RESEARCH ARTICLE

EXPECTING OF CORROSION RATE IN A MATERIAL AFFECTED BY DIFFERENCES SOIL TYPE IN CONTROLLED ENVIRONMENTS.

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ARTICLE DETAILS

ABSTRACT

Research has been done on corrosion rates growth in SA 283 material which is influenced by differences in soil types in controlled environments. A283 grade D materials which are carbon steel formed into pipes with a diameter of 30" which is used to distribute raw water for industrial needs. Weight loss methods that are in accordance with the ASTM G 162 standard have been used in this study. The buried time of the test specimen is 720 hours as one of the variables in calculating the value of the corrosion rate that occurs. The study was conducted at the Laboratory by controlling the soil structure, reducing potential, moisture level, soil pH level so that it did not change. The results of the study on soil types with a potential redox value of 60.6 mV with a pH level of 5.67 showed the greatest corrosion rate in material A283 that is 19.67 MPY or equal to 0.499 mm/yr. The results of this study concluded that the type of soil and its environment greatly affect the corrosion rate of carbon steel, so special attention is needed in protecting the pipe from corrosion attack.

KEYWORDS

carbon steel, corrosion rate, Laboratory, corrosion attack, ASTM G 162.

1. INTRODUCTION

Within large-scale industries, the use of pipelines is one of many key elements upon distributing liquid raw material and essentials material (Roberge, 2000). Pipelines are used as a distribution tool to fulfill many industrial needs such as water pipelines to fulfill the needs of industries and many residential areas. Pipelines are buried underground from the water source until it reaches the location of the factory, only a few parts of the pipelines that corrode in the surface of the soil. The soil who in this case acts as the media that buried the pipelines has a range characteristic depending on the environment (Fontana, 1986). Soils are one of the factors that cause corrosion to occur. Corrosion within the soil is considered as the most important factor, especially when the pipeline structure is buried for a long time. Variation of properties and characteristics of the soil are the main factor why corrosion occurs when the structure is buried.

A few factors which speed up the corrosion process within the soil such as texture and structure of the soil, relativity, acidity (pH), humidity (moisture content), salt solubility, aeration (oxygen content), a content of Sulphate, a content of Chloride, and Microbiology Activity. Conditions of soil are determined by the process of evolution because the soil can develop and change as time pass. Climate factor like rainfalls, wind circulation, and sunlight can cause changes to the soil. Rainfall is highly connected with the acidity or alkaline content in which developed along with the change of the soil structure. When rainfalls are high, water is filtered in the soil and dissolve any soluble material. The acidity of soil is formed by many factors

including the first layer of the mineral content within the soil, biological activity, and temperature, in corresponding with the humidity. pH is a scale that counts the percentage of hydrogen ion in the media.

Soil usually have a pH of 5-8 so it has less effect on the rate of corrosion. Within the range, pH is not the dominant cause of the effect that changes the rate of corrosion. If the property of soil contains a high acid base it can cause serious risk to steel, cast iron, and zinc coating. Levels of acidity within the soil are caused by leaching mineral, Industrial waste, acid rain, and a few microbiology activities (Fontana, 1986). Corrosion that usually occurs in the soil is an Aqueous type and it is caused by the mechanism of electrochemistry (Fontana, 1986). However, the condition of the soil is able to cause an atmospheric shift and change the condition dimmer depending on the density of soil and the crystal content. Even though the mechanism is electrochemistry, there are many soil characteristic which can increase the rate of corroding such as rain, Climate or microbiology activity within the soil. Moisture holding capacity of soil (Moisture-holding capacity) is an ability of soil to bond with water in a capillary form.

The water capacity in the soil is affected by the texture of the soil itself. Soil humidity plays an important role in the process of corrosion, for example, a soil that contains dry sands are more immune to corrosion than soil that contains wet clay. According to the evaluation that has occurred, the value of resistivity along the path of pipeline installation point and the result of measuring from cathodic on the underground pipeline that is monitored

using test box in over 25 points shows protection results in several points. The result of the first evaluation also showed an indication which some part is not protected especially with the pipes that are exposed and the internal area is prone to corrosion (Putra et al., 2018). If the coating layer is damage this will trigger galvanize corrosion and this will occur within the pipelines. The decreasing ability of protection by the cathodic protection system is due to the drastically environment change on the installation area and the damage in the coating due to overage usage (Robergo, 2000; Fontana, 1986; Putra et al., 2018).

