P-ISSN : 2598-1277
E-ISSN : 2621-3966

JOURNAL OF GREEN SCIENCE AND TECHNOLOGY

THE EFFECT OF WATER RESISTIVITY ON THE CORROSION RATE OF STEEL PLATE IRRIGATION IN LABORATORY

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ABSTRACT

Corrosion is one of the processes of metal damage or degradation due to redox reactions between a metal and various substances in its environment that produce undesirable compounds. In the water one of the environmental parameters is water resistivity. By knowing the connection between water resistivity and corrosion rate, it is possible to monitor laboratory tests with water environments that have different levels of corrosiveness. Therefore, it is necessary to conduct an analysis to determine the effect of water resistivity on water corrosivity, understand the factors that influence the corrosion rate and calculate the corrosion rate of the irrigation gate steel plate on the water environment. This analysis uses a laboratory scale, analysis with talagasari irrigation water media, domestic wastewater, PDAM water and dead river estuary water. All water media used have a high level of corrosiveness. The factor that causes the low resistivity value is the large amount of inorganic minerals containing metal in the water so that at low resistivity values the corrosion rate increases. In the results of this laboratory analysis, it is proven that the more acidic the water medium, the faster the corrosion rate and the more alkaline the water medium, the slower the corrosion rate.

Keyword: *Corrosion, Corrosion Rate, Water Resistivity.*

I. INTRODUCTION

At this time it has been indicated that there are physical changes and even damage to water resources infrastructure caused by the effects of corrosion due to chemical, physical and biological processes in water. These indications have never been studied in depth, but theoretically can be stated as the impact of water pollution and even natural phenomena of the water environment capable of releasing substances that are corrosive to the water environment, especially to infrastructure.

The main problem that exists today is the identification of water sources that can be corrosive to water resource infrastructure, such as weirs, dams, sluice gates, irrigation canals and so on.

One of the environmental parameters in water is the resistivity of water. By knowing the relationship between water resistivity and corrosion rate, of course, laboratory test monitoring can be carried out with water environments that have different levels of corrosiveness. Therefore, it is necessary to know the relationship between the resistivity of water and the rate of corrosion that causes corrosion of metals.

II. LITERATURE REVIEW

2.1 Resistivity Value in Water Environment

The resistivity value is the value of the water's ability to inhibit electric current. The resistivity value is strongly influenced by the content of ions dissolved in the water. Ions dissolved in water have an influence on the chemical properties of water whether the water is acidic, basic, or neutral. The resistivity value of water is one of the important factors used as an indicator to assess the corrosivity of water. Low resistivity values can result in high levels of corrosivity.

Based on research, the greater the resistivity value of water, the water will tend to have better quality because it can be assumed to have a little organic and inorganic mineral content, so it tends to be better utilized than water with a lower resistivity value (Tambunan,2014). Table 1 is a table that can be used to predict the corrosivity of water with respect to the resistivity value of water qualitatively.

Table 1. Water Resistivity Value Based on Corrosion Level

Resistivity (Ω cm)	Corrosion Rate
>20,000	Basically non-corrosive
10,000 – 20,000	Mild corrosive
5,000 – 10,000	Medium corrosive
3,000 – 5,000	Corrosive
1,000 – 3,000	Very corrosive
<1,000	Once Corrosive

Source: (Kiswara,2009)

Measurement of the amount of soil/water resistivity can be calculated by 2 methods, namely by field testing using the Wenner Four Pin Method or testing in the laboratory using the Soil Box Resistivity Test (Kiswara,2009).

2.2 Corrosion

Corrosion is the degradation of a material due to the electrochemical reaction of the material with its environment (Bardal,2003).

Corrosion of metal occurs due to the flow of electric current from one part to another on the metal surface. This current flow will cause metal loss in the part where the current is released to the environment (oxidation or anode reaction). For this reason, protection is needed to avoid the occurrence of corrosion (Irwanto,2013).

