The Role of Geoscientists in Nuclear Resources Exploration and Exploitation: A Key Tool for Sustainable Economic Development and National Security

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DOI: 10.29322/IJSRP.8.10.2018.p8234
http://dx.doi.org/10.29322/IJSRP.8.10.2018.p8234

"The peaceful and appropriate usage of nuclear and radioactive substances plays a crucial role in sustaining economic development"

Abstract-

The aim of this study is to expand on the role and relevance of Geoscientists in improving economic development and national security through nuclear resources exploration, exploitation, supply, application, safety assessment and security. Geoscientists follow paths of exploration and discovery in quest to finding solutions to some of the society's most challenging problems which include sustainable energy supply, climate change, food insecurity, crime and high poverty level amongst others. When nuclear and radioactive materials are not properly explored and exploited they can have adverse effect and security implications on people, property and the environment. In the light of the above, the mission of nuclear related organizations including the World Institute for Nuclear Security (WINS), the International Atomic Energy Agency (IAEA), the Nigerian Nuclear Regulatory Authority (NNRA) amongst others and the role of the Geoscientists in the domestic and industrial applications of nuclear and other radioactive materials will be enumerated. Nuclear and other radioactive sources are used in key sectors of the world economy. The key sectors include Oil and Gas, Health, Manufacturing, Security, Agriculture, Mining, Construction, Education and Research, Water Resources. The petroleum sector is the largest importer and user of nuclear and radioactive sources in Nigeria. Most of these materials are imported from Europe, United State of America and South Africa. During Oil and Gas exploration activities, radioactive substances are used for Nuclear Well logging to determine the quantity and quality of petroleum in the reservoir rock which assist in crucial business decision making. In Oil wells, nuclear gauges are used both onshore and offshore for quantification and quality control of water in Oil and Gas phases. The benefits of the extensive exploration and usage of nuclear and radioactive resources and the role these resources play in improving sustainable economic development and National security cannot be overemphasized, hence the need to unravel its relevance.

Key Words: Geoscientists, Nuclear Resources, Radioactive sources, Climate Change, Sustainable Development

I. INTRODUCTION

Nuclear energy is produced from fission, which splits the large atoms of heavy elements like uranium and Thorium into smaller atoms releasing enormous amount of energy. The discovery of the neutron in 1932 by Chadwick James is a very great force that triggered Man's quest to utilize the large conserved energy in the nucleus of atom (Jonah, 2011). Through the analysis of materials and products derived from the nucleus-induced reactions, nuclear fission was later discovered. This discovery opened the prospect of obtaining limitless energy from the nucleus of several radioactive elements and thus the quest for technology to exploit this new source of energy began in earnest. Exploration and exploitation as well as application of nuclear energy resources in Nigeria will be discussed to include the historical development of nuclear science and technology in the country and the status of progress made by stakeholders and several organizations with regards to the introduction of nuclear option in Nigerian's energy mix.

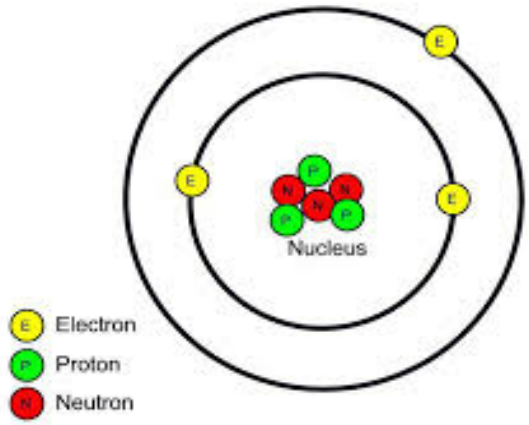


Figure 1: Neutron with enormous energy (source -www.girlscientistmagazine.blogspot.com)

