

EFFECT OF INDUSTRIAL ACTIVITIES ON THE CONCENTRATION OF CORROSION PRODUCTS OF MILD STEEL BURIED IN CLAY SOIL

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ABSTRACT

The effect of Industrial activities on the concentration of anionic contaminants in corrosion products of mild steel buried in clay soils was assessed, and the presence of Cl^- , SO_4^{2-} , HCO_3^- , and CO_3^{2-} ions increased with increase in concentration of the corrodents, with SO_4^{2-} and CO_3^{2-} ions having the highest concentrations as 39.345 and 34.121ppm, respectively and it was observed that where the anodic reaction products build up, a limited amount of Cl^- , SO_4^{2-} , CO_3^{2-} or HCO_3^- ions also move up into the formed oxide or hydroxide films, more so, the presence of CO_3^{2-} and HCO_3^- ions in the corrosion products stifles the corrosion process.

Keywords: Effect, Concentration, Corrosion, Mild Steel, Clay Soil

INTRODUCTION

Soils have a wide range of compositions and sensitivity to corrosion, whose variables comprise moisture, oxygen, salinity, alkalinity and acidity as well as various bacterial forms. High moisture content, high conductivity, high acidity and high solvents, especially chlorides and sulphates, are the most corrosive (Industrial Galvanizers Corporation, 2003). Moisture that contains dissolved oxygen is the primary corrosive substance, but other agents, comprising dissolved oxides of sulphate compounds (SO_x), sodium chloride (NaCl) and carbon oxide compounds (CO_x), may also be affected. Diluted sulphuric acid solutions in industrial environments can also lead to corrosion.

Marine environments are highly corrosive due to sodium chloride (NaCl). The water environment has a diversity of texture and corrosion properties. Fresh water usually contains dissolved oxygen as well as other minerals, many of which are hardened. Sea water contains about 3.5% of salt (mainly NaCl) as well as a few other minerals and organic substances and therefore it is more corrosive than fresh water and often produces stinging and corrosion. Cast iron, steel, aluminum, copper, brass and other stainless steel are commonly used for fresh water, while titanium, brass, other bronze, copper nickel alloys and nickel-chromium molybdenum alloys are highly corrosion-resistant in seawater.

All metals are unstable, and their instability is due to their tendency to revert to their original native state when in any reactive environment. Thus, in acidic, alkaline or neutral environment metals will react – this is the foundation of corrosion. Corrosion quickly occurs in acidic environments and gradually or not at all when alkaline is added (Davies, 2000; Industrial Galvanizers Corporation, 2003). The reaction of metals in the environment is related to the movement of electrons and is classified as an electrochemical reaction. The ability to lose electrons varies from metal to metal and the greater the readiness the more reactive or corrosive is the metal. Formed corrosion products, or oxides, are usually insoluble and form a protective skin on the metal surface. In general, corrosion is an oxidation- reduction reaction involving an electron gain or loss (Ferreira et al., 2007; Terence, 2019).

In the presence of various metals conducting fluid, known as the electrolyte, the electric potential is generated which causes the current to flow when there is a suitable path. Such electrical potential can also be developed between two regions of a single component made of metal due to small variations in structure or differences in metal surface exposure conditions (Davies, 2000). The corroding area which is the section of metal element is known as “anode” and the one acting on the other disk of the battery is called "cathode" and it is not corrosive but is an integral part of the system.

MATERIALS AND METHODS

Mild steel pieces with dimensions 2.5 x 2.5 x 0.4cm were cut out with a lathe machine in the Science and Engineering Workshop of the University of Port Harcourt. A hole of 2.5mm in diameter was bored at one end of each of the mild steel coupons.

Each of the mild steel coupons was then fastened to long copper wires through the hole with the aid of araldite. The surface of the specimens was polished using No. 120 grade abrasive paper. This is to ensure a smooth and clean surface, free of existing corrosion products. This was followed by greasing to prevent the surfaces of the metals to get corroded before weighing, and before the experiment proper. The specimens are first degreased by immersing them in a 0.3M acetone solution for 5 minutes; they were cleaned, dried and then weighed to note the initial weights. They were then buried in clay soil at Eastern bypass, an Industrial area for eight months. The weight of the specimens at the eight month was determined before and after the removal of the corrosion products.