2.3 Factors Affecting Corrosion Rate

1. Direct contact with H2O and O2

Corrosion on metal surfaces is a process that involves redox reactions. The reaction that occurs is a mini Voltaic cell. for example, corrosion of iron occurs in the presence of oxygen (O2) and water (H2O). The metallic iron atom (Fe) acts as the anode and the C atom as the cathode. Oxygen from the air dissolved in water will be reduced, while water itself serves as a medium where redox reactions take place in corrosion events. If the amount of O2 and H2O that is in contact with the metal surface is increasing, the faster corrosion will occur on the metal surface.

2. Temperature Factor

Increasing temperature generally increases the corrosion rate, although in fact the solubility of oxygen decreases with increasing temperature. If the metal is at a non-uniform temperature, it is likely that corrosion will form.

3. Metallurgy

a. Metal Surface

A rougher metal surface will cause a potential difference and have a tendency to become a corroded anode.

b. Galvanic Coupling Effect

The low purity of the metal indicates the number of atoms of other elements contained in the metal so that it triggers the galvanic coupling effect, namely the emergence of a potential difference on the metal surface due to the difference in E° (electrode potential) between atoms of different metal elements found on the surface. low purity metal. This effect triggers corrosion of the metal surface by increasing the oxidation reaction in the anode region.

c. Microbes

The presence of microbial colonies on metal surfaces can cause microbial colonies on metal surfaces to increase corrosion of metals.

d. pH factor

Neutral pH is 7, while pH < 7 is acidic and corrosive, while pH > 7 is alkaline as well as corrosive. But for iron, the corrosion rate is low at pH between 7 to 13. The corrosion rate will increase at pH < 7 and at pH > 13 (Sidiq,2013).

2.4 Corrosion Environment

There are several influences of the general corrosion environment, which are as follows:

a. Water environment. Water or moisture in small or large quantities will affect the corrosion rate of the metal.

b. Air environment. Temperature, relative humidity, abrasive particles, and aggressive ions contained in the ambient air greatly affect the corrosion rate.

c. Acidic, alkaline and salt environment. In the sea water environment, the concentration of NaCl or other types of salts will cause fast metal corrosion rates (Afriani,2014).

2.5 Corrosion Rate

Corrosion rate is the speed of propagation or the rate of deterioration of the quality of the material with time. To find the value of the corrosion rate, we use the weight loss method and the electrochemical method.

The weight loss method is to re-measure the initial weight of the test object (the object you want to know the corrosion rate that occurs to it), the less weight than the initial weight is the weight loss value (Ardianto,2017).

$$Corrosion\ Rate\ = \frac{((K\ X\ W))}{((A\ X\ T\ X\ D))} \qquad [1]$$

Where:
K = Constant = 3.45 x 106 (mpy)
W = Mass Loss (grams)
D = Density of specimen (g/cm³)
A = Specimen area (cm2)
T = Time required (hours)
(Priyatomo, 2013)

The electrochemical method is a method of measuring the corrosion rate by measuring the object's potential difference to obtain the corrosion rate that occurs, this method measures the corrosion rate at the time of measurement which estimates the rate with a certain time.

$$CR(mpy) = K\ \frac{ai}{nD} \qquad [2]$$

where :
Corrosion rate in mm/year or mmpy
a = atomic weight of metal corroded (grams/mol)
i = ikorr = current density (µA/cm2)
k = constant (0.129 for mpy units and 0.00327 for mmpy units)
n = number of electrons released on the corroded metal
D = density of corroded metal (gram/cm3)

Conversion:
1 mpy = 0.0254 mm/yr = 25.4µm/yr = 2.90 nm/yr = 0.805 pm/SG

2.6 pH (degree of acidity)

Neutral pH is 7, while pH < 7 is acidic and corrosive, while pH > 7 is alkaline as well as corrosive. But for iron, the corrosion rate is low at pH between 7 to 13. The corrosion rate will increase at pH < 7 and at pH > 13 (Sidiq,2013).
Based on PP no 82 of 2001 dated December 14, 2001 it is stated in article 8 paragraph 1 that the classification of water quality is set into 4 (four) classes, namely class one, class two, class three, and class four (Pristianto,2016).

2.7 Electrical Conductivity

The ability of water as a conductor of electricity is influenced by the number of ions or salts dissolved in the water. The more dissolved salt, the higher the electrical conductivity that occurs.

