Science World Journal Vol. 20(No 2) 2025
www.scienceworldjournal.org
ISSN: 1597-6343 (Online), ISSN: 2756-391X (Print)
Published by Faculty of Science, Kaduna State University
https://dx.doi.org/10.4314/swj.v20i2.19

Full Length Research Article

ASSESSMENT OF RADIATION LEVELS IN SOIL OBTAINED FROM OTTAMIRI AND NWORIE RIVER EXCAVATION SITES AND THEIR IMPACTS ON CONSTRUCTION PROJECTS IN OWERRI METROPOLIS, IMO STATE, NIGERIA

*George Nkeiru Nzenwa, Ketachukwu Bierechi Okeaoma, Anthony Ohajianye

School of Physics Science, Department of Physics, Federal University of Technology Owerri, Imo State, Nigeria

*Corresponding Author Email Address: nkeirugeorge1@gmail.com

ABSTRACT

When ionizing radiation interacts with the human body, it can damage living cells and lead to various health effects. The challenge always, is how we can determine the threshold that can lead to this damage. This study tends to assess radiation levels in soil obtained from Otamiri and Nwaorie River Excavation sites and some Construction Sites in the Owerri Metropolis, Imo State, Nigeria. We also measured the back ground radiation of both sites. 5 soil samples were collected from the Excavation and 5 from Construction Site respectively, 10 samples in total were measured using a Durridge Rad7 detector. The background radiation of both sites was also measured; a total numbers of 100 readings were taken, 50 from Excavation and 50 from Construction Site, 10 readings from a point of distance from each location, using a Digital Geiger-Mueller Counter*(GCA- 07).* Soil gas radon was measured with the concentration values obtained ranging from 0.1 ± 4.6Bq/ m^3 to 28 ± 1.4Bq/m^3, the total across all sampling location is 101.3 Bq/m^3 with average of 10.13 Bq/m^3. Absorbed dose was estimated to be 25.3nGy^{-1},equivalent dose rate is 2.53mSvy^{-1} with Annual Effective dose equivalent (AEDE) of 3.63mSvy^{-1}. For Background Radiation, from the construction site, the absorbed dose is 28.15nGy^{-1}, Equivalent dose rate is 0.776 mSvy^{-1}. Annual Effective dose equivalent (AEDE) is 0.212mSvy^{-1}, Excess Life Cancer Risk (ELCR) of 0.813. The Excavation site, estimated absorbed dose is 0.0105nGy^{-1}, equivalent dose rate of 0.878mSvy^{-1}, annual effective dose equivalent (AEDE) of 0.0849mSvy^{-1}. Excess Life Cancer Risk (ELCR) of 0.728. All these values are within or even lower than the recommended value level of 1.0mSvy^{-1} The background radiation is not an issue of health concern from this resaerch. In 2017, the Imo State Local Government issued a warning against using water from the river, suggest radioactively contaminated water, any radionuclide found in the water reflects in the soil, but in this case, it is different. However, the government has to do more by regulating human activities that goes on at the excavation site.

Keywords: Soil, Radionuclide's, RAD 7, Excavation, Geiger Mueller, Counter, Construction, Site, Alpha, Particles

INTRODUCTION

Living organisms are exposed to one form of radiation or the other. Because of the hazard that comes with radiation environmental exposure. There is a pubic health concern associated with soil called 'Radon'. Radon is the decay poduct of uranium, radon gas decays into radioactive particles that can get trapped in human lungs when one breathes. IEPA, (2024) Hasan A.K, et al, (2011) . These particles release small bursts of energy that can damage the lung tissue and lead to lung cancer throughout a lifetime. NCI, (2011). It is a public health concern especially in areas with high radon levels in soil and water, the International Commission for Radiology Protection (ICRP) and Envromental Protection Agency (EPA) decided to strongly adopt means and ways of minimizing the level of all forms of exposures, Augustine et al, (2014). The world WHO estimated that radon is responsible for 3-14% of all lung cancer deaths worldwide, it is a risk factor for lung cancer, especially for people who have never smoked, and it has even more synthetic effects when combined with smoking increasing the risk of lung cancer WHO (2022). All sources of radiation in the environment and buildings are dangerous, if the level exceeds a certain threshold, creating problems for the people living in and around. Agbalagba (2017)

Soils obtained from the Otamiri and Nworie River Excavation Site contains some form of ionizing radiation, this is largely due to man-made activities that usually go on at the river banks, like depositing of refuse, which are dumped at the riverbank. Usikalu et al, (2017). As the river flows it carries a lots of these dirt's into the river, which in-turn affects the surface water, soil and the underground soil, the soil are therefore contaminated due to the accumulation of radionuclides in the atmosphere, seepage and precipitation from the dumpsite leachate, Terminizi et al (2014), Sadiq A.A & Egba E.H (2011) these dirt, which most of the time contains chemical, medical, and other hazardous materials that form radionuclides such as ^{238}U, ^{232}Th and ^{40}K, which when decay emits Alpha, Beta and Gamma particles..