Sing at al has done research on the relation between soil resistivity and the increase in the rate of corrosion on the tropical area, steel coupon was installed underground for a duration of 12 months in five different points in Peninsular Malaysia (Sing et al., 2013). The logarithmic model gave the best coloration between the rate of corrosion and resistivity of soil. This research showed that the measurement of soil resistivity can act as an indicator for the first development of corrosion. Anyanwu did research with the modeling of mathematics to find the relation of steps in developing corrosion on carbon steel with the effect of pH and soil resistivity (Anyanwu, 2014). The result of the research shows that both parameters have an effect on the buried steel, and the soil resistivity value is more dominant comparing to the effects of pH levels in the soil. This research shows that the model that was developed corresponds with the prediction on the rate of corrosion development with the soil pH and the resistivity of soil, both are set as an independent variable. A few research about the underground pipe and other structure corrosion has been done (Biezma et al., 2018; Wasim et al., 2018; Wang et al., 2018; Atanov et al., 2018; Thalib et al., 2018; He et al., 2012; Velayudhan and Yameni, 2012).

This result shows many factors that cause corrosion in the underground pipelines like metals that are different within the pipeline, variable properties on soil, surface condition on a pipe, different electrolysis and attacks by different bacteria within the soil. According to previous research, the value of soil resistivity located in the underground pipelines has potential as the cause of why corrosion occurs (Putra et al., 2018). This research was part of the mapping to show the levels of soil corrosion within the pipeline that worked as water distribution to one of the companies in the city of Lhokseumawe. This research was used to predict the rate of corrosion using the material SA 283 on a controlled environment with a variety of soil type as the corroding media.

2. MATERIALS AND METHODS

Material that is used by this research is carbon steel with a diameter of 30 inches and thickness of 15 mm. This pipe has a specification ASTM SA 383 which is a grade D carbon steel with a strength between 415-550 MPa (ASTM International, 2003). This material has been analyzed using metal analyzer that is presented in table1. This pipe material is cut into coupons with an average size of 25 x 50 mm using a hacksaw. The use of a hacksaw is to avoid any defect within the material that is caused by the heat caused by the friction.

Table 1: Chemical Composition of SA 283 Carbon Steel

C	Si	Mn	P	S	Cu	Fe
0,28731	0,42212	0,59832	0,00072	0,00518	0,20532	Balance

The specimen that has been cut (coupon) and are cleaned according to the standard of ASTM G1 (ASTM International, 1999). The next process is to give each coupon a number. After giving each coupon initial numbers, the next step is to weight the specimens for the first time, coupon each separated to a group of 4 pieces for every variation type of soil to produce an average value. Soil as a buried medium is taken from several locations where pipelines have been installed by other companies. Location of a sample taken is in the of latitude 5°13' N and 5°14' N, and longitude 96°57' E and 96°59' E. 5 types of different soil have been taken from the following location to get some different and similarities can be seen in figure 1.

Soils are taken from the surface until the depth of 80 cm. The volume of soil took is adjusted according to the size of the coupon and was tested

according to standard ASTM G 162 (ASTM Norma G, 2004). The soil was taken to the lab to check physical properties and mechanical properties. Buried the coupon is carried in the laboratory right after the soil was extracted. 4 coupons are buried in one type of soil on a plastic container. Time of the coupon buried in the soil was 720 hours or 1 month. Levels of acidity are measured every week for one month so we can get an average pH value (ASTM Norma G51, 2000).