Table 2. Water Classification Based on DHL

Water Class	DHL (μmhos/cm)	Information
I	0-250	Very good
II	>250-750	Well
II	>750-2000	Good
IV	>2000-3000	Not good
V	>3000	Not suitable

Source: (Astuti,2014)

III. METHODOLOGY

This research was conducted in a laboratory by taking water samples from 4 places that pass through the irrigation area. the samples from Talagasari irrigation water, domestic wastewater, regional drinking water company and dead river Estuary water. After getting the four samples, then testing the laboratory with the procedure below :

1. Using Personal Protective Equipment (PPE)
2. Pour 150 ml of water into the 250 ml Beaker Glass.
3. Measuring and weighing Steel Plate.
4. Calibrate the pH Meter using a 7 and 10 . Buffer solution
5. Measuring the pH of water media using a pH Meter
6. Calibrate the Conductometer using 0.01M . KCL solution
7. Measuring Electrical Conductivity (DHL) of talagasari irrigation water media
8. Clean the Steel Plate using tap water.
9. Putting the Steel Plate into the Glass Beaker which has been filled with water media.

IV. RESULT AND DISCUSSION

4.1 Effect of Water Resistivity on Water Corrosivity

4.1.1 Resistivity Value Based on Corrosion Level

Resistivity values in water with various types of water obtained from laboratory test result are presented in Table 3.

Table 3. Result of DHL Value and Water Resistivity at SDA Bintek Laboratory

No	Sample	DHL (μmhos/cm)	Resistivity (Ω cm)	Level Corrosion
1	talagasari water	631	1584,786	Very Corrosion
2	Domestic Wastewater	520	1923,076	Very Corrosion
3	PDAM water	374	2673,796	Very Corrosion
4	Dead River Estuary Water	700	50.761	Corrosion Once

Each type of water has a different level of corrosiveness. In the result of this laboratory test, the type of water that has a low resistivity value is dead-end river estuary water, which has a resistivity value of50.761 cm, The factor that causes a small resistivity value is the large amount of inorganic minerals containing metals in the water. The result of the highest resistivity value in laboratory tests is PDAM water by producing a resistivity value of 2673,796 cm, The resistivity value is high because there are few inorganic minerals containing metals in the water.

If viewed from the theory of the influence of the DHL value with resistivity on the corrosion rate, the higher the DHL value, the lower the resistivity value and the faster the corrosion rate occurs. seen from Table 3 where the DHL value of PDAM water is lower than the DHL value of dead-end estuary water, then the resistivity value of estuary water is lower than PDAM water, as well as other water media.

From the result of laboratory tests based on Table 1 that 4 kinds of water are used as water media for this Final Assignment experiment, all of these water media include a corrosive water environment. It can be seen in Table 3 that the resistivity value is <1000 cm, then the result of the corrosion rate are very corrosion, it is proven in the laboratory test result that the resistivity value of the dead river estuary produces a resistivity <1000 cm, which is 50.761 cm and for water media that has a resistivity value of 1000-3000 cm, the result of the corrosion rate are very corrosion, which is very corrosion, it is proven that the result of laboratory tests for talagasari water media, domestic wastewater and PDAM water show the resistivity value is between 1000-3000 cm.

4.1.2 Effect of Water Resistivity on Ph

Table 4. pH Value Measurement Result at SDA Bintek Laboratory

Laboratory Test	Talagasari Water	Domestic Wastewater	PDAM water	Dead River Estuary Water
1	6.92	7.44	6,416	7.85
2	7.51	7,917	7.69	6,721
3	7,136	7.529	7,417	6,671
4	7.505	7,662	7,682	6.76
5	7,682	7,612	7.56	5,978
6	7.28	7.62	7.54	5,658
7	7.578	7.915	7,784	5.32
8	7.9	7,716	7.41	4,856
9	7,752	7.9	7,814	7.81
10	8.04	7,892	5.576	5.57

In the laboratory test result, the dead-end river estuary water, in the 8th data, decreased by 0.464, with the result of the reduction that the dead-end river estuary water was detected as more acidic and corrosive water with a pH <7, the decrease in pH was caused by an increase in corrosive iron deposits.

