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Outdoor Radiation and Health Risk Assessment Near Fuel Filling Stations

Nasir Tijjani Sidi, Andrew Narcissus and *Emmanuel Joseph

Department of Physics, Federal University Dutsin-Ma, Katsina State, Nigeria

*Corresponding author's email: ejoseph@fudutsinma.edu.ng

ABSTRACT
Humans and man-made activities are well known processes that contribute to background radiation. In this study, the assessment of outdoor background radiation near fuel filling stations Kaduna state, Nigeria has been conducted. An in-situ measurement for outdoor background exposure rate for twenty (20) different locations was taken using a portable nuclear radiation detector model XR1- Tool0015, with G-M technology, at an elevation of 1.0 m above ground level with a geographical positioning system (GPS) for geographical location. Using established radiological relations, the radiological health hazards, values were obtained and compared with recommended permissible limits in order to determine the radiological hazard status of the environment. The mean values of the outdoor background exposure levels (0.13 µSv/h), Annual Effective Dose Equivalent (0.16×10^{-3} mSv/y), and excess lifetime cancer risk (0.57×10^{-3}). The mean value of the background exposure and annual effective dose equivalent are below the recommended safe limit of 1.0 mSv/y. The mean value obtained is 0.57×10^{-3}. This mean value is higher than the world average value of 0.29×10^{-3}. This high value for excess lifetime cancer risk indicates that there exist the possibilities of cancer development by residents who wish to spend all their life time in the area. Generally, the study shows that the radiological indices evaluated was found to be within the acceptable safe limit of 1 mSv/y for the public and the excess lifetime cancer risk was found to be higher than the safe limit.it is therefore advisable that residence take precautionary measures as they live within this study area.

Keywords:
Radiation,
Fuel Stations,
Annual effective dose,
Excess lifetime,
Background exposure.

INTRODUCTION

For the past few decades nuclear event and accident have made people alert and anxious of radioactivity and terms related to it. Although not much is known about the distribution of radioactive materials in the natural environment. The advent of industrialization coupled with poor environmental management systems have resulted to the release of various forms of toxic, corrosive and radioactive contaminants or pollutants into the environment. The negative health impact of industrial activities in the environment has been an issue of discussion in contemporary times. Environmental contamination and degradation are a global concern because of its negative health impact. Radioactivity is a phenomenon associated with unstable atomic nuclei which spontaneously decompose emitting particles such as beta, alpha and neutron or electromagnetic radiation in the form of gamma rays (UNSCEAR 2010). As already mentioned, an unstable nucleus will eventually become more stable by emitting particulate and/or electromagnetic radiation. The type of radiation emitted will depend on the type of instability. If a nucleus has too many neutrons for the number of protons (i.e., it is below the line of stability) it will tend to become more stable by essentially converting a neutron to a proton and emitting an electron. Electrons emitted from the nucleus are called beta particles (β-radiation). Typically, additional electromagnetic energy will also be emitted. Electromagnetic energy from the nucleus is called gamma radiation (γ-radiation). Radiation plays an important and sometimes vital role in our everyday lives. Everyday each of us is exposed to naturally occurring quantities of radiation through the air we breathe, the soil on which we walk the water we drink, the food we eat and even within our bodies (Ademola, 2008). Furthermore, certain industrial activities such as crude oil exploration result in enhanced ionizing radiation in the environment. Ionizing radiations such as α, β and γ radiations are often found in the petroleum matrix due to both contamination by radionuclides in the earth's crust and the materials used in the drilling process (Chad-Umoren, 2012; Laogun *et al*., 2006). Gamma rays are highly penetrating and are products of the radioactive materials containing radon. These substances may be ingested or inhaled thereby exposing both the hydrocarbon industry personnel and members of the host communities to increase in the risk of lung cancer, eye cataracts and mental imbalance (Laogun *et al*., 2006). Also, it has been reported that naturally occurring radioactive materials (NORMS) associated with oil and gas production contain radioactive uranium, thorium and their progenies Ra-226 and Ra-228 (Abison, 2001; Avwiri *et al*., 2007a; Chad-Umoren, 2012). At present, various environments suffer from the excessive accumulation of radioactive pollutants and their hazardous results, where radionuclides naturally decay. Examples of such radionuclides are: ^{226}Ra, ^{228}Ra, ^{222}Rn, ^{210}Pb, ^{40}K etc., which decay along with many other man-made radionuclides. Approximately 80% of human exposures to radiation comes from the radioactive sources that naturally occur, which may lead to several harmful effects on humans, animals, or the environment. NORMs are an integral part of the planet, our bodies, the food we eat, the air we breathe, the places we live and work, and the products we use. Treatment of some natural resources enhances naturally occurring radionuclides to the extent that they may pose risks to humans and the environment. These by-products are named as follows: technically enhanced naturally occurring radioactive materials (TENORMs). Apart from geophysical and geological factors, some human activities can also enhance the natural radiation background levels (Rose *et al.,* 1995). These activities include burning of fossils, mining and milling operations (Saleh *et al*., 2007). This operation brings large amount of otherwise buried materials containing NORM. By ingesting and inhaling the radionuclides in the NORMS or by just staying close to large volume of NORM, people are inadvertently exposed to enhanced level of radiation which can result in health hazard and risk (Saleh *et al*., 2007; Turhan and Gunduz, 2007). In the hydrocarbon industry, oil spillage, gas flaring and drilling activities are believed to raise the natural background radiation of the environment (Sigalo and Briggs- Kamara, 2004). Also, it has been reported that NORMS associated with oil and gas production contain radioactive uranium, thorium and their progenies Ra-226 and Ra-228 (Abison, 2001; Avwiri *et al.,* 2007a; Chad-Umoren, 2012).