The metal specimens were immersed in 100ml of distilled water and boiled for about 5 minutes, which was followed by gently scrubbing with a brittle brush until a clean metal surface was observed. The metal (specimen) was then removed, while the resultant products were further treated for further analysis. The resulting solution from above is further heated for 5 minutes, and then 3ml of concentrated nitric acid was added and heated for another 5 minutes to dissolve most of the insoluble products. The resulting solution was then filtered and transferred into a 200ml volumetric flask and made up to the mark with distilled water.

Concentrations of anionic contaminants in corrosion products of mild steel was determined using the following corrodents; 0.46M sodium hydroxide, 0.46M sodium chloride, 0.46M sodium sulphate, 0.46M sodium carbonate, 0.46M sodium carbonate, 0.06M magnesium chloride, 0.06M magnesium sulphate, 0.01M calcium chloride, 0.01M calcium bicarbonate and

0.1M potassium chloride solutions, respectively.

(a) Test for chloride ions

Titrimetric method was used in determining the chloride ion concentration in the corrosion products. This was done by measuring 50ml each of a sample solution and a blank solution (a solution similar in all respect to the sample solution except the corrosion products), into separate 250ml conical flasks. 5ml each of 40g/L sodium hydroxide solution is added into the flasks, followed by the addition of 1ml of potassium chromate indicator. The result of solution mixtures were then titrated against 0.025N silver nitrate solution to a brick red end point.

Calculation

$$\text{Chloride ion concentration (ppm)} = \frac{(A - B)N \times 71 \times 100}{V}$$

Where, A = sample titre value (ml)
 B = blank titre value (ml)
 N = Normality of titrant
 (0.025N AgNO₃)
 V = Volume of sample used
 71 = Equivalent weight of Cl⁻
 1000 = Conversion factor

(b) Test for sulphate ions

The turbidimetric method was used to determine the sulphate ion concentration. First a calibration curve was prepared using a standard potassium sulphate solution (this was already computed in the instrument). 50ml of the sample was measured into a 100ml volumetric flask, this was followed by the addition of 5ml of sodium chloride, and then 10ml of glycerin solution (1:2

mixture of glycerol and ethanol), and then 0.3g of barium chloride salt. The resultant mixture is allowed to stand for 5 minutes to develop a white turbid solution. It was properly shaken and then, the absorbance of the solution at 420nm was measured using a 5mm cell against a blank solution. The instrument gives the concentration of sulphate ions in ppm (parts per million).

(c) Test for carbonates and bicarbonate

50ml of the sample was measured into a 250ml conical flask, which was followed by the addition of two drops of phenolphthalein indicator. The resultant solution is titrated with 0.1N hydrochloric acid. The volume of the acid used at the end point, correspond to half the volume of carbonate present in the system. Another 50ml aliquot of the sample solution is then titrated with the same standard acid, but using bromophenol blue indicator. The titre value here corresponds to total carbonate + bicarbonates present in the system.

Calculation:

Let titre value for first titration be A,
 Volume of carbonates present = 2A
 Let titre value for bromophenol blue titration be B,
 Volume of bicarbonate = B - 2A
 Using the relationship,
 Concentration (ppm) = $\frac{AN}{B} (1000)$

Where, A = volume of titrant (ml)
 B = volume of sample used (ml)
 N = normality of titrant (N)
 The titration was carried out using an automatic titrator. All calculations and results are done by the instrument.

RESULTS AND DISCUSSION

The results of the concentration of anionic contaminants in mild steel corrosion products are as shown below. The presence of Cl^- , SO_4^{2-} , HCO_3^- and CO_3^{2-} ions

increases with increase in the concentration of the corrodents with SO_4^{2-} and CO_3^{2-} having the highest concentrations as 39.345 and 34.121ppm, respectively.

