CHARACTERIZATION OF EXTERNAL INDUCED CORROSION DEGRADATION OF AJAOKUTA-ABUJA GAS PIPELINE SYSTEM, NIGERIA

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ABSTRACT

Characterization of External Induced corrosion degradation of Ajaokuta- Abuja gas pipeline system was successfully carried out. The objective of this work is to analyze the mechanism of corrosion, analyze the effect of the corrosion on oil and gas pipeline and to evaluate the corrosion potential of a pipeline route. These were achieved by carrying out resistivity experiment on every one kilometer on the right of way (ROW) of the pipeline. Soil and water aggressiveness test was also carried out on soil and water sample of the pipeline route respectively. The resistivity result was considerably high, chemical analysis revealed that the soil and water acidity is between the pH of 6.7 and 8.2 respectively, which is moderately alkaline in nature, which makes the soil environment not conducive for pipelines due to potential for corrosion attack. The chloride content of the soil and water were also high. Based on the experimental results, it was proposed that the pipe should be laid on 2-5m below the ground and that the galvanic anode for cathodic protection be located 1m below the ground, in order to avoid corrosion. It is therefore necessary to note that characterization of external corrosion is quite different from internal pipeline corrosion characterization.

Keywords Corrosion, pipeline, corrosion mechanism, pipes, soil, water

INTRODUCTION

Corrosion is nature's way of reducing metals to its original states. (Andrew *et al*, 2007). Metals especially iron in the form of carbon steel have found usage in all facet of human development through the ages. Corrosion damage are not always considered in the design and construction of many engineering systems, even when considered, unanticipated changes in the environment in which the structure operate can lead to unexpected corrosion damage (Chalk, 1992). Engineering material are sometimes put into use in extreme environmental condition outside their design requirements and as a result decreases the integrity of the materials, which can result in unexpected failures.

The world is walking towards green energy or what is generally regarded as renewable energy, it must be stated that the world's capacity is still a far lacking when compared to present day energy need. As a result of this demand for oil and gas is still on the increase, pipelines are recognized as the safety and most efficient way of transporting oil and gas and are mostly made of carbon steel. Corrosion could be a major problem in the transportation of oil and gas from where they are produced to where they are needed. Pipeline buried beneath the earth are prone to external corrosion since the condition for corrosion to have effects on these pipes are always present. The presence of chemical substances such as Chloride, Oxygen (0_2), carbon dioxide (0_2) hydrogen sulphide (H_2S), water and microbiological bacteria could cause severe corrosion problem depending on the pH values, temperature, pressure, materials flow rate and flow profile of the system.

This work – Characterization of External Induced Corrosion of Ajaokuta-Abuja Gas Pipeline System seek to evaluate the corrosion potential of the pipeline by evaluating the presence and the intensity of these chemical substance.

The consequences of corrosion failures can be grouped into three broad categories such as safety consequences, environmental consequences and business or economic consequences. Under safety consequence, the problem of fatalities, injuries, fire and property damage that result from thermal radiation from fire fueled from high pressure escaping fluid from the point of pipeline leak or rapture pipeline failure in the past have led to destruction of life and property. Environmental consequences are basically pollution of the ground water table and water course both at the location of failures and the surrounding area where drain-down can occur. (Ezeh, 2010). The impact of oil spillage in the Niger Delta of Nigeria is enormous in the area of agricultural activities, water-related occupation such as fishing and subsequently the economic life of the people.

There is also the business and economic angle to pipeline corrosion failure as product loss always result to revenue loss, the corporate image of the company whose pipeline failed would also be affected and this would affect the economic fortune of the company. A typical example is the recent failure and spillage of the platform owned by British petroleum in the Gulf of Mexico. In the United State the annual cost associated with corrosion damage of structural components is greater than the combined annual cost of natural disasters including hurricanes, storms, flood, fire and earthquakes. Similar findings have been made by studies conducted in the United Kingdom Germany and Japan that internal corrosion is responsible for approximately 15% of all reportable incidents affecting gas transmission pipeline over the past several years. (Depual, 1957).

