection which may lead to bias result, the coatings of the samples were removed in a bid to allowing the coupons corrode under worst case scenario. As such, the samples were thoroughly cleaned before installation to avoid any contamination or any possible entities that could affect the corrosion process. A sample was subjected to chemical analysis using the metal analyzer. This was done by exposing the well-polished surface of the sample to light emission from the spectrometer. The elements

A know mass of dry soil was weighed accurately to 0.1g (W) and was transferred into a stack of sieves. The stack sieves was run through a shaker for about 10 to 15 minutes and the amount of soils retained on each sieve was weighed and recorded.

Soil chemical analysis

Test procedure: soil pH (pH apha 4500 H^+): Measurement was carried out in 1:1 soil to water suspension by means of a Win Lab pH meter, which was calibrated in the laboratory. Calibration was checked by measuring standard buffer solutions.

Test Procedure: Soil Resistivity: Electrical Conductivity was carried out based on APHA-2540-C standards. Measurement was carried out in 1:1 soil to water suspension by means of a Win Lab conductivity meter, which was calibrated in the laboratory. Calibration was checked by measuring standard Conductivity reference solutions. Soil resistivity being reciprocal of conductivity was, however computed using.

ER=1/EC

Where,
ER = Electrical resistivity
EC = Electrical conductivity

Burial of Samples

The coupons were totally buried inside plastic containers containing the respective soils gotten from different villages in a laboratory and closely monitored A total of 4 steel coupons were buried and allowed to corrode naturally for a period of Ten days(240 hours).

Nagapattinam Mayiladuthurai Velankanni Thiruvarur

Figure 1. Soil Samples in Containers Ready For Coupon Burial

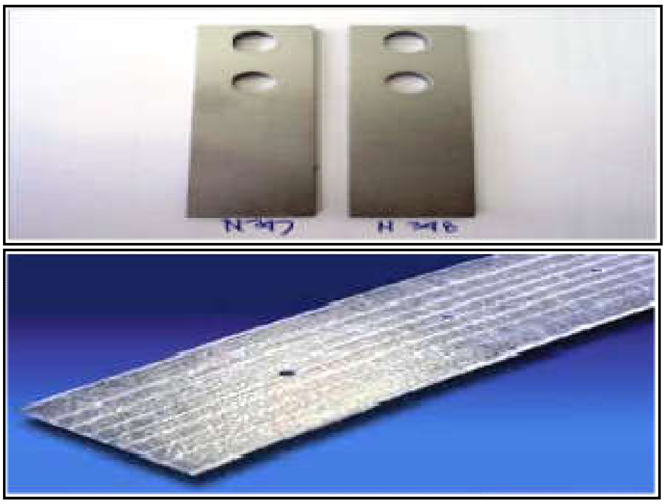


Figure 2. Coupon Condition (Before Burial of Coupon in Soil Samples)

Figure 3. Burial of Coupon In Soil Samples

Retrieval of Coupons

Coupon retrieval was carried out periodically every seven days. As such, in order to get a time-function data of metal loss, every single sample was assumed uniform in terms of strength, thickness and corrosion resistance.

Figure 4. Retrieval of One of The Coupons From Soil

Weight Loss Measurement

To remove accumulated impurities and corrosion products from the coupons, two cleaning techniques were employed, which included mechanical cleaning and chemical cleaning as shown in Figure 5.

Figure 5. Washing the Coupons

The mechanical cleaning was carried out to remove the soil particles on the surface of samples using a soft brush. After washing, all the coupons were neutralized by 5% sodium carbonate and again washed with water. After neutralization, the coupons were soaked in Acetone for 5 minutes and then allowed to dry properly in sun. The weight of the sample prior (W1) and after being exposed to soil environment (W2) were recorded using an electronic weighing scale to determine the corrosion rate. The difference in weight of the sample is most often used as a measure of corrosion or the basis for calculation of the corrosion rate.

W=W1-W2

Where,
W = weight loss
W1- Initial weight
W2- Final weight after exposure to soil with time (240 hrs.)