These radionuclides are also found in building materials that have specific activities and their products depends extensively on the geographical condition, geochemical and geological characteristics of the these materials. UNSEAR,(2000). The decay products of these radionuclides contribute to radiation doses received by humans, which can come from both natural sources (lakes, water bodies, and ocean) which accumulates into food chain and artificial sources (human activites) nuclear accidents, nuclear weapon tests etc. George,A.C (2011), Ali. M. A (2020) Long exposure to these radionuclides and human inhalation of short-lived decay products like radon can cause cellular effects which may damage the chromosomes (gene, DNA) and produce macro observable negative health effects on human organs or tissues. Abiodun et al; (2019).

Locatioin and Geology of the Area

The study area is located in the Owerri Metropolis, Imo State, Nigeria, West Africa. Imo State southeastern Nigeria lie within the Latitude of 4^{0}45^{0}N and 7^{0}15^{0}W and Longitude of 6^{0}50^{0}E and

https://dx.doi.org/10.4314/swj.v20i2.19

7⁰25⁰E, an area of about 100sqkm, with estimated population of 5.4million. Minstry of Land and Survey,(2010), is characterized by gently undulating topography with an average elevation of 230.00m above sea level, within the tropical humid region. The climate conditions common to the equitorial belt of the Southeatern Nigeria are divided into two, wet and dry seasons with annual temperatures of 28°C, rainy season starts in April to October with heavy downpours in June/July, and the remaining months with little or no rain. Vangard;(2015) Ojo;(1997). Owerri is bordened by the Ottamiri river to the east and the Nworie river to the South. The River location is between two latitudes circles 4^0 54'14.00'N and Longitude 7^0 08'30.00E. The geological setting of Imo State is a complex geological envieonment with several natural resources. Vangard Nigeia,(2015). Nworie river passes though three local government, Owerri north, Owerri municipal and Owerri west, and trains into Ottamiri river at Nekede. The Nworie river is heavily polluted, in 2017 the local government issue warning against using water from the river, because of the poor waste management in Owerri which contributes to the river's pollution, most of the wastes from the metropolis are dumped at the Avu land filling in Owerri West on the Port Harcourt highway creating a high concentration of phosphate and nitrate in the River. However, economically, the soils or sand, sand stones and clay shale presence on the bank of the river shows that 86% of the soil particles can be used for a wide range of activities, construction of houses and glass-making, this can create employment and in turn increase the state financial income. IMSLA; (2017).

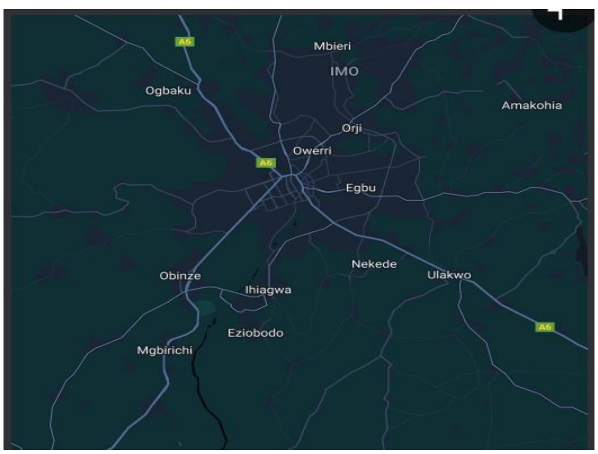

Figure 1. Map showing Ottamiri/Nworie river link www.researchgate.net.figure

MATERIALS AND METHODS

Durridge Rad 7, Portable Geiger Muller, a soil Probe , a clean plastic bucket, a towel, permanent markers, sample bags, clipboard and paper ,GPS enabled smartphone, a Pen, and a book for recording.

COLLECTIOIN OF SAMPLES

A total of 10 samples were collected, five (5) soil samples were taken from different points at each location at the excavation site and five (5) samples also taken from different location of the construction sites. Random Soil sampling method was used where the soil were collected from the study area, using soil corer or pumping machine.

Generally, two techniques are involved in measuring radon in air, which are the active and passive methods, using the active methods which requires power for collecting the samples, while the passive method do not require power to collect the soil samples. The active method are widely used for short-time radon measurement and the passive method is used for the long-time scale, using it for long scale surveys but moderate costs (Eman et al, 2012, Kumar et al, 2010,) For this study the active method was used.