Figure 1: Location of Soil Sampling

Corrosion is a defect of material which is caused by the environment surrounding it. Everything that affects the chemical reaction will also affect the rate of corrosion. The rate of corrosion is linear with a few currents that flow to the electrochemical corrosion cell. If currents are measured certain and right calculation from the loss of metal can be determined. Certain measurement in amp or milliamp mathematically can result in a calculation of kilogram per year. Different metals have a different rate of corrosion. On this research, the rate of corrosion is presented upon a perspective that includes a live specimen, by measuring the missing mass that is caused by corrosion. This test specimen is cut into a simple shape which is called a coupon. The test specimen was piped with a specification of SA 283.

This tasting method of a rate of corrosion includes the process of the coupon burial to the soil that was extracted from 5 different location until the coupon itself corrode as time pass, the specimen will become thinner due to the loss of mass. The standard procedure for this method is ASTM G 162 (ASTM Norma G, 2004). Measurement loss of mass in a specific amount of time (720 hours) done by calculating the gap of mass between before and after using analytical balance produced by VIBRA. The rate of corrosion can be calculated using this equation. Corrosion rate = (K x W)/(A x T x D), where is K = a constant (8.76 x 104), T = time of exposure in hours to the nearest 0.01 h, A = area in cm^2, W = mass loss in gr, and D = density in g/cm^3 presented by unit millimeter per year.

3. RESULTS AND DISCUSSION

3.1 Chemical Analysis of Soil Properties

With a point to affect the rate of corrosion in an underground pipeline using a variety of soil, therefore we have to do a chemical analysis and physical analysis for each soil. Results chemical analysis on the different type of soil can be viewed in table 2, and for physical analysis is presented in table 3.

Table 2: Chemical analysis of Experimental Soil

No	Location	pH	Potential Redox (mV)
1	Reulet Barat 1	6,3	40,3
2	Reulet Barat 2	5,35	35,2
3	Paloh Awe	5,67	60,6
4	Pinto Makmur 1	6,3	38,2
5	Pinto Makmur 2	6,47	20,8

	Table 3: Physical analysis of Experimental Soil					
No	**Location**	**Condition**		**Soil Texture**		**Moisture (%)**
			Dust (%)	Clay (%)	Sand (%)	
1	Reulet Barat 1	silty clay soil	23,29	38,295	38,415	4,4
2	Reulet Barat 2	loamy soil	6,855	32,995	60,15	2,95
3	Paloh Lada	silt clay soil	13,94	31,365	54,695	6,4
4	Pinto Makmur 1	sandy soil	8,52	13,98	77,5	2,7
5	Pinto Makmur 2	humus soil	22,595	15,385	62,02	2,3

From table 2 we can make a conclusion from every testing soil sample contains acidity but the difference isn't significant. The average value of pH that was produced stands between 5 until 6 whereas the general value of neutral is 7. A lot of potential points for redox shows a massive surplus of oxygen within the soil which are the main variable of why the corrosion occurs. in table 3, the average value of the soil texture is sand which stands at 50 %, this shows that the soil that was extracted came from the surface. For the soil moisture also varies between 2 to 6 % which indicates that its soil that was extracted from the surface. During the research, each soil type has a diverse size of the particle.

3.2   Analysis of Corrosion Rate

To see the rate of corrosion that occurs in all the different types of soil that was extracted, therefore test coupon that has been buried for 720 hours is extracted and cleansed from the corroding part. After we clean it, every test coupons are re-measured to see the difference in the before after (gr). The value that is presented in figure 2 is the results of our measurement which we take the average from all the soil.
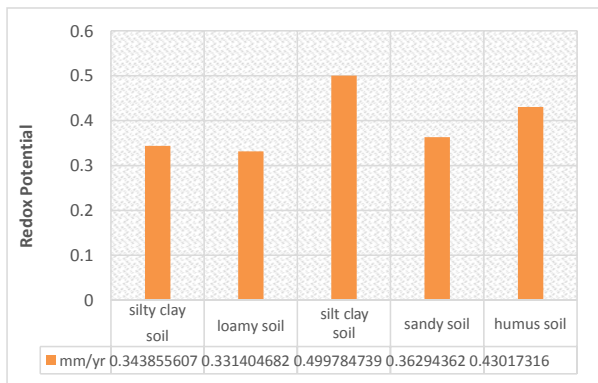

Figure 2: The rate of corrosion in a different type of soil.