Background radiation is created from both naturally existing radionuclides (such as the radiation sent out from radioactive terrestrial components and cosmic rays) and the man-made radionuclides that produce radiations from activities such as the medical procedures that use radiopharmaceuticals for imaging or therapeutic purposes and radioactive uranium that use as fuel for electricity generation.

Background ionization radiation (BIR) could be considered as environmental contamination especially when it exceeds safe occupational and public limits (Agbalagba et al., 2016). BIR in the environment which was originally due to natural sources of terrestrial primordial radionuclides and extraterrestrial cosmic rays has over the years increased due to human activities and especially in the industrial environments. This is because raw materials used in industries contain NORM (Ademola and Olatunji, 2013) which are later released into the environment as waste after undergoing some industrial processes. Enhanced levels of naturally occurring radionuclides may be associated with certain natural materials, minerals and other resources used as raw materials in industries due to their region and origin (Lu and Zhang, 2006; Ademola and Olatunji, 2013). The most important are the series ^{238}U and ^{232}Th and their decay products as well as non-series ^{40}K. Research data available on BIR levels assessment in some cities and towns worldwide show regions of low and high BIR levels. In Nigeria for example, Agbalagba et al. (2016) reported high radiation levels within Ughelli metropolis and its environs due to the industrial nature of the area. Agbalagba (2017) documented mean BIR exposure value of 0.022 ± 0.006 mRh^{-1} in industrial zone of Warri city. James et al. (2013) studied the radiation levels of industrial area of Abuja and recorded low radiation doses in the area. Akpabio et al. (2005) also studied the environmental radioactive levels in Ikot– Ekpene and reported that the radioactivity levels in the area is generally low ranging. Within Keffi and Akwanga towns of central Nigeria, Termizi-Ramli et al. (2014) also reported low radiation levels that are within recommended safe limits for the areas. Outside the country, Zarghani and Jafari (2017) recorded low range radiation doses in Birjand, Iran. In Chihuahua City, Mexico, Luevano-Gurrola et al. (2015) observed high outdoor gamma dose rates ranging from 113 to 310 ηGyh^{-1}. The basic level of natural background radiation varies with the variation of the geological and geographical features of the area. The terrestrial component varies with geography, and the cosmic source component depends on the altitude. It is believed that exposure to high radiation levels will cause cancer. Background exposure from normal levels of the NORMs are present in all environmental materials and do not vary remarkably from place to place. Where human activities (Laboratory activities, pollution, mining and others) have increased the relative concentration of the radionuclides, they are referring to as the TENORMs (Akinloye & Olomo, 2005). The ambient radiation encompasses both the natural and artificial radioactivity in the environment (Alharbi *et al.*, 2011). Survey taken by the World Health Organization (WHO) and the international commission on radiological

