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TRACE CHARACTERISTICS OF IONIZED RADIATION IN CORROSION INDUCED OIL AND GAS PIPELINES

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ABSTRACT

Tracer elements used in the oil and gas industry exhibit characteristic radioactive reactions with quantized ionized radiations. The physico-chemical behavior, half life, specific gravity, type and energy of radiation are some of the main parameters that characterize ionized radiations as monitored with automatic high spectrum gamma monitor of type UK-1.5m. On the other hand, steel structures, pipeline wall thickness, machine parts and other metallic equipment are governed largely by the operating conditions of pressure and temperature that is further influenced by the intensity of the radiation corrosivity. In this research, characteristics of ionized radiation in metallic structures and pipelines have been investigated using the guided direct measurement with Electron Microprobe Analyzer for measurement and weight loss determination respectively. The results obtained indicated that ionized radiation intensity varies according to operating conditions of temperature and pressure and rapidly influence corrosion activities at stress points, rapid Oil spills and Gas leaks with increased pollution in the inland basins and offshore Niger Delta. Corrosion tolerant limit values (0.064, 0.072 and 0.078mpy) tend to increase more when the pipelines are shut down and abandoned. This research is useful for real time surveillance, planning and good decision making for a sustainable Oil and Gas industry.

INTRODUCTION

The increasing global demand in knowledge base nuclear science and technology in general and its peaceful application in the oil and gas industry in particular is important for the socio economic and political development of any nation. However, naturally occurring radioactive materials (norm) and radionuclide of the type I4C, 4Ok 87Rb, 232Th and 288U with frequent decay series are classified into the Technology Enhanced Natural Radiation (TENR) which are dangerous for pure environmental healthy living (Mallam *et al.* 2001). Some of the industrial activities identified as major contributors to TENR in the environment are pronounced in oil and gas prospecting, drilling and abstraction, mining and geosciences, operations including building materials from mine waste, production of fertilizer etc., (Neeka *et al.* 2006). Most often, institutional frameworks that support core radiation protection and safety which would address the issue of improving the capacity to manage radioactive waste and harmonized environmental moni-

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toring approach and measurement are either obsolete or not available. Although there are facilities, installations and instruments in the industries with radioactive source, there are evidences that radiation protection and safety practices in managing radioactive waste especially in oil and gas operations are grossly inadequate (Radiotracer Techniques for Leak Detection: International Atomic Energy Agency Regional Cooperative Agreement, India 2004.) In most cases radiotracers as viable interim measures are useful in leak detection in oil and gas pipelines especially internal leaks in tube walls. This approach in itself is not preventive but more post mortem. Highly sensitive detection through ionized radiations are done through the use of radiotracers, which are injected into the system to mixed with the flowing fluid thereby providing sharp pulse for easy detection. Several types of ionizing radiation are used in the oil and gas industry broadly cap into radioactive and x-ray substances. The main areas of application are in well logging, surface gauge, scanning, Non Destructive Testing (NDT), x-ray diffraction in drilling, instrumentation (level/density/measurement control, calibration and thickness measurement, Tracer and testing etc., which are good corrosion inducers (Maduabuchi, 2005). By natural phenomenon the process of corrosion is nature's way of returning metals to its original state. However, ionized radiations enhance the destruction of metal by electrochemical reactions with the environment through thermal processes. Coating and coating techniques available for various industrial purposes differ greatly from time to time and for different types and kind of corrosion failures. Thus corrosion induced-failure of pipelines has grave consequences on the oil and gas process lines such as uncontrolled fire outbreak, pollution and environmental degradation (International Atomic Energy Agency (IAEA) 2003). Peaceful application of ionized radiation in the oil and gas sector should be connected with nuclear safety and radiological protection, including security and physical protection of nuclear materials radiation monitoring and coordination of the intervention activities due to radiation emergency. The situation could influence rapid pipe weight loss and thus increase corrosion related failure (James Griffin, 2008). The knowledge base TENR, Scanning Electron Microscope (SEM) and Auger Electron Spectroscopy (AES) used in non-destructive testing gives a microanalyzed effect to detecting fractures. The process is studied through the application of qualitative, quantitative and numerical analysis methods. The characteristic pathway of ionization of radioactive material in corroded pipes in respect of the service life of the structural members could be evaluated using the Lussel's mortality curve as reference (Jacob, 2013).