Because of the dreadful impact of the French nuclear test on Sahara Desert region in the 1960's,
Nigeria became aware of the threat in nuclear radiation. This lead to the setting up of the Federal Radiation Panel in 1961 and the Federal Radiation Protection Service in 1964. Prior to this, Radium needles and X-ray machines have been used in medical application across the country by some hospitals. Also, the University College Hospital in Ibadan had used Cesium sources for cancer treatment (Jonah, 2011). The Nigeria Atomic Energy Commission (NAEC) as created by Act 46 of 1976 by the Federal government of Nigeria as the national focal agency charged with the responsibility for the promotion of the peaceful development of atomic energy and for all matters relating to the peaceful use of atomic energy. The Federal Government in 1978, following the enactment of NAEC act in 1976, established two University based research and training centers; Center for Energy Research and Training (CERT) at the Ahmadu Bello University, Zaria and Center for Energy Research and Development at the Obafemi Awolowo University, then University of Ife, Ile- Ife. These research centers were given the mandates to conduct research, train and develop man power in nuclear technology, engineering and sciences. In 1988, the Nuclear Technology Center (SHESTCO) at Sheda Complex in Abuja was established as the third training and research center in nuclear technology. NAEC in 2010 also created two more centers; these are Center for Nuclear Energy Studies and Center for Nuclear Energy Training and Research located at the University of Port-Harcourt and University of Maiduguri Respectively. The country's proposal is to specifically develop nuclear science and technology for application in Medicine and Human Health, Oil and Gas, Manufacturing, Defense and Security screening, Agriculture, Mining, Construction, Education and Research, Water Resources, Energy sector among others.

For proper security and safety to be ensured in the use of nuclear resources and other radioactive materials, the Nigerian Nuclear Regulatory Authority (NNRA) was established in 1995 by the Nuclear Safety and Radiation Protection Act 19 but was inaugurated in 2001. Since its inception, the NNRA has emplaced an effective regulatory framework within the context of the Act to fulfill its primary regulatory function. The NNRA also regulates the use of radioactive substances in the upstream, midstream and downstream sectors in the oil and gas which is the mainstay of the Nigerian economy. On 27 July 2008, Nigeria's President Umaru Yar'Adua urged the country to embrace and exploit the enormous energy in nuclear resources in order to meet its growing energy needs.

II. THE CONTRIBUTIONS OF NUCLEAR AND RADIOACTIVE RESOURCES TO SUSTAINABLE ECONOMIC DEVELOPMENT AND NATIONAL SECURITY

With constantly growing energy demands, it's imperative we explore nuclear as a dependable energy source. Nuclear energy should be the preferred option, as it is not intermittent and clean. Nuclear power plants require small areas of land to site, but produce much energy. The enormous benefits attached to nuclear and radioactive resources are numerous as individuals, organizations and governments have gained from it either directly or indirectly.

Hydrocarbon exploration and production

Figure 2: Geoscientists using radiation sources in hydrocarbon exploration (source - www.geoservices.co.id/drilling-services)

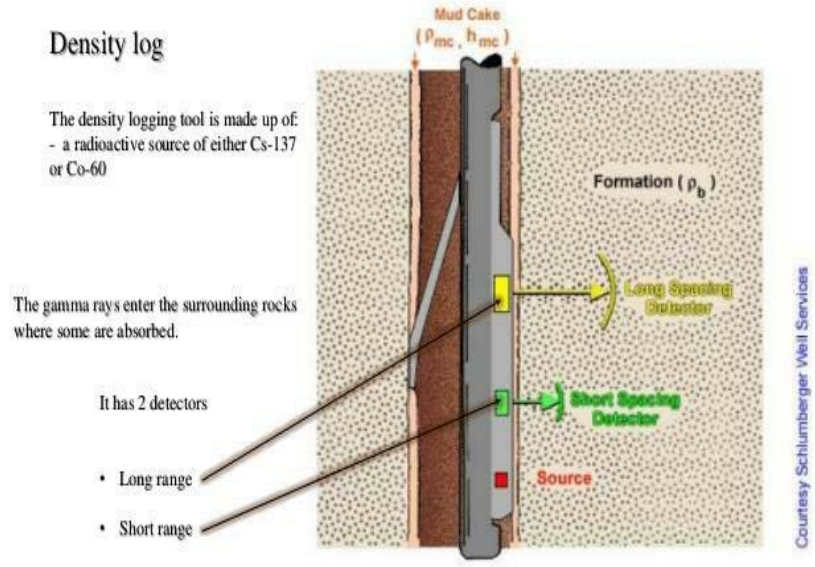
Over the last two decades, nuclear logging has grown to become one of the most important peaceful applications of the principles of nuclear geology in the oil industry. The oil and gas industry are heavily dependent upon the use of radiation from nuclear and radioactive substances to conduct business. Of the many reasons for drilling and logging wells, hydrocarbons offer one of the most lucrative motivations. A well log is an account of the geological factors present in the hole. It analyzes test wells to determine the potential for economically viable oil deposits. Well logs feature information on the feasibility of extracting oil and gas. Geoscientists as hydrocarbon explorers wish to gain information on the quality and characteristics of the test wells.