Table 1: Concentration of Anionic contaminants in mild steel corrosion products

Sample	Corrodent	pH	W_o (g)	W_f (g)	Concentration of contaminants (ppm)				
					ΔW	Cl^-	SO_4^{2-}	HCO_3^-	CO_3^{2-}
A	NaOH	11.38	9.80	9.65	0.15	–	–	–	–
B	Na_2CO_3	9.86	10.25	10.00	0.25	–	–	11.103	34.121
C	NaCl	7.23	10.15	9.30	0.85	21.30	–	–	–
D	NaHCO_3	8.98	10.25	10.15	0.10	–	–	10.090	25.260
E	Na_2SO_4	8.00	9.80	9.20	0.60	–	39.345	–	–
F	MgCl_2	5.76	9.80	9.00	0.80	14.20	–	–	–
G	CaCl_2	6.33	9.80	9.65	0.15	3.55	–	–	–
H	MgSO_4	6.03	9.70	9.50	0.20	–	20.854	–	–
I	KCl	7.25	9.70	9.40	0.30	7.10	–	–	–
J	CaHCO_3	6.89	9.80	9.70	0.10	–	–	17.545	30.011
K	Distilled water	7.15	9.80	9.20	0.60	7.10	–	–	–

W_o = Initial weight of specimen

W_f = Final weight of specimen after exposure

Δ_w =Weightloss.

Corrosion monitors are used to alarm for upsets, to control processes and to help determine the cause of corrosion. The method of measuring the concentration of contaminants in corrosion products is used here. In the analysis, it was observed that where the anodic reaction products build up, a limited amount of Cl^- , SO_4^{2-} , CO_3^{2-} or HCO_3^- ions also move up and build into the formed oxide or hydroxide films. The results obtained showed that the presence of CO_3^{2-} and HCO_3^- ions in the corrosion products stifles the corrosion process of mild steel due to the formation of protective carbonate films.

On the other hand the presence of Cl^- and SO_4^{2-} ions stimulates corrosion, and this effect increases as the concentration of these ions increases. It was also observed that the

effect of Cl^- ions are more pronounced. Finally, the corrosion phenomenon was found to be more prominent on mild steel in the chloride ion environment.

CONCLUSION

Though corrosion monitoring is not relatively a new technology, the idea of measuring concentration of anionic contaminants in corrosion products will help in determining the cause of corrosion and to assess which ions stimulate corrosion and of course, possible ways of corrosion control in soil. The results obtained proved that for a successful corrosion control process, a consistent maintenance of the desired cycles of concentrations is very important.

Each corrosion challenge has its own enhancement (if any). Some corrosion can be controlled by electric means (cathode protection) or by using a non-metallic barrier, eg coating. Such barriers should be 100% pores when used in highly aggressive fluid and since this is rarely the case, they do not form a common hardener for metallic corrosion. Sometimes metal produces its own barrier from corrosion products (eg metal oxide); the metal is then in a passive state (Douglas, 1982; Sam-Bradford, 2001). Another control method consists in the addition of certain chemicals to the corrosive liquid (corrosion inhibitors). One of the most important methods is to find an economical mixture/environment combination in which the mixture is in a passive state and is much less eradicated than the metal hence the presence of Cl^- and SO_4^{2-} ions stimulates corrosion.

REFERENCES

- Davis, J .R. (2000). Corrosion. Understanding the Basics. *ASM International*. 563pp.
- Deani, J.G., Bosqui, F.L.&Lanovette, K.H. (1992). Corrosion of Metals in Soil. *Environmental Science Technology*, 6(6), 518-522.
- Douglas, F.A. (1982). *An Introduction to Chemical Corrosion*. Macmillan Press Ltd, London. 4 – 58.
- Ferreira, C.A.M., Ponciano, J.A.C., Vaitsman, D.S., & Perez, D.V. (2007). “Evaluation of the Corrosivity of the Soil through its Chemical Composition”. *Science of the Total Environment*, 388(250-255).
- Industrial Galvanizers Corporation (2003). Steel Underground. *INGAL Civil Products*, 1-3.
- Sam- Bradford. (2001). *Practical Handbook of Corrosion Control in Soils*. CASTI. 31Ppp.
- Terence, S.B. (2019). What is Corrosion. <https://en.m.wikipedia.org>corrosion>.