ASSESSMENT OF CORROSION PROTECTION PRACTICES ON NIGERIAN NATIONAL PETROLEUM CORPERATION PIPE LINES IN ONDO STATE FOR SECURITY OF LIFE AND PROPERTIES

BY

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Abstract

This study was designed to assess the corrosion protection practices on Nigerian National Petroleum Corporation (NNPC) pipelines in Ondo State for security of life and properties. A descriptive survey design was adopted for the study. Three research questions and two hypotheses guided the study. The respondents randomly sampled were 80 Pipeline Maintenance Technicians and 30 Engineers who have served for at least 6 months. Mean scores were used to answer research questions while independent t-test was used to test the hypotheses. The findings revealed among others that: NNPC complied with most of the policies concerning pipeline design standards, physical routine checks on pipes, computer monitoring system were adopted as maintenance strategies and that fusion-bonded epoxy (FBE) coating as one of the modern ways of corrosion protection techniques is being complied with. It was therefore recommended among others that preventive maintenance should be carried out on weekly basis to prevent breakdown of pipeline system and on occasions of rupture or spillage due to corrosion, breakdown (corrective) maintenance should always be emphasized, external corrosion should be tackled using fiberglass reinforced polymer (FRP) for the security of life and properties of people leaving around NNPC pipelines.

Keywords: *Corrosion, environment, maintenance, pipelines, properties, security.*

Introduction

For more than four decades, Nigeria has continued to experience remarkable increases in the operational activities in her oil and gas exploration and exploitation, refining and products marketing. The on-shore activities centered mainly in the heart of Niger Delta area; (Ondo State inclusive), which have generated massive economy for the nation and this is nationally acknowledged, that the natural blessings of this area, known for its difficult land terrain of swampy rain and mangrove forests, have contributed mostly to the socio-economic development of the entire country especially in the areas of foreign exchange earnings, provision of job opportunities (employment), physical infrastructure in education, health, communications, power, among others (Ukoli, 2008). Behind this glossy facade of the financial benefits however, the industry has created serious health issues and environmental problems for the country in general and the host communities of the oil companies in particular due to the defects and or failure of NNPC transmission pipelines.

Oil and gas provide 60% of the world's primary fuel (Phil, 2002). Most of this oil and gas are transported in pipelines. These pipelines are called transmission pipelines; the general public will not normally see these lines as they are either under the sea, or buried in the ground, but they are the main arteries of the oil and gas transportation systems. They are usually of large diameter and operate at high pressures to allow high transportation rates. They are designed, built and operated to well-established standards and laws, because the products they carry can pose a significant hazard to the surrounding population and environment; but the combination of good design, materials, operations and corrosion protection practices has ensured that transmission pipelines have a good safety record. Corrosion is the gradual destruction of material, usually metals; by chemical reaction with its environment. Nordin, Norhazilan and Siti (2011) argued that the most common use of the word, corrosion means electrochemical oxidation of metals in reaction with an oxidant such as oxygen. Michael (2008) stressed that corrosion in metals needs two basic environmental factors; water/moisture and atmospheric oxygen. Amir, (2013) in his studies, argued that the reason of corrosion and leakage from pipelines is carbon dioxide (sweet corrosion). According to Charng and Lasing (1982) corrosion also resulted from condensing moisture, dissolved salt, sulfur dioxide from fuel combustion, dust bearing corrosives, and the remoteness of structures and equipment from washing effects of rain water. Microbiologically influenced corrosion is caused by the activities of microbes. This general class covers the degradation of materials by bacteria, moulds and fungi or their by-products. Sylvester (2012) also maintained that low temperature can have effect in the corrosion rate of a material. A 10^{0C} rise doubles the corrosion rate.