Figure 3: Shell deep sea oil rig (source - www.synergen.com)

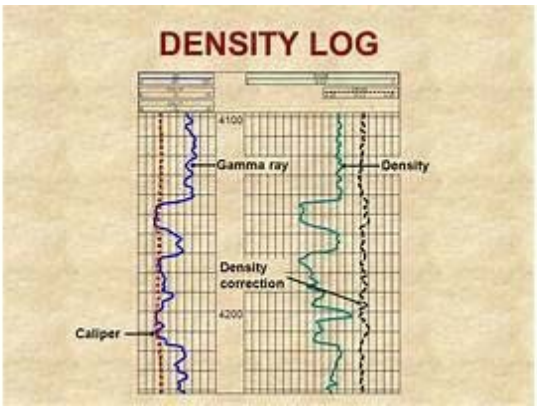
Well Logging provides the best techniques of borehole investigation, classification and understanding as accurate analysis of the borehole determines the success of the operation. Nuclear well logging techniques are of different types with almost the same principle governing all of them. Neutron probes when lowered into the test wells constitute one technique. Neutron generators inject fast bursts of neutrons into the surrounding earth and the amount of hydrocarbons present can be determined by measuring

the resulting slow neutrons detected at a known distance from the source (Kerr et al., 2011). Gamma ray backscattering techniques can also be employed in a similar manner. Geoscientist carryout different types of well logging using radiations from nuclear and radioactive sources to ascertain the quality and quantity of hydrocarbon that is present in a proposed field. These logs include Density logging Spectral Log, Gamma ray log, Nuclear Magnetic Resonance (NMR), Compton Scattering and so on.

Density Logging approach pays attention to rock bulk density. Density logging analyses both the minerals in the rock and the trapped hydrocarbon in the pores. Density logging mainly refers to gamma radiation logging and the way gamma waves reflect rock density.



a) (Source – Soran University, Department of petroleum engineering www.slideplayer.com)



b) (Source - https://www.slideplayer.com)

Figure 4: a) Density radiation logging b) results obtained

In Compton scattering, a radioactive source shoots medium-energy gamma rays into a rock and the particles in the wave crash into the rock's electrons. The gamma radiation transfers its energy into the electrons as each successive round occurs. This causes the gamma to slow down. The level of density determines how much power the gamma loses. The source reads the rate of gamma energy loss and determines the mineral or element type based on this atomic density rate of energy transfer (Worthington et al., 2011). This will then be interpreted to give useful information on the characteristics and potentials of the reservoir.

Gamma ray logging uses gamma radiation as implied by them name to give read-outs on the minerals in the hole. Each type of rock substance handles gamma differently this is because each rock type emits different gamma radiation signature. Rocks like dolomite and limestone produce fewer gamma waves than other sedimentary rocks like shale. This occurs because radioactive potassium occurs at a higher rate in these minerals and thus, it implies that they handle radioactivity better than shale (Killeen, 1982). Geologists study the information of the reactions to gain knowledge of the interior rock and reservoir composition.

NMR logging is mostly used in the measurement of the porosity quality of the well to determine the porosity and permeability potentials of the reservoir rock. NMR uses a neutron source to record the presence of hydrogen in a borehole. Hydrogen atoms in boreholes often appear as hydrocarbons (Coates et al., 1999). The levels of measured hydrogen help predict the presence of these elements. NMR logging uses the same type of technique as gamma ray logging.

Efficient refinery operation is also a very important part of the oil industry. Whereas it is difficult to install and maintain diagnostic probes inside the distillation towers (due to the extreme environment), gamma probes can be easily installed on the exterior of the towers and then be moved up and down the tanks to easily record the composition of ingredients at various vertical levels. Any malfunctions within the tanks can be readily detected.

