REGULATORY CONTROL AND REDUCTION OF RADIOACTIVITY IN OIL & GAS WASTES IN NIGERIA

BY

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ABSTRACT

Naturally occurring radioactive materials (NORMs) are ubiquitous in the environment. Moreover, technologically enhanced natural radioactive materials (TENRaMs) are associated with all Oil & Gas exploration and production (E&P) wastes in Nigeria. Some of these radioactive materials, primarily radioactive tracers or logging tools are deliberately brought to the Oil & Gas E&P locations for use during logging with wireline tools. Radioactive tracers are commonly used in injection wells to determine points of fluid entry into the formation, hydraulic fracture height and/or fluid leaks in the cement behind casing. About 95% of all drilling mud comprises water, clay and barite. In a newly developed technology of synthetic drilling mud, materials with natural radioactivity (MNR) are used as drilling mud components. The size of MNR particles is controlled in accordance with the size of the drilling mud component. MNR is therefore introduced into the drilling mud to ensure irreversible sequestration of the MNR particles concentration in the mud to suppress their radioactive nature. Commonly used radioactive tracers for liquid phase measurements include antimony – 124, (as antimony oxide), iridium – 192 (as potassium hexachloroiridate), scandium – 46 (as scandium chloride) and iodine – 131 (as sodium iodide). Krypton – 85 has been used as a vapor phase tracer. The occurrence of environmentally high concentrations of radioactive materials, especially radium isotopes in oil field production waters (also called oil field brines, produced water, produced wastewater or formation water) is well documented. The radionuclides appear to be leached from the clay minerals and are associated with the decay of uranium and thorium atoms. Environmentally high concentrations of naturally occurring radionuclides (e.g. Ra – 226, Pb – 210) in precipitates collected from the bottom of oil-water separators and from ditches and pits used for disposal of production water have also been reported. Contaminated piping from Refineries has been found in scrap iron yards outside Nigeria. The magnitude of the problem of radioactivity of oil & gas wastes is difficult to estimate, regulate and control but it is not unrealistic to expect contamination in all oil & gas E&P locations and pipe handling facilities for the oil & gas companies in Nigeria.

Three general principles are usually employed in the management of radioactive wastes, namely: Concentrate and contain, Dilute and dispose, and Delay and decay. While the first two methods are also applicable to other wastes, the last method is however, unique to radioactive waste management.

This paper highlights the sources of radiation in oil & gas E&P operations in Nigeria. It reviews the current status of research in the area as well as summarizes the apprehensions/ concerns usually expressed about radioactivity in oil & gas wastes. It recommends some action plans including the inclusion of radiation policy in respective oil companies HSE objectives as well as strategic partnering with relevant stakeholders to ensure regulatory control and reduction in radioactivity in oil & gas wastes in Nigeria.

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INTRODUCTION

Many Oil and Gas drilling sites and production facilities have radioactive materials associated with them. Some of these radioactive materials, primarily radioactive tracers or logging tools, are deliberately brought to the site for use, while other materials are naturally occurring and are called naturally occurring radioactive materials (NORMs). These radioactive materials technologically enhanced by human activities are generally referred to as technologically enhanced natural radioactive materials (TENRaMs).

Naturally occurring radioactive materials (NORMs) are found virtually everywhere on the earth, including ground and surface waters. During the production of oil and gas, radioactive materials that naturally occur within the earth can be coproduced. Where the concentrations of NORM are usually very low, these materials can be concentrated during production: the concentration level can become high enough to cause a health hazard if improperly managed.

Radioactive sources are used primarily during logging with wireline tools. Both gamma ray and neutron sources are available. These sources are sealed within the logging tools and are normally not a problem.

Radioactive tracers are commonly used in injection wells to determine points of fluid entry into the formation, hydraulic fracture height, and/or fluid leaks in the cement behind casing. The tracer is injected into the well bore and a gamma ray detector is then logged through the well to determine depths at which the radioactivity is high. Commonly used radioactive tracers for liquid phase measurements include antimony – 124 (as antimony oxide), iridium – 192 (as potassium hexachloroiridate), scandium – 46 (as sodium chloride), and iodine – 131 (as sodium iodide). Krypton – 85 has been used as a vapour phase tracer (Reis, 1996).

