FUDMA Journal of Sciences (FJS)
ISSN online: 2616-1370
ISSN print: 2645 - 2944
Vol. 9 No. 2, February, 2025, pp 256 - 261
DOI: https://doi.org/10.33003/fjs-2025-0902-3068

DETERMINATION OF RADIONUCLIDES IN SOME SELECTED DUMPSITES WITHIN KANO METROPOLIS, KANO STATE NIGERIA

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ABSTRACT

This research investigated the emission of radiation from refuse dumpsites in some selected areas in Kano metropolis. The readings were taken using Geiger Muller tube detector at gonad level (about 1 meter above the ground level) and at an interval of 5m away from point of reference up to 20m in five sampling locations; coded as RD1, RD2, RD3, RD4 and RD5 respectively while the natural radioactivity concentrations were determined using a gamma ray spectrometer with two calibration point sources, Cs-137 and Co-60. The results indicated that the ranges of activity concentrations of ^{40}K, ^{226}Ra and ^{232}Th in the samples were 304.66 – 460.96 BqKg^{-1}, 18.57 – 32.72 BqKg^{-1} and 12.22 – 53.63BqKg^{-1} respectively. The highest activity concentration of ^{226}Ra, ^{232}Th and ^{40}K were found to be 32.72±3.12 Bqkg^{-1}, 53.63±3.49 Bqkg^{-1} and 460.96±7.78 Bqkg^{-1} respectively which obtained from RD2 and RD4 locations. However, the highest magnitude of Radium Equivalent Dose ($R_{eq.}$) of 137.60 Bqkg^{-1} at RD2 was found to be below the permissible limit of 370 BqKg^{-1} as recommended by UNSCEAR, (2000). Moreover, the highest average value of the background radiation detected at RD1 and RD3 was 0.414mSv/year which is below the ICRP (2006) bench mark of 3.0mSv/year. Therefore, the radionuclide activity concentration and the average exposure rate may not be hazardous. These results will help the health and environmental agencies in developing waste management systems.

Keywords: Activity concentration, Radionuclides, Radiation emission, Refuse dumpsites

INTRODUCTION

Refuse dump sites constitute an environmental health hazards to the public in major cities of the world not only in terms of the odors or the presence of disease causing microorganisms, but also the radiation emanating from such dump sites (Emelue et al., 2013). Radiation comes in many forms. Some forms come from natural environment, some from human activities and technological devices (Muhammad et al., 2017). In the past few decades, nuclear applications have been on the increase worldwide and so are the risks of abuse and accident. It is therefore important to measure the levels of the different components of radiation present in the environment at a given time in order to adequately assess the risk to the population (Olubosede, Akinnagbe, Adekoya, Olubosede, & Akinnagbe, Obi, 2012).

Some radiation can harm or actually kill cells in the body causing serious diseases such as cancer, tumor, genetic mutation and DNA damage. However, on the other hand, radiation can be used to detect or cure diseases in health centers through inhalation, and ingestion. Based on this fact, there has been a growing concern about the dangers incurred by radiation, on how to avoid them and possibly control or monitor it using measurable quantities (Ladi, 2007). Geiger Muller tube is one of the radiation measurement instruments, which is used in determining the radiation emanating from refuse dumpsites (Delacroix et al., 2002). The sources of most of the naturally occurring radioactive isotopes are those of ^{238}U and ^{232}Th and their progeny. Other radionuclides of concern are those formed from the decay of ^{226}Ra and ^{228}Ra (Delacroix et al., 2002). There are also man made sources such as ^{137}Cs, ^{134}Cs, and ^{90}Sr etc. which are usually released and dispersed from nuclear power plants. These man made sources add to the radiation levels due to the natural background radiation whenever they are released into the environment. Naturally Occurring Radioactive Materials (NORM) give rise to a very much larger radiological effect on the public than that caused by the nuclear industry and other anthropogenic sources of radiation because of their wide distribution (Iryna, 2017).

Despite the worldwide concern for the radioactivity concentration emanating from refuse dump sites of major commercial cities in Nigeria. There is a scarce documented radioactive measured data for the activity concentration at dumps sites in Kano state. This implies that it is impossible to accurately assess the occupational and public health and environmental burden due to these natural radioactive materials in the refuse dump sites. Though efforts have been in progress in environmental radioactivity studies of major cities in Nigeria from which some results have been reported(Galanda et al., 2009). But there is need for measurements evaluation to ascertain the health risk due to the radioactive concentrations at selected close by resident refuse dumps site in Kano metropolis.