Prepararion of Samples

The collected soil sample were then dried at 20 -30 ºC at room temperature for 3 days, to ensure complete removal of available moisture until a constant mass was attained. Dried samples passed through a 2mm sieve, this helps to remove lumps, gravels and any organic materials that may be present in the soil samples, and 100g of each sample were placed in a tight plastic tablets, 10cm in diameter with a total capacity of 300 cm^3. The samples were then kept in zip-lock bags and labeled accordingly, each were weighted and sealed to allow for equilibrium, then taken to the laboratory.

Measuring the radon concentration using the Durridge RAD7. A hole was drilled in the soil to the desired depth usually 1-2meters, while inserting a sampling tube or soil gas probe into the drilled hole, Pump the soil into radon detector or sampling device, then radon concentration was measured in the soil gas using a radon detector and the masurement was recorded.

Measuring the Background Radiation using Portable Geiger Muller Counter to measure the background radiation. Turn on the device, set the range, the range was set using the lowest range, then the unit, unit was choosen in Counts Per Minute (CPM), the probe was held (geiger tube) about 1-2 meters above the ground level., then reading was taken in multiple times of about (5-10 times) at different location to account for variations in background radiation, the data obtained was threfore recorded in mSv/h for public areas.

RESULTS

Radon Concentration for the Ten Samples of Excavation Site and Construction Sites.

Science World Journal Vol. 20(No 2) 2025 https://dx.doi.org/10.4314/swj.v20i2.19
www.scienceworldjournal.org
ISSN: 1597-6343 (Online), ISSN: 2756-391X (Print)
Published by Faculty of Science, Kaduna State University