Corrosion Rate Determination: The surface area of each coupon was calculated using:

Surface Area (A) = 2X [(L X B) + (B X T) + (L X T)]

Where,

L = Length of the coupon.
B = Width of the coupon.
T = Thickness of the coupon.
D = Diameter of hole in coupon

The weight loss of the coupons which were used to compute the corrosion rates of the coupons was measured using the KERRO BLG 2000 electronic scale having a precision of up to 0.01gm. Hence the corrosion rate was computed using the formula:

$$\text{Corrosion rate (mmpy)} = \frac{97.6 \text{ X Weight loss}}{\text{Area X time X Density}}$$

Where:

W = weight loss in milligrams
A= area of coupon in square cm
T = time of exposure of coupon in hours

RESULTS AND DISCUSSION

Weight Loss of Samples

In order to see the influence of soils from different locations on the coupons buried, the initial weight of the coupons was recorded and with time the weight differences were checked. The weight loss plotted as shown in Figure 6. Figure 6 shows that the weight loss was highest in WLR i.e. the soil gotten from Rivers State. During the incubation periods, the coupons gained weight possibly due to moisture adsorption. But with time after 672 hours, the coupons started losing weight with WLR being the highest followed by WLA. Weight loss in WLB seemed higher than WLD during the first 2016 hours but afterwards, WLD began to be higher than WLB. This is could be traced to the fluctuations in the resistivity of the soils and other factors, knowing full well that corrosion in soil is a complex phenomenon. However with this trend, at the weight loss of coupon in delta soil would be highest since the increase with time seems increasingly fast.

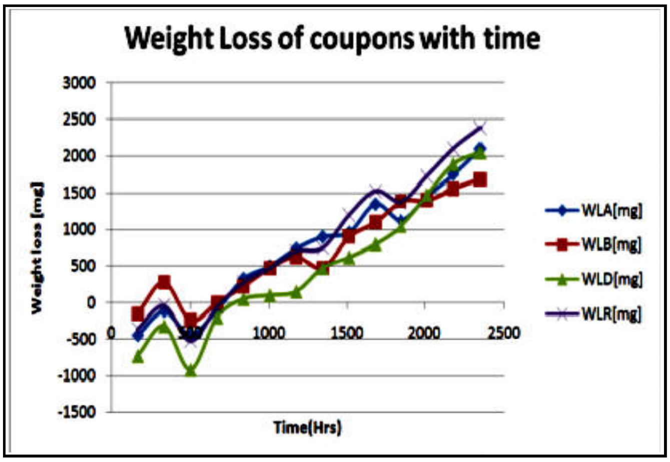
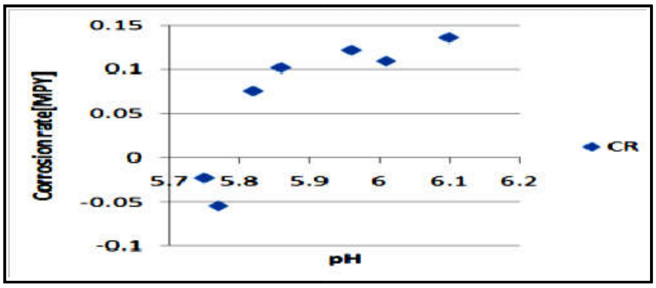


Figure 6. Weight Loss Against Time

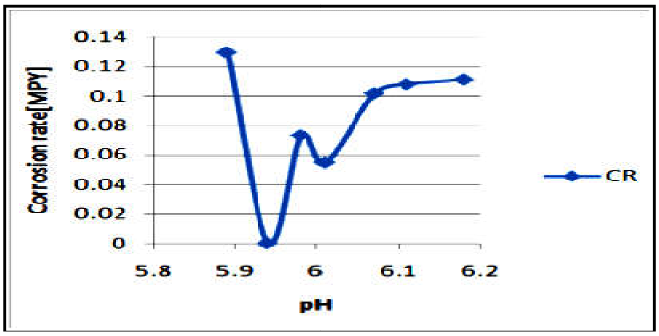
Corrosion Rate against Soil pH

From experimental results obtained, it could be seen that as time goes on the corrosion rate of all samples as shown in the figures below kept increasing with time, as much as pH increased. This however agreed somewhat with the observations in weight loss against time, which shows a good correlation between both.