Ugwuanyi *et al.,* (2021) evaluated the level of background radiation in some selected dumpsites in Nnewi and compared the background radiation dose levels with the worldwide recommended average natural dose of 2.4mSv/yr to humans. The results show that, the mean of the calculated Annual Absorbed Dose Rates recorded at 21 and 24 meters was marginally greater than the accepted exposure rate for the public with the values of 1.5mSv/year respectively. At 12 and 27 meters, the value was found to be 1.5mSv/year respectively. However, other distances were below the limit of 1mSv/year for the public and also below the dose limit of 20mSv/year for radiation workers as recommended by the ICRP. Ogungbemi *et al*., (2023) assessed the potential radiological risks associated with the activities on Olusosun dump site on workers and dwellers of Olusosun community. The mean value of background radiation was found to be 1.46Sv/yr. This value is about 46% higher than the recommendations reference level of 1.0mSv/year for the public. The mean activity concentration of ^{238}U, ^{232}Th, and ^{40}K in the soil samples were also found to be 19.1±3.2, 29.1±4.4, 171.1±6.1 Bq/kg, respectively which are about

45.4%, 35.3% and 59.2% lower than the world's average levels. Samuel O. Inyang & Ekong, (2024) measured the exposure rate and calculated the annual effective dose rates for the waste dumpsites in Calabar. The results found that, dump sites C was found to have the highest value annual effective dose rate of 0.36 mSv/yr. The corresponding observed maximum values of cancer incidence for male and female respectively were 110 and 154 persons per 100,000 persons while the cancer mortality for male and female were respectively 61 and 86 persons per 100,000 persons.

This study was aimed at investigating the existence and the determination of the concentrations of radionuclide from some selected residential refuse dump sites within Kano metropolis using gamma ray- spectrometer and Geiger Muller tube.

MATERIALS AND METHODS

Kano has many major and minor dump sites at different locations around the city. The study considered some major and minor refuse dumpsite in Gwale Local Government, Kano State which among are Diso, Dandago, Sani mainagge, Kabuga and Dorayi quarters. The five (5) samples levels as RD1, RD2, RD3, RD4 and RD5 as shown in Table1 were collected from the aforementioned locations respectively. The background radiation emission was determined around each dump suite using Geiger Muller tube before the samples collection. The background radiations were measured at proximity of 25m at the interval of 5m from each dumpsite to the nearby residential buildings.

Table 1: Locations at which the measurements were taken

Dumpsites	Locations
RD1	Diso (sakateriya)
RD2	Dandago (makaranta)
RD3	Dorayi babba (Tasha)
RD4	Kabuga (yan azara)
RD5	Sani mainagge (Jan ruwa)

Moreover, the samples were inserted into water proof nylon bag and transported to the research center of radiation and energy training for analysis, Zaria. About 0.2Kg of each samples were air dried and crushed to fine powder with the use of pulverizer and later Package into radon impermeable cylindrical plastic containers which were selected based on the space allocation of the detector vessel of 7.6cm by 7.6cm in dimension. However, to prevent radon-222 from escaping, the packaging in each case was triple sealed and the process included smearing of the inner rim of each container lid with Vaseline jelly, filling the lid assembly gap with candle wax to block the gaps between lid and container, and tight sealing lid-container with masking adhesive tape. Radon and its short lived progenies were allowed to reach secular radioactive equilibrium by storing the samples for 30 days prior to gamma spectroscopy measurements. The analysis was carried out using 76mm by 76mm thallium doped sodium iodide NaI (TI) detector crystal which is enclosed in a 6cm lead shield with cadmium and copper sheets.

This arrangement is aimed at minimizing the effects of background and scattered radiation. The detector crystal is optically coupled to a photomultiplier tube (PMT). The PMT is externally supplied with a one kilovolt (1KV) of electricity; this PMT is incorporated into amplifier which is connected to analog to digital converter (ADC). The ADC is coupled with a multi-channel analyzer (MCA) which is in data acquisition software. When a gamma ray from a radioactive sample enters the crystal, some combination of three physical processes was occurred: photoelectric emission of an electron that absorbs all of the gamma energy, Compton scattering of the gamma ray photo off electron in the crystal, or pair production of an electron positron pair. In order for the last process to occur with any likelihood, the incoming gamma must have an energy that is at least twice the rest mass energy of the electron (2×0.511Mev = 1.022Mev). Although a couple of the radioactive samples will emit gammas in this range, unless the gamma is substantially more energetic than 1.022Mev, the pair- production mechanism is not observable. The electron liberated by the photoelectric effect is quite likely to scatter around in the NaI crystal, losing energy, until it is captured by an atom in the crystal with an electron vacancy.

