Faculty of Health and Applied Scinces

Excess lifetime cancer risk due to natural radioactivity in soils: A case of Karibib town in Namibia

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Outline

1. Introduction
2. Materials and Methods
3. Results
4. Discussion
5. Conclusion
6. References