MATERIAL AND METHODS

Test procedure

According to IAEA standard (2000), the installation and use of automatic high spectrum gamma monitor of type U K-1.5m with scintillation devices sensitive enough to detect low capacity gamma.-ray contaminations were installed along corrosion flash points in the typical salty deltaic region. Pipeline network of dimension and type 24" 18" 10" and 8″ respectively, were serially arranged horizontally along pathways and cleaved together, buried deep into the earth at some points and resurfaced at another for easy maintenance. Portable dosimeters and contamination monitors were also installed at suspected leakage points along coated pipelines. However, possible mathematical model equations for the determination of the quantum of ionized radiation emitted through radiotracer method.

Developing Models for Radiation Characterization

The model presents an axial dispersion of tracer elements moving with the traced fluid such that the maximum concentration of the ionized tracer is given as:

$$C(x, t)_{\max} = \frac{Q}{S\,(4\pi\,Dt)^{1/2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

Where:

- C (x, t) = concentration of ionized tracer element moving with the system fluid at time t and point x (Bq/m^3)
- D = fluid axial dispersion coefficient (m^2/s)
- Q = quantity of ionized tracer element in the inlet fluid flowing through the pipes
- S - pipe size (diameter) m^2

When plug flow regime without axial dispersion is considered, the result is satisfactory.

If certain concentration of the tracer elements is imputed into the flowing fluid as impulse, at point x and as a function of time t, then the material balance for the tracer from equation 1 is given as:

$$Q = \phi\, \xi C(t)dt \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

Where: ϕ is volumetric flow rate (m^2/s) and C (t) is the ionized tracer concentration in the flow. However, the total quantity of the tracer element counted as a function of time at any determined point on the pipe network could be accounted for by simplifying equation 2 above thus:

$$Q \frac{\varphi\pi\alpha\tau}{2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3$$

Where π and *áT* are the calibration coefficients and total number of counts accumulated during tracer measurements respectively. Though the formula method is applied and approximate, there are empirical techniques that can be used to determine ionized radiations in completely homogenized now through corroded pipes. But the purpose of characterization is to ensure safety by reducing risk of system failure and cost. So that if we assume certain volumetric factor of ionized radiation F over the discretized pipe network, and building the concept of cost then equation (3) yield;

$$Q = \frac{yFc}{ypaT} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 4$$

Where

F is the design safety factor and C is the quantum of the ionized radiation at time T.

$$Q = \frac{RFc(1+a)m}{yPaT(r+r^2)^m} \quad \ldots\ldots\ldots\ldots\ldots\ldots 5$$

Where

$$\frac{(1+r)^m}{[(r+\pi]^2)^m} - 1$$

is the cost of replacing failed pipes along identified Routes Right of Way (ROW) and R is the Rate of radiation emission.

R

While (1+ r) m is the risk factor that should be determined at the design and experimentation stage under a given flow regime.

RESULTS AND DISCUSSIONS

The control of radiation sources, handling of hazardous waste and response capabilities in the case of a radiological emergency could contribute to a better perception of risks associated with deficiencies in or lack of industrial protection control mechanisms. Establishment of a radioactive waste management center designated for the collection, analysis and deconcentration of the ionized particles could be a panacea for easy control. Normally the tracer element mixed with the fluid of the pipe moved towards the expected leak point in the pipelines. Measurement of the ionized radiation from the tracer help in discovering the possible corroded parts and hence leak points. Radiation protection is important. This is why radiotracer activity to be injected is calculated based upon fluid. How rate, detection sensitivity and suspected corrosion damage size. Thus radiation processing especially using electron beam treatment is a promising tool for effective disposal of industrial pollutants as well as facile modification of corrosive materials in metallic structures in oil and gas industries. From the analysis of the result as shown in table 3: the tensile strength and corrosion resistance of steel material exposed to radioactive radiation are in the order AISI 430 > AISI 316 >AISI 410> AISI 403> AISI 304> AISI 405. Current density of pipes maintained at 85OmV over the entire length of the pipes, s pikes occurrences in the pipe-to-soil at intervals. The pipe-to-soil potential maintained at some radiation flash points were at 2.5km,9.3km and l7km for AISI 430 > AISI 316 >AISI 410 respectively. As radiation intensity increases pipeline protection level decline over time. Increased coating conductance of pipes reduced the penetration of irradiated ions which result in fluctuations in the tensile strengths of pipe networks at intervals. In most cases, epoxy powder with ployamide-cured coal tar is more suitable for protection.