Figure 2 shows the average rate of corrosion on coupon SA 383 that has been buried for 720 hours in the laboratory. Soil that contains water has a higher rate of corrosion comparing to the soil that has a loamy soil texture. Water as a good electron bridge to cross have a greater impact on the cause of corrosion in the coupon, whereas soil that is high act as an inhibitor for the electron to react with the coupon. According to the internal corrosion category research, the value of the corrosion rate is between 0.3 until 1 mm/year shows that this is on a midrange of corrosion (Fontana, 1986). The difference between rates of corrosion that happened to compare to the level of similarities in a soil can be viewed in figure 3.
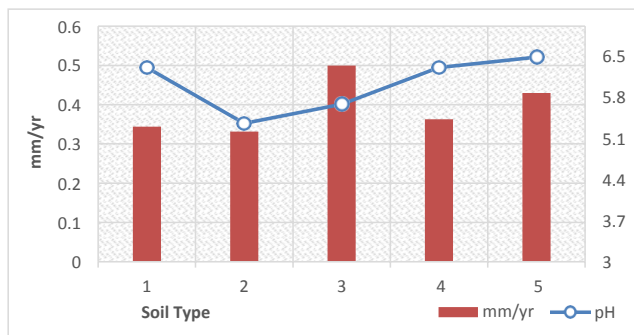

Figure 3: Correlation of corrosion rates and soil acidity (pH).

From figure 3 it can be concluded that the acidity level is not a dominant factor in the rate of corrosion that occurs. Lowest pH was 5.35 and only cause a rate of corrosion of 0.33 mm/yr. Meanwhile, pH 6.47 can cause until 0.43 mm/yr that's 0.1 mm/yr difference. According to literacy and previous research, similar content causes an effect on the rates of corrosion in a range below pH 4. The connection between rates of corrosion and redox potential can be seen in figure 4.
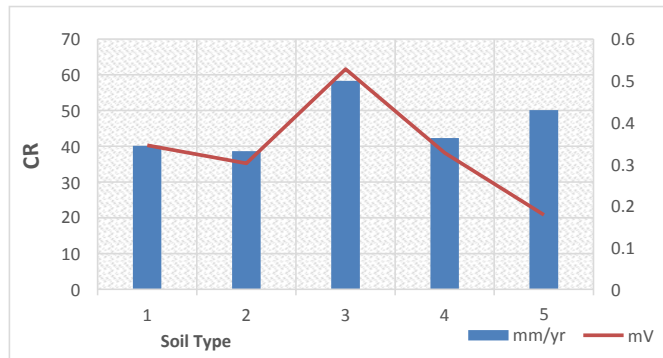

Figure 4: Correlation of corrosion rates with redox potential.

Figure 4 above shows a significant correlation between the rate of corrosion that occurs with the redox potential value of each type of soil. Biggest potential value is 61.6 mV is equal to the highest rate of corrosion which is 0.5 mm/yr on the silt clay soil that is wet. And the humus soil, the potential value is low, about 20.8 mV but has a high rate of corrosion which is 0.43 mm/yr which indicates there is an internal factor such as microbes which interfere with the test. Figure 5 shows the rates of corrosion compared to the humidity of the soil measured in the lab.
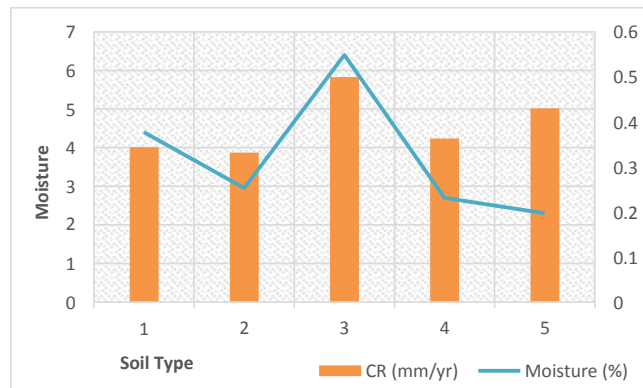

Figure 5: Correlation of corrosion rates with moisture.