protection (ICRP) shows that residents of temperate climates spend only about 20% of their time outdoor and about 80% indoor (homes, schools offices or other buildings) (Idris *et al.*, 2021; Olubosede *et al.,* 2012; Chibowski 2002).
Therefore, there is need to investigate the outdoor background radiation levels and radiological hazard of radioactive waste materials around the vicinity of household around filling stations. The aim of this research is to assess the Outdoor Radiation and Health Risk Assessment Near Fuel Filling Stations in Kaduna State in order to measure the gamma radiation dose level and to estimate the radiological hazards of the study area.

MATERIALS AND METHODS

Materials

Hand Held Global positioning system (GPS)

A GPS is used for the measurement of elevation, geographic coordinates and the LOS (line of sight) of the various data locations from the base station.

Nuclear Radiation detector

measurement of outdoor exposure level was done using a portable nuclear radiation detector model XR1-Tool0015, with G-M technology. It is capable of measuring beta, gamma and x-ray. It has a sensitivity of 80cmp/μSv/h with a test accuracy of 0.01μSv/h, mean time error of ≤ 3 % and real time error of ≤ 10%.

Method

Measurement of exposure level was carried out using a nuclear radiation detector model XR1 meter which measure the gamma dose rate in μSv/h. The meter was switched on and allowed to absorb radiation for a few seconds and the meter read at the highest stable point. The meter was placed 1m above ground level and reading were taking in the afternoon between 1pm to 4pm for efficient monitoring and response of the meter to environmental radiation exposures according to the method of Inyang et al. (2009). A total of twenty locations were measured with nuclear radiation meter. For effective computation of the experimental data from Exposure level (in μSv/hr) to other hazard parameters, the following formulas was used.

Calculation of Radiological Hazards Indices

According to (Idris et al., 2021; Etuk *et al*., 2015) The exposure (σ) measured in μSv/h is converted to annual absorbed dose rate ADR in mSv/yr is given as

$$ADR\left(\frac{mSv}{yr}\right) = \sigma\left(\frac{\mu Sv}{h}\right) \times OF \times 24\ hrs \times 365.25\ days\ \times 10^{-3} \quad (1)$$

OF is the occupancy factor and absorbed dose is obtained in Gy/h from the measured exposure in μSv/h using the relationship

$$D(nGy/h) = \sigma \frac{\left(\frac{\mu Sv}{h}\right)}{Q} \times 10^{-3} \quad (2)$$

Q is the quality factor=1.0 for gamma radiation
The annual effective dose rate (AEDR) per year received by workers and the population is obtained from equation (UNSCEAR, 2000)

$$AEDR\left(\frac{mSv}{yr}\right) = D\left(\frac{nGy}{h}\right) \times 8760\ h\ \times CF\ \times OF \quad (3)$$

CF is the conversion factor of the absorbed dose in air to the effective dose

$$CF = 0.7\,\frac{Sv}{Gy}, \quad (4)$$

OF is the occupancy factor, the expected period the members of the population would spend within the study area. OF = 0.2 for outdoor as it is expected that human beings would spend 20 % of their time outdoors. Therefore, according to (Idris et al., 2021; Gupta and Chauhan 2011) AEDR for outdoor is obtained from the equation,

$$AEDR\ \left(\frac{mSv}{yr}\right) outdoor = D\left(\frac{nGy}{h}\right) \times 8760\ h \times 0.7\ \frac{Sv}{Gy} \times 0.2 \times 10^{-3} \quad (5)$$

The excess lifetime cancer risk (ECLR) is calculated from the equation

$$ECLR = AEDR \times DL \times RF \quad (6)$$

Where DL is the duration of life (70 years) and RF is the risk factor, which is the fatal cancer risk per sievert. ICRP 60 recommend RF = 0.05 for the public (Taskin *et al.,* 2009), for stochastic effect.

