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Assessment of radiation levels and radiological health hazards in Keffi Dumpsite, Nasarawa State, Nigeria using inspector alert nuclear radiation monitor (Dose to Organs (D_{organ}) Approach)

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ABSTRACT

Aim: The study was aimed at assessing the radiation levels and radiological health hazards in Keffi Dumpsite, Nasarawa State, Nigeria using Inspector Alert Nuclear Radiation Monitor.

Method and Materials: The inspector Alert Nuclear Radiation Monitor with the serial number 35440, made in USA by ion spectra (International Med. Com. Inc) using alkaline battery 0f 9.0volts, a scientific calculator, personal computer (laptop), pen and exercise book were used. Radiation was measured by using radiation monitor with in-build Geiger Muller tube operating in the Dose Rate mode to determine the background ionizing radiation level from selected dumpsites of Keffi.

Results: The mean annual effective dose rate for Keffi dumpsites were 0.19 mSv/y. The finding finally revealed that the mean D_{organ} values for the lungs, ovaries, bone marrow, testes, kidney, liver and whole body for Keffi dumpsites were 0.122, 0.110, 0.131, 0.156, 0.118, 0.087 and 0.129 mSv/y respectively.

Conclusion: It was concluded that background radiation in Keffi dumpsites is not an issue of health concern except when accumulated over long period of time which may cause cancer to the indoor members on approximately seventy years of exposure.

Keywords: Radionuclides; Dumpsites; D_{organ}; Radiation; Effective Dose; Excess Lifetime Cancer Risk.

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Introduction

Background exposure from normal levels of the naturally occurring radioactive materials (NORMS) are present in all environmental materials and do not vary remarkably from place to place (Akpa, 2010). Where human activities (Laboratory activities, pollution mining and others) have increased the relative concentration of the radionuclides, they are referred to as the technologically enhanced naturally occurring radioactive materials (TENORMS) (Chad-Umoren et al., 2007). Natural radioactivity has great ionizing radiation effect on the world population due to its presence in our surrounding at different amounts (Dawdall et al., 2004). The ambient radiation encompasses both the natural andartificial radioactivity in his environment (Farai and Vincent, 2006) 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, school's offices or other buildings) (Felix et al., 2015).

Materials used for building (soil and rock) are major source of radiation exposure to the population and also a means of migration for the transfer of radionuclide into the environment. Natural radioactivity in soil is mainly due to ^{238}U, ^{40}K, ^{226}Ra which cause external and internal radiological hazards due to emission of gamma rays and inhalation of radon and its daughters (UNCSEAR, 1988). ^{222}Rn results from radioactivity of uranium-238 and itself decays with a half-life of 3.82days. When it is inhaled it penetrates into the lungs. It's most dangerous daughters are α-emitters (^{218}Po and^{241}Po) which emits α-particles with high energy of 6.0 MeV and 7.69 MeV respectively (Huyumbu et al., 1995). The continuous deposition and interaction of such high energy particles with the lung leads to its damage and the incidence of lung cancer. It has been establishing that chronic exposure to even low dose rate of nuclear radiation from an irradiated building has the potential to induce cytogenetic damage in human beings (James et al., 2015). One of the radionuclides around man's environment that contributes high amount of potential lethal dose is radon; which causes the majority of deaths resulting from lung cancer (Maria et al., 2010). Of particular concern for indoor background ionizing radiation is the incidence of the invisible, odorless radioactive gas ^{222}Rn which is a member of the Uranium radioactive series (Nisar et al., 2015). Estimate shows that of the 2.4mSv/yr annual exposure from all ionizing sources, 40% is contributed by internal exposure to radon alone (Norma, 2008).