The occurrence and behavior of defects in pipelines has been the subject of extensive research and development for over 35 years (Phil, 2002). Oil and gas transmission pipelines have a good safety record. This is due to a combination of good design, materials and corrosion protection practices; however, like any other engineering structures, pipelines do occasionally fail. The most common causes of damage and failures in on-shore and off-shore oil and gas transmission pipelines are external interference (mechanical damage) and corrosion (Andrew & Phil, 2004). Pipe manufacturing has evolved over the last 30 years such that steel chemistry has allowed the development of high strength steels for use as line pipe (Banach, 2004). However, corrosion rates are more dependent on environmental factors and pipeline operating conditions than on pipe steel chemistry. When iron or steel is exposed to atmospheric oxygen in the presence of water, the well-known rusting process takes place; the metal is degraded to form ferric rust, a red-brownish compound, which is a sure sign of electro-chemical oxidation of the underlying metal. The degradation of metals by corrosion is a universal reaction, caused by the simple fact that the oxide of a metal has a much lower energy than the metal itself. Hence there is a strong driving force for the oxidation of metals (Bushman, 2009). It is important to realize that corrosive attack on a metal can only occur at the surface of the metal, hence any modification of the surface or its environment can change the rate of reaction.

Despite precautions, accidents do occur periodically in the course of various processes and activities in the production, refining and distribution of petroleum products. Gas flaring remained a common occurrence in the oil producing areas of Ondo State (Fatusin, Aribigbola & Adetula, 2010). The World Bank report (1998), claimed that 76% of the Nigerian gas is flared into the environment. While this problem has increased in recent past, it has created serious problems to the quality of life, health, farming, income and social equilibrium. These may result from accidental discharges attributed to equipment failure, malfunctioning, deterioration occasioned by corrosion, ageing of pipelines, deliberate or willful acts of vandalization, neglect in carrying out proper maintenance and or even human error; about 900 cases were reported in year 2000 (Ukoli, 2008). Crude oil or refined petroleum products spillage has caused damages to the environment in many ways in Ondo State. One of the most obvious negative implications of oil activities is the damage to water resources. Due to these activities, many surface water bodies became polluted, some directly from oil and gas flaring, others from the hydrocarbon leakage from tankers (Gbadegesin & Adewumi, 1997). Oil film floating on the water surface could prevent natural aeration and lead to the death of fresh water or marine life. Fish may ingest spilled oil or other food materials impregnated with oil. Such fish have been observed to be unpalatable (Ojo & Adebusuyi, 1996). Another problem of oil spills is that; areas that have been known to be fertile for farming in the past have suddenly become barren or are getting closer to being so (Alawode, & Ogunleye, 2011). The mangrove forest is slowly withering away and the Agricultural industry is suffering. This is particularly sad because the natives, who used to make their living through subsistence farming, have to look elsewhere for their livelihood.

Defects occurring during the fabrication of a pipeline are usually assessed against recognized and proven quality control limits. However, a pipeline will invariably contain larger defects during its life, and these will require a 'fitness-for-purpose' assessment to determine whether or not to repair the pipeline. Consequently, the past 40 years has seen the development of a number of methods for assessing the significance of defects (Andrew & Phil, 2004). Some of these methods have been incorporated into industry guidance; others are to be found in the published literature. However, there is no definitive guidance that contains all of the assessment techniques, or assesses each method against the published test data, or recommends best practice in their application.

Oil spill is inevitable; but in Niger delta especially in Ondo State; they occur with an alarming frequency and magnitude because most of the oil delivery infrastructure are obsolete and inadequately protected (Abosede, 2010). A poorly protected pipeline is a poorly monitored pipeline and it's like a time bomb dangerously waiting to be detonated. Annually, millions of gallons of oil are discharged into the oceans due to leakage of oil into a body of water, like a river or stream (Alawode & Ogunleye, 2011). This has very unpleasant ramifications on the surrounding eco-system. These affect the hydrology of the seasonally flooded fresh water swamp and the brackish water of the mangrove forest, killing crops, destroying fishing grounds and damaging the drinking water supply. There is usually an urgent need to repair and regularly inspect/maintain the pipeline networks and keep the environment clean of any oil spill. This involves huge capital expenditure from the oil companies and the Federal Government to improve on the safety of pipelines and the environment by overhauling aging pipelines. The Niger Delta region is a sensitive and fragile ecosystem. In spite of the damaging impact of oil exploitation on the environment and livelihoods of the host communities, scientific data on the overall and long-term effects of oil exploitation on the area are only beginning to emerge (Nwachukwu, 1999; Aluko, 1999; Onosode, 2003).