RESULTS AND DISCUSSION

The outdoor data obtained from the in-situ measurement from the study area were processed by mean value by adding up the data collected and dividing it by the number of data taken to get the mean value of the location. The result is shown in table 1. Radiological parameters such as calculated annual absorbed dose rate (ADR), the annual effective dose rate (AEDR) and estimated excess cancer lifetime risk (ECLR) are calculated using equation (1) to (6) and presented in table 1.

Table 1: Measured exposure and calculated radiological hazard indices

Location code	Latitude (E)	Longitude (N)	Exposure σ (μSv/h)	ADR (mSv/y)	D (nGy/h)	AEDR (mSv/y)	ELCR ($\times 10^{-3}$)
RD1	007°28.911'	10°24.747'	0.14	0.245	0.14×10^{-3}	0.17×10^{-3}	0.60×10^{-3}
RD2	007°28.892'	10°24.588'	0.14	0.245	0.14×10^{-3}	0.17×10^{-3}	0.60×10^{-3}
RD3	007°28.885'	10°24.767'	0.15	0.263	0.15×10^{-3}	0.18×10^{-3}	0.64×10^{-3}
RD4	007°29.013'	10°24.933'	0.13	0.228	0.13×10^{-3}	0.16×10^{-3}	0.57×10^{-3}
RD5	007°29.056'	10°24.948'	0.14	0.245	0.14×10^{-3}	0.17×10^{-3}	0.60×10^{-3}
RL1	007°29.798'	10°24.133'	0.14	0.245	0.14×10^{-3}	0.17×10^{-3}	0.60×10^{-3}
RL2	007°29.789'	10°24.078'	0.13	0.228	0.13×10^{-3}	0.16×10^{-3}	0.57×10^{-3}
RL3	007°29.796'	10°24.022'	0.15	0.263	0.15×10^{-3}	0.18×10^{-3}	0.64×10^{-3}
RL4	007°29.808'	10°23.957'	0.12	0.210	0.12×10^{-3}	0.15×10^{-3}	0.51×10^{-3}
RL5	007°29.795'	10°25.031'	0.11	0.193	0.11×10^{-3}	0.14×10^{-3}	0.47×10^{-3}
SG1	007°29.844'	10°25.073'	0.13	0.228	0.13×10^{-3}	0.16×10^{-3}	0.57×10^{-3}
SG2	007°29.889'	10°25.130'	0.12	0.210	0.12×10^{-3}	0.15×10^{-3}	0.51×10^{-3}
SG3	007°29.810'	10°25.168'	0.17	0.298	0.17×10^{-3}	0.21×10^{-3}	0.73×10^{-3}
SG4	007°29.764'	10°25.181'	0.17	0.298	0.17×10^{-3}	0.21×10^{-3}	0.73×10^{-3}
SG5	007°29.693'	10°25.099'	0.15	0.263	0.15×10^{-3}	0.18×10^{-3}	0.64×10^{-3}
OV1	007°29.246'	10°25.958'	0.15	0.263	0.15×10^{-3}	0.18×10^{-3}	0.64×10^{-3}
OV2	007°29.187'	10°25.986'	0.11	0.193	0.11×10^{-3}	0.14×10^{-3}	0.47×10^{-3}
OV3	007°29.138'	10°26.002'	0.12	0.210	0.12×10^{-3}	0.15×10^{-3}	0.51×10^{-3}
OV4	007°29.078'	10°26.037'	0.10	0.175	0.1×10^{-3}	0.12×10^{-3}	0.43×10^{-3}
OV5	007°29.122'	10°26.144'	0.10	0.175	0.1×10^{-3}	0.12×10^{-3}	0.43×10^{-3}
Mean			0.13	0.234	0.13×10^{-3}	0.16×10^{-3}	0.57×10^{-3}

The radiological hazard indices obtained shows that the mean exposure ranges from 0.10 μSv/h to 0.17 μSv/h and the calculated absorbed dose rate ranges from 0.175 mSv/y to 0.298 mSv/y, while the corresponding calculated AEDR ranges from 0.12×10^{-3} mSv/yr to 0.21×10^{-3} mSv/yr. The corresponding estimated ECLR ranges 0.43×10^{-3} to 0.73×10^{-3}.