There are four radionuclides most commonly found in NORMs in upstream petroleum industry: radium – 226, radium – 228, radon – 222, and lead – 210. Radium – 226 is probably the nuclide with the greatest potential for environmental impact for the petroleum industry. Radium (both 226 and 228) is highly soluble and is produced as a dissolved solid with the produced water. The levels of radium in produced water vary significantly. Radium is co-precipitated with barium, calcium and strontium sulphate as scale in tubulars and surface equipment during production. This concentrates the radium and makes the scale radioactive. Radium can also be concentrated in various production sludges through its association with solids in the sludge.
NORM, elements that are radioactive in their natural physical states, can be associated with oil and gas production and includes the elements uranium, thorium, radium and radon and their daughter products. NORM has been found in downhole tubing scale, in above-ground processing equipment, salt water disposal/injection wells and associated equipment, and soils contaminated by well workovers, tank cleaning, water leaks, pipe cleaning, and other associated operations.

Under various circumstances, the radionuclides, primarily from the radium and thorium decay series, can contaminate the environment to the extent that they pose real or potential public health risks. The investigation and regulatory control of the impacts of most of these sources have been overlooked by federal and state agencies in the past, while stringent controls were placed on X-ray and other man-made sources of radiation. This lack of strict regulatory controls has been due, in part, to the fact that the federal government has limited capacity in terms of human and material resources to deal with the problems of regulatory controls and reduction of radioactivity in the Oil & Gas wastes in Nigeria.

While there are over 100 naturally occurring radionuclides but public health problems are usually limited to the 30-odd radionuclides in the Uranium and Thorium decay series because of their relative abundance and toxicity. These radionuclides are generally the result of some technologically enhancement of the isotopes.

SOURCES OF RADIOACTIVE WASTES FROM OIL & GAS OPERATIONS

OIL & GAS PRODUCTION ACTIVITIES THAT GENERATE WASTES

In the upstream petroleum sector, waste is generated from a variety of activities associated with Oil & Gas production. These activities include drilling, production, stimulation, gas processing and deliberate disposal of the wastes (Reis, 1996).

Drilling

Drilling for crude oil is the process in which a hole is made in the ground to allow subsurface hydrocarbon to flow to the surface. Drilling activities generates a variety of different types of wastes. These wastes include produced water, drilling fluids and the formation cuttings generated during drilling (Reis, 1996).

Produced water is also called "oil field production waters", "oil field brines", "produced wastewater", or "formation water".

The water produced in drilling for oil almost always contains impurities that can have environmental impacts. These impurities include high concentrations of salt, suspended and dissolved hydrocarbons, formation solids, hydrogen sulphide, carbon dioxide, and a deficiency of oxygen. Dissolved solids, such as calcium, magnesium, potassium, barium, strontium, radium, lead, arsenic, manganese, iron and antimony, may also be present. Additives such as coagulants to assist the separation of oil and solids from the water, corrosion inhibitors, emulsion breakers, biocides, dispersant, paraffin – control agents, and scale inhibitors, often need to be used to alter the properties of the produced oil and water (Reis, 1996).

Produced water sometimes contains low levels of naturally occurring radioactive materials (NORMs). Although the NORMs content of produced water is usually insignificant, radium can be concentrated in tubing and equipments through co precipitation with barium, strontium and calcium scales. Radioactive lead can collect as a thin film inside gas-processing equipment. Radon gas can also be produced and concentrated in low-lying areas. Through these contraction mechanisms, sufficient levels of NORMs can accumulate to create a health risk.

Drilling fluids (drilling mud) are used to remove cuttings from the hole, control the formation of pressure to prevent blow-outs, maintain hole integrity before casing is installed, and cool and lubricate the drill bit and string. According to Thurber (1992), water is the most common base fluid for drilling mud. A number of additives are required, however to alter its properties to make it suitable for this application. The most common additives are clays to increase its viscosity and enhance the removal of cuttings from the hole and barite (Barium sulphate) to increase the mud density to control the formation pressure. Since clays in water tends to agglomerate (flocculate) thus lowering the mud viscosity, deflocculants such as chrome – lignosulfonate are often used to maintain the appropriate mud viscosity. Other additive commonly used in drilling muds include caustic soda (Sodium hydroxide) to control the pH, corrosion inhibitors, biocides, lubricants for deviated or horizontal wells, lost circulation materials, and formation-compatibility agents (Reis, 1996).