A strong correlation between radon exposure (inhalation) and the prevalence of lungs cancer have also been reported (Sadiq and Agba, 2012). In Malaysia, cancer (stomach, breast, lung, liver, leukaemia and thyroid) is one of the major health problems, it has been certified medically that cancer is the fourth leading cause of death (Tikyaa et al., 2017). Natural sources of radiation include; extraterrestrial cosmic radiation (consisting of 87% proton, 12% α-particles and 1% heavier nuclide) (Ghoshal, 2007) and terrestrial radiation from primordial elements in the earth. Radiation dose depend on the intensity and energy of radiation, type of radiation, exposure time, the area exposed and the depth of energy deposition. Quantities, such as the absorbed dose, the effective dose and the equivalent dose have been introduced to specify the dose received and the biological effectiveness of that dose (Rilwan et al., 2021). The absorbed dose (D); specifies the amount of radiation absorbed per unit mass of material. Its S.I unit is gray. ($1Gy=1Jkg^{-1}$). The absorbed dose rate (DR); is the rate at which an absorbed dose is received its units are (Gys^{-1} and $mGyhr^{-1}$). It is however important to mention that the biological effect depend not only on the total dose the tissue is exposed to, but also on the rate at which the dose was received. The equivalent dose rate (EDR); the absorbed dose does not give an accurate indication of the harm that radiation can do since equal absorbed doses do not necessarily have the same biological effects.

An absorbed dose of 0.1Gy of alpha radiation is more harmful than an absorbed dose of 0.1Gy of beta or gamma radiation. To reflect damage done in biological systems from different types of radiation, the equivalent dose is used. It is defined in terms of the absorbed dose weighted by a factor which depends on the type of radiation. It unit is Sievert (Sv). Exposure to ionizing radiation poses a high risk and this risk may include cancer induction, radiation attracts ogenesis, and indirect chromosomal transformation. The practice being to keep one's exposure to ionizing radiation as low as reasonably possible is known as the ALARA principle. However, Radon (^{222}Rn) finds its way indoor through building materials, diffusion, and convection and through the soil under the building. Some of the materials used in the construction of buildings are known to be radioactive (Rilwan et al., 2021).

Considering these source of indoor background ionizing radiation, and the cold nature of the university, it is obvious that laboratory technologies, staff as well as students spend more time inside the laboratory either in search of warmness or carrying out research. Hence background ionizing radiation profile within and without those laboratories is crucial to assess the level of health risk of exposure to which the occupants and users of such laboratories are exposed when compare to the average effective dose of about 2.4 mSv/yr reported by (Rilwan et al., 2021).

The study was aimed to assess the Radiation Levels and Radiological Health Hazards in Keffi Dumpsite, Nasarawa State, Nigeria using Inspector Alert Nuclear Radiation Monitor.

Materials and Methods

Materials

The inspector Alert Nuclear Radiation Monitor with the serial number 35440, made in USA by ion spectra (International Med. Com. Inc) using alkaline battery 0f 9.0volts, a scientific calculator, personal computer (laptop), pen and exercise book were used.

Method

Radiation was measured by using radiation monitor with in-build Geiger Muller tube operating in the Dose Rate mode to determine the background ionizing radiation level from the selected dumpsites of Keffi. The Geiger Muller tube generated a pulse of electrical current each time radiation passes through the tube which cause ionization. Each pulse was electrically detected and registered as a count mSv/hr, but CPM, been the most direct and appropriate method of measuring alpha and beta activity was choose as the correct mode. The inspector Alert was held above the ground level (1m above). The device was turn on and measurements were taken after a deep sound that indicates the statistical validity of the readings on the liquid crystal display (LCD) of the monitor.

Study Area

Keffi is a town in Nasarawa State, Nigeria. Its headquarters are in the town of Keffi. Keffi is 50 kilometers from Abuja. Nasarawa State university is located in Keffi sitting along Keffi-Akwanga express way. It has an area of 138 km^2 and a population of about 92,664 at the 2006 census. The postal code of the area is 961 [19].

