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Study of Corrosion of Ferrous and Non-Ferrous Metals in Aqueous Medium

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Abstract

Metals, like ferrous and non-ferrous, interact on their interface to develop corrosion cells. The aqueous medium produces a hostile environment due to the availability of dissolved oxygen, acids, bases, salts, bio-waste, and effluents. The solubility of acidic gases oxide of carbon, oxide of nitrogen, and oxide of sculpture create an acidic medium for metal. These unfriendly environments accelerate corrosion reactions and metals exhibit uniform, galvanic, pitting, crevice, stress, and lynching corrosion. The other factors responsible for aqueous corrosion are the composition of dissolved pollutants, pH, temperature, conductivity, concentration of corrosive substances, and degree of oxygenation, micro and macro-organisms. Such an ambient corrosive atmosphere alters the physical, chemical, and mechanical properties of metals. They can change the interfacial appearance of metals. The above-mentioned corrosive medium produces their impact on production, equipment repair, accidents, and economic growth. The author needs to distinguish the difference between experimental and review manuscripts, the abstract did not point out whether the manuscript is a review manuscript or an experimental manuscript, therefore clear distinction is needed. The abstract did not provide any contribution to the body of knowledge, rather it stated the obvious existing theory of corrosion which can ordinarily be applied in the introduction session of the manuscript with relevant references.

Keywords: Ferrous metals, non-ferrous metals, aqueous medium, macro-organism, micro-organism

INTRODUCTION

Corrosion is a major problem with ferrous and non-ferrous metals [1]. Industries spend huge money on corrosion protection [2]. The rivers [3], ponds [4], and lakes [5] are contaminated by the discharge of chemicals [6], domestic sewage [7], industrial waste [8], human waste [9], and other activities. These sources pollute water [10] enhance the concentration of acids and decrease the concentration of oxygen thus a hostile environment generates metals [11]. It produces corroding effects. Coal mining industries [12] release the bulk amount of water in rivers which is acidic in nature to change the pH of water [13]. Oxygen deficiency [14] occurs in contamination, so it develops a corrosive environment for metals [15]. The variation in temperature [16] of water generates a corrosive medium [17]. Acid rain [18] alters the pH values of water and is responsible for corrosion. The ferrous and non-ferrous metals [19] are engineering materials. Water uses in the fields of construction and infrastructure [20] development work. The contaminated water produces chemical, electrochemical, and biochemical reactions [21] with building block materials [22] thus they undergo a process of chemical and electrochemical corrosion reaction. Corrosion reaction dismantles the binding forces of building block components.

The introduction did not provide any existing literature on work done in studying the corrosion of ferrous and non-ferrous metals in aqueous medium.

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The author needs to reference existing research or similar research done in this area and identify the gap and reason for the study.

METHODOLOGY

It is essential to analyze the composition of ferrous and non-ferrous metals before using. The used metals get proper design and shape during dipping into water. Metal corrosion rates can be determined by various sources of body water. Study the nature of water use in the construction of buildings. It is necessary to measure pH, concentration of oxygen and temperature of used water. It is tried to remove other harmful corrosive substances. It produces dissolving and swelling corrosion. The corrosion rate was calculated by gravimetric technique. A potentiostat is used to determine electrochemical corrosion.

What are the names of the study metals and non-metals under investigation and how they were subjected to corrosion tests, how many, seconds, minutes, days, months, or years were these monitored? The equipment used to carry out the test.

RESULTS AND DISCUSSION

- *Corrosive Environment in Aqueous Medium:* Factors involved in the corrosion of ferrous and non-ferrous metals in aqueous media which are concerned with effluents, pollutants, pH, temperature, conductivity, concentration of corrosive substances, concentration of oxygenation, micro and macro-organism and various types of wastes. The formation of corrosion cell in aqueous medium is written as:

$$M|M^{n+} \,||\, H^{+}|H_2 \qquad (1)$$

$$M|M^{n+} \,||\, O_2|OH^{-} \qquad (2)$$

$$M|Mn^{+} \,||\, O_2|H_2O \qquad (3)$$

The cell formation produces a corrosion reaction thus metals exhibit galvanic, pitting, stress, crevice, cavity, erosion corrosion, etc.

Ferrous and non-ferrous metals, like Fe, Al, Cu, Pb, and Zn, corrode in acidic and alkaline mediums when the pH of the aqueous medium is less than 6 or more than 12 and their dissolution is observed in Figure 1.