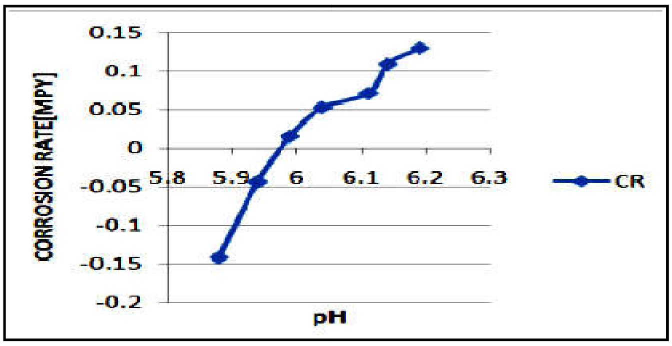
Corrosion Rate against pH (Nagapattinam)



Corrosion Rate against pH (Mayiladuthurai)



Corrosion Rate against pH (Velankanni)



Corrosion Rate against pH (Thiruvarur)

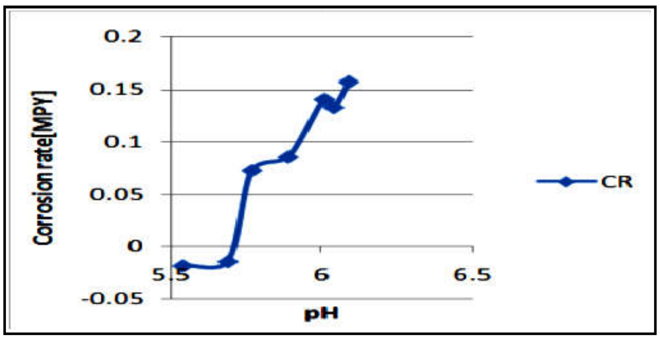


Figure 7. Corrosion Rate Against pH for Nagapattinam Sample

pH Against Time

Soil pH with time appears to increase with corresponding time. Nagapattinam Delta sample had the highest values of pH while Thiruvarur Rivers sample had the least pH values although there were minor fluctuations. These values had a huge influence on the corrosion rates of the coupons.

(Graphical depiction of pH against time for all samples)

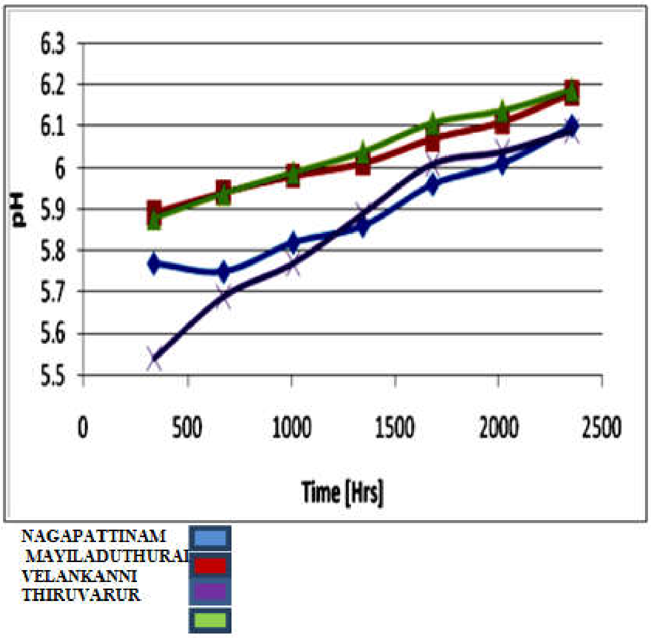
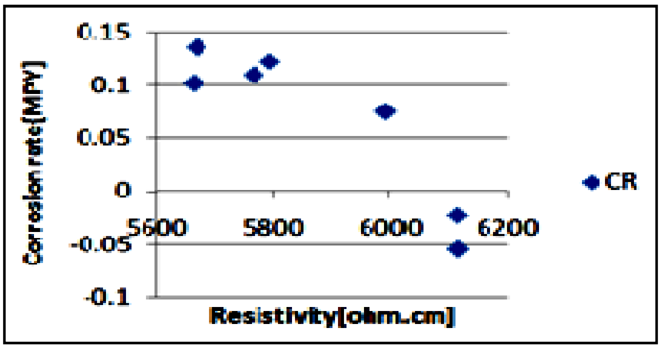
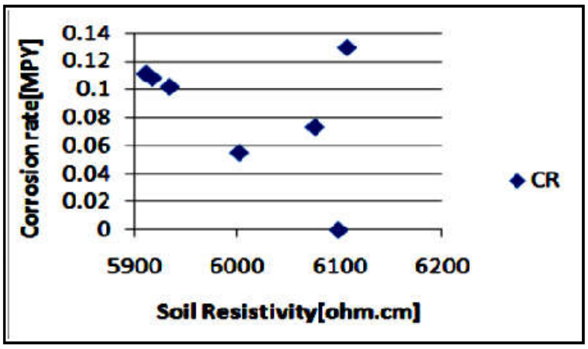