Keffi town was founded around 1802 by a Fulani warrior leader Abdu Zanga who took the title of emir. His small dominion was subject to the Zaria emirate to which it had to pay an annual tribute of slaves [19]. In 1902, Keffi was the location of an incident that led to the British invasion of Northern Nigeria, after the "Magaji", a representative of the Zaria sultan killed a British officer. When the Magaji found refuge in Kano, this was the pretext for Lugard to invade the northern caliphate (Agba et al., 2000).

Method Data Collection and Measurement

Inspector Alert Meter was a relatively economical meter frequently used to perform surveys of very low radiation fields. It can be measured variations in background dose rate. The measuring range was 0 to 5000 μR/hr. (For μSv/h, use Model 19 Series 8, P/N: 48-2582.) The cast aluminum instrument housing with a separate battery compartment and accompanying metal handle offer an industrial robustness and quality that promote long lasting protection.

The meter was held one meter above the ground to reflect abdominal level of human readings in count per minute. Readings were taken three times in μR/hr after which the average reading was calculated for each of the camp work visited. The analytical procedure was conducted for three days, in Keffi dumpsite.

Method of Data Analysis

Recommended indoor and outdoor occupancy factors of 0.8 and 0.2 respectively (UNCEAR, 2000). This occupancy factor is the proportion of the total time during which an individual was exposed to a radiation field. Eight thousand seven hundred and sixty hours per year (8760hr/yr) were used. Equation (1) converts from Gamma Activity in milli Röentgen per hour to Exposure Dose Rate in micro – Sievert per hour, equation (2) converts the Exposure Dose Rate in micro – Sievert per hour to Indoor Annual Effective Dose Rate in milli Sievert per year, equation (3) converts the Exposure Dose Rate in micro – Sievert per hour to Outdoor Annual Effective Dose Rate in milli Sievert per year, equation (4) evaluates the Indoor Excess Lifetime Cancer Risk, while equation (3.5) evaluates the Outdoor Excess Lifetime Cancer Risk.

$$10 \text{ mR/hr (GA)} = 1 \text{ μSv/hr (EDR)} \quad (1)$$

$$\text{AEDR mSv/yr} = \text{(EDR) μSv/hr} \times 8760 \text{ hr/yr} \times 0.8 \div 1000 \quad (2)$$

$$\text{ELCR} = \text{AEDE} \times \text{DL} \times \text{RF} \quad (3)$$

$$D_{organ} = \text{AEDE} \times \text{F} \quad (4)$$

Results and discussion

Gamma activity level was obtained from the field, after which equations (1) – (4) were used to evaluate the Exposure Dose Rate (EDR), Annual Effective Dose Rate (AEDR), Excess Lifetime Cancer Risk (IELCR) and Effective Dose to different organs of the body (D_{organ}) and were presented.

It was presented raw data obtained from gamma activity level at the different points of Keffi dumpsite. The mean gamma activity varies from 0.16 mR/h at AC to 0.51 mR/h at LA with an average value of 0.27 mR/h. It was also evaluated results for exposure dose rate at different offices of the Keffi dumpsite. The mean exposure dose rate varies from 0.016 μSv/h at AC to 0.051 μSv/h at LA with an average value of 0.027 μSv/h. Similarly, the evaluated results for annual effective dose rate at different offices of the Keffi dumpsite were presented. The mean annual effective dose rate varies from 0.011 mSv/y at AC to 0.36 mSv/y at LA with an average value of 0.19 mSv/y.

Results for excess lifetime cancer risk at different offices of the Keffi dumpsite were also evaluated. The mean excess lifetime cancer risk varies from 0.39×10^{-3} at AC to 1.26×10^{-3} at LA with an average value of 0.67×10^{-3} and 0.18×10^{-3} (Table 1).

It showed that the estimated mean D_{organ} values for the lungs, ovaries, bone marrow, testes, kidney, liver and whole body due to radiation exposure and inhalation in Keffi dumpsite were 0.122, 0.110, 0.131, 0.156, 0.118, 0.087 and 0.129 $mSvy^{-1}$ respectively (Table 2).