Drilling mud can also have significant levels of hydrocarbons. In high temperature – formations (formation containing water – sensitive materials, clay or reactive gases) or in wells where high degree of lubrication is needed, drilling mud with oil as the base fluid is sometime used. One common oil-based mud is a water-in-oil emulsion using No.2 diesel. Because of the high toxicity, mineral oil have been developed for use as the base fluid. Even when water-based drilling muds are used, oil and grease can accumulate in them, particularly when drilling through oil—bearing formations or when organic lubricants are used (Deuel, 1990).

In the newly developed technology, materials with a natural radioactivity (MNR) are used as a drilling mud component in the technological process of drilling mud production. The size of MNR particles is controlled in accordance with a size of the drilling mud component. Thereafter, NMR is introduced in the drilling mud to ensure irreversible sequestration of MNR particles concentration in the mud to suppress their radioactive nature (Davidson, 2001).

According to Reis (1996), another common constituent of drilling mud is heavy metals. The two most common heavy metals in petroleum production wastestream are barium and chromium. Barium enters the mud from the added barite and from the formation, where it occurs naturally. Chromium entered the mud from the chrome-based deflocculants and from naturally occurring minerals in the formations and can enter the drilling fluid during drilling or through the added clays. Pipe dope, which is used when making up a drill string to keep the treads from seizing, normally contain such heavy metals as cadmium and lead, which can enter the drilling fluid particularly if an excess of pipe dope is used (Deuel, 1990, Udotong, 1995, 1999).

PRODUCTION

According to Stephenson (1992) crude oil production process generates produced water as the largest waste-stream source in the entire petroleum E&P process, whose volume can be more than ten times the volume of hydrocarbon produced, over the entire economic life of a producing field. The basic components of produced water have been reviewed by Reis (1996) and Stephenson (1992) to include oil, heavy metals, radionuclides or NORMs, treating chemicals, salts and dissolved oxygen (Udotong, 1995, 1999).

OTHER PETROLEUM E & P ACTIVITIES.

According to Canadian Petroleum Association (1990) other petroleum E&P activities have been found to generate a variety of associated wastes. These however, constitute only a few tenths of a percent of the total industry waste volume. The three common associated wastes are (a) the sludges and soils that collect in surface equipments and tank bottoms during oil production, (b) water softener wastes from treatment of water to be injected in the oil formation, and (c) scrubber wastes from cooling tower and steam – injection projects.

Another waste stream is generated from stimulating wells to enhance oil production. Two common ways to stimulate wells are oxidizing and hydraulic fracturing (Canadian Petroleum Association, 1990). Both of these use a variety of chemicals that eventually become wastes. Also, well work-over fluids constitute another waste stream in this category (Reis, 1996).

TENRAMS CONTAMINATION OF EQUIPMENT AND FACILITIES

There are indications that oil pipelines, oil storage tanks, other oil facilities have been found to be contaminated with TENRaMs at different levels. Some of such findings as reported by State of Louisiana's DEQ (1988) include the following.

Radioactive "scale" resulting from the production of oil and associated brines (produced water), which contains Ra-226 concentrations up to 100,000 pCi/gm has been reported (Smith, 1987). Gott and Hill (1953) have reported environmentally high concentrations of naturally occurring radionuclides (eg. Ra-226, Pb-210) in precipitates collected from the bottom of oil-water separators and from ditches and pits used for disposal of production water.

DEQ's Nuclear Energy Division (NED) has recently obtained information indicating radium-226 radioactivity of up to 8,700pCi/gm in soil contaminated with radioactive scale at pipe storage areas (Scott, 1988; Louisiana Nuclear Energy Division, 1986; 1988). Natural background radium-226 activity in Louisiana ranges from less than one to about 7pCi/gm (Beck et al, 1986). State of Louisiana's DEQ has reported that contaminated piping from refineries has been found in scrap iron yards in New Orleans, Baton Rouge and Lake Charles. NED has found the concentrations of radium in oil field production ponds (waste pits) to be elevated (State of Louisiana's DEQ, 1988).

