Corrosion Resistance of Pipe Materials Used in Water Distribution System

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Abstract: *This study investigates corrosion rate behaviors of stainless steel and galvanized iron in different acid, alkali and salt concentrations. All samples were prepared based on the testing specification requirement and the mass of specimen were obtained using electronic weighing balance of sensitivity 0.001g. To obtain corrosion rate, weight loss test was conducted and the samples were immersed in three different aqueous solutions which were hydrochloric acid sodium hydroxide and sodium chloride. Diameter of the material and height were obtained using divider and meter rule to calculate the area of the specimen. Result shows that in acidic solution, the percentage mass loss in ten days were 15.3(%) and 9.17(%) for galvanized iron and stainless steel respectively. For alkaline solution, the average mass loss for ten days were 7.41(%) and 3.79(%) for galvanized iron and stainless steel respectively. For salty solution, the average mass loss for ten days were 12(%) and 4.85(%) for galvanized iron and stainless steel respectively. The rate of corrosion determined from this experiment showed that stainless steel is not totally unaffected by corrosion.*

Keywords: *Corrosion resistance, galvanized iron. stainless steel, aqueous solution*

INTRODUCTION:

Choice of construction material for design of water distribution system is crucial in order to control corrosion. Another factor to be considered is cost because corrosion-resistant materials are less economical in terms of procurement and installation. (Weber , 2004). Over the years before World War II, black iron pipe was predominately used in water system. Later on, galvanized steel was adopted in place of black iron because of its zinc coating which serves as a protection against corrosion of the underlying steel. This help to extend the useful life of piping system. The rate of corrosion of both steel and iron are steady within a pH range of 4.5 to 8.5. For galvanized pipe, the zinc coating is steady within 6.5 to 12 but corrodes faster at a pH value that is less than 6.5 (Banov,2014). Water quality that is to be transported through a pipe system is a factor in determining the proper material of construction. Soft and de-mineralized water are seen to be corrosive and so demands a pipe material that is more corrosion-resistant stainless steel and plastics. However, water that contains high chlorides and low oxygen concentrations increase pitting corrosion in stainless steel. Concentration of dissolved gases is a major contributor of corrosion in most metals. For instance, the higher the concentration of dissolved oxygen, the higher the corrosion rate of iron and steel. However, oxygen is required to establish and maintain a defensive corrosion limit on stainless steel and galvanized steel (Snyder, et al; 2002). Engineers generally turn to stainless steel which is perceived as a corrosion-resistant material, whenever they want to transport high quality water. Nevertheless, stainless steel is not totally exempted from corrosion attack. The name simply implies, that it just “stains less.” Rouge discoloration on the steel surface, corrodes in the presence of heat and chlorides (pitting corrosion) and difficult to weld are some limitation of stainless steel (Kruger, 2000). According to American Water Works Association Research Foundation (AWWARF) (1996), damage cause each year by corrosion of water distribution systems causes billions of dollars bills. Some people are of the opinion that corrosion of pipe is as a result of attack by water. Others believe that corrosion is caused by use of unsuitable construction materials in aqua environment. Water distribution is a fundamental facility for water supply system which has been a huge challenge in terms of its safety from pathogens. Corrosion has a destructive effect both to the metal and can cause failure in water facilities (Fontana,1987). Three distinct problems of corrosion includes: mass lost of pipe materials, head loss and reduction in volume of water and colour change in water at faucet. This study aims at evaluating the resistances offered by pipe materials used in construction of water distribution system.

METHODS:

Preparation of Galvanized iron and stainless steel pipes

Galvanized iron and stainless steel pipes were mechanically cut into cylindrical shape of 1.2cm and 2.4cm in diameter and 0.3cm and 0.1cm in heights respectively. The specimens were cleaned thoroughly to remove any grease. Weight of the samples was taken before and after the test.

Preparation of aqueous solution

100ml of distilled water was poured into clean beakers after which 4g, 8g, 12g, 16g, 20g of hydrogen chloride was added to obtain 1M, 2M, 3M, 4M and 5M. The aqueous solution was poured into two sets of different containers labeled AG1, AG2, AG3, AG4, AG5 and AS1, AS2, AS3, AS4, AS5 for testing galvanized iron and stainless steel respectively. The pH readings in the acidic solution were in ranges of 6.7, 6.4, 6.0, and 5.7.