It serves as a dielectric shield, improving the current distribution resistance in the metals as well as reducing the number of anodes required for protecting the pipelines. The potential drop in the pipes indicates that corrosion resistance in pipes is directly related to the elemental composition of the metal. Thus it is evident that the lower the intensity of radiations, the greater the pipe diameter the better the durability. This is the reason why increasing recognition should be given to radiation protection authorities and pipeline surveillance activities that are interdependent or the need to adopt holistic approaches where necessary in nuclear radiation management techniques in oil and gas pipelines. For example, management of the marine and terrestrial environmental and aquatic environments are related to pollution control and the impact of climate change is linked to better understanding of the water cycle which are directly related to the volume of concen-

Table 1. Sources of radiation Emitting Devices and status in Nigeria.

Practice	Source/ Device	Number Authorized	Initial Activity	Status
Radiography	X- rays	16	185TBq	Commissioned
Mammography	X-rays	4	N/A	-do-
Tomography	X-rays	5	N/A	-do-
Angiography	X-rays	2	185TBq	-do-
CT	X-rays	3	N/A	Reactor
Brachy therapy	Cs-137	2	185 TBq	Custom control
Teletherapy	Co-60	1	185TBq	Reactor
Nuclear medicine	Tc-99m	1	7GGq/2wks	Commissioned
Surface Gauge	Cs ^{137}+ Am^{241}	14	55.2MBq	Reactor
Brachy therapy	Ra226	19	190mg	Decommissioned
Thickness Gauge	Sr90	16	37-74MBq	Reactor
XRF	Cd90	1	111MBq	Custom control
Oil Logging	Cs ^{137} Am^{241}	14	78.8GBq 740GBq	Reactor
Moisture Gauge	Am241+Cs ^{137}	3	111GBq	Reaction
Diffraction	X-rays	4	21GBq	Commissioned
Irradiation	Co ^{60}	2	1850Bq	Customer control
Calibration	Cs ^{137}	1	37GBq	Commissioned
Scanning	2Mev X-rays	5	3.7GBq	Reactor
Container	5Mev X-rays	3	1011 n/s	Custom control
Radioactive Tracing	Cs^{137}+ Am^{241}	8	21.2GBq	Reactor

Table 2. lionized radiation frequency and corrosion rate.

Time/Yrs	288U	CR	^{226}Ra	^{137}Cs
0	0.32	0.034	0.032	0.032
0.05	0.055	0.041	0.052	0.051
0.15	0.033	0.054	0.034	0.032
0.35	0.049	0.058	0.042	0.052
0.31	0.051	0.064	0.051	0.049
0.36	0.052	0.072	0.053	0.048

trated CO_2 emission from a polluted hydrocarbon source.

CHALLENGES AND PROSPECTS

Radioactive waste is an unavoidable remnant from the use of radioactive substances and nuclear technology. It is produced by the beneficial practices such as nuclear research in industry and from industrial activities that uses naturally occurring radioactive materials such as the mining of radioactive ores, oil and gas prospecting and pipeline surveillance in oil and gas etc. Radioactive wastes are potential hazards to health and must be managed to protect human and the environment. Back tracking of orphan sources is on- going, which is effected through a strategy of periodic press releases and information from collaborators and regulators such as FEPA, DPR, NOSDRA, CUSTOM and EXCISE, SON etc. The effectiveness of the back tracking mechanism depends largely upon the collaborators and co-operation of all stakeholders and the general public in notifying NNRA about orphan sources. As a matter of policy therefore authorization procedure should require registrants and licensees to provide information about the radioactive waste management option for their spent sources and waste generated. Because radiation is hazardous prescribed safety and legal regulations must be followed. There should be proper optimization of radiation exposures and doses for the health of human and the ecosystem. The optimization of ionized radiation primarily depends upon distance, time and shielding. Thus proper distance from the source must be maintained according to the stipulated regulatory and legal framework. The time spent in handling ionized elements must be reduced to the barest minimum. Personnel in contact with radiation source should use an optimum thickness of the shielding material between him and the source. Finally proper environmental awareness campaign is needed to prevent chemical genocide in operational areas.

