Assessment of Corrosion of Mild Steel Buried In Soils of the Niger Delta, Nigeria

1G.C. ONWUGBUTA 2G.N. JOHN

1Department of Biochemistry/Chemistry Technology,
2School of Science Laboratory Technology, University of Port Harcourt

Abstract:

This study determines the corrosion rate and percent weight loss of mild steel buried in soils of the Niger Delta Area of Nigeria. Six geologic zones representing the upland and wetland soils were used for the assessment. The corrosion rates of mild steel in these soils were monitored to assess the extent of corrosion. However, the upland soils (Odagwa, Ogoni, Ahoada and Omoku) were more resistant to corrosion than the wetland (Kaiama and Elebele) soils. The corrosion rate of mild steel at the 24th month was in the following order of corrosivity: Elebele > Kaiama > Omoku > Ahoada > Ogoni > Odagwa. The percent weight loss was higher at the 24th month, with the highest values found at the Meander Belt Deposits of Elebele. Alternately, the Coastal Plain Sands were found to have the least percent weight loss with the lowest value recorded at Odagwa site at the 24th month. The percent weight loss at the 24th month is in the following order: Elebele > Omoku > Kaiama > Ahoada > Ogoni > Odagwa. The variation in corrosion rate and weight loss of mild steel buried in the different soil types is caused by the aquic moisture regime of the soils, anthropogenic activities carried out, microorganisms present in the soils, and also, the physico-chemical properties of the soils.

Keywords: Corrosion rate, weight loss, mild steel, soil

Introduction:

In the Niger Delta area of the humid tropics, there are automobile workshops which make use of iron. There are also, iron in dumpsites where metal scraps are deposited, which wash away from water drainage lines into the lagoons, and the effect of corrosion of farming machinery, including tools and implements, irrigation facilities used for agricultural production, ancillary structures, crude oil pipelines and other buried archaeological artefacts has been, and continues to be a serious ecological problem (Akdogen, 2000). When metals interact with soil, corrosion is bound to occur. Soil corrosion is a geologic hazard that affects buried metals and concrete that is in direct contact with soil or bedrock.

Corrosion of underground structures is primarily a result of corrosive factors characteristic of the soil itself, and of stray currents. The various factors which have been associated with soil aggressivity or corrosivity include low soil resistivity, low redox potential in association with anaerobic sulphate reducing bacteria, low pH, high concentration of soluble iron, and structural properties of the soil which could contribute to oxygen...
concentration cells (Davies, 2000). In addition, soils with high moisture content, high electrical conductivity, high acidity and high dissolved salts are usually the most corrosive (National Association of Corrosion Engineers, NACE, 2000). The process involving gradual chemical or electrochemical reactions between a metal and its environment, leading to the destruction or denaturing of the metal surface (coloradogeologicalsurvey.org/geologic-hazards/corrosive-soils/) is known as corrosion. The most commonly observed corrosion process is the rusting of iron exposed to air or moisture (Douglas, 1982; Raymond, 2010).

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. Steel quickly corrodes 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).

Some of the major harmful effects of soil corrosion can be summarized as follows:

- Reduction of agricultural productivity through metal contamination of soils (predominantly by iron and aluminium).
- Ecological damage to aquatic and riparian ecosystems through precipitation of iron, fish kills, increased fish disease outbreaks, dominance of acid-tolerance species, etc. (Erker and Yuksel, 2005)
- Contamination of groundwater with iron and other heavy metals, etc.

The specific objective of this study is to determine the corrosion rate of mild steel in different soil types, mild steel being used as a predictive tool for monitoring corrosion in soils using weight loss technique.

**Materials and Methods:**

Six sampling locations were selected within the Niger Delta. The area has a surface area of 19,420sq.km, out of which 15,570sq.km of the land is on submerged or saturated conditions for most part of the year. However, while the submerged or saturated part of the land forms the wetland soils, the remaining part of the land (3,850sq.km) forms the upland soils (Mordi, 1986). The sites are located within latitudes 4°15’and 5°47’N and longitudes 5°22’ and 7°37’E.

The study was carried out on three geologic units representing:

a) Coastal Plain Sands (upland), e.g. Odagwa and Wiyakara-Ogoni (CPS),
b) Sombriero-Warri Deltaic Plain (Upland), e.g. Ahoada and Omoku (SWD) and
c) Meander- Belt Deposits (Wetland), e.g. Kaiama and Elebele (MBD).

(1) Odagwa site is situated at Adaobi at the back of the Assemblies of God Church 100m away from the crude oil pipeline in Etche Local Government Area;

(2) Ogoni site situates at Wiyakara (200m away from the river) in Khana local Government Area;

(3) Ahoada pedon was sampled 6km away from Ahoada town along the East-West road, 150m off the road in Ahoada West Local Government Area, while

(4) Omoku pedon was along the palace road (2km off Ahoada – Omoku road) in Ogba/Egbema/Ndoni Local Government Area of Rivers State;
(5) Kaiama location was also, sited at Lalapou in Kaiama, 1km away from River Nun along the East – West road in Yenegoa Local Government Area, and

(6) Elebele site situates at Ogbia community, immediately after the Agip Oil Green River Project Field in Brass Local Government area of Bayelsa State.