In the process of scattering, photons in the visible and ultraviolet (UV) region of the electromagnetic spectrum are emitted. Likewise with the Compton scattering process, the recoil electron will ultimately deliver most of its energy as visible and UV photons. The low frequency (visible and UV) photons produced when a gamma interacts with scintillator crystal, enter a photomultiplier tube (PMT), in which a cascade of electrons is generated, again via the photoelectric (and secondary electron) effect and then reaching the amplifier. This has the effect of turning a pulse as the current flows through the 50 ohm resistor at the node.

In general the more energy the original gamma ray had, the larger the voltage pulse that the PMT will produce. The ADC converted the voltage pulse into digits (number), the pulse height analyzer MCA divides the range of all possible voltages into bin, or channels, and keeps a running count of how many pulses arrive in each bin, thus producing a graphical spectrum of the number of counts. For each sample, the counting time is 29000 seconds, and the detection limit of NaI (TI) detector system for ^{226}Ra, ^{232}Th and ^{40}K are 3.84, 9.08 and 14.54 Bq/kg respectively. The peak area of energy in the spectrum was used to compute the activity concentrations. Lastly, the detected nuclides activity levels are reported in Becquerel/kilogram (Bq/kg) using Equation (1).

Radionuclides concentration

The actual quantity of radioactivity is the amount of each radionuclide present in a refuse and is calculated as follows: for each spectral peak, the activity in Becquerel per kilogram for the radionuclide responsible for producing that peak is: (Nations & Programme, 2000)

$$C\ (Bq.kg-1)\ = {}^{C_n}\!/_{C_{fk}} \qquad (1)$$

where,

C = activity concentration of the radionuclides in the sample given in Bq.kg^{-1}

C_n = count rate (counts per second) (cps)

C_{fk} = conversion factor or calibration factor of the detecting system: for K-40= 0.000643, Ra-226= 0.000863 and Th-232=0.000877(CERT, 2018).

Radium equivalent (Ra_{eq})

Radium equivalent concentration is the quantity representing the external γ irradiation dose associated with material or samples. In order to compare specific activity of material containing different amounts of ^{226}Ra, ^{232}Th and ^{40}K, the radium equivalent activity Ra_{eq} is used as defined by, (Tchokossa et al., 2011)

$$Ra_{eq} = A_{Ra} + 1.43A_{Th} + 0.077A_k \quad (2)$$

where,

A_{Ra}, A_{Th}, and A_K are the activity concentrations in BqKg^{-1} of ^{226}Ra, ^{232}Th and ^{40}K, respectively. The value of Ra_{eq} must be less than 370 BqKg^{-1} for the radiation hazard to be negligible (Nations & Programme, 2000)

Conversion Parameters

1CPM = 3.10×10^{-6} mSv/hr (Ladi, 2007).

Conversion in years

1year = 52×7×24hr = 8736hr

1hr = $\frac{year}{8736}$

Replacing 1CPM above we have,

1CPM = 3.10×10^{-6} ×8736mSv/year

RESULTS AND DISCUSSION

The locations, concentration of the radionuclides found at located dump sites and their average exposure rate were presented in tables 1 to 3 and in figures 1 to 5 respectively. Table 2 contains the activity concentration of radionuclides which include; ^{226}Ra, ^{232}Th and ^{40}K. The results revealed that all the dump sites contains radionuclides which agrees with the existing knowledge that; "all the materials composed of rock and soil contains natural radioactive isotopes (Ehirim & Itota, 2013).