Figure 8. pH Against Time

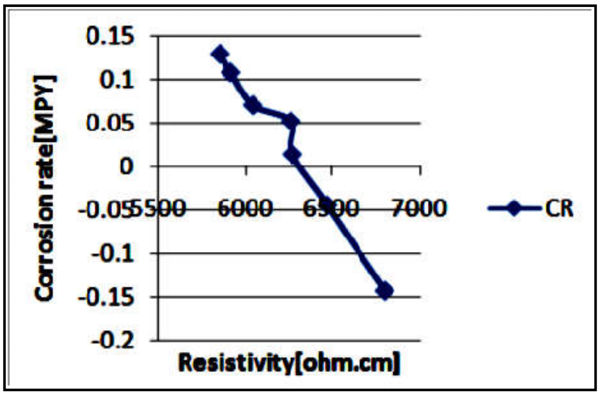
Corrosion Rate Against Resistivity (Nagapattinam)



Corrosion Rate Against Resistivity (Mayiladuthurai)



Corrosion Rate against Resistivity (Velankanni)



Corrosion Rate against Resistivity (Thiruvarur)

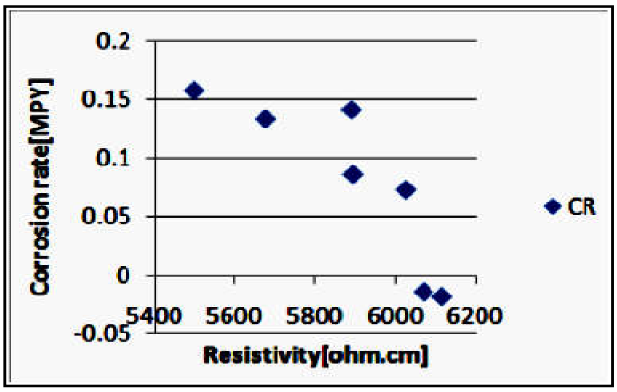


Figure 9. Corrosion Rate against Resistivity for Nagapattinam Sample

Soil Resistivity Influence

Soil resistivity is an obviously an indicative of soil corrosivity. As such in all samples studied, the lower the resistivity the higher the weight loss and corrosion reactions. Also experimentally it appeared that the resistivities gradually dropped with time thus leading to a steady rise in the corrosion rate.

Corrosion Rate against Resistivity

Based on the results obtained, it showed that the resistivity's of most samples increased with time leading to an increase in corrosion rate. This seemed to agree with the opinion of some authors, where they opined that the lower the resistivity of a soil, the better the soil's electrolytic properties and the higher is the rate at which the corrosion can proceed.