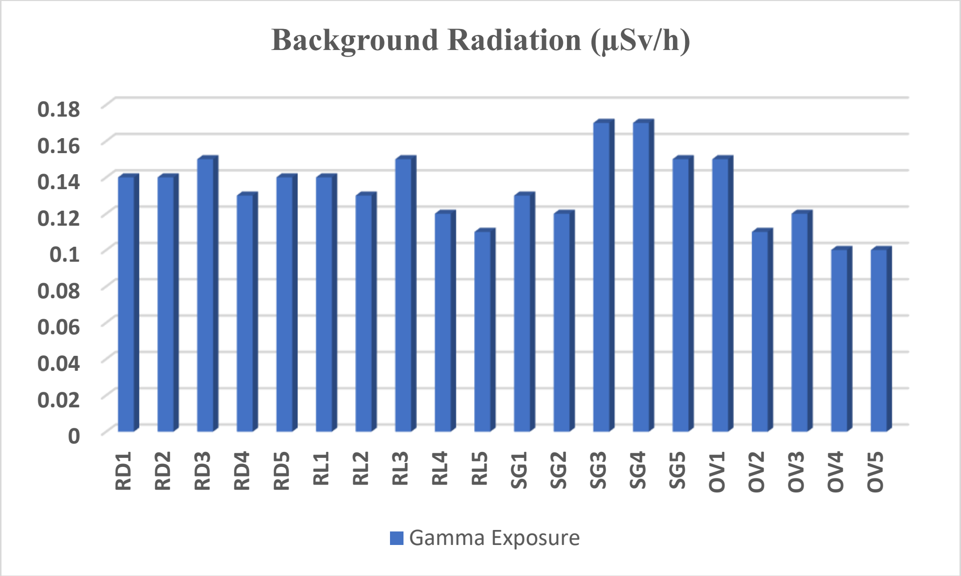

Figure 1: Background radiation measured in μSv/h

As shown in figure 1, slight spatial variations were observed among the sampling locations. The highest exposure rates (0.17 μSv/h) occurred at SG3 and SG4, while the lowest values (0.10 μSv/h) were recorded at OV4 and OV5. These variations may be attributed to differences in soil composition, geological background radiation, and the accumulation of radionuclides from petroleum-related activities. When converted to the annual dose rate (ADR), the values ranged between 0.175 mSv/y and 0.298 mSv/y, which are all below the recommended public exposure limit of 1.0 mSv/y set by the International Commission on Radiological Protection (ICRP, 2007). This indicates that, although the observed radiation levels vary slightly across locations, the overall exposure remains within the safe range for the general population. Therefore, the results suggest that the radiological health risks associated with outdoor radiation around the studied fuel filling stations are minimal and not likely to pose significant health hazards to nearby residents or workers.