Table 2: Activity Concentration of Radionuclides in (Bqkg^{-1})

S/N	Sample ID	Activity concentration in (BqKg^{-1})			
		^{40}K	^{226}Ra	^{232}Th	$R_{eq.}$
1	RD1	416.5281	19.6987	12.2282	69.25
2	RD2	460.9857	25.4126	53.6311	137.60
3	RD3	411.2726	18.5799	25.2428	86.34
4	RD4	343.2724	32.7247	16.9072	80.93
5	RD5	304.6603	19.6987	19.6974	82.52

From the results obtain, the highest activity concentration of ^{40}K, ^{226}Ra, and ^{232}Th are 460.98 BqKg^{-1}, 32.72 BqKg^{-1} and 53.63 $BqKg^{-1}$ respectively. The highest concentration is found at the RD2 for ^{40}K, RD4 for ^{226}Ra, and RD2 for ^{232}Th. However, all the concentrations are below the permissible limit of 370 BqKg^{-1} as recommended by United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), 2000. The highest radium equivalent ($R_{eq.}$) was found at RD2 as 137.60 BqKg^{-1}, which was also below the permissible limit of 3.0mSv/year as recommended by International Commission on Radiological Protection (ICRP), 2006. The variation of the radionuclide activity concentration in the studied dumpsites is due to the different items or materials deposited by the people around those areas. The expected materials at RD2 dump sites may contain much potassium, thorium and radium; this raised the $R_{eq.}$ level more than the other sites while for RD1 may contain the lowest values.

To access the health risk around the dump sites, the average exposure rate reference to the horizontal distance were obtain as shown in Table 3. The average exposure rate against the horizontal distance was plotted as shown in figure 1 to 5, so as to observe the exposure trend within the communities.

Table 3: Average of exposure rate in mSv/year

Location	0(m)	5(m)	10(m)	15(m)	20(m)	Average of exposure rate (mSv/year)
RD1	0.503	0.465	0.400	0.368	0.335	0.414
RD2	0.481	0.427	0.400	0.346	0.286	0.388
RD3	0.509	0.465	0.400	0.368	0.329	0.414
RD4	0.503	0.427	0.400	0.335	0.264	0.385
RD5	0.460	0.400	0.346	0.297	0.259	0.342

From the result, the average exposure rates at all the dump sites were decreased with increase in the horizontal distance. Presences of market and bus stop at RD1 and RD3 locations, made the locations to have the highest average exposure rate as shown in table 2. The highest exposure rate demonstrates that these locations are at front to health risk.