4.2 Factors Occurring Corrosion Rate

a. Water and humidity

Water also plays a role in the corrosion process. The more often the steel plate is exposed to water, the faster the steel plate will corrode.

b. pH factor

Based on the theory, the neutral pH is 7 while pH < 7 is acidic and corrosive while pH > 7 is alkaline as well as corrosive. But for iron, the corrosion rate is low at pH between 7 to 13. The corrosion rate will increase at pH < 7 and at pH > 13.

From the result of laboratory tests in Table 4 that the pH of dead-end estuary water tends to be acidic, compared to the pH of talagasari water, domestic wastewater and PDAM water, the corrosion rate occurs faster in the media of dead-end estuary water.

4.3 Measurement Result Data

After conducting the corrosion rate experiment, it has been analyzed in the form of data recap and tables. Measurement of dimensions, weight, and calculation of the corrosion rate according to the level of corrosion, the calculation of the corrosion rate using the formula for the weight loss method.

4.3.1. Corrosion Rate Results Data

Table 5. 1st Laboratory Test Data of Steel Plate at SDA Bintek Laboratory

Media Name	Talagasari Water	Domestic Wastewater	PDAM water	Dead River Estuary Water
Long (Inch)	1.9685	1.9685	1.9685	1.9685
Wide (Inch)	1.9685	1.9685	1.9685	1.9685
Thick (Inch)	0.0787	0.0787	0.0787	0.0787
Density (g/cm3)	7.85	7.85	7.85	7.85
Heavy Beginning (grams)	39.6128	42.3466	37.7956	40.0533
Heavy End (grams)	39.6050	42.3294	37.7797	40.0297
Time (hour)	96	96	96	96