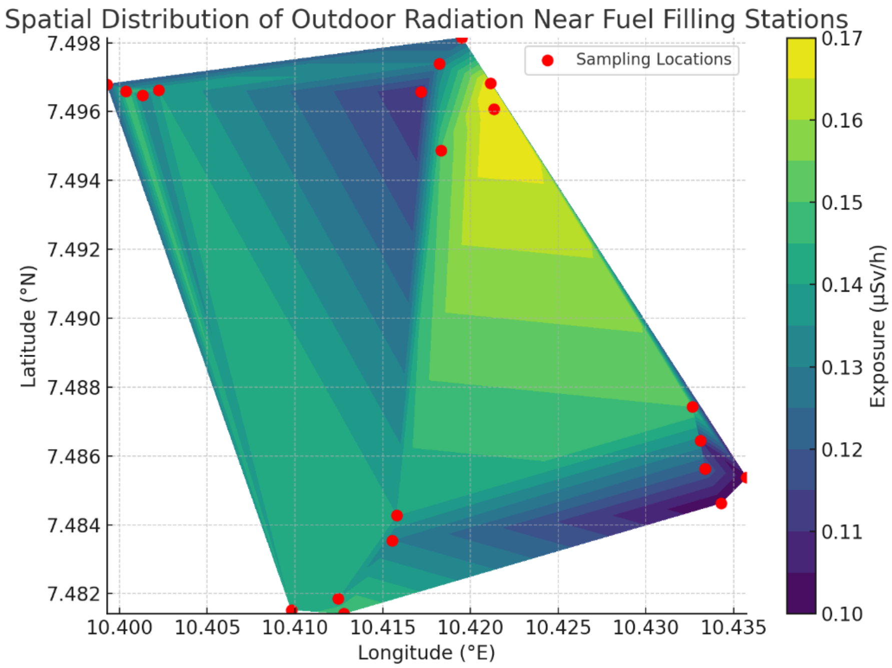

Figure 2: Spatial Distribution of Outdoor Radiation Near Fuel Filling Stations

The contour map (Figure 2) reveals spatial variations in radiation intensity across the study area. Regions toward the central and eastern portions show slightly elevated exposure rates (≈0.16–0.17 µSv/h), corresponding to locations SG3 and SG4, while the southern and western zones exhibit lower radiation levels (≈0.10–0.12 µSv/h), notably around OV4 and OV5. This spatial pattern has shown that the variation may be due to background geology, accumulation of petroleum residues, or proximity to active filling stations and vehicular activity. Overall, even though the radiation levels vary spatially, they remain within the recommended safety limits for public exposure, indicating no significant radiological health risk in the investigated region.

Annual Effective Dose Equivalent

The AEDE is used in radiation assessment and protection to quantify the whole body absorbed dose per year. It is used to assess the potential for long-term effects that might occur in the future. The calculated absorbed dose rates were used to compute the AEDE within the study area using equation (5). The calculated annual effective dose rate for outdoor radiation presented in Table 1 shows that annual effective dose rate is higher than world average value of 0.07 mSv/y (ICRP, 2007; UNSCEAR, 2008; Agbalagba, 2017) but within ICRP and UNSCEAR recommended permissible limits of 1.00 mSv/y for the general public (ICRP, 2007; UNSCEAR, 2008). This implies that the studied location is radiologically contaminated due to the industrial activities taking place in the area. However, the contamination does not constitute any immediate radiological health effect on residents of the area. The AEDR values (outdoor) is lower than those obtained in similar investigation elsewhere and the worldwide average background radiation of 2.4 mSv/yr (Avwiri & Olatubosun, 2014).

Excess Lifetime Cancer Risk (ELCR)

The excess lifetime cancer risk is used in radiation protection assessment to predict the probability of an individual developing cancer over his lifetime due to low radiation dose exposure, if it will occur at all. The calculated ELCR value ranges from 0.43×10^{-3} to 0.73×10^{-3}. The mean value obtained is 0.57×10^{-3}. This mean value is higher than the world average value of 0.29×10^{-3}. This high value for excess lifetime cancer risk indicates that there exist the possibilities of cancer development by residents who wish to spend all their life time in the area. The ELCR values report here are lower than those reported by Agbalagba (2017) in industrial areas of Warri Nigeria and also lower than those for Okposi Okwu Salt

Lake and Uburu Salt Lake environments of Ebonyi State, Nigeria reported by Avwiri et al. (2016).
The International Commission on Radiological Protection (ICRP-2007) recommends that any exposure above the natural background radiation should be regulated and kept as low as reasonably achievable (ALARA).

CONCLUSION
The reading was collected from twenty (20) different location around NNPC Kaduna where individuals reside with domestic/ livestock activity high. The result obtained for the annual effective dose was found to be lower than the ICRP recommended effective dose rate of 1.0 mSv/yr, a limit for the public. The AEDR values (outdoor) is lower than the worldwide average background radiation of 2.4 mSv/yr. The value of the ELCR was found to be higher than the world average value of 0.29×10^{-3}. This high value for excess lifetime cancer risk indicates that there exist the possibilities of cancer development by residents who wish to spend all their life time in the area. The radiation exposure level around the vicinity of households at various filling stations in Kaduna, Kaduna state Nigeria was carried out to assess the radiological implication to the people. The result shows that the radiological indices evaluated was found to be within the acceptable safe limit of 1mSv/yr for the public and the excess lifetime cancer risk was found to be higher than the safe limit which means that there is a possibility for developing cancer to resident who wishes to spend their entire lifetime in that area.

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