(Graphical depiction of pH against time for all samples)

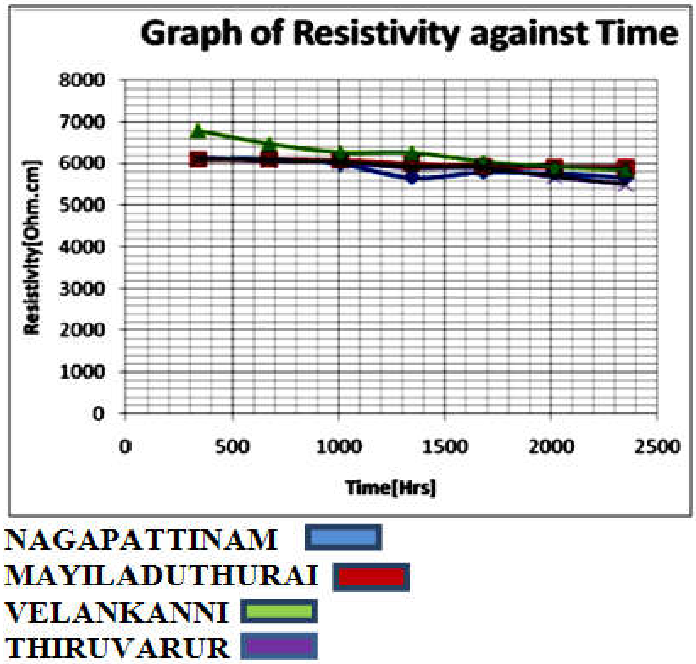


Figure 10. Resistivity against Time

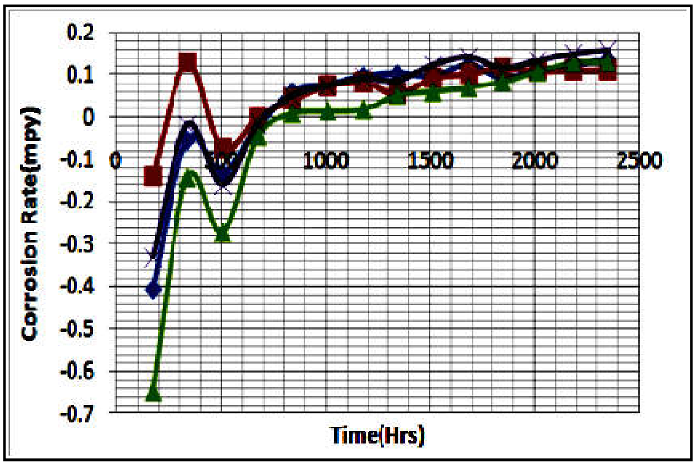


Figure 11. Graph of Corrosion Rate against Time

Hence the progressive reduction in resistivity with time, led to corrosion increase as shown in Figure.10.

Corrosion Growth Rate

The corrosion growth rate has always been a function of time. Upon inspection based experimental data recorded, it seemed evident that the corrosion rate of coupons increased with time after the initial stage. The initial phase where an increase in weight was observed instead of a loss in weight could be attributed to absorption of moisture which invariably led to an increase in weight. Then, with time, it was noticed that possibly the passivity film might have been broken down which now led to the observed weight loss. Hence this agrees with what other writers have opined, where steel naturally tries to passivate itself with respect to the environment in which it finds itself within the first few days. Figure 11 shows explicitly the relationship between corrosion rate and time. From the figure below WLR had the highest corrosion rate which is an indicative of the inherent properties of the soil. But based on the trend with time, delta sample would be the most corrosive.

Conclusion

The aim of the study was to determine a relationship between soil pH and soil resistivity upon corrosion growth rate of carbon steel. As a matter of fact, this paper tried to isolate individually the above mentioned soil properties from all other possible factors which is believed to govern metal loss of buried steel coupon and later correlated with corrosion growth rate as measured through laboratory experimental data. Soil resistivity was found to have greater influence than soil pH towards the acceleration of a corrosion reaction in most soil samples examined, if not all, due to distinct pattern of relationship between variations of averages corrosion rates and soil properties. Also time plays a major role in corrosion rate of steel buried underground. Further research work is necessary to study better the influence of moisture content, soil pH and microbial load of soil as it affects corrosion of underground steel. The measured corrosion rates from the loss of weight of buried steel coupon may be dominantly caused by other factors such as fungi, bacteria, chloride content, sulphate content, organic content and salinity.

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