Table 1: exposure levels and related radiological health indices in in Keffi dumpsite

Room Code	Geographical Location		GAL (mR/h)	EDR (μSv/h)	AEDR (mSv/y)	ELCR×10^{-3}
	North	East				
UL	8.862922	7.834466	0.36	0.036	0.25	0.88
HC	8.862869	7.831048	0.28	0.028	0.20	0.70
UK	8.859802	7.833828	0.19	0.019	0.13	0.46
AC	8.860137	7.829871	0.16	0.016	0.11	0.39
LA	8.861546	7.831622	0.51	0.051	0.36	1.26
UG	8.861473	7.830152	0.26	0.026	0.18	0.63
UD	8.862397	7.833128	0.20	0.020	0.14	0.49
GM	8.861753	7.832853	0.22	0.022	0.15	0.53
SK	8.860623	7.831494	0.28	0.028	0.20	0.70
KH	8.861156	7.832198	0.29	0.029	0.20	0.70
Mean			0.27	0.027	0.19	0.67

Table 2. Dose to different organs of the body in Keffi dumpsite

Sample Code	**D_{organ} (mSv/y)**						
	Lungs	**Ovaries**	**Bone Marrow**	**Testes**	**Kidney**	**Liver**	**Whole Body**
UL	0.160	0.145	0.173	0.205	0.155	0.115	0.170
HC	0.128	0.116	0.138	0.164	0.124	0.092	0.136
UK	0.083	0.075	0.090	0.107	0.081	0.060	0.088
AC	0.070	0.064	0.076	0.092	0.068	0.051	0.075
LA	0.230	0.209	0.248	0.295	0.223	0.166	0.245
UG	0.115	0.104	0.124	0.148	0.112	0.083	0.122
UD	0.090	0.081	0.100	0.115	0.087	0.064	0.095
GM	0.196	0.087	0.104	0.123	0.093	0.069	0.102
SK	0.128	0.116	0.138	0.164	0.124	0.092	0.136
KH	0.128	0.116	0.138	0.164	0.124	0.092	0.136
Mean	0.122	0.110	0.131	0.156	0.118	0.087	0.129

Comparison of results with united nation scientific committee on effect of atomic radiation

In section, the results were presented that were used to plot charts in order to compare the results of the present study with United Nation Scientific Committee on Effect of Atomic Radiation.

Comparison of annual effective dose rate with united nation scientific committee on effect of atomic radiation

The data were used to plot a chart in order to compare the result of annual effective dose rate with United Nation Scientific Committee on Effect of Atomic Radiation. It is observed that the Annual Effective Dose Rate for all the areas was found to be lower than that of United Nation Scientific Committee on Effect of Atomic Radiation (Fig. 1).

Comparison of excess lifetime cancer risk with united nation scientific committee on effect of atomic radiation

The data were used to plot a chart in order to compare the result of excess lifetime cancer risk with United Nation Scientific Committee on Effect of Atomic Radiation. It was observed that the Excess Lifetime Cancer Risk was found to be higher compare to United Nation Scientific Committee on Effect of Atomic Radiation (Fig. 2).

Comparison of dose to different organs of the body with united nation scientific committee on effect of atomic radiation

The data were used to plot a chart in order to compare the result of Effective Dose to different organs of the body with United Nation Scientific Committee on Effect of Atomic Radiation. It was observed that the D_{organ} was found to be lower compare to United Nation Scientific Committee on Effect of Atomic Radiation (Fig. 3).