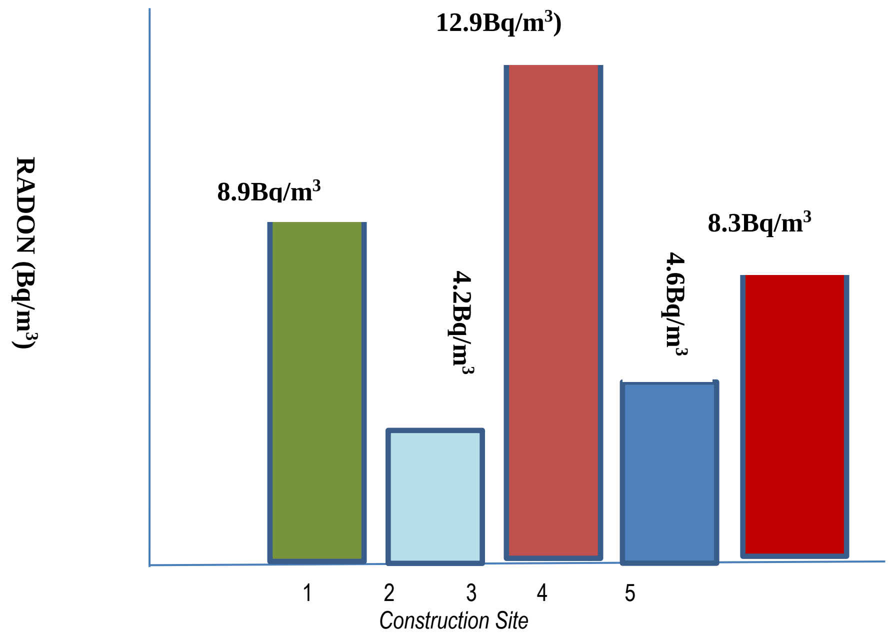

Figure 1 Concentration of Radon in Construction Site

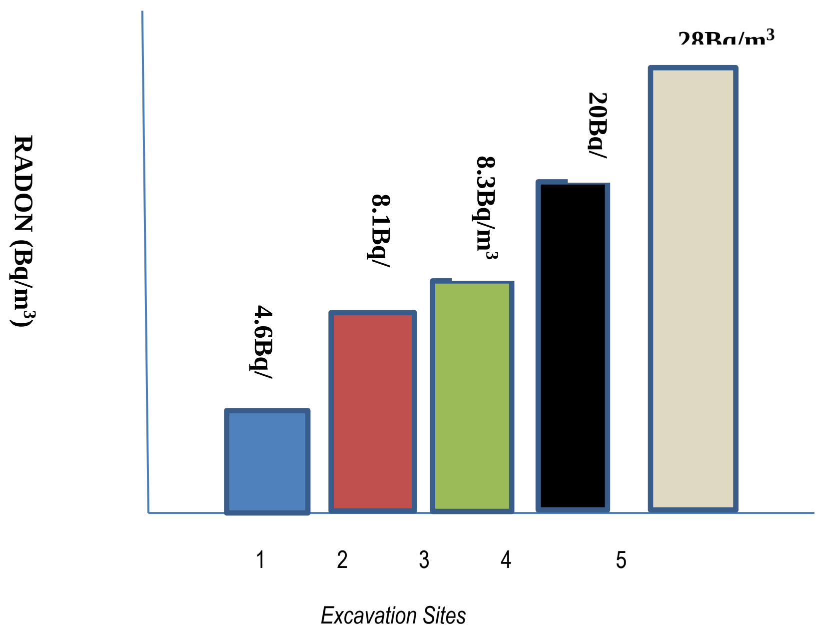

Figure 2 Concentration of Radon in excavation Site

Using bar charts to describe the radon gas concentration from both the excavation and consttruction sites with different colors. From fig.1 and 2 above, soil gas radon concentration values obtained across all the sampling location ranged between 0.1 Bq/m^3 to 28Bq/m^3 with mean of 13.1kBqm^3. The Construction Sites values of 4.6 ± 0.1, 8.1 ± 0.2, 8.3 ± 0.5, 20 ± 1.3 and 28 ± 1.4, from the Excavations sites value varies from 8.9 ± 0.7, 4.2 ± 0.5, 12.9 ± 0.9, 4.6 ± 0.3 and 8.3 ± 0.7 respectively. The total radon concentration given as 101.3 Bq/m^3 and mean average radon concentration is

Science World Journal Vol. 20(No 2) 2025
www.scienceworldjournal.org
ISSN: 1597-6343 (Online), ISSN: 2756-391X (Print)
Published by Faculty of Science, Kaduna State University
https://dx.doi.org/10.4314/swj.v20i2.19

10.13 Bq/m^3. For every 1 Bq/m^3 of radon level concentration contributes about 0.025μSvy^{-1}, as published by ICRP in it's report 1994(Somashekar and Ravikumar, 2010). From the above we can calculate the Absorbed dose, the Equivalent dose rate, the Annual efective dose equivelant and (ELCR) Excess Life Cancer Risk, using the formua below.
Equivalent Dose rate, the equivalent dose rate was calculated using the conversion factor of
1 rad $^{-1}$ = 1.0 x 10Svy^{-1}
(1)
To get the absorbed dose, *the Equivalent dose multiple by 100^{-1}*
(2)
The Annual Effective dose equivalent (AEDE) was computed from the Equivalent dose rate following equation given by:

$$D_w = C_w \times D_{cw} \quad (3)$$

Where D_w is Annual equivalent dose (Svy^{-1})
C_w is Radon concentration in soil (Bq/m3)
D_{cw} is the Dose Conversion factor (5 x 10^{-9})
The Excess life caner risk was also computed using the follwing equation

$$ELCR = AEDE_{mSvy-1} \times LE \times RF \quad (4)$$

Where LE is the life expectance which was taken as 55years for Nigeria as given by the
World Bank Records (2020), while RF is the fatal risk factor which is taken as 0.05Svy^{-1}.

Background Radiation Construction Site

Table 1 Location	Average Exposure Rate mR/hr	Absorbed dose μGy^{-1}	Equivalent Rate μSvy^{-1}	AEDE μSvy^{-1}	ELCR (x 10^3)
1.	0006.0 ± 0006.9	68.591	0.081	0.2933	0.9743
2.	0014.7 ± 0008.6	464.893	0.175	0.0433	0.1514
3.	0015.6 ± 0006.0	731.652	0.856	0.0273	0.9696
4.	0011.2 ± 0009.5	12.956	0.133	1.5525	0.0184
5.	0016.9 ± 0004.3	129.560	0.201	0.5434	0.5434
	Average	**0.0355**	**0.776**	**0.212**	**0.813**

Background Radiation Excavation Site

Table 2 Location	Average Exposure Rate μR/hr	Absorbed dose μGy^{-1}	Equivalent Rate μSvy^{-1}	AEDE μSvy^{-1}	ELCR (x 10^3)
1.	0006.9 ± 0021.6	1879.20	0.257	0.0107	0.0395
2.	0006.0 ± 0011.2	9740.40	0.1331	0.0206	0.0720
3.	0002.5 ± 0009.5	826.50	0.1129	0.0243	0.0850
4.	0005.2 ± 0014.7	1278.9	0.1748	0.0157	0.0550
5.	0004.3 ± 0016.9	1470.3	0.2009	0.0137	0.4790
	Average	**0.0105**	**0.878**	**0.08498**	**0.728**

From table 1 above, the construction site we can see that the exposure rate ranges from 0006.0 ± 0006.9 to 0004.3 ± 0016.9 μR/hr. The equivalent dose rate are 0.081, 0.175, 0.856, 0.133, 0.201, with an average mean of 0.776. The Annual Effective dose equivalent (AEDE) ranges from 0.2933, 0.0433, 0.0273, 1.5525, 0.5434, average mean of 0.212, with the Excess Life Cancer Risk (ELCR) of 0.9743, 0.1514, 0.9696, 0.0184, 0.5434, with average mean of 0.813 all the average values are within or even lower than the recommended level of 1.0μSvy^{-1}
Table 2 is the excavation site above, we can see that the exposure rate ranges from 0006.9 ± 0021.6 to 0004.3 ± 0016.9 μR/hr. The equivalent dose rate are 0.257, 0.1331, 0.1129, 0.1748, 0.2009, with an average mean of 0.878. The Annual Effective dose equivalent (AEDE) ranges from 0.0107, 0.0206, 0.0273, 0.0157, 0.0137 with average mean of 0.0849, and the Excess Life Cancer Risk(ELCR) ranges from 0.0395, 0.0720, 0.0850, 0.0550, 0.4790 with average mean of 0.728, all the average values are within or even lower than the recommended level of 1.0mSvy^{-1}