RECOMMENDATIONS AND THE WAY FORWARD

- Training and Development unit should be created for real time radiation detection experts

Table 3. Elemental Composition of the Stainless Steel Samples Studied.

Type/pipe size	Sample	C	Cr	Ni	Mo	Si	Mn	S	P
Austentic 10	AISI 304	0.08	18.40	9.00	N/A	0.42	0.53	0.03	0.03
Austentitic 18	AISI 316	0.05	18.94	10.15	2.13	0.65	1.58	0.04	0.04
Martensitic 10	AISI 403	0.16	12.14	N/A	N/A	0.48	0.52	0.03	0.05
Martensitic 18	AISI 410	0.12	12.20	N/A	0.65	0.52	0.38	0.04	0.03
Ferritic 10	AISI 405	0.08	13.52	10.15	N/A	N/A	1.50	0.03	0.02
Ferritic 18	AISI 430	0.16	16.89	16.89	2.40	N/A	0.45	0.05	0.02

Table 4. sources of Ionizing Radiation in Nigeria

Radiographic Technique (industrial and medical	
Industrial y and X-ray radiography NDT	10^{12}Bq 192 and 140 KVp X-rays.
Medical Diagnostic radiography	30-130 KVp X-rays
Beta Radiography	^{14}C (40KBq/g).
Neturton radiography	^{252} CF (5 g).
Analytic Technique (Industrial)	
X-ray florescence	40-60 KVp (up to 40 KBq y- source)
Neutron Capture	
Gauging Techniques (Industrial)	
Transmission Gauges (Beta and Photons)	0.04-49MBq sources
Electron capture	Low energy Y – sources
Gamma Backscatter Gauge (Industrial)	
X-ray fluorescence	^{241} Am
Photon switching level gauge	Low energy y-sources (40GBQq)
Selective y-absorption	Liquid ^{241} Am (4 GBq)
Gamma Scattering	^{137} Cs (500 MBq)
Irradiation Techniques	
Radiation Beam Therapy (Teletherapy)	^{60} Co (100 TBq), Linear Accelerator.

Table 5. Commonly Used lionized Radiotracers for Leak Detections

Radioisotope	Half-life	Radiation and Energy (MeV)	Chemical Form	Tracing of Phase
Sodium-24	15h	Y:1.37(100%) 2.75(100%)	Sodium Carbonate	Aqueous
Bromine-82	36h	Y:0.55 (70%) 1.32 (25%)	Ammonium Bromide Methyl Bromide	Aqueous Gases
Iodine-131	8.04d	Y: 0.36(80%) 0.64(9%)	Potassium lodidelodobenzene	Organic
Molybdenum-99	67h	Y: 0.18 (4.5%) 0.74(10%)	Sodium molybdate	Aqueous
Technetium-99m	6h	Y:14 (15%) 0.78 (4%)	Sodium technetate	Aqueous
Krypton-85	10.6y	Y:05.51 (0.7%)	Krypton	Gases
Krypton-79	35h	Y:0.51 (15%)	Krypton	Gases
Xenon-133	5.27d	Y:0.018(37%)	Xenon	Gases
Argon-41	110min	Y:1.29 (99%)	Argon	Gases

and integrated into the Nigerian content Development programme in the Petroleum sector.

- Statistical inventorization of the type, source and manufacturing data of ionized instruments/equipment should be carried out periodically by the Nigerian Nuclear Regulatory Agency (NNRA) and the department of Petroleum Resources (DPR).
- An efficient data base should be developed for research and documentation in the sector.
- Characterization of ionized radiations should be done in collaboration with the manufacturing firms in order to safeguard the lives of workers engaged in handling such equipment.

- Personnel protective equipment should be made compulsory and routine inspection carried out on compliance standard for industry workers.
- Equipment and material prone to Corrosion should be properly coated and protected from radiation emission in order to avoid Corrosion susceptivity and equipment failure.
- Baseline studies on impact assessment should be mandatory for operators and service providers involved with the supply and use of radiation equipment.

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