BIOLOGICAL EFFECTS OF RADIOACTIVITY AND RADIOLOGICAL PRECAUTIONS

BIOLOGICAL EFFECTS OF RADIOACTIVITY

Large doses of ionizing radiation are harmful to living organisms, damaging the DNA of living cells. Based on the extrapolation from the biological effects in high dose range, low doses of radiation are supposed to be harmful. This is, however, an assumption from the viewpoint of radiation protection. Exposure levels from cosmic and natural radioactive sources are low, but over geologic ages may have significantly contributed to "spontaneous" mutations, which form the basis for natural selection. Recently, biological effects of low dose radiation have been investigated, and it has been demonstrated that living organisms have great capacity to respond against radiation. Damage induced by UV-B radiation has been studied and classified into two categories: damage to DNA (which can cause heritable mutations) and damage to physiological processes. Repair of DNA damage to prevent the biological effects caused by UV-B radiation has been shown to be essential for plants to survive.

RADIOLOGICAL PRECAUTIONS

In view of biological effects of ionizing radiations, the following precautions should be taken to minimize exposure to TENRaMs-contaminated materials in Oil & gas locations in Nigeria:
i. Employees and contractors should be advised of the presence of this contamination and of procedures to minimize exposure.
ii. Direct skin contact with radioactive scale and solids should be avoided to the extent reasonably possible.
iii. Eating, drinking, smoking and chewing should not be allowed in the work area where work is being performed on contaminated equipment or where contaminated soil is being handled.
iv. Personnel should thoroughly wash their hands and face after working with TENRaMs-contaminated equipment, and before eating, drinking, or smoking, and at the end of the day.
v. The number of personnel in TENRaMs-contaminated work area should be kept to a minimum.
vi. If possible, openings on TENRaMs-contaminated equipments should be sealed or wrapped in plastic. Work on TENRaMs-contaminated equipment, such as cutting, grinding, sandblasting, welding, drilling, or polishing should be kept to a minimum as much as possible.
vii. If work requires any action that might produce dust from TENRaMs-contaminated pipes or soil or if loose contamination is suspected, the following additional precautions should be taken:
a. A respirator appropriate for radioactive particulates should be worn.
b. Suitable coveralls and gloves should be worn.
c. Activities should be conducted in well-ventilated areas to which access has been restricted.
d. Plastic ground covers should be utilized to the extent possible to contain contaminants and facilitate cleanup.

e. Gloves, respirators, coveralls, and rags should be decontaminated or placed in double bags, sealed and held for proper disposal,
f. The need for Personnel Monitoring and Bioassay should be evaluated and provided if necessary.

In addition to the general guidance given above for pipe scale, additional radiological precautions should be given by regulatory agents about other industrial operations such as vessel entry, dismantling of equipment, refurbishing of equipment or transportation, which may also require precautionary procedures.

APPREHENSIONS/CONCERNS ABOUT RADIOACTIVITY IN OIL & GAS WASTES IN NIGERIA :

