

Soil Physico-Chemical Characteristics And Metallic Corrosion In Parts Of The Niger Delta

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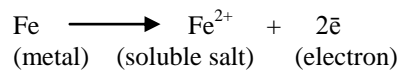
Abstract— Soil physico-chemical parameters such as pH, organic matter, chloride and sulphate contents were investigated to assess their effect on buried metallic pipes for a proposed gas processing plant facility at Ovade-Ogharefe, Delta State, Nigeria. Ten sampling points along the pipeline route were investigated. Thus, a total of 10 borings each to a depth of 10.0m were drilled along the pipeline route using the Shell-and-Auger Percussion Rig to collect subsurface soil samples for laboratory analyses for physico-chemical characteristics. Soil pH was determined in-situ electronically using the glass electrode method with a standard calibrated pH meter. On the average, the soil is sandy clayey in nature and the results of the parameters tested are as follows: pH (5.2-7.5), chloride (8.9-85.4ppm), sulphate (126.3-266.5ppm) and organic matter content (0.41-0.42%). The low pH values of 4.2, 5.2, 5.3 and 5.5 as well as the high sulphate contents above permissible limit respectively at locations BH7, BH8, BH9 and BH10 implies that the soil is acidic and deleterious to buried metallic pipes which is characteristic of clayey soils. It is recommended that the metallic pipes along the pipeline route be buried within the depth of 2.0 to 3.0m because that is the zone or layer of high pH, low chloride and low sulphate contents. However, the impressed current cathodic protection method is therefore recommended to minimize corrosion impact on the proposed gas pipeline.

Index Terms— Cathodic Protection, Corrosion, Metallic Pipes, Soil Resistivity

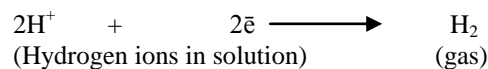
I. INTRODUCTION

Statistics have shown that the quantity of gas flared in Nigeria exceeds 40% of the gas flared annually across Africa, which amounts to above \$7billion in waste [1]. As a measure to curb this environmental problem, the Pan-Ocean multi-national oil company decided to take advantage of the economic benefits in converting the flared gas into liquefied natural gas, domestic cooking gas and other uses. This has necessitated the construction of gas transportation pipelines where metallic pipes are buried underground to transport the gas by land from the production area to the distribution terminal. All such pipelines are buried beneath the earth surface to a depth of about 1.5 meters for the purpose of security and safety. However, variations in soil properties and characteristics can have a major impact on corrosion process of any buried metallic structures. Typically, according to [2], the most corrosive soils are those with low resistivity, low pH, high concentration of chlorides and sulphates. Wet conditions are particularly difficult since these can result in concentration of corrosive species and mechanical action that

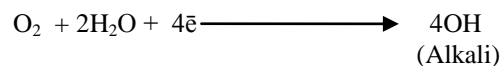
tend to breakdown protective corrosion films and coatings on the metal surface. Iron rusts when it comes into contact with air and water because electrochemical cells are set up at the surface of contact [3]. Thus corrosion is an electrochemical process that involves the passage of electric currents on a micro or macro scale. The change from the metallic to the combined form according to [4] occurs by 'anodic' reaction:



This reaction produces free electrons, which passes within the metal to another site on the metal surface (the cathode) where it is consumed by the cathodic reaction. In acid solutions, the cathodic reaction is:



In neutral solutions, the cathodic reaction involves the consumption of oxygen dissolved in the solution:



Corrosion thus occurs at the anode, but not at the cathode (unless the metal of the cathode is attacked by alkali).

Sometimes the anode and cathode in a corrosion process may be on two different metals connected together to form a bimetallic couple, or as with rusting of steel, they may be close together on the same metal surface [4].