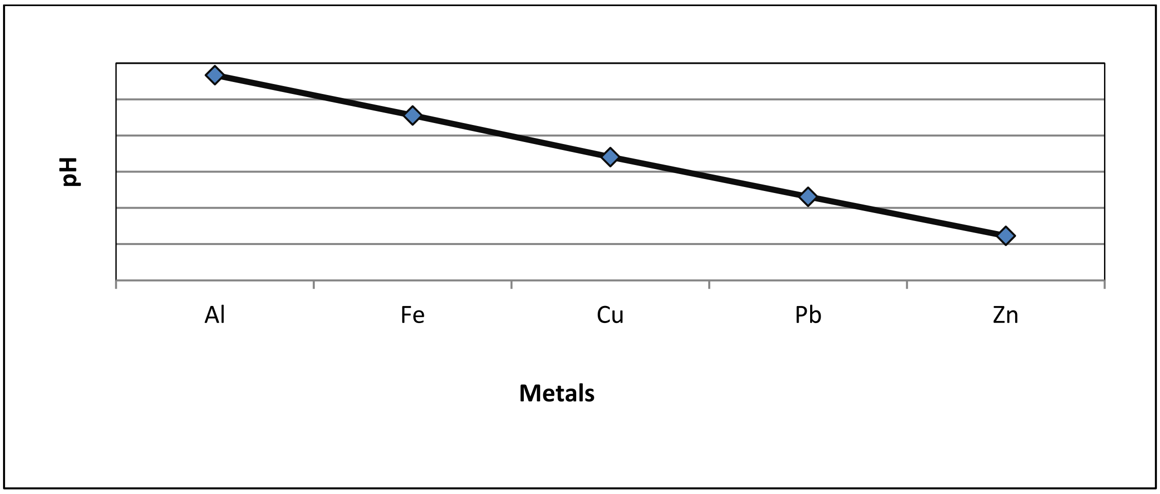

Figure 1. Corrosion of metals in low and high pH.

Iron corrodes in the acid medium under pH 4, more slowly up to pH 9, and not at all above pH 9.5 as shown in Figure 2. Copper is dissolved in acids under oxidizing conditions.

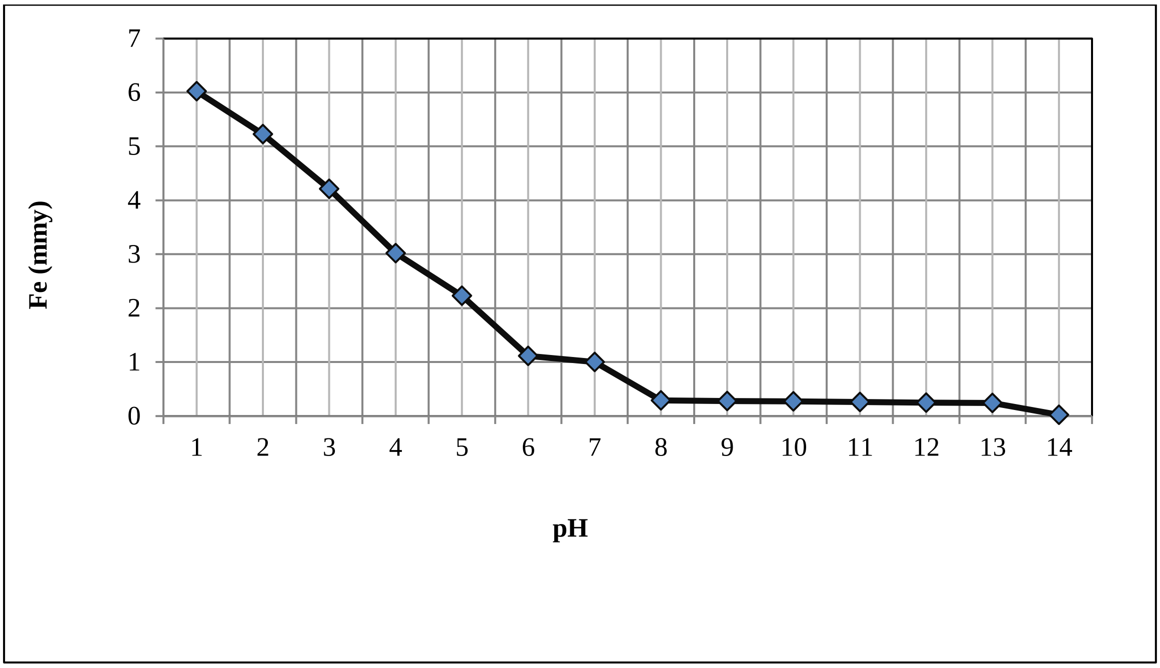

Figure 2. Corrosion of Fe in different pH values**.**

- *Water Sources:* The availability of water, can be divided into two parts surface water and groundwater. Surface waters are soft and mild salty because their source is rainwater and molten snow. The groundwater contains dissolved oxygen and carbon dioxide because it is passed through silicate rocks, granite, gneiss, and low lime mica. Groundwater extracts salt from the soil when its path is reemerged from the surface. Dissolved carbon dioxide in water reacts with calcium and magnesium carbonates to form calcium and magnesium bicarbonates which are cause of temporary bicarbonate hardness. The salts of sulfates and nitrates are present in water. Groundwater is harder with respect to surface water because it contains less dissolved carbon dioxide and oxygen. Tap water is slightly hard and its contents have oxygen and carbon dioxide. These three factors govern the corrosion processes in the installation of pillars of bridges and pipelines. Additional factors are responsible for corrosion like pH, velocity of flow, buffer capacity, and other impurities.