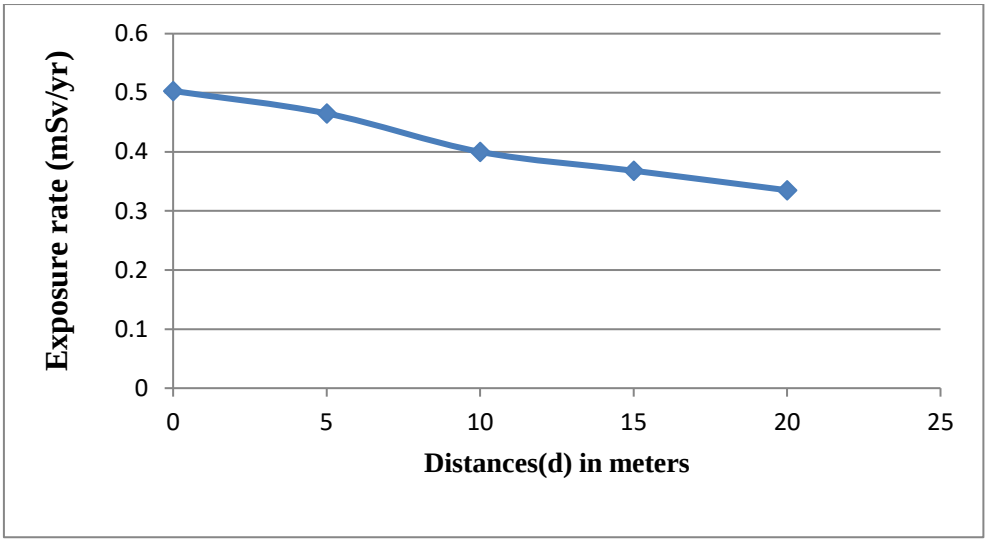

Figure 1: Graph of exposure rate against distance for RD1

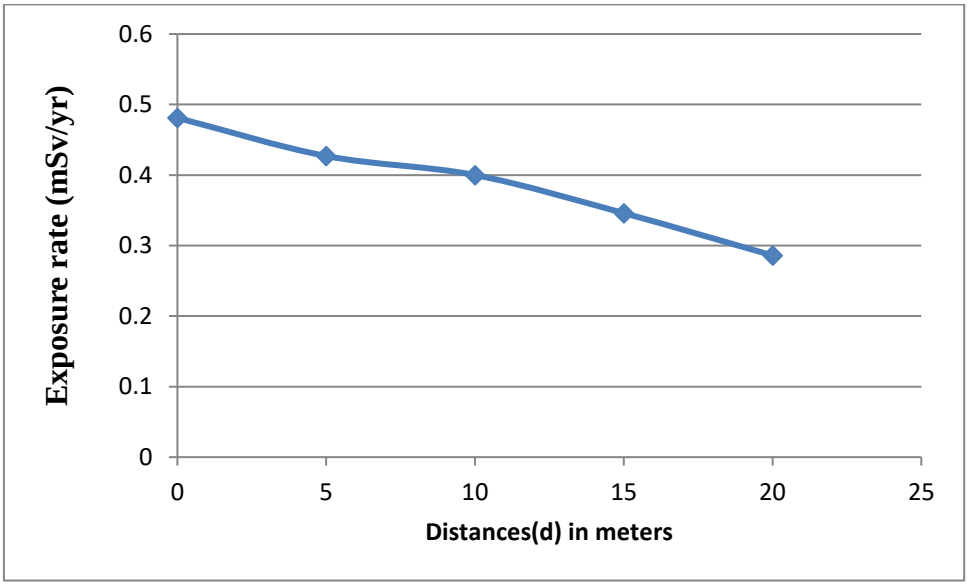

Figure 2: Graph of exposure rate against distance for RD2

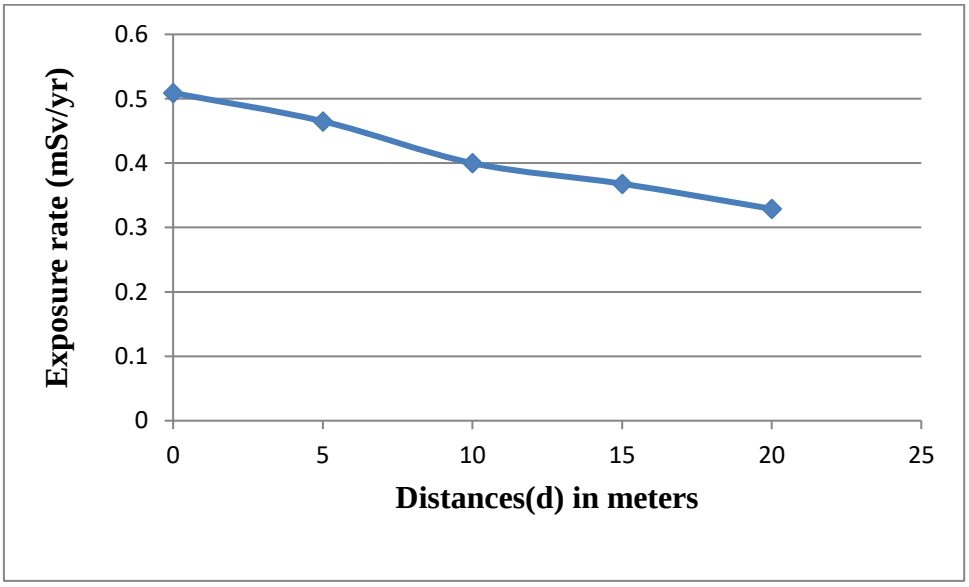

Figure 3: Graph of exposure rate against distance for RD3

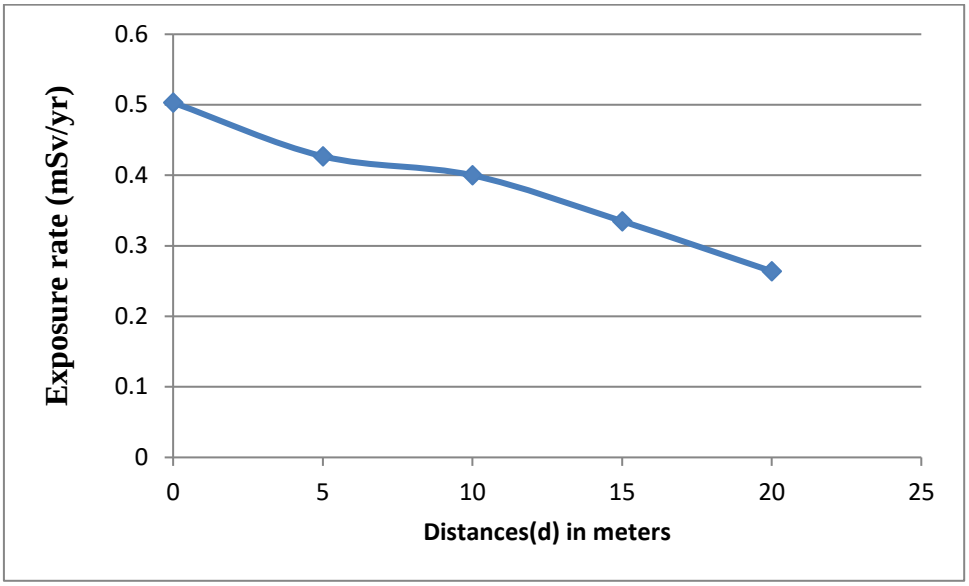

Figure 4: Graph of exposure rate against distance for RD4

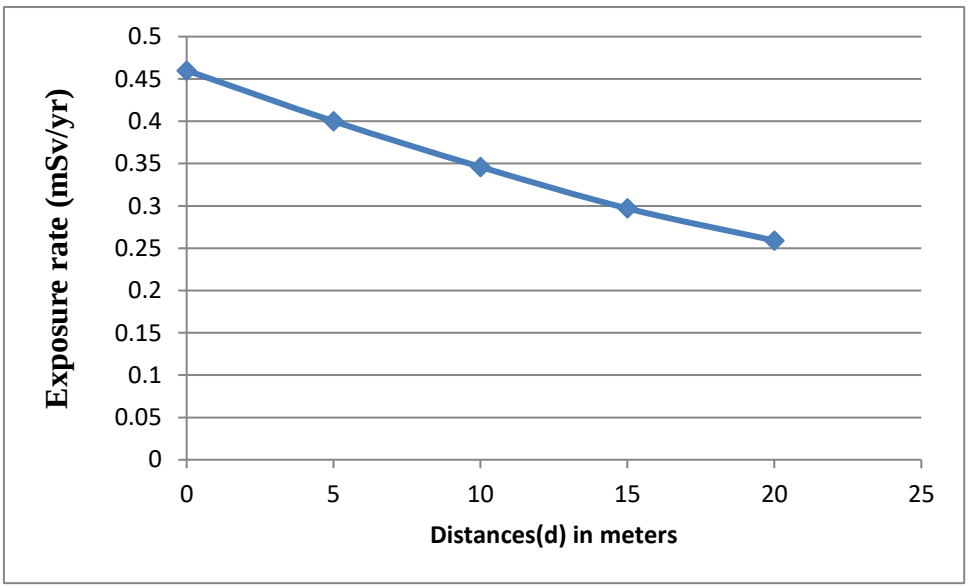

Figure 5: Graph of exposure rate against distance for RD5

Although, the others meteorological parameters such as temperature, rain fall, wind and wind direction were not considered in this research due to instrumentals limitations. Therefore, the average exposure rate at the study area cannot definitively be classified as hazardous or nonhazardous.

CONCLUSION

This study found that, the RD2 and RD4 are the locations among the five dump sites having the highest activity concentration of 460.98 $BqKg^{-1}$, 32.72 $BqKg^{-1}$ and 53.63 $BqKg^{-1}$ for ^{40}K, ^{226}Ra, and ^{232}Th respectively. The highest average value of radium equivalent ($R_{eq.}$) was found to be 0.414mSv/year which obtained at the RD1 and RD3 locations. The results revealed that, the exposure rate is decreases with increase of horizontal distance from the dump sites. Therefore, the closer to the dump sites, the greater the health risks. Although, the radionuclides activity concentrations and the average exposure rate are below the recommended hazard level of 370 $Bqkg^{-1}$ and 3.0mSv/year respectively. However, the exposure rate obtain from this work cannot directly classified as hazardous or nonhazardous due to lack of instrument for measuring others meteorological parameters during the experiment. The results will help in waste management and health risk evaluation through waste segregation of the related toxic waste and intense public awareness at RD2 and RD4 locations.

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