Most pipelines are made up of low carbon steel allied with C-Mn. Low carbon steel, although susceptible to corrosion is widely used because of its low cost, high strength and the ease of field make up by welding. Crude oil and gas pipelines in Nigeria are usually protected externally by wrapping with cement or polyamide or epoxy resin coating couple with a cathodic protection system with minimum specific potential of -850mv (Cu/CuSO₄). Corrosivity of soils to buried structures is mainly influenced by 6 soil parameters such as moisture content, pH, resistivity, oxidation-reduction potential, chloride contents and sulphate contents [5], [6], [7], [8], [9] and [10] opined that it is important to maintain the structural integrity and prolong the effective lifetime of pipeline systems through the design and installation of cathodic protection (CP) systems.

Cathodic Protection is an effective method of preventing stress corrosion cracking such that electrochemical potential is measured with reference electrode. Copper – Copper (II) sulphate electrode are used for structures in contrast with soil or fresh water. Silver chloride electrodes are used for sea water applications [11], [12].

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Chloride Content

The Chloride Contents ranged from 8.9 ppm to 51.4 ppm with an average of 21.30 ppm, indicating that chloride level is below the maximum level of 100 ppm as recommended by AASHTO T-290-291; hence it has no serious corrosive effect on buried metals. However, in an acidic environment this level of chloride in the soil is seen to be mildly corrosive (table 2). Although chloride values are low, the presence of chloride in the soil also tends to decrease the soil resistivity which makes it to be potentially harmful to buried metallic pipes.

Organic Acid (Matter) Content

The organic matter contents of the soil materials in terms of Total Carbon were observed in some borings to be between 0.40% and 0.43% and at some points not indicated at all, which indicates absence of any trace of crude oil pollution within the area at the time of investigation. According to AASHTO T-267-86, for Total Organic Content to preclude the formation of anaerobic pockets, it should be limited to 1% by weight of the total soil fraction. Therefore, the presence of organic matter in the area will not be deleterious to the buried metal pipes.

Table 2: Degree of Corrosivity as a Function of Soil resistivity, Soil pH, Water Soluble Chloride and Sulphate Concentrations in the Soil [18]

Soil Resistivity (Ω m)	Water Soluble Chloride Concentration (ppm)	Water Soluble Sulphate Concentration (ppm)	pH Level	Degree of Corrosivity
0.5	Over 5,000	Over 10,000	-	Very Severe
5-10	1,500-500	1,500-10,000	<5.5	Severe
10-20	500-1,500	120-1,500	5.5-6.5	Moderate
20-100	Below 500	-	6.5-7.5	Mild
Above 100	-	0-150	> 7.5	Negligible

pH Values

Water table was not reached at the depth of boring, but the pH of soil samples were obtained with an average value of 5.9. [19] suggested that acidic environment with $\text{pH} < 6$ are more corrosive than pH from 6-8 or alkaline ($\text{pH} > 8$). When compared with the pH scale in table 3, the soils are seen to be moderately acidic which are characteristic of clayey soils and this will create un-conductive environment for buried metal pipes.

Table 3: pH Scale [20]

pH	Denomination or Classification
<3.5	Ultra Acidic
3.5-4.4	Extremely Acidic
4.5-5.0	Very Strongly Acidic
5.1-5.5	Strongly Acidic
5.6-6.0	Moderately Acidic
6.1-6.5	Slightly Acidic
6.6-7.3	Neutral
7.4-7.8	Slightly Alkaline
7.9-8.4	Moderately Alkaline
8.5-9.0	Strongly Alkaline
>9.0	Very Strongly Alkaline

V. CONCLUSION

Corrosion risk assessment has been estimated by [18] where the soil resistivity, chloride ion concentration, sulphate ion concentration and pH values are used to predict the degree of corrosivity of soil as described in table 3. Comparing tables 1 and 3 we observe that the chloride ion concentration, sulphate ion concentration and pH values of the soil for this study falls in the category of mild to moderate degree of soil corrosivity. The aggregate effect of clayey soil, acidic environment, low sulphate concentration and low chloride concentration in the soil within the area makes for increased reactivity that will trigger off corrosion on any buried metallic pipe. Thus, clayey soils have low resistivity and high corrosivity at low pH, and those that are contaminated with crude oil and saline water are severely corrosive at low pH values less than 5.5. To mitigate/control the effect of any corrosion, the impressed current cathodic protection method is recommended since the average soil resistivity value of $50\Omega\text{-m}$ (which is the threshold value between the impressed current cathode protection and the sacrificial (Galvanic) anode cathodic protection) can be achieved in this environment.