The above background radiation was computed using the formula below:
Absorbed dose (D) *1 μRh^{-1} =8.7nGh^{-1}= 8.7 x 10-3 μGyy^{-1} = 76.212 μGyy^{-1}* (1)
(1/8760y)
Equavalent dose Rate *(EDR)= $D_{nGyh}$$^{-1}$ x 0.8 x8760 x0.7svGy^{-1}*
(2)
Annual Effective dose equivalent (AEDE)
1 μRh/h = 0.01μSv/h-= 1 μSv/h = 870mGy/h
(3)
Excess Life Risk *(ELCR) = ELCR = AEDEμsy^{-1} x LE x RF*
(4)
Where *LE* is the Life Expectancy, RF is the Risk factor.

DISCUSSION
The radon level obtained from the Excavation site ranges from 4.6 to 28Bq/m3 with mean value of 13.1Bq/m^3 and the radon level obtained from Construction site ranges from 4.2 Bq/m3 to 12.9 Bq/m3 with mean value of 7.16Bq/m3, with total average mean of 20.17 Bq/m^3, Osimobi et al. (2015), ICRP, (2007), Agbalagba et: al, (2016). The results from the Excavation site though, higher than the Construction site, but did not exceed the permissible limits permissible limits of 48.1 Bq/m^3. The higher levels of radon at excavation site are suggestive of radioactively contaminated water. Any radionuclide found in water sometimes reflects on the soil, but in this case, it is different. Imo State LGA,(2017). The activities carried out at the river banks of the excavation site, like refuse dumping, can be a hazard most of which contain chemical and petroleum products, geographical characteristics can also be a factor that leads to variation in radon levels in both sites, such factors are shown in related places containing radioactive elements. Agbalagba; (2016). The level of radon soil in excavation

https://dx.doi.org/10.4314/swj.v20i2.19

and construction site are within the world average dose rate of 2.85 x 10^3μSvh^{-1} Monica et al. (2016), Agbalagba et al. (2017) and the recommended limit of 48.1Bq/m^3(UNSCEAR 2008, Onunugbo and Mgberrese, (2016).

With the result of the level of radon at the excavation site it is very unlikely to provide any immediate (short time) health risk to the resident and excavators(worker at the site), but could be potential risk for long time health hazard in the future, that is, if the activities at the site continue to increase and the level reaches somewhat 97.44 ± 20.42 and 97.44 ± 12.17, the exposure might become too high, Bowen & Ugbede (2018) then people living around need to stop using especially water that comes from the river, because it becomes a public health concern..

The second part of this study is the determination of the background radiation of both the Construction Site and the Excavation Sites. From the Excavation site, the exposure rate ranges from 0006.9 ± 0021.6 to 0004.3 ± 0016.9μR/hr, the absorbed doses are 1879.20, 9740.40, 826.50, 1278.9, 1470.3 with average mean of 0.0105μGy^{-1}, The equivalent dose rate are 0.257, 0.1331, 0.1129, 0.1748, 0.2009, with an average mean of 0.878. The Annual Effective dose equivalent (AEDE) ranges from 0.0107, 0.0206, 0.0273, 0.0157, 0.0137 with average mean of 0.0849, and the Excess Life Cancer Risk(ELCR) ranges from 0.0395, 0.0720, 0.0850, 0.0550, 0.4790 with average mean of 0.728, all these values are within or even lower than the recommended level of 1.0mSvy^{-1} average mean of 0.776. The Annual Effective dose equivalent (AEDE) ranges from 0.2933, 0.0433, 0.0273, 1.5525, 0.5434, average mean of 0.212, with the Excess Life Cancer Risk (ELCR) of 0.9743, 0.1514, 0.9696, 0.0184, 0.5434, with average mean of 0.813 all these values are within or even lower than the recommended level of 1.0mSvy^{-1}.

Conclusion

The Excavation and the Construction Sites the results of radon concentration at the excavation site is a little bit higher than the radon conentration at the construction site, the reason is the presence of radioactive materials present in the soil sample collected from the excavation site. This is suggestive of radioactive contaminated water, most times any radionuclide in the water is reflected in the soil. Imo State LGA, (2017). However, the equivalent dose, absorbed dose, and Excess Life Cancer Risk (ELCR) are not higher than the world average dose rate of 2.85 x 10^{-3} μSvh^{-1} Monica et al. (2016), Agbalagba et al. (2017) and the recommended limit of 48.1Bq/m^3 UNSCEAR (2008), Onunugbo and Mgberrese, (2016) Bowen and Ugbede; (2018).