Assessments are needed to determine the severity of defects when they are detected in pipelines. These include well-structured activities which involve pipeline monitoring, maintenance, corrosion protection practices among others. Therefore, this study is to assess the corrosion protection practices carried out on Nigerian National Petroleum Corporation (NNPC) pipelines for safety of life and properties in Ondo State in order to adequately minimize the rate of corrosion on the pipelines which usually lead to oil spillage on the surrounding communities.

Research Questions

This study will provide answers to the following questions:-

1. What extent has NNPC complied with government policies concerning pipeline design standards?
2. What is the current maintenance activities adopted in pipeline protection in Ondo State?
3. What is the extent of NNPC compliance with modern ways of corrosion protection techniques?

Hypotheses

The following null hypotheses were formulated to guide the study:

H_{01}: There is no significant difference in the mean responses of pipeline maintenance technicians and engineers on the level of NNPC compliance with government policies concerning pipeline design standards

H_{02}: There is no significant difference in the mean responses of pipeline maintenance technicians and engineers on the extent of NNPC compliance with modern ways of corrosion protection techniques

Methodology

A survey research design was adopted for this research. The reason for choosing the survey design is that it deals with relatively large population on which samples will be drawn (Babbie, 1998), secondly, The survey research design was considered appropriate because the study focused on the collection of data from group of people on the existing conditions. This study sought the opinions of engineers and technicians on the corrosion protection practices on NNPC pipelines in Ondo state.

The research work was carried out in NNPC depot at Ore, located in Odigbo local-government area of Ondo State, Nigeria. The target population for this study consisted of 120 pipeline maintenance personnel comprising 90 pipeline maintenance technicians and 30 engineers employed at NNPC, Ore. A purposive sampling technique was used to select 80 pipeline maintenance technicians who have served for at least 6 months at the depot. All the 30 engineers were used giving rise to 110 respondents that were involved in the study.

The research instrument for the study was a structured questionnaire titled: Pipeline Corrosion Protection Practices Questionnaire (PCPPQ). The instrument was validated by three experts, two lecturers from the Department of Industrial and Technology Education, Federal University of Technology, Minna and a pipeline maintenance Engineer from NNPC depot Pogo Niger State. To establish the reliability of the instrument, a pilot test was conducted using four (4) maintenance engineers and Ten (10) pipeline maintenance personnel from NNPC depot Pogo Niger State. These personnel were not used for the main study; the reliability coefficient of 0.79 was established using Cronbach Alpha. The instrument was therefore adopted for the study since the homogeneity has been confirmed statistically.

The questionnaires were administered by the researchers and with the help of two personnel assistants at the NNPC depot Ore. Four point rating scales of Highly Complied (HC), Moderately Complied (MC), Poorly Complied (PC), Not Complied (NC), Highly Adopted (HA), Adopted (A), Fairly Adopted (FA), Not Adopted (NA)., High Extent (HE), Medium Extent (ME), Low Extent (LE), Poor Extent (PE).The data collected was analyzed using mean and t-test. Mean was used to answer the research questions while t-test was used to test the hypotheses formulated for the study. The mean value of 2.50 was used as decision point for every questionnaire item. Consequently, any item with a mean response of 2.50 and above was considered as meeting the criteria (complied, adopted, high extent) and those with a mean response less than 2.50 were considered not meeting the criteria.

Research Question 1

What extent has NNPC complied with government policies concerning pipeline design standards?

Table 1

Mean response of technicians and engineers on the extent NNPC complied with government policies concerning pipeline design standards

		$N_1 = 80$			$N_2 = 30$
S/N	***ITEMS***	$\bar{X}_1$	$\bar{X}_2$	$\bar{X}_t$	***REMARKS***
1	Pipeline system should be designed in accordance with the standard ANSI/ASME B 31.4 – 1979	1.93	3.67	2.80	Complied
2	Pipelines for liquid products should be materials conforming to the ASTM A 106 Grade B or API 5L Grade B for low pressure range and any of the API 5LX range for high working pressure.	2.57	3.00	2.79	Complied
3	Pipelines for gas products should be materials conforming to the specifications of the reference Standard ASME B31.8	2.57	3.00	2.79	Complied
4	The pipelines should be seamless in fabrication and Electric Resistance Welded (ERW) or Double Submerged Arc Welded (DSAW)	1.60	2.17	1.88	Not complied
5	The design should generally follow the specifications and procedures prescribed in NACE RP 0169-96.	2.79	3.60	3.19	Complied
6	The pipelines should be protected with coatings.	2.79	3.60	3.19	Complied