Overall, the graph in figure 5 has a similar pattern to figure 4, where the highest soil moisture value of 6.4% occurs in wet soils containing silt clay. Soil texture like this is able to maintain its volume of water for a long time because of clay soil a small diameter of the particle which is 0.002 mm (Roberge, 2000).

4. CONCLUSION

The results show that in general, the corrosion products formed are influenced by the chemical properties of the soil. The highest corrosion rate occurs at Paloh Awe location with clay and wet soil types of 0.499 mm/yr. Where the soil at this location also indicates a high humidity level of 6.4% with a redox potential of 61.6 mV. Both of these chemical properties are a significant factor in the process of growth of corrosion rates in SA 283 material with a buried time of 720 hours. However, the corrosion rate level in the area was still needed for further research.

REFERENCES

Anyanwu, I., 2014. Experimental Investigations and Mathematical Modelling of Corrosion Growth Rate on Carbon Steel under the Influence of Soil pH and Resistivity. Research gate, 4, Pp. 7–18.

ASTM International, 1999. Standard Practice for Preparing Cleaning and Evaluating Corrosion Tes Significance, 90, Pp. 1–9.

ASTM International, 2003. Standard Specification for Low and Intermediate Tensile Strength Carbon Steel Plates, Pp. 3–5.

ASTM Norma G 51, 2000. Standard Test Method for Measuring pH of Soil for Use in Corrosion Testing, 95, pp. 7–9.

ASTM Norma G, 2004. Standard Practice for Conducting and Evaluating Laboratory Corrosions Tests, 99, Pp. 1–4.

Atanov, N., Gorshkalev, P., Chernosvitov, M., Smirnova, A., 2018. Pipelines corrosion during water supply process. IOP Conf. Series: Materials Science and Engineering, 365, Pp. 042073.

Biezma, M.V., Agudo, D., Barr´on, G., 2018. Fuzzy Logic method: Predicting pipeline external corrosion rate. International Journal of Pressure Vessels and Piping, 163, Pp. 55-62.

Fontana, M., 1986. Corrosion engineering. (New York: McGraw Hill)

He, B., Han, P.J., Hou, L.F., Lu, C., 2012. Role of typical soil particle-size distributions on the long-term corrosion behavior of pipeline steel. Materials and Corrosion, 67 (5), Pp. 471–483

Putra, R., Huzni, S., Muhammad, Fonna, S., 2018. Prediction of corrosion rate in SA 283 material affected by differences soil type in controlled environments. IOP Conference Series Materials Science and Engineering, 536, Pp. 012-010.

Roberge, P.R., 2000. Handbook of corrosion engineering (McGraw-Hill), Pp. 1-725.

Sing, L.K., Yahaya, N., Othman, S.R., Fariza, S.N., Noor, N.M., 2013. The Relationship between Soil Resistivity and Corrosion Growth in Tropical Region. Journal of corrosion science and engineering, 16, Pp. 1–11.

Thalib, S., Ikhsan, M., Fonna, S., Huzni, S., Ridha, S., 2018. Identification of corrosion product on medium carbon steel under the exposure of Banda Aceh's atmosphere. IOP Conf. Series: Materials Science and Engineering, 352, Pp. 012-004.

Velayudhan, T.K.M., Yameni, M.D., 2012. Quality of Work Life – A Study. IOP Conference Series: Materials Science and Engineering, 197 (36), Pp. 10–12.

Wang, W., Robert, D., Zhou, A., Li, C. 2018. Factors Affecting Corrosion of Buried Cast Iron Pipes. Journal of Materials in Civil Engineering, 30 (11), Pp. 1–12.

Wasim, M., Shoaib, S., Inamuddin, N.M., Asiri, A.M., 2018. Factors influencing corrosion of metal pipes in soils. Environmental Chemistry Letters, 16, Pp. 861–879.