Background radiation of both the Excavation and Construction Sites, Construction Site: exposure rates like the absorbed doses is 28.15μR/hr, .equivalent dose rate is 0.776, with Annual Effective dose equivalent (AEDE) of 0.212. Excavation site: the absorbed dose is 0.0105 μR/hr equivalent dose rate are 0.878. Annual Effective dose equivalent (AEDE) of 0.0849, Excess Life Cancer Risk (ELCR) of 0.728, all these values is within and even lower than the recommended level of 1.0mSvy$^{-1.}$. The background radiation is not an issue of health concern from this resaerch.

REFERENCES

Abiodun, et al;(2019), *Evaluation of Radioactivtiy and Its rediologival Impact on Soil Samples around Transmision Company of Nigeria*.Radiation Science and Technology, 5(4).41-46.

Abdul J, et al; (2010). *Measurement of soil radioactivity levels and radiation hazard* assessment in southern Rechnainterfluvial region, Pakistan. Environ Monit Assess 169:429–438

Avwiri G O and Olatubosun S. A. (2014) *Assessment of environment radioactivity in selected dumpsites* in Port-Harcourt, Rivers State, Nigeria International Journal of Scientific & Technology Research 3 263.

Avwiri, G. O. Egieye, J. F., and Ononugbo, C. P. (2013). *Radiometric survey of Aluu land fill* in Rivers state, Nigeria. Advan. Phys. Theory Appl. 22:24-30

Avwiri G.O and Onunubgo (2012), *Natural Radioactivity in surface soil* of Ogba/Egbma/Ndoni oil and Gas fields. Energy Science and Technology 4(2):92-101.

Ajayi, J.O., Adedokun, O. and Balogun, B. B. (2012). *Levels of Radionuclide contents in stream waters* of some selected Rivers sin Ogbomoso land, south west Nigeria. Research Journal of Environmental and Earth Science, 4(9): 835 – 837.

Ajayi, N. O. and Laogun (2006).*Variation of Environmental Gamma Radiation* in Benin with vertical height. Nig. J .space Res. 2:47-54.

Batchelor. A.L, Philips, R.J.S and Searle, A.G. (19 69) *Effectiveness of chronic irradiation with neutrons and gamma rays in inducing mutations in female mice*. Br. J Radialogy:42:448-451(PbuMed) 10th February 2023.

Bamidele, L. (2013). Measurement of ionizing radiation in high altitude town of Imesi-Ile, Osun State, Southwestern Nigeria. Environmental Research Journal. 7 (4-6): 79-82. ISSN: 1994-5396

Bernard L.C.(1995) "*Test of the Linear-No Threshold Theory of Radiation Carcinogenesis for Inhaled Radon Decay Products,*" Health Physics 68, 157-174 (1995). 20th January; 2023, 6pm.

Brent, R.L., and Go Rason R.O.(1972). Radiation exposure in pregnancy. Correctional Problems. Radiology. vol. 2, no. 5. 10th February; 2023.

Brewen, J.G., R.J. Preston, and N. Gengozian. (1975). Analysis of X-ray-induced chromosomal *translocations in human and marmoset stem cells*. Nature 253:468-470. [PubMed]

Cardis E., et al., (1995). "*Effects of Low Doses and Low Dose Rates of External Ionizing Radiation*, Cancer Mortality among Nuclear Industry Workers in Three Countries," Radiation Research 142, 117-132 (1995). Indoor Radon. 20th March; 2023, 6pm

Cahil, D.F et al; (1976) Continous exposure to tritium and lead in the rat. A symposium on Boilogical Efects of Low-Level Radiation Petinent to Protection of Man and and His *Environment International Atomi Agency* , Vienna, Chicago 1975,10th February,2023.

Cavalli-Sforza, L.L., and W.F. Bodmer.(1971). *The Genetics of Human Populations*. W.H.O Freeman and Company, San Francisco.

Emelue ,H.U, Eke, B. C Ogbome P, and Ejiogu B. C (2013) *Evaluation of radiation emission from refuse dump sites* in Owerri, Nigeria IOSR Journal of Applied.

Farai, I. P., & Jibri, N. N. (2000). *Baseline studies of terrestrial outdoor gamma dose rate levels in Nigeria.* Radiation Protection Dosimetry. 88(3): 247-254. 20th January; 2023, 6pm.

https://dx.doi.org/10.4314/swj.v20i2.19

Farai, I. P., & Vincent, U. E. (2006). Outdoor radiation level measurement in Abeokuta Nigeria, by *Thermo luminescent Dosimetry.* Nigeria. Journal Physic 18(1): 121-123. Foland, 20th January; 2023, 6pm

Faraj K. A., (2013). Saeed. Quality Control and Radiation Dose Rates Measurement from *Diagnostic X-Ray Examination* at Different Places of Hospitals in Sulaimania. IJRRS; Vol. 16 (2013) [2]. 10th February; 2023.