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REFERENCES

- [1] A. Adejugbe and B. Onamade. *Gas Flaring in Nigeria, Challenges and Investment Opportunities*. Retrieved from <http://www.mondaq.com/nigeria...on> 28th December, 2016; 2014.
- [2] P. J. Smith. *Topics in Geophysics*. Oxford, The Open University Press; 1975.
- [3] O. Y. Ababio. *New Certificate Chemistry* (3rd Edition), Nigeria: Africana First Publishers Limited; 2001.
- [4] J. H. Morgan. *Cathodic Protection. National Association of Corrosion Engineers (NACE)* (2nd Edition); 1987.
- [5] H. H. Uhlig and R. W. Revie. *In Corrosion and Corrosion Control: an Introduction to Corrosion Science and Engineering* (3rd Edition). John Wiley and Sons, New York; 1991.
- [6] J. Bhattarai. *Frontiers of Corrosion Science* (1st Edition). Kshitiz Publishers, Kirtipur, Kathmandu; 2010.
- [7] J. Bhattarai. Study on the Corrosive Nature of Soil Towards the Buried-Structures. *Scientific World*, 2013; **11(11)**: 43-47.
- [8] T. C. Irunkwor. Electrical Resistivity Investigation for Cathodic Protection of gas/crude oil Pipeline at Ovade-Ogharefe, Delta State, Nigeria. (*Unpublished M.phil Thesis, Rivers State University, Port Harcourt*; 2009.
- [9] S. A. Ngah. and T. K. S. Abam. Shallow resistivity measurements for sub-soil corrosivity evaluation in Port-Harcourt Metropolis, Nigeria. *International Journal of Science and Technology*. 2013; **3(2)**: 85-91.
- [10] M. U. Osakuni. and T. K. S. Abam. Shallow resistivity measurement for cathodic protection of pipelines in the Niger Delta. *Environmental Geology*. 2004; **45(6)**: 747-752.
- [11] S. Baeckmann, P. Schwench and T. Prinz. *Handbook of cathodic protection* (3rd Edition). ISBN 0-88415-056-9; 1997.
- [12] D. A. Roberge. and R. Pierre. *Handbook of corrosion Engineering*. ISBN 0-07-076516-2; 1999.
- [13] P. D. S. Kinako, B. L. Nyananyo. and A. I. Hart. *Introduction to Ecology and Systematics*. Belks Publishers, Port-Harcourt, Nigeria; 1993.
- [14] V. A. Oyenuga. Agriculture in Nigeria. Food and Agriculture Organization of the United Nations. (FAO), Rome, Italy, P.308; 1967.
- [15] N. P. Iloeje. *A new geography of Nigeria. New Revised Edition*. Longman Nigeria PLC; 2001.

- [16]A. Edet, A. Ukpong. and T. Nganje. The Concentrations of Potentially Toxic Elements and Total Hydrocarbon in Soils of Niger Delta Region (Nigeria). *Journal of Environment and Earth Sciences*, 2014; **4(1): 23-34.**
- [17]R. K. Meindinyo. and E. O. Agbalagba. Radioactivity Concentration and heavy metal assessment of soil and water, in and around Imirigin oilfield, Bayelsa State, Nigeria. *Journal of Environmental Chemistry and Ecotoxicology*. 2012; **4(2): 29-34.**
- [18]G. C. Davenport, E. E. Rinne. and A. M. Zamora. Geotechnical Investigations for corrosive soils. *United Nations Assistance Mission (UNAM) Proceedings*; 1981.
- [19]S. A. Bradford. *Corrosion Controls*. New York, Van Nostrand Reinhold; 1993.
- [20]United States Department of Agriculture, Natural Resources Conservation Service Handbook 18. *Soil Survey manual*, chapter 3, selected chemical properties; 1993.