Another set of pH reading in the ranges of 7.5, 7.8, 8.0 and 8.2. in alkaline solution by dissolving 10g, 20g, 30g, 40g and 50g sodium hydroxide in 250ml of water. The following concentrations 1M, 2M, 3M, 4M and 5M were obtained. The aqueous solution was poured into two sets of different containers labeled BG1, BG2, BG3, BG4, BG5 and BS1, BS2, BS3, BS4, BS5 for testing galvanized iron and stainless steel respectively.

Sodium chloride solutions were made by dissolving 10g, 20g, 30g, 40g and 50g mass of sodium chloride in 1000ml of water and poured in different containers for testing galvanized iron and stainless steel

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Corrosive Rate by weight loss method

The specimens' initial weights were measured and immersed in the aqueous solutions for ten days. After 24hours,the specimens were taken out, washed thoroughly with distilled water, dried completely and their final weights were noted. From the initial and final weights of the specimen, the loss in weight was calculated Then, the corrosion rate (mpy) was calculated using the equation:

$$\text{Corrosive rate (mm/y)} = \frac{87.6*W}{A*D*T} \qquad (1)$$

Where:

W = weight loss in milligrams

T = time of exposure of the metal sample in hours

D = metal density in g /cm^3

A = area of sample in cm^2

RESULTS:

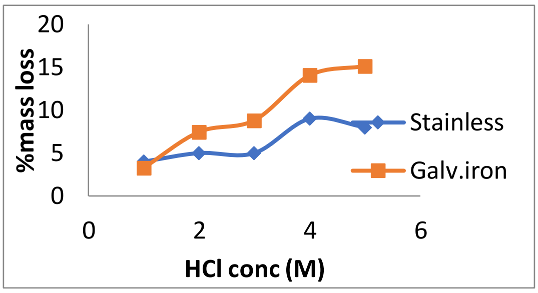

Fig.1: percentage mass loss of galvanized and stainless steel material in acidic concentrations

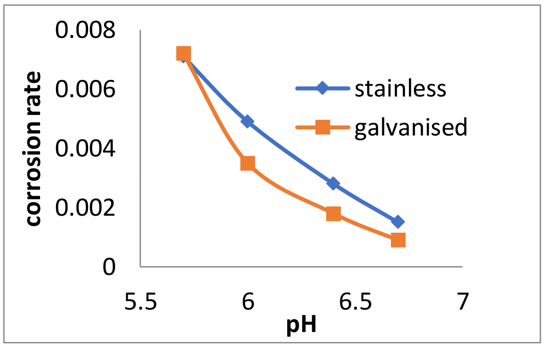

Fig 2: corrosion rate of stainless steel and galvanized iron with pH

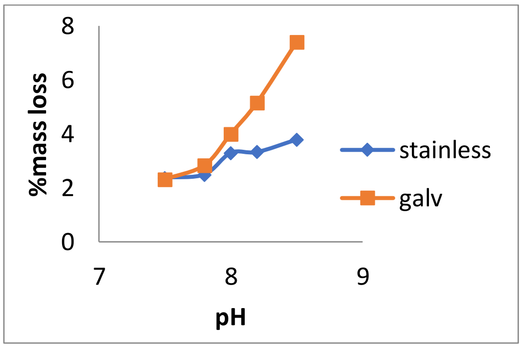

Fig.3: percentage mass loss of galvanized and stainless steel material in pH values

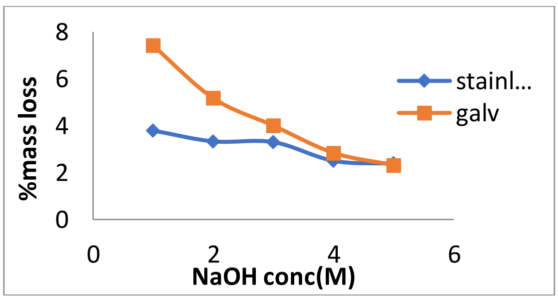

Fig 4: percentage mass loss of galvanized iron and stainless steel material in alkali concentrations