Florida Department of Environmental Protection (FDEP) (2019)] *Occurrence of Radon in Florida's Public Water Supplies. ;2018 Available online:* https://floridadep.gov/water/source-drinking-water/content/occurrence-radon-floridas-public-water-supplies.

Gbadebo, A.M.,(2011). Natural radionuclides distribution in the Granitic rocks and soils of abandoned quarry sites, Abeokuta, Southwestern Nigeria. Asian J. Applied Sci., 4: 176-185.

Greening, J.R., Green, S., Charles, M.W. (2010). Fundamentals of radiation dosimetry (3rd ed.).London:

Guide for absorbed-dose mapping in radiation processing facilities. ISO/ASTM 52303:2015. [7].

Hendee W. R. and Edwards F. M, Health Effects of Exposure to Low-level Ionizing Radiation (Institute of Physics Publishing, Bristol, UK, 1996). National Research Council, Biological Effects of Ionizing Radiations (National Academy Press, Washington, DC, 1990). 20th March; 2022, 7pm

Hiroshima-N, and William J. S, (1995) *Effects of Atomic Radiation: A Half-Century of Studies* From Hiroshima and Nagasaki (Wiley-Liss, New York, 1995). 20th January; 2023, 6pm.

ISO. (2013). Practice for calibration of routine dosimetry systems for *radiation processing.*

ISO/ASTM 51261:2013. [5]. ISO. (2013). Guide for performance characterization of dosimeters and dosimetry systems for use in radiation processing. ISO/ASTM 52701:2013. [6]. ISO. (2015). \\s\

ISO. (2015). Guide for estimation of measurement uncertainty in dosimetry for radiation processing. ISO/ASTM 51707:2015. [8].

Jay H. Lubin and John D. Boice, Jr., (1997) "*Lung Cancer Risk From Residential Radon:* Meta-analysis of Eight Epidemiological Studies," Journal of the National Cancer Institute, 89, 49-57 (1997) 20th January; 2023, 6pm.

Jibiri, N. O., Alausa, S. K., Owofolaju, A. E. and Adeniran, A. (2011). A terrestrial gamma dose rates and physical-chemical properties of farm soils from ex- tin mining locations in Jos-Plateau, Nigeria. *African Journal of Environmental Science and Technology;* 5(12):1039-1049. 17th January; 2023.

Jibiri, N. O., Alausa, S. K., Norman, E. B. (2008) Review of common occupational hazards and safely concerns for *nuclear medicine technologist*. Journal of Nuclear Med Tech, 36: 11-17.

Kirland C.K., et: al; (1995). *Observed Climatic Variations and Changes* (IPCC scientific Assessment). New York: Cambridge University Press. pp: 101-105.

Korir G. K., (2011). Estimation of annual occupational effective doses from external ionizing *radiation at medical institutions* in Kenya. SA Journal of radiology, 15(4), 116-119 (2011) 10th February; 2023.

Memon,S. A.et:al. (2013) *Radiation Workers' Occupational Doses:* Are We Really Careful or Over-conscious. Radiology 1(1.73), 8-7 (2013) 7th February; 2023.

Merril E and Thomas Gesell, (1997) Environmental Radioactivity: From *Natural, Industrial, and Military Sources*, 4th Edition (Academic Press, San Diego, 1997). 20th March; 2022, 7pm

Mondini M, Levy A, Meziani L, Milliat F and Deutsch E(2020) *Radiotherapy-immunotherapy combinations-Prospective and challenges* Mol Oncol14, 1529-1537.

Norman, E. B. (2008) Review of common occupational hazards and safely concerns for *nuclear medicine technologis*t. Journal of Nuclear Med Tech, 36: 11-17.

Ngiam KY and Khor IW (2019) *Big data and machine learning Algorithm for health-care delivery.*

Ononugbo, C. P., Avwiri, G. O., & Chad-Umoren, Y. E. (2011). *Impact of Gas Exploitation on the Environmental Radioactivity* of Ogba/Egbema/Ndoni Area, Nigeria. Energy and Environment, 22(8), 1017-1028. 7th February; 2023.

Orji, C. E. (2016) *Evaluation of background ionizing radiation levels in some X-ray Centres in Owerri,* Imo State, Nigeria", International Journal of Current Research, 8, (03), 28527-28529 (2016). 10th February; 2023.