**Preparation of Specimen:**

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 (Plate 1). Each of the mild steel coupons was then fastened to long copper wires through the hole with the aid of araldite. The coupons were polished with silicon carbide paper, degreased with acetone and stored in the desiccator prior to commencement of experimental procedure. The mild steel coupons under study were taken from the desiccator and labeled. Each labeled specimen was carefully weighed using mettler H35 AR analytical balance. This weight was recorded as initial weight. The soils were excavated by digging a mini-pit in each location up to 80cm covering the A and B horizons. Ten weighted mild steel coupons were buried in each soil type, five at the depths of 0-30cm and the other five at the depths of 30-80cm, respectively. The investigation was carried out under natural environment. The metal coupons were periodically monitored every four months for two years. After each four months, the buried mild steel coupons were dug out from the ground and taken to the laboratory for weight measurement. Before weighing, they were cleaned with a pickling solution to remove corrosion products from the surface, washed with distilled water using a clean brush, and with ethanol to remove grease or oil and finally rinsed in a fast drying solvent, acetone (National Association of Corrosion Engineers {NACE}, 2000). The coupons were finally weighed and the average weights obtained were recorded as the final weights for each of the four months.

**Plate 1: Showing some mild steel coupons buried in the soils**

The Corrosion rate and % Weight loss of the mild steel buried in the different soil types were then calculated using the first order equation below:

\[
\text{Loss in weight} = \frac{W_o - W_f}{t}
\]

\[
\text{Corrosion rate, } K \text{ (g/month)} = \frac{1}{t} \ln \left( \frac{W_f}{W_o} \right)
\]

Where, \( W_o \) = Original Weight of Specimen

\( W_f \) = Final Weight of Specimen in the \( x^{th} \) month.

\( t \) = Duration of buried mild steel (\( x^{th} \) month).

**Source:** National Association of Corrosion Engineers (NACE, 2000).
Results and Discussion:

The results of the corrosion rate and percent weight loss of mild steel coupons buried in soils of the Niger Delta are shown in Figs. 1(a-f) and 2(a-f), respectively. Corrosion rate is the speed at which any metal in a specific environment deteriorates. The rate or speed is dependent upon environmental conditions, as well as the type and condition of the metal (corrosionpedia). The corrosion rates from 4th to 24th month for all the locations (Figs. 1a-f) show that the corrosion rate of the surface and sub-surface soils of Odagwa ranged from $1.0 \times 10^{-3}$ g/month (sub-surface soil) at the 16th month to $2.8 \times 10^{-3}$ g/month (surface soil) at the 20th month, Ogoni ranged from $2.0 \times 10^{-4}$ g/month (surface and sub-surface soils) at the 16th month to $3.6 \times 10^{-3}$ g/month (surface soil) at the 20th month, while Ahoada ranged from $2.0 \times 10^{-4}$ g/month (surface and sub-surface soils) at the 8th, 12th and 16th month to $3.7 \times 10^{-3}$ g/month (sub-surface soils). The corrosion rate of Omoku soils ranged from $6.0 \times 10^{-4}$ g/month (surface and sub-surface soils) at the 16th month to $4.2 \times 10^{-3}$ g/month (surface and sub-surface soils) at the 24th month, Kaima ranged between $2.5 \times 10^{-3}$ g/month (sub-surface soil) at the 12th month and $8.5 \times 10^{-3}$ g/month (surface soil) at the 24th month, while Elebele ranged from $3.0 \times 10^{-3}$ g/month (sub-surface) at the 8th month to $9.4 \times 10^{-3}$ g/month (surface soil) at the 12th month, respectively.

The corrosion rate of the Coastal Plain sands are low with the least value of $2.0 \times 10^{-4}$ g/month found in the surface and sub-surface soils of Ogoni at the 16th month and the highest value of $3.6 \times 10^{-3}$ g/month found in the surface soils of Ogoni pedon at the 20th month. Alternately, the highest value of corrosion rate ($9.4 \times 10^{-4}$ g/month) was obtained in the surface soil of Elebele Meander Belt Deposits of Ogbia Local Government Area of Bayelsa State. However, the upland soils (Odagwa, Ogoni, Ahoada and Omoku) were more resistant to corrosion than the wetland (Kaima and Elebele) soils. This could be due to their aquic moisture regime, parent material and the type of microorganisms that can survive in such environment. The corrosion rate of mild steel at the 24th month was in the following order of corrosivity:

Elebele > Kaima > Omoku > Ahoada > Ogoni > Odagwa
Percentage Weight Loss of Mild Steel Buried in Soils of the Study Area:
The percent weight loss of mild steel in the areas studied (Figs. 2a-f) ranged from 0.1% at both the surface and sub-surface soils of Ahoada to 1.9% at Elebele surface soil in the 4th month, while at the 8th month it ranged between 0.2% at both the surface and sub-surface soils of Ahoada and 2.5% at the sub-surface soils of...
G.C. ONWUGBUTA and G.N. JOHN / Assessment of Corrosion of Mild Steel Buried In Soils of the Niger Delta, Nigeria

Elebele. The range of the percent weight loss at the 12th month was between 0.2% and 11.2%, with the lowest value found at the surface and sub-surface soils of Ahoada and the highest found at the surface soils of Elebele, while the percent weight loss in the 16th month was recorded from 0.3% at Ahoada surface and sub-surface soils to 12.0% at Elebele surface soils. At the 20th month, the percent weight loss of mild steel ranged between 3.8% at Ahoada sub-surface soils and 14.6% in the surface soils of Elebele, while at the 24th month, it ranged from 5.8% at the sub-surface soils of Odagwa to 20.8% in Elebele surface soils, respectively.

The percent weight loss was higher at the 24th month, with the highest values found at the Meander Belt Deposits of Elebele. Alternately, the Coastal Plain Sands were found to have the least percent weight loss with the lowest value recorded at Odagwa site at the 24th month. The percent weight loss at the 24th month is in the following order:

Elebele > Omoku > Kaiama > Ahoada > Ogoni > Odagwa

**Fig. 2c: Percentage Weight Loss of Mild Steel Buried in Ahoada Site**

**Fig. 2d: Percentage Weight Loss of Mild Steel Buried in Kaiama Site**

**Fig. 2e: Percentage Weight Loss of Mild Steel Buried in Omoku Site**

**Fig. 2f: Percentage Weight Loss of Mild Steel Buried in Elebele Site**
Conclusion:

These results imply that Odagwa soils are less corrosive and therefore, the mild steels buried in them will have higher life expectancy than in the other locations, while Elebele in Meander Belt Deposits are most corrosive among the soils studied because of its aquic moisture regime. Generally, the corrosion rates tended to be higher in the surface than in the subsurface soils, which signified a higher activity zone, resulting from both human and microbial activities. While the effects of corrosive soil can cause structural failure and financial burden, it also has attendant effect on the pollution of the environment, for example, oil pipeline rupture and leakages (Nduuku, 2015) leading to low fertility of the soil and low crop yield. Because of the changes in soil properties as a result of oil spill and waste deposition, and their effects on plant growth, the problem of the quality of pipes (iron) to be laid becomes a great challenge to the agronomists in order to reduce corrosion rate and avoid oil leakages and high iron and heavy metals accumulation in soils.

References:

1. Akdogen, A.B.E. (2000). The Effect of Corrosion on Agricultural Machinery and Prevention Methods. 8 Denizli Material Congress. 26-28 April, Denizli, Turkey. 4pp.
2. Davis, J. R. (2000). Corrosion. Understanding the Basics. ASM International. 563pp.
3. Douglas, F.A. (1982). An Introduction to Chemical Corrosion. Macmillan Press Ltd, London. 4 – 58.
4. Erker, B. & Yuksel, E. (2005). Solutions to Corrosion Caused by Agricultural Chemicals. Trakia Journal of Science, 3(7), 1-6. ISSN 1312-1723.
5. 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).
6. https://www.corrosionpedia.com/an-introduction-to-soil-corrosion/2/1431.
7. http://www.slideshare.net/rfmengr/corrosion-in-soils. Mechanism of Corrosion and Control Measures (2010).
8. Industrial Galvanizers Corporation (2003). Steel Underground. INGAL Civil Products, 1-3.
9. Koch, G.H., Brongers M.P.H, Thompson N.G., Virmani, Y.P. & Paper, J.H. (2001). Corrosion Costs and Preventive Strategies in the U.S. Washington, D.C. FHWA. 395.
10. Mordi, R.I. (1986). Characteristics of Soils of the Meander Belts of Rivers State, Nigeria. M. Phil. Thesis (Unpublished). Rivers State University of Science and Technology, Port Harcourt. 258pp.
11. National Association of Corrosion Engineers. (2000). International Basic Corrosion Course Handbook. NACE. Houston, Texas. 196 pp
12. Raymond, F.M. (2010). Corrosion in soil: In Slideshow https://www.slideshare.net/rfmengr/corrosion-in-soil.
13. Terence, S.B. (2019). What is Corrosion? https://en.m.wikipedia.org>corrosion.
14. Urgen, M. (1989). Corrosion on Stainless Steel. Corrosion Science and Technology Journal, Ankara, Turkey. 3pp.