7	The pipelines should be protected with cathodic system as stated in the policy	2.57	3.00	2.79	Complied
8	The points of connection of any attachment to the pipeline should be sealed with the coatings, together with the attachments themselves.	1.79	2.77	2.28	Not complied
9	The cathodic protection system should be installed in such a way that it mitigates corrosion.	1.51	2.37	1.94	Not complied
10	The cathodic protection system should be electrically isolated at all inter-connections to other pipeline	1.94	2.10	2.02	Not complied
11	The cathodic system should be protected against damage by atmospheric electrical discharges, underground cables and power lines.	1.70	3.13	2.42	Not complied
12	A minimum separation of 3 meters should be maintained between electric transmission tower footings, ground cables and earthlings, power lines and the pipelines under protection.	3.87	3.93	3.90	Complied
	Grand Mean	**2.30**	**3.02**		

Key

N_1 = Number of Technicians, N_2 = Number of Engineers

$\bar{X}_1$ = Mean response of Technicians, $\bar{X}_2$ = Mean response of Engineers

$\bar{X}_t$ = Average Mean response of Technicians and Engineers

Table 1 revealed that NNPC complied with 7 out of 12 government policies on design standards with mean scores ranging from 2.79 – 3.90 while they failed to comply with items 4,8, 9 10 and 11 with mean score ranging between 1.88 and 2.42. The Grand mean of technicians and engineers were 2.30 and 3.02 respectively.

Research Question 2

What is the current maintenance activities adopted in pipeline protection in Ondo State?

Table 2

Mean Responses of technicians and engineers on the current maintenance activities adopted in pipeline protection in Ondo state.

		N_1 = 80		N_2 = 30	
S/N	***ITEMS***	$\bar{X}_1$	$\bar{X}_2$	$\bar{X}_t$	***REMARKS***
13	Physical routine checks on pipes.	4.00	4.00	4.00	Adopted
14	Computer monitoring system.	3.01	3.33	3.17	Adopted
15	System to detect exact location of corrosion along pipeline system in remote areas and underground.	1.39	1.83	1.61	Not Adopted
16	Weekly checks of pipeline to ascertain needed repair	2.01	2.07	2.04	Not Adopted

17	Monthly physical checks on pipelines.	3.60	3.97	3.79	Adopted
18	Annual physical checks on pipelines.	4.00	4.00	4.00	Adopted
19	Breakdown maintenance	1.60	2.43	2.02	Not Adopted
20	Internet facilities to monitor the status of pipeline systems	1.34	1.47	1.40	Not Adopted
21	Real time alarm to monitor leaks in pipeline systems	1.00	1.17	1.08	Not Adopted
22	Usage of helicopter for the surveillance of pipeline tracks.	1.00	1.33	1.67	Not Adopted
23	Maintenance according to management instructions.	4.00	4.00	4.00	Adopted
24	Camera surveys to monitor the activities of the pipelines	2.01	3.57	2.79	Adopted

Table 2 revealed that NNPC adopted 6 (50%) of 12 current maintenance activities suggested for pipeline protection in Ondo State. These techniques had mean scores ranging between 2.79 and 4.00. Items 15 - 16 and 19 – 22 were not adopted; they had mean scores ranging between 1.08 and 2.04.

Research Question 3

What is the extent of NNPC compliance with the modern ways of corrosion protection techniques in Ondo state?

Table 3

Mean response of technicians and engineers on the extent NNPC complied with the modern ways of corrosion protection techniques in Ondo state.