4.3.2. Corrosion Rate Result Data for 1 Month

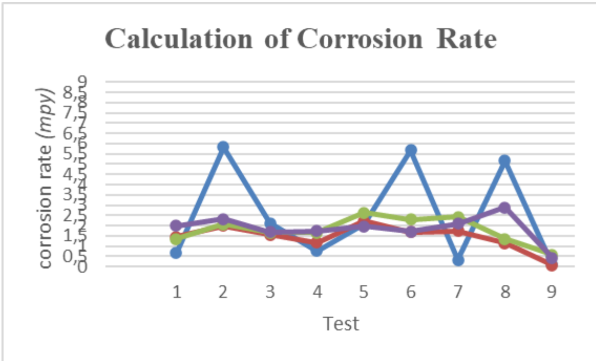

Figure 1. Calculation of Corrosion Rate at SDA Bintek Laboratory

4.3.3. Comparison Result of Corrosion Rate to pH

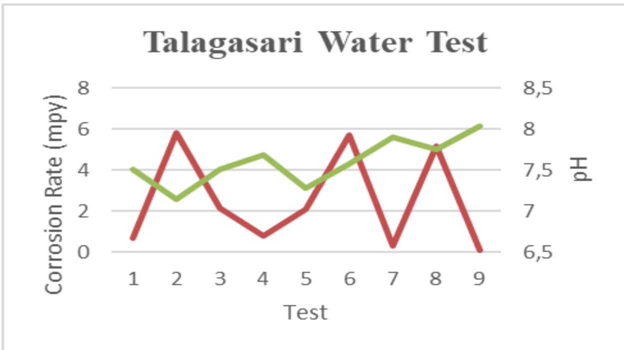

Figure 2. Talagasari Water Test at SDA Bintek Laboratory

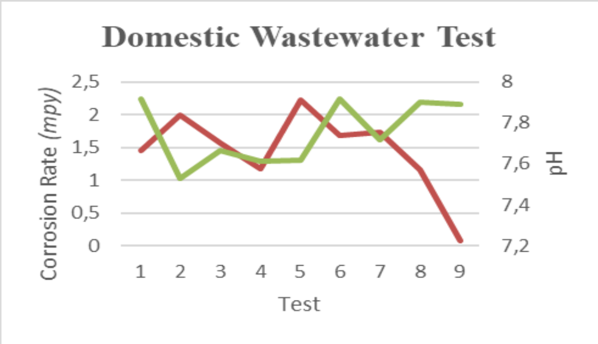

Figure 3. Domestic Wastewater Test at SDA Bintek Laboratory

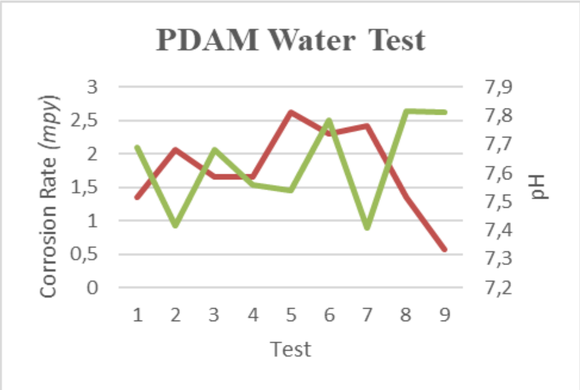

Figure 4. PDAM Water Test at SDA Bintek Laboratory

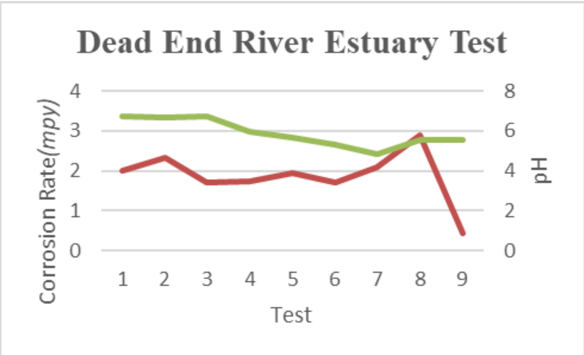

Figure 5. Dead End River Estuary Test at SDA Bintek Laboratory

V. CONCLUSION

The conclusion that can be drawn from this research are :

1. The type of water that has a low resistivity value is dead-end river estuary water, which has a resistivity value of 50.761 cm, the factor that causes the resistivity value to be small is the large amount of inorganic minerals containing metal in the water, therefore the corrosion rate is faster at low resistivity values.
2. In general, the corrosion rate is caused by the water environment and air humidity, another factor that affects the corrosion rate is pH.
3. The optimum value in the talagasari water media test is 0.0983 mpy with a pH of 8.04. The optimum value in the domestic wastewater test is 0.0678 mpy with a pH value of 7.892. The optimum value in the PDAM water media test is 0.5766 mpy with a pH value of 7.81. The optimum value in the media test of dead water estuary is 0.4409 mpy with a pH of 5.57. In the result of this laboratory test, it is proven that the more acidic the water medium, the faster the corrosion rate and the more alkaline the water medium, the slower the corrosion rate.

VI. REFERENCES

Afriani, Fitri et al. 2014. Cathodic Protection Sacrificial Anode Method To Control Corrosion Rate. Faculty of Engineering, University of Riau Vol.1 No.2

Ardianto, Pieter. 2017. The Effect of Coating Defects and Salinity Differences on Corrosion Rates in Splash Zone Areas Using A36 Steel Material. Ten Movember Institute of Technology. Surabaya.

Astuti, Arieyanti Dwi. 2014. Irrigation Water Quality in terms of DHL, TDS, pH Parameters in Rice Fields in Bulumanis Kidul Village, Margoyoso District. Starch

Bardal, Einar. 2003. Corrosion And Protection. London : Springer – Verlag.

Irwanto, Deddy et al. 2013. Corrosion Study on Pipes Using the Impressed Current Method at Petrochina International Jambi. Technology Dissemination Journal. Vol 1, No.2.

Kiswara, Reza. 2009. The Effect of Soil Resistivity on Steel Potential Measurement With Digital Multimeter and ATMega8353 Microcontroller. University of Indonesia.

Pristianto, Hendrik et al. 2016. Water Quality Management Practicum Module. Muhammadiyah University. push.

Priyatomo, Gadang. 2015. Practical Book of Corrosion and Metals for Students. Write Books

Sidiq, M. Fajar. 2013. Analysis of Corrosion and Its Control. Journal of Foundry Vol. 3 No. 1.

Tambunan, Walfred et al. 2014. Determination of Electrical Conductivity and Study of Water Quality of Siak River Using Wheatstone Bridge Method. Bina Widya Pekanbaru, Vol 1, No.2.