Because of the ubiquity of TENRaMs and reports of NORMs and TENRaMs in in oil & gas wastes as shown above, there are some apprehensions/concerns by stakeholders in the Nigerian environment about radioactivity in oil & gas wastes. Some of the apprehensions/concerns of the stakeholders on radioactivity in oil & gas wastes in Nigeria can be summarized as shown below: ? Billions of gallons of produced water containing TENRaMs contamination are being released annually to the environment, particularly in coastal oil producing areas in Nigeria.? We have very little or no information on the fate and effects of TENRaMs in aquatic and terrestrial environments and on potential movement of TENRaMs into food chains resulting in possible consumption by humans. ? Environmental consequences and health risks associated with disposal of TENRaMs-contaminated oil & gas wastes (e.g. incineration and land farming) are largely unknown in Nigeria.? Several burrow/wastes pits (where drill cuttings and drilling mud and fluid were dumped several years back before the introduction of treatment of drill cuttings by regulatory agencies) littering the Niger Delta region may have been contaminated by TENRaMs. Considering the long half-life of some of these radioactive materials (e.g. Radium-226 has half-life of 1620 years), some of these contaminated sites will be of concern for centuries. ? In view of the above long decay period, some of these contaminated sites cannot be reclaimed and be used for residential or commercial purposes. If buildings were constructed over radium-contaminated soil (for example), the resulting radon concentrations could pose a serious health threat to the residents.? The current method of dumping of drill cuttings and dredge spoils (with possible TENRaMs contamination) in the high sea raises a major source of concern about the problem of regulatory control and reduction of radioactivity in Oil & Gas wastes in Nigeria. ? Workers employed in the area of cutting and reaming oil field pipes for pipeline laying may be exposed to dust particles containing levels of alpha-emitting radionuclides that could pose very serious health risks. ? TENRaMs-contamination in varying degrees of severity may exist at every oil and gas production locations and pipe handling facilities in Nigeria, and may have also entered in substantial quantities into scrap yards and metal reclamation facilities without notice.? There are little or no sponsored studies on the radioactivity in oil & gas wastes in Nigeria. There are therefore some questions on potential liabilities for environmental contamination, evaluation of exposure pathway to man and necessary remedial measures that must be answered if we must achieve regulatory control and reduction of radioactivity in oil & gas wastes.?Legal and Institutional framework as well as regulations governing TENRaMs contamination in oil & gas wastes handling and disposal and effective instruments for regulatory compliance and enforcement should be put in place and effectively enforced to ensure strict compliance. ? There are some very difficult questions concerning potential liabilities for environmental contamination, workplace exposure to radioactive materials, and necessary remedial measures about regulatory control and reduction of radioactivity in oil & gas wastes in Nigeria, which cannot be answered now.

MANAGEMENT OF RADIOACTIVE WASTES TO ENSURE REDUCTION OF RADIOACTIVITY IN OIL & GAS WASTES IN NIGERIA

Radioactive wastes comprise a variety of materials requiring different types of management to reduce radioactivity and thus protect people and the environment. They are normally classified as low-level, medium-level or high-level wastes, according to the amount and types of radioactivity in them.

Another factor in managing radioactive wastes is the time that they are likely to remain hazardous. This depends on the kinds of radioactive isotopes in them, and particularly the half lives characteristics of each of those isotopes. The half life is the time it takes for a given radioactive isotope to lose half of its radioactivity. After four half lives the level of radioactivity is 1/16th of the original.

The various radioactive isotopes have half lives ranging from fractions of a second to minutes, hours or days, through to billion of tears. Radioactivity decreases with time as these isotopes decay into stable, non-radioactive ones. The rate of decay of an isotope is inversely proportional to its half life; a short half life means that it decays rapidly. Hence, for each kind of radiation, the higher the intensity of radioactivity in a given amount of material, the shorter the half lives involved.

Three general principles are usually employed in the management of radioactive wastes, namely:
i. Concentrate and contain,
ii.. Dilute and dispose, and
iii. Delay and decay.

While the first two methods are also applicable to other wastes, the last method is however, unique to radioactive waste management. This last management technique implies that the wastes is segregated and stored and its radioactivity is allowed to decrease naturally through decay of the radioisotopes in it (UIC, 2002).

Final disposal of high-level waste is decayed to allow its radioactivity to decay, for example, forty years after removal from the reactor less than one thousandth of its initial radioactivity remains, and it is much easier to handle. Hence canister of vitrified waste, are stored under water in special ponds or in dry concrete structures or casks for at least this length of time.

The ultimate disposal of vitrified wastes without reprocessing, requires their isolation from the environment for long periods. The most favored methods is burial in dry, stable geological formations some 500meters deep. After being buried for about 1,000 years most of the radioactivity will have decayed.

Thus to ensure that no significant environmental releases occur over periods of tens of thousands of years after disposal, a "multiple barrier" disposal concept is used to immobilize the radioactive elements in high level (and some intermediate-level) waste and to isolate them from the biosphere.

There is a general agreement among geologist and other scientist that deep geological containment is the best long-term solution. After treatment of radioactive waste to reduce the volume of the radioactive material and transform them to a non soluble, relatively inert substance such as glass, they would be encapsulated and placed in engineered tunnels (Press and Siever, 1994).