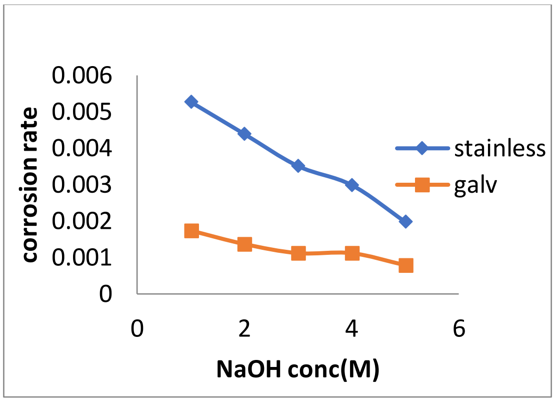

Fig 5: percentage mass loss of galvanized iron and stainless steel material in alkali concentrations

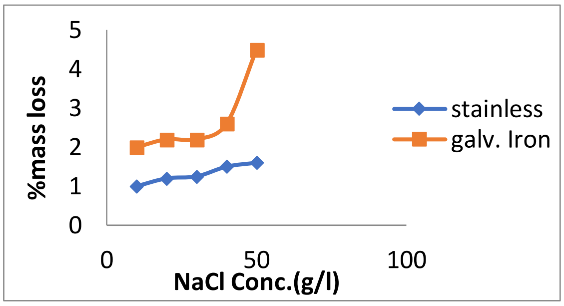

Fig 6: percentage mass loss of galvanized and stainless steel material in NaCl concentrations

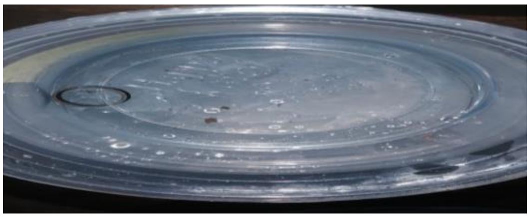

Plate 1: stainless steel in acidic container after ten days

Plate 2: galvanized iron in a acid container after ten days

DISCUSSION & CONCLUSIONS:

Discussion:

Figure 1 shows that the percentage mass loss is increasing in both pipe materials with increase in concentration of acid. It can be deduced also that galvanized iron mass loss is higher than stainless steel in the acidic solution. Percentage mass loss in galvanized iron increases in the increasing order of 3.28%, 7.46%, 8.82%, 14.06% and 15.3%, as concentration of acid increases from 1M, 2M, 3M, 4M, and 5M. Stainless steel on the other hand, increases from 2.94%, 5%, 6.23% 6.92% and 9.17%.

Figure 2, indicates a near-linear decrease in corrosion rate with increasing pH in both materials. Corrosion rate however decreases more slowly for stainless steel than galvanized iron.
Mass loss is generally found to increase with increasing pH in the range 7 to 8.5 for both stainless steel and galvanized iron as shown in figure 3.

In Figure 4 and 5, increase in alkalinity leads to lower mass loss and corrosion rate in the two pipe materials. Percentage loss decreases from 7.41%, 5.17%, 4%, 2.84% and 2.32%. Stainless on the other hand decreases from 3.79%. 3.33%, 3.3%, 2.5%, and 2.38% as the concentration increases.

From figure 6 it can be observed that galvanized iron corrodes faster in salty solution than alkali solution. Percentage mass loss in galvanized iron varies from 2.27%, 4.92%, 5.12%, 6% 12% as sodium chloride (NaCl) concentration increases. Also, stainless steel corrodes faster in NaCl solution than NaOH solution. Percentage mass loss in stainless steel varies from 2.7%, 2.87%, 4%, 4.29% and 4.85% as the concentration of NaCl increases.

Plates 1 and 2 reveal colour changes in the aqueous solutions. It can be seen from plate 1 that the colour of the solution changed to deep blue while the colour in plate 2 changes to reddish-brown. There was also presence of metal particles in the solution which shows that corrosion took place after ten days

Conclusion:

This implies that solution that contains elevated levels of chloride cause rapid corrosion on galvanized iron and stainless steel material when used in water distribution. The corrosion may be attributed to mechanical removal of zinc coating on galvanized iron by aqueous solution. Stainless steel on the other hand, are designed with low carbon content containing microalloying elements (chromium and nickel) which remains uncombined in the ferrite thereby enhancing corrosion resistance of stainless steel. This study shows that aqueous solution increases the corrosion rate of both galvanized steel and stainless steel. It can be observed also that mass loss of both pipe materials in alkali solution is less compare to mass loss in acidic solution.

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