Agriculture:

"Using nuclear science and technology to feed the world"

In the agricultural sector, nuclear application relies on the use of isotopes and radiation techniques to combat pests and diseases, increase crop production, protect land and water resources, improve soil and water balance, ensure food safety, security and authenticity and increase livestock production (FAO and IAEA, 2016).

FOOD SAFETY AND SECURITY: it is pivotal that food as a valuable commodity should be preserved once grown and protected against contamination until consumed by an increasingly hungry world. Infestation and damage tragically prevent at least one-fourth of the annual food production in the world from reaching the mouths of its citizens. The percentage of harvested seafood that never reaches the consumers is even higher—sometimes well over 50%. This is particularly the case in countries with warm and humid climates, characteristic of many of the developing nations including Nigeria (FAO, 2017).

Figure 5: Improving crop productivity, safety and security through nuclear techniques (courtesy of FAO/IAEA)

Food preservation methods have evolved historically from the earliest days of sun drying to salting, smoking, canning, heating, freezing and the addition of chemicals such as methyl bromide. Fortunately, food irradiation is now positioned to provide a substantially superior method. Food irradiation involves subjecting the food to carefully controlled amounts of ionizing radiation, such as beta particles or gamma rays, to break the DNA bonds of targeted pathogens. This is especially effective in destroying the reproductive cycle of bacteria and pathogens. It is important to note that the goal of food irradiation is not to eliminate biological contamination, but rather to reduce it to as low as 0.001 percent of its original value (Alan E.W, 2002). One of the prime advantages of food irradiation is that it sterilizes food without altering its form or taste.

The older methods of food processing, which rely on temperature extremes (heating or freezing), extreme drying, salting or chemical treating, often change the nature and taste of the food that is treated (Alan, 1994, 1995 and 2003).

Rice is the major source of food for over 50% of the global population and is especially important in African and Asian diet. More than 430 mutant varieties of rice have been developed, of which half were developed from gamma radiation. Because of radiation, Thailand has become the largest exporter of aromatic rice in the world. During the decade from 1989 to 1998, Thailand produced $19.9 billion of milled rice (FAO). Wheat is the staple grain for many countries, including the United States. In Italy, the Durham wheat Creso's mutant was developed through radiation. By 1984, this mutant reached 53.3% of the Italian market—such that over 50% of the pizza consumed today in Italy is the direct result of harnessed radiation. Barley is a prime ingredient in making malt. Mutant varieties such as Diamant's and Golden Promise are two radiation products that have made a major impact to the European brewing and malting industry. This industry provided Scotland with a revenue of approximately $417 million over the last quarter century. Both the United Kingdom and Ireland likewise make wide use of Golden Promise for their beers and whiskey (Alan, 2001).

Animal health and productivity:

Livestock productivity and trans-boundary animal diseases prevention have been improved through the impact of nuclear science and technology (IAEA). Farm animals, essential for providing commodities such as milk, meat, wool, and leather, have likewise benefited from the application of radiation techniques. In many parts of the world, most of the livestock are the primary fed with native grass and rice straws which often lacks sufficient protein, energy, and minerals needed for a balanced diet.

Figure 6: Healthy livestock as a result of nuclear science

Employing tracer radioisotopes to determine the key nutritional deficiencies has been used quite effectively in many Asian countries (Alan, 2003). Radioisotopes have also been used to develop vaccinations that are effective for certain animal diseases.

Nuclear medicine:

The use of radiation in the medical and health sector can be classified broadly into 3 segments – Diagnostic and interventional practices, Nuclear medicine and Radiotherapy. The earliest use of radiation in the medical field was to employ portable x-rays sources in World War I, where such devices helped field surgeons save many lives. Radiation techniques have since then made their most significant contribution to enhance health care in the diagnosis of ailment in the field of medicine. There are countless examples in every corner of the globe where an early and exact diagnosis of an ailment could have prevented tragic results. Dental x-rays, chest x-rays, mammograms, and a plethora of other tests are in routine use today in the medical/dental professions).

Figure 7: Nuclear medicine; useful in diagnosis and treatment of diseases (www.mayo.edu/mayo-clinic-school-of-health...)