Oxygen is the most important corrosive component for iron and copper. It oxidizes these metals directly and stimulates electrochemical corrosion. Soft waters have dissolved oxygen and carbon dioxide to produce a strongly corrosive medium. Soft water has a total hardness of less than 3 milliequivalents/liters which does not contain oxygen or carbon dioxide but it behaves unfavorably because they do not form any protective layers. If they form a thin or uneven protective barrier, corrosion cells can form and cause corrosion. The formation of a protective barrier is disturbed by the presence of small quantities of chloride in soft water. The interaction of tap water with various building materials is expressed below.

Aluminum forms a protective barrier of aluminum oxide and hydroxide. The protective barrier strength depends upon pH, velocity of flow, and temperature of the water.

Lead is passive to water which has an average or high degree of hardness (minimum hardness 2.9 milliequivalents/liter) due to the absence of carbonic acid. A protective layer of lead and calcium carbonate is developed. Soft waters containing carbonic acid do not provide a protective layer, so corrosion occurs on the interface. As dissolved lead solutions are poisonous, lead piping is totally unsuitable for the supply of drinking water.

Water equilibrium can be stabilized by lime and carbonic acid. There is sufficient carbon dioxide in the solution to stabilize the carbonate. The equilibrium occurs between dissolved calcium bicarbonate and carbonic acid and sparingly soluble calcium carbonate.

$$CaCO_3 + H_2CO_3 \rightarrow Ca\,(HCO_3)_2 + H_2O \quad (4)$$

If the minimum hardness is 2.2 milliequivalents/liter, waters form layers of mixed lime and rust that work as a safeguard for steel piping against further corrosion. When water contains an excess amount of carbonic acid to mitigate the formation of protective layers, the presence of oxygen stimulates corrosion in unprotected steel.

The above-mentioned conditions are somewhat favorable with zinc. The excess of carbonic acid develops a protective layer of zinc hydroxide and carbonate. Galvanized steel pipes offer electrochemical protection in any corrosion that less noble zinc goes into solution first. When temperature increases the corrosion also enhances because the lime-carbonic acid equilibrium is shifted to the left so that sparingly soluble calcium carbonate precipitates thus free carbonic acid concentration increases correspondingly. There is subsequent cooling by the circulation of warm water and hot water appliances. Equilibrium is not regained but an excess of carbonic acid remains in such a condition corrosion can take place. It depicts the corrosion of carbon steel (0.15%) in water at 60^0C as a function of the oxygen and carbonic acid dissolved in the water.

Temperature plays an important role in zinc corrosion. Zinc is dissolved in distilled water at about 70°C. The main reason for this is probably that the corrosion products produced within this temperature range are in the form of loose scales and do not adhere in contrast to the situation at lower and higher temperatures when strongly adherent protective layers are formed. Galvanized coating provides protection at about 70°C. The protective layer is damaged to produce pitting corrosion since a destructive attack takes place in this way. Zinc is suitable for warm water and hot water piping, where temperatures are above 60°C, coating the nature of the water. A zinc layer of about 350 g/m^2 is sufficient for pipelines that carry water of average composition.

Plants are heated with circulating water which contains oxygen in water to form protective layers. After short periods of operation, the heated water is stripped of oxygen and in consequence, there is no further danger of corrosion. However, oxygen is supplied too frequently, e.g., by changing or supplementing the heating water when there are leaks or when pumps are defective corrosion damage can be expected. Oxygen is the main cause for corrosion and other impurities in the water are of very slight consequence in comparison.

Traces amount of copper present in steel and zinc piping accelerate pitting corrosion when the protective layers are not very dense. Due to this reason, copper pipelines should only be laid downstream of steel or galvanized steel piping. Cement and mortar resist corrosion of cast iron piping and steel pipes.

Copper is a good construction material for cold and warm water piping. Copper oxide is used for coating copper pipes. Later it changes into basic copper carbonate and copper hydroxide chloride (patina). It takes place when the water possesses at least average hardness and oxygen. Pitting corrosion can be noticed in cold water piping during the first three years of operation. It does not occur very frequently. Soft water contains carbonic acid to produce hindrance for the formation of a protective layer, so it creates direct corrosion. Irregular and perforated coating is the cause of pitting corrosion. However, copper piping is found to be in good condition, and the concentration of chloride is more than

100 mg/liter. In addition, other impurities, like soldering flux or grains of rust, can induce pitting corrosion. Very high oxygen concentrations in the water and internal stress within the copper due to cold forming also favor corrosion. Clean and smooth copper surfaces offer the least corroding effect. Waters have ammonia and nitric acid attack copper. Brass is somewhat more troublesome because of its tendency to dezincification in the presence of chloride when the zinc content is 15–30%. The corrosion rate of brass is usually between 0.07 and 0.7 mm/year.