Okedeyi, S.A., Gbadebo A.M., Arowolo T.A. and Tchokossa P.,(2012). Measurement of *Gamma-emitting Radionuclides in Rocks and Soils* of Saunder Quarry Site, Abeokuta, Ogun State, Nigeria. Journal of Applied Sciences, 12: 2178-2181.

Owofolaju, A. E.,and Adeniran, A. (2011). A terrestrial gamma dose rates and *physical-chemical properties of farm soil*s from ex- tin mining locations in Jos-Plateau, Nigeria. African Journal of Environmental Science and Technology; 5(12):1039-1049.

Ruedig E, and Johnson ,T.E.(2015) An evaluation of health risk to the public as a *consequence of in situ uranium mining* in Wyoming, USA. Journal of Environmental Radioactivity. 2015; 150: 170–178, 10th February; 2023.

Sadiq, A. A. and Agba, E. H. (2011). *Background Radiation in Akwanga, Nigeria*. FuctaUniversity: Working and Living Enviro`mental Protection 8(1):7-11 7th February; 2023.

Springer Heidelberg Dordrecht, (2010) London, New York. 1-2. ICRP, 2010. Publication 115: *Introduction to Radiation Protection*. ISBN:978-3-642-02586-0, 17th January; 2023.*Lung cancer risk from radon and progeny and statement on radon.* 40(1) 1-64.

Sakoda A., (2010) *Differences of natural radioactivity and radon emanation fraction constituent amongminerals of rock or soil*. *Appl. Radiat. Isot.* 2010;68:1180–1184. doi: 10.1016/j.apradiso.2009.12.036. 10th February; 2023.

Termizi,(2014). *Effective dose from natural background radiation in Keffi and AkwangaTowns, cenrtral Nigeria.* International Journal of Radiation Research, 12(1):1-6. 7th February; 2023

https://dx.doi.org/10.4314/swj.v20i2.19

Termizi, Ramli A., Aliyu, A. S., Agba, E. H., and Saleh, M. A. (2014). Effective dose from natural background radiation in Keffi and Akwanga Towns, cenrtral Nigeria. *International Journal of Radiation Research,* 12(1):1-6

Usikalu, M.R. et al.(2016).*Background radiation dose of dumpsites in Ota and Environs,*Department of Physics, Covenant University, PMB 1024, Ota, Ogun State, Nigeria Email: moji.usikalu@covenantuniversity.edu.ng, 2016. 10th February; 2023.

Usikalu, M.R and Mojisla(2017). *Department of Physics, Covenant University,* P.M.B 1023, Otta, Ogun State, Nigeria, *Centre for Atmospheric Research..* 10th February; 2023.

Yamini K., and V. Gopal. (2010). Natural radioprotective agents against ionizing radiation–an overview on international Journal of *PharmTech Research*, 2(2), 1421-1426 (2010). 10th February; 2023.

Haydari A (2011) Determination of specific activity of 226Ra, 232Th and 40K for assessment of environmental hazards of radiation from building rock samples used in Yemen. RadiatProtDosim 1–8. doi:10.1093/rpd/ncr031

Al-Haydari A (2011) Determination of specific activity of 226Ra, 232Th and 40K for assessment of environmental hazards of radiation from building rock samples used in Yemen. RadiatProtDosim 1–8. doi:10.1093/rpd/ncr031

Al-Haydari A (2011) Determination of specific activity of 226Ra, 232Th and 40K for assessment of environmental hazards of
radiation from building rock samples used in Yemen. RadiatProtDosim 1–8. doi:10.1093/rpd/ncr031

Al-Haydari A (2011) Determination of specific activity of 226Ra, 232Th and 40K for assessment of environmental hazards of
radiation from building rock samples used in Yemen. RadiatProtDosim 1–8. doi:10.1093/rpd/ncr031

Al-Haydari A (2011) Determination of specific activity of 226Ra, 232Th and 40K for assessment of environmental hazards of
radiation from building rock samples used in Yemen. RadiatProtDosim 1–8. doi:10.1093/rpd/ncr031

Al-Haydari A (2011) Determination of specific activity of 226Ra, 232Th and 40K for assessment of environmental hazards of
radiation from building rock samples used in Yemen. RadiatProtDosim 1–8. doi:10.1093/rpd/ncr031

Al-Haydari A (2011) Determination of specific activity of 226Ra, 232Th and 40K for assessment of environmental hazards of
radiation from building rock samples used in Yemen. RadiatProtDosim 1–8. doi:10.1093/rpd/ncr031

Al-Haydari A (2011) Determination of specific activity of 226Ra, 232Th and 40K for assessment of environmental hazards of
radiation from building rock samples used in Yemen. RadiatProtDosim 1–8. doi:10.1093/rpd/ncr031

U.S. Environmental Protection Agency . *Radiation: Facts, Risks, and Realities.* U.S Environmental Protection Agency; Washington, DC, USA: 2012.