On annual effective dose rate, finding of this study have revealed that the mean annual effective dose rate for Keffi dumpsites are 0.19 mSv/y. Which implies that the annual effective dose rate in those areas were less than 0.45 mSv/y as agreed by Basic Safety Standard (BSS) and may not cause radiological hazard to the public and workers. The findings were in line with the finding of Tikyaa et al (2017) and Ghoshal (2007). However, Rilwan et al (2021) investigated the indoor and outdoor ionizing radiation level at Kwali General Hospital, Abuja Nigeria using a well calibrated Geiger Muller counter and found the average annual effective

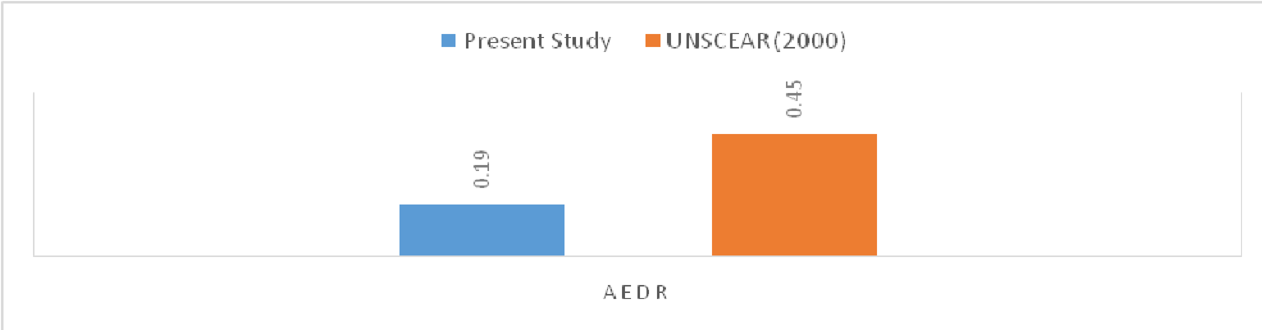

Fig. 1 Comparison annual effective dose rate with UNSCEAR

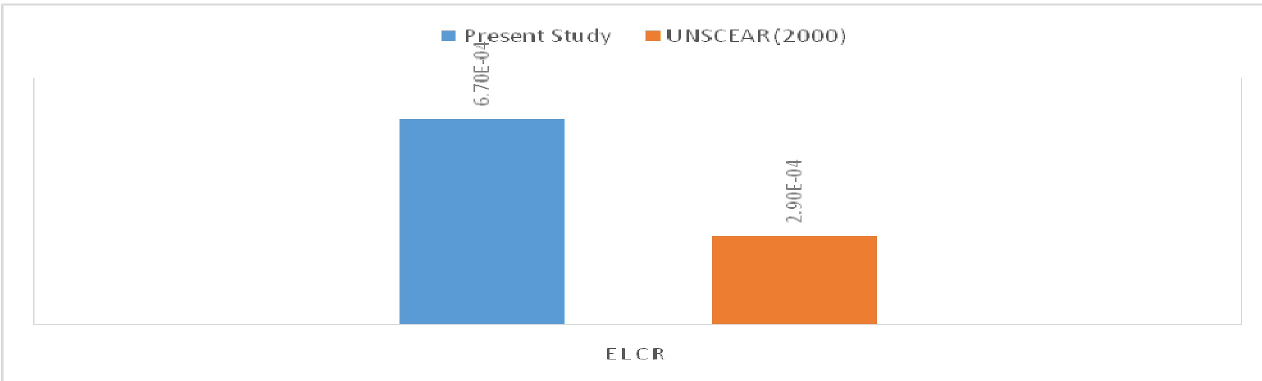

Fig. 2: Excess lifetime cancer risk with UNSCEAR

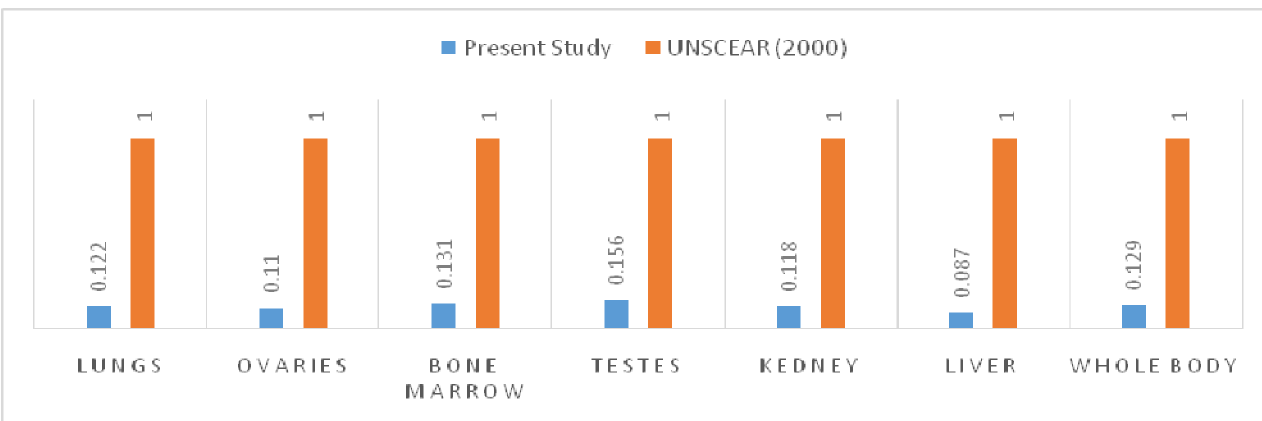

Fig. 3: Comparison of D_{organ} with UNSCEAR

dose rate as 0.750± 0.020 mSv/yr and 0.189±0.005 mSv/yr for indoor and outdoor measurements respectively. Contraey, Rilwan et al (2021) assessed the background ionizing radiations at Biochemistry, Chemistry, Microbiology and physics laboratories of Plateau State University Bokkos using Gamma-scout Radiometer and found the mean annual effective dose rate of the laboratories for indoor and outdoor to be 1.54 mSv/yr and 0.44 mSv/yr respectively.

On excess lifetime cancer risk, finding of this study have revealed that the mean excess lifetime cancer risk for Keffi dumpsites are 0.67 × 10^{-3}. Which implies that the excess lifetime cancer risk in those areas is greater than 0.29 × 10^{-3} as agreed by Basic Safety Standard (BSS) and may cause radiological hazard to the public and workers. The findings were in line with the finding of Tikyaa et al (2017) and Ghoshal (2007). However, Rilwan et al (2021) investigated indoor and outdoor ionizing radiation level at Kwali General Hospital, Abuja Nigeria using a well calibrated Geiger Muller counter and found the average excess lifetime cancer risk as 2.63 × $10^{-3}$and 0.66 × 10^{-3} for indoor and outdoor measurements respectively. Contrary, Rilwan et al (2021) assessed the background ionizing radiations at Biochemistry, Chemistry, Microbiology and physics laboratories of Plateau State University Bokkos using Gamma-scout Radiometer and found the mean excess lifetime cancer risk of the laboratories for indoor and outdoor background radiation level to be 1.54 mSv/yr and 0.44 mSv/yr respectively.

On Dorgan values for the lungs, ovaries, bone marrow, testes, kidney, liver and whole body, finding of this study have revealed that the mean Dorgan values for the lungs, ovaries, bone marrow, testes, kidney, liver and whole body for Keffi dumpsites are 0.122, 0.110, 0.131, 0.156, 0.118, 0.087 and 0.129 mSv/y respectively which implied that Dorgan values for the lungs, ovaries, bone marrow, testes, kidney, liver and whole body in those areas is below the international tolerable limits of 1.0 mSv annually which further stress that the radiation levels do not constitute any immediate health effect on residents of the area. The findings were in line with the finding of Sadiq and Agba (2012), Tikyaa et al (2017) and Ghoshal (2007).

Conclusion

From the findings presented, it can be concluded that the background radiation in Keffi dumpsites is not an issue of health concern except when accumulated over long period of time which may cause cancer to the indoor members on approximately seventy years of exposure.

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