Naturally-occurring radioactive materials (NORMs) are widespread throughout the environment, although concentrations are very low and they are not normally harmful. Soil naturally contains a variety of radioactive material-uranium, thorium, radium and radioactive gas radon which is continually escaping to the atmosphere (UIC, 2002). It is important to note that man's activities in the environment can make NORM harmful.

RECOMMENDATIONS AND CONCLUSION

RECOMMENDATIONS

To address the apprehensions/concerns expressed about regulatory control and reduction of radioactivity in oil & gas wastes, the following recommendations have been proposed.

a. Strategic partnering with relevant stakeholders including the academia will be necessary.
b. The regulatory agencies should articulate a comprehensive action plan for effective control and reduction of radioactivity in oil & gas wastes in Nigeria. Prominent amongst this is that all oil & gas company operators should include a radiation policy in their respective HSE policy objectives.
c. There is the need for regulatory agencies to urgently set realistic discharge limits for all TENRaMs-contaminated oil & gas wastes. For example, the following TENRaMs-contaminated oil & gas wastes discharge limits have been set for produced water and contaminated soil.

Produced water.

i. EPA proposed drinking water standards restrict the permissible Ra-226 content to less than 5pCil/liter.
ii. NRC regulations governing the operations of licenses permit no more than 30pCi/liter in liquid discharges to unrestricted access areas.
iii. EPA regulations set 50pCi/liter as the level of activity that distinguishes between hazardous and non-hazardous wastes.

Soil
i. EPA has proposed a cleanup limit for radium-226 in Uranium mill tailings of 5pCi/gm above background (7pCi/gm) in the top 15cm (6in) of soil and 15pCi/gm at depths below the top layer.
ii. The conference of radiation control program directors (CRDPD) has proposed remedial action of 6pCi/gm.

d. Other recommended action plans will include the following:
To be able to effectively deal with the problem of regulatory control and reduction of radioactivity in Oil & Gas wastes in Nigeria, the following recommended action plans, which have once been adopted by the Department of Environmental Quality (DEQ) of State of Louisiana, USA has been proposed.

i. Develop and disseminate an interim policy for handling TENRaMs-contaminated materials and protection for those working at contaminated sites and with contaminated pipes and equipment.
ii. Develop preliminary pathways and potential health effects of exposure to TENRaMs-contaminated materials (inhalation, ingestion, external exposure), as well as fish and shellfish consumption, if applicable.
iii. Define and initiate a small strategic sampling effort to answer immediate information needs.
iv. Establish a unit in the Federal Ministry of Environment (FMENV), Abuja and Department of Petroleum Resources (DPR) and indeed all other regulatory agencies in Nigeria to assist in dealing with the TENRaMs-contamination and the problem of regulatory control and reduction of radioactivity in Oil & Gas wastes in Nigeria.

v. Research and develop legal and institutional framework for regulating TENRaMs-contaminated wastes from Oil & Gas Industries in Nigeria.
vi. Develop and implement strategies for characterizing and mitigating the problem of regulatory control and reduction of radioactivity in Oil & Gas wastes in Nigeria.
vii. Identify potential sources of financial, human and material resources that could be applied to the problem of regulatory control and reduction of radioactivity in Oil & Gas wastes in Nigeria.
viii. Obtain funding to deal with the problem of regulatory control and reduction of radioactivity in Oil & Gas wastes in Nigeria.

CONCLUSION

Naturally occurring radioactive materials (NORMs) are ubiquitous in its environment including oil and gas production locations/facilities. NORMS that are radioactive in the their natural physical state are associated with oil and gas production and includes the elements Uranium, thorium, radium, radon and their daughter products.

During the production of out of gas, radioactive materials that naturally occur within the earth are coproduced. Where the concentrations of NORM are usually very low, these materials can be concentrated during production; the concentration level can become high enough to cause a health hazard if improperly managed.

There is lack of strict regulatory control and management of radioactive wastes from oil and gas industries in Nigeria. This paper therefore recommends that all oil & gas company operators should include radiation policy in their respective HSE policy objectives as well as adopt the international standards/limits for management of radioactive wastes from Nigeria's oil and gas industries.

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