Nuclear medicine is primary used for imaging of cancers, cardiovascular organs and brain and spine scans. Radionuclide substances are usually combined with pharmaceuticals in Nuclear Medicine. Two of the most common approaches used in modern nuclear medicine diagnosis are single photon emission computed tomography (SPECT) and positron emission tomography (PET). SPECT is widely used for routine clinical work because it is relatively inexpensive and utilizes radioisotopes available from nuclear reactors. A SPECT scan integrates two technologies to view the human body: computed tomography (CT) and a radioactive material (tracer). The tracer is what allows the doctors to see how blood flows through tissues and organs (MBSMC, 2008). PET is a technique that measures physiological function by looking at blood flow, metabolism, and radiolabeled drugs. The PET system offers quantitative analyses, thus, allowing relative changes over time to be monitored as a disease process evolves or in a response to specific stimuli (USNLM, 2002). PET systems tend to be more expensive than SPECT systems, partly because of the sophistication of the counting system and partly because the radioisotopes that emit positrons typically have a very short half-life (minutes).

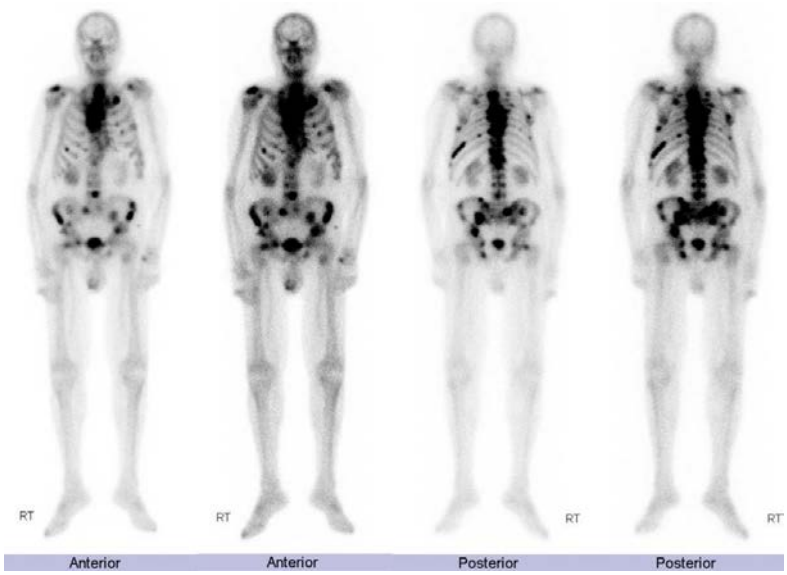


Figure 8: Nuclear medicine and technology used for diagnosis and treatment of bone metastasis

Radiotherapy is another widespread use of radiation. Radiotherapy simply means the use of radiation for treatment and cure of ailments. This has been more effective in the treatment of cancer and cardiovascular abnormalities. Most of the current procedures utilizing radiation to kill cancer in humans are based on delivering the radiation to the patient externally.

III. NATIONAL SECURITY

Nuclear and radioactive materials emit ionizing radiations from radio detectors which have played a key role in National security. Radiation from radioactive sources have been used in an increasing role for public safety, including seaport and airport screening, smoke detectors, crime solving, deterrence of terrorism at points of entry, archeology dating, precious gem embellishments, etc. Computerized tomography machines are used to scan and check luggage at airports and also to scan the contents of cargo ships in

seaports. The use of Am-241 in smoke detectors has undoubtedly saved thousands of lives and associated property damage due to the avoidance of fire. The list of applications of radiation to enhance our modern life style literally goes on and on (Alan, 2003).

IV. CONCLUSION

We are optimistic that the world's desire to increase the current global hydrocarbon output of 92.6 million barrels per day can be achieved if radioactive sources are used in the geological and geophysical exploration and examination of new oil fields as this will provide qualitative and quantitative information than any other exploration technique. The cost of production and maintenance of refinery facilities can also be reduced if radiotracers are used in measurements of flow rates of petroleum products in pipelines and Non-Destructive Testing (NDT) services during pipeline infrastructure development and maintenance. In many nations of the world, the use of nuclear and radiation technology in agriculture, water resources, mining, construction, pest control, healthcare delivery system, material analysis amongst other sector has contributed immensely to their economic growth and development. Other countries that are yet to exploit the enormous potentials in nuclear and radioactive resources should join the train to enjoy the trend of sustainable development attached to it.

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