Corrosion of Metals in River Water

Pure river water compares with tap water. The degree of purity is found in drinking water and effluent water. For this reason, one cannot expect any uniform aggressive properties. It shows that the aggressive properties depend on the concentration of impurities present. It is a rough approximation that unalloyed steel corrodes in river water at an average rate of about 0.01 mm/year.

Corrosion of Metals in Seawater

The Atlantic and Pacific Oceans have 3.36% salt content due to this fast rate of corrosive attack would be expected. Zinc produces good protection against corrosion because coating layers are formed on its surface by magnesium and calcium salts. A hot dipped in zinc with an average zinc coating layer of 9240 g/m^2 showed no appreciable rust damage after 7 years of use in seawater. Similar observations were made with other zinc-coated parts. An additional treatment with adherent paint coatings increases the life of the structure quite appreciably.

- Pure aluminum is corroded in seawater, but it alloys with Mg. Si and Mn produce corrosion resistance in seawater.
- Seawater shows resistance with copper alloys like copper-nickel-iron alloys, copper-zinc-aluminum alloys and copper-zinc-tin alloys. Pure copper exhibits good corrosion resistance.
- Unalloyed steel has no corrosion resistance properties in natural seawater. Seawater rust creates very strong corrosion inducing. It is expected that the corrosion rate is about 0.12 mm/year. But austenitic chromium-nickel-molybdenum steel has good corrosion resistance capacity in seawater well. Although one cannot guarantee that no pitting corrosion will ever take place with austenitic chromium-nickel-molybdenum steels, chromium-nickel steels are certainly more likely to exhibit such damage.
- Under the long-term action of seawater the iron in gray cast iron is dissolved out of the basic structure. The graphite framework which remains has little strength. Nickel-alloyed cast iron (15-30% nickel) behaves very much better as can be mentioned in Table 1 and Figure 3.

Table 1. The corrosion rate of iron in aqueous medium.

Iron	Corrosion Rate (mmpy)
Unalloyed steel [Fe (Ni)]	0.331
Unalloyed cast iron [Fe (CU)]	0.223
Nickel alloy cast iron [Fe (SUA)]	0.182

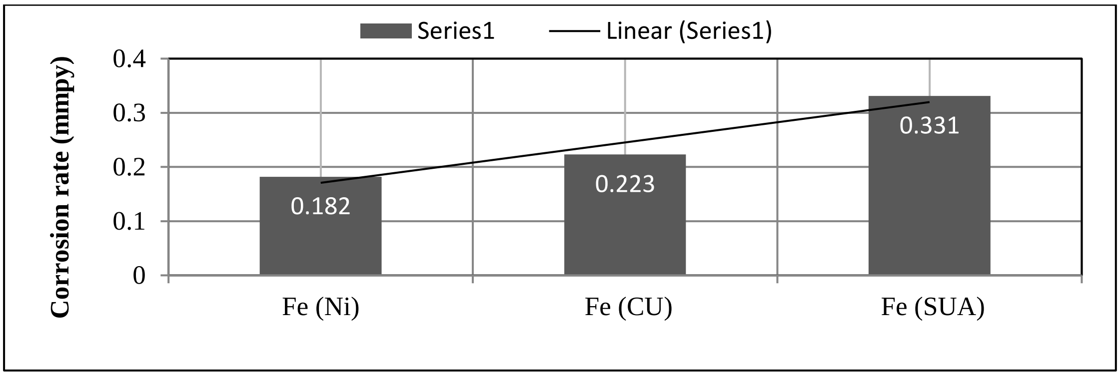

Figure 3. Corrosion rate of Fe in form alloy and unalloyed.

CONCLUSIONS

Ferrous and non-ferrous metals corrode in different sources of water. They create hostile environmental materials. The water sources are contaminated by various unwanted substances like industrial wastes, effluents, human waste, agricultural wastes, household waste, bio-waste, and other types of waste. They can change the pH of water and accelerate the corrosion of materials. The enhancement of temperatures is also a major cause of the corrosion of materials. The concentration of oxygen decreases in water to increase its corrosive character. Salty water develops a corrosive environment for metals. Metal can be protected using cathodic and anodic methods.

In conclusion, the manuscript is not the same as classroom homework. You need to do a major work in distinguishing whether it is a review paper or experimental work. Either way, you need to provide accurate data and focus on discussing the problem you are trying to solve and not necessarily providing general corrosion data information that is open to the public.

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