In oil and gas production, corrosion occur at any stage and anywhere along the production line, corrosion can occur from the bottom of the well in any of the equipment used to process oil and gas for sale. Corrosion is common in bottom hole pumps and accessories drilling fluids. If left between well and external surface of the casing could cause considerable corrosion. High-pressure gas well head equipment, well head valves made of dissimilar metals are vulnerable to corrosion at high velocity, this is usually aggravated by the presence of H_2S (Bijimi, 2005).

Corrosion is usually a problem in process equipment such as separators, compressors, dehydrating equipment and columns, cooling water systems, gas turbines, pumps, scrubbers, glycol regenerating units and heat units. The presence of oxygen is undesirable and if not removed would precipitate corrosion. Corrosion and potential piping leakage do exist due to the presence of CO_2 and H_2O in gas in high pressure and low pressure gas compressors and suction headers. There is potential of tube leak due to water ingress in low pressure suction cooler and scrubbers (Bijimi, 2005). Instances of corrosion in crude oil discharge pumps causing oil leakage exist, these leaks are common around crude oil stabilization coolers. High pressure test header, low pressure flare and scrubbers are susceptible to corrosion caused by Co_2, H_20 and other corrosive species such as H_2S.

MATERIALS AND METHODS

RESISTIVITY SURVEY

Resistivity was measured based on Wenner "Four-Pin" method. Soil resistivity is derived from voltage drop between the centre pair of pins with current flowing between the two outside pins. (Kings *et al*, 2006). An alternating current from the soil resistance meter causes current to flow through the soil, between the two outside pins, the voltage or potential is then measured between the two inside pin. The meters register the resistance reading. Resistivity of the soil is then computed from the instrument according to the formula

$\int = 2\pi AR$, (Bijimi, 2005)

Where:

$\int$ is the soil resistivity (Ohm-m)

A is distance between probes (meter)

R is soil resistance (Ohms), instrument reading

Test Equipments

The following are the equipments used in the survey.

1. Digital soil resistance meter serial No 40-3112

2. Tetrameter SAS 400 for Anode ground bed resistivity
3. Magellan colour TEK DGPS equipment for co-coordinating the proposed ground bed position
4. Corrosion resistance conducting steel rods.
5. Insulated copper conductor of standard length
6. Meter rule

Measuring Procedure

Along the pipeline route, the measurement of the top soil layer was performed at a depth of 0.5, 1, 1.5, 2, 3 and 5 for each kilometer for every one kilometer interval. The resistivity values obtained represent the average resistivity of the soil to a depth equal to the pin spacing. The soil resistance meter was utilized for the entire exercise; the resistance values were recorded at every test point directly on the instrument.

SOIL ACIDITY

Soil description and test sample was conducted in accordance to BS5930, ASTM, ACS standard.

Acids are chemical substance consisting of hydrogen and non metallic oxides which easily combine with metals to form metallic salts

$$Fe_2\,O_3 + 3H_2S0_4 \longrightarrow 3Fe_2S0_4 + 3H2O$$

Test Equipments

The following test equipment were used:

1. pH meter (H198127)
2. De-ionized water
3. Soil sample

Measuring Procedure

Two parts of distilled or de- ionized water per part of soil sample were mixed, and was allowed to settle down at the bottom of the container. The pH value of the solution at the top was then read directly from the pH meter

CHLORIDE TEST

Soil description and test sample was conducted in accordance to BS1377, ASTM and ACS standard Chlorine belong the group of non metals called halogen it readily gives up its valance electron to form compound with other metals. Most salts are readily soluble in the presence of high chloride content.

Test Apparatus

1. Standard silver Nitrate Titrant, 0.014IN
2. Standard sodium chloride, 0.0141N
3. Nitric Acid, HNO_3 concentrated
4. Pipets:250-ml
5. Beakers 250-ml
6. Measuring flasks: 500-ML

Measuring Procedure

100g of the soil sample was weighed int a 500ml measuring flask, 300ml of distilled water was added to the sample and the solution was mixed by shaking rigorously for 15 minutes. The mixture was then filtered and titrated for the concentration of the chloride.

RESULTS AND DISCUSSION

RESISTIVITY RESULT

Table I: High and Low Resistivity Values of Ajaokuta Compressor station Abajana Tie-in

Soil depth (M)	Low Resistivity value (ohm-m)	High resistivity value (ohm-m)
0.50	820	2071.143
1.00	1188	3029.143
1.50	1282. 286	3535.714
2.00	1219.249	3281.143
3.00	1338.857	3884.000
5.00	1230.000	4620.000

Table II: High and Low Resistivity Values between Abajana and Lokoja

Soil depth (M)	Low Resistivity value (ohm-m)	High resistivity value (ohm-m)
0.50	1071.714	5958.857
1.00	1420.571	9579.429
1.50	1480.286	10428.00
2.00	1043.429	11377.143
3.00	1150.286	13671.429
5.00	1194.299	16,091.429

Table II: High and Low Resistivity Values between Lokoja and Izom Section

Soil depth (M)	Low Resistivity value (ohm-m)	High resistivity value (ohm-m)
0.50	301.714	3774.571
1.00	264.00	4506.857
1.50	188.571	5034.857
2.00	339.429	4802.286
3.0	230.057	5468.571
5.0	282.857	7260.00

Table III: High resistivity and low resistivity Values between Izom and Sarki Pawa

Soil depth (M)	Low Resitivity value (ohm-m)	High resistivity value (ohm-m)
0.50	311.143	6414.571
1.00	383.143	10754.857
1.50	386.571	11361.429
2.00	339.429	12609.143
3.00	301.714	14,124.00
5.00	345.714	17662.857

PH RESULT

Table IV: Soil and Water pH Results of the test Sample

ITEM DESCRIPTION	LOWEST VALUE	HIGHEST VALUE
SOIL	8.2	6.7
WATER	8.2	6.7

CHLORIDE RESULT

Table V: Chloride concentration Results of the test Sample

ITEM DESCRIPTION	LOWEST VALUE	HIGHEST VALUE
SOIL	83.1 $CL^{-\ mg/L}$	10.3 $CL^{mg/L}$
WATER	88.8 $CL^{-mg/L}$	13.1 $CL^{mg/L}$

DISCUSSION OF RESULTS

From the above results, it could be observed that the resistivity values of the samples vary greatly. From the results in tables I to IV above, it was observed that the higher resistivity values tend to increase with depth while the lower resistivity values represent a uniform soil condition through out the various locations. The high and low resistivity values due to the properties of the soil at the various sections. Though resistivity value is generally high, the low resistivity value between the Lokoja/Izom section and the Izom/Sarki Pawa section was less than 1000 ohm-m. The soil and water acidity was between 6.7 and 8.2 which is moderately alkaline in nature. The chloride content of the soil sample shown in table V above was considerably high.

CONCLUSION

The upward resistivity trend with depth was a result of the average effect of the resistivity from the top layer of the soil, the low values were presumably obtained on the clay layer, while the high result were obtained on sedimentary rock formation, these high values are expected since basement rocks are volcanic and metavolcanic rocks. From the resistivity result it could be seen that the soil was highly corrosive to underground pipeline.

The chemical analysis showed that soil environment is conducive and a potential corrosion threat for buried bare pipeline. Any buried bare pipeline along these routes would be subjected to oxygen corrosion, organic acid attack. The pipeline would be prevented against corrosion attack by the combination of external coating and cathodic protection (CP). From the resistivity result, it could be concluded that the pipeline would be laid at depth of 1-2m because the resistivity represents a uniform soil condition and the galvanic anode for cathodic protection should be located at 1m depth.

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