S/N	ITEMS	$\bar{X}_1$ ($N_1 = 80$)	$\bar{X}_2$ ($N_2 = 30$)	$\bar{X}_t$	REMARKS
25	Impressed current cathodic system	3.43	3.50	3.46	High extent
26	Galvanic Anode cathodic system	2.64	3.13	2.89	High extent
27	Fusion-bonded epoxy (FBE) coating	3.43	3.50	3.46	High extent
28	Cold-applied tapes	1.79	1.83	1.81	Poor extent
29	Shrink sleeves	1.71	1.83	1.77	Poor extent
30	Syntho-Sleeve	1.71	1.83	1.77	Poor extent
31	Concrete coatings	1.29	1.17	1.23	Poor extent
32	Metallic coatings	3.21	3.40	3.31	High extent
33	Fiberglass Reinforced Polymer (FRP)	1.00	1.00	1.00	Poor extent
34	polyethylene-coatings	1.31	2.00	1.66	Poor extent
35	Galvanization of pipes	3.14	3.63	3.39	High extent
36	Thermal spraying coatings	2.21	3.00	2.61	High extent
	Grand Mean	**2.24**	**2.49**		

Response of technicians and engineers on Table 3 revealed that NNPC complied with 6 (50%) of 12 modern ways of corrosion protection techniques in Ondo State. These techniques had mean scores ranging between 2.61 and 3.46 while those not being used by NNPC had mean scores between 1.00 and 1.81. Grand mean of technicians and engineers were 2.24 and 2.49 respectively, indicating non compliance with modern ways of corrosion protection.

Hypothesis 1

H_{01}: There is no significant difference in the mean responses of pipeline maintenance technicians and engineers on the extent NNPC complied with government policies concerning pipeline design standards.

Table 4

t-test Analysis of technicians and engineers on the extent NNPC complied with government policies on pipeline design standards.

N/S	*NNPC STAFF*	*Number*	$\bar{X}$	*SD*	*df*	*t-cal*	*t-table*
1	Technicians	80	2.30	0.66	108	- 0.82*	± 2.00
2	Engineers	30	3.02	0.48			

Key: ** Not significant,* ***df*** *= degree of freedom,* ***t-cal*** *= t-test calculated,* ***SD*** *= Standard deviation*

Table 4 revealed that calculated t-value is - 0.82 while table value is 2.00 showing that t-calculated is less than the table value, the null hypothesis is therefore accepted. The result of this test suggests that there is no significant difference in the opinions of technicians and engineers on NNPC compliance with government policies on pipeline design standards.

Hypothesis 2

H_{02}: There is no significant difference in the mean responses of pipeline maintenance technicians and engineers on the extent of NNPC compliance with modern ways of corrosion protection techniques.

Table 5

t-test Analysis of technicians and engineers on the extent NNPC complied with modern ways of corrosion protection techniques

N/S	*NNPC STAFF*	*Number*	$\bar{X}$	*SD*	*df*	*t-cal*	*t-table*
1	Technicians	80	2.24	0.54	108	- 0.58*	± 2.00
2	Engineers	30	2.49	0.35			

Key: ** Not significant,* ***df*** *= degree of freedom,* ***t-cal*** *= t-test calculated,* ***SD*** *= Standard deviation*

Table 5 revealed that calculated t-value is - 0.58 while table value is 2.00 showing that t-calculated is less than the table value, the null hypothesis is therefore accepted. The result of this test suggests that there is no significant difference in the opinions of technicians and engineers on NNPC compliance with modern ways of corrosion protection techniques.

Discussion of the Findings

Findings revealed that NNPC pipeline system in Ondo state is designed in accordance with the standards of American National Standards Institute (ANSI), American Society of Mechanical Engineers (ASME) and National Association of Corrosion Engineers (NACE). This is supported by Phil (2002), ho maintained that all pipelines must sure compliance with codes and gislations; the system must satisfy local d national standards and laws. The study so revealed that the pipelines are rotected with cathodic system and rotective coatings. This is in agreement with sections 33 & 34 of the Oil and gas pipeline Act, CAP 338 of the Law of the Federation of Nigeria (1990). It states that "Corrosion protection of welded pipeline shall constitute the minimum requirements and the procedure for cathodic protection of ferrous pipe and its components from internal and external corrosion. The design of which shall generally follow the specifications and procedures prescribed in National Association of Corrosion Engineers (NACE) RP 0169-96. This shall consist of application of coatings to the pipeline and its cathodic protection. Also, the findings revealed that the protective coatings are not adequately applied and the points of connection of pipeline attachments to the system are not sealed. This is against the recommendations of Oil and Gas pipeline Act, CAP 338 of the Law of the Federation of Nigeria, (1990). The law recommended that points of connections of any attachment to pipeline shall be equally sealed with the coatings, together with the attachments themselves. This submission is corroborated by t-test analysis (Table 4) of technicians and engineers that revealed no statistically significant difference in their opinion.

Findings on the current maintenance activities adopted in pipeline protection revealed that weekly checks of pipeline are not carried out to ascertain needed repair. This is in line with the claims of Balogun and Kareem (2013) that Oil companies' negligence and poor maintenance are key factors adding large quantities of hydrocarbon into the environment. The hydrocarbon quantity in this respect is estimated at 13.5 % while other rare cases such as pipeline explosion, waste from oil companies and pipeline vandalism are 4.5% by volume respectively. The findings also indicated that NNPC in Ondo state has adopted computer monitoring system but do not have system to detect the exact location of corrosion along its pipeline system in remote areas and underground. It is also revealed that NNPC do not use real time alarm to monitor leaks on its pipeline systems. This can be corroborated by the recommendation of Abosede (2010) that Oil companies are obliged to adopt all practicable precautions including the provision of advanced equipment such as oil leak detector, real time alarm and un-manned aircraft to monitor the activities of their pipelines. The findings indicated that breakdown maintenance is not always emphasized. This confirmed the report of This Day (7th October, 2013) on a ruptured NNPC pipeline in Ugho kingdom of Ondo state. The pipeline was discovered a week after and a team of oil workers, including engineers, were drafted to repair only the damaged portion.

Findings on the extent of NNPC compliance with modern ways of corrosion protection techniques further revealed that impressed current cathodic system, Galvanic Anode cathodic system, Fusion-bonded epoxy (FBE) coatings are highly used for corrosion protection. This agreed with the work of Abboud (2007) that the application of cathodic protection alone to protect against corrosion of welded pipelines would not be practicable, because the amount of current required is proportional to the exposed area, and it would be too expensive to cathodically protect a long, bare pipeline. This is in line with Micheal (2008), that primary method of preventing or mitigating external corrosion on buried pipelines involves a combination of cathodic protection and coatings. Morgan (1987) also argued that cathodic system has widespread application on underground pipelines. The findings revealed that modern corrosion protection techniques such as Fiberglass Reinforced Polymer (FRP) and polyethylene-coatings have not been used. This may be as a result of cost implication. Table 5 revealed that technicians and engineers do not differ in their opinions on the extent of NNPC compliance with modern ways of corrosion protection techniques.

Conclusion

In conclusion, the findings revealed that NNPC Pipeline system in Ondo State was designed in accordance with some specified national and international standards and regulations. NNPC however failed to comply with some government policies on pipeline design standards; this make pipelines an easy target for corrosion. However, the rate of this degradation can be controlled with application of cathodic system and advanced coating system. Meanwhile, the study indicated that NNPC, Ondo State has not adopted the modern corrosion protection techniques such as Fiberglass Reinforced Polymer (FRP), polyethylene-coatings for its maintenance on the pipeline system and Use of helicopter for the surveillance of pipeline tracks.

Recommendations

Based on the findings of the study, the following recommendations are made:

1. Ministry of Petroleum resources should review the Oil and gas pipeline Act in order to establish an effective regulatory and monitoring mechanism for oil pipelines in order to safe life and properties.
2. There should be improved supervisory teams that adequately check the activities of the industries to ensure compliance with standards, specifications and regulations.
3. Preventive maintenance should be carried out on weekly basis to prevent breakdown of pipeline system and on occasion of rupture or spillage due to corrosion; break-down (corrective) maintenance should always be emphasized.
4. There should be appropriate legislation that will compel NNPC to use best practices available to the industry, in order to safe life and properties of surrounding communities.
5. Modern corrosion protection techniques such as Fiberglass Reinforced Polymer (FRP) and polyethylene-coatings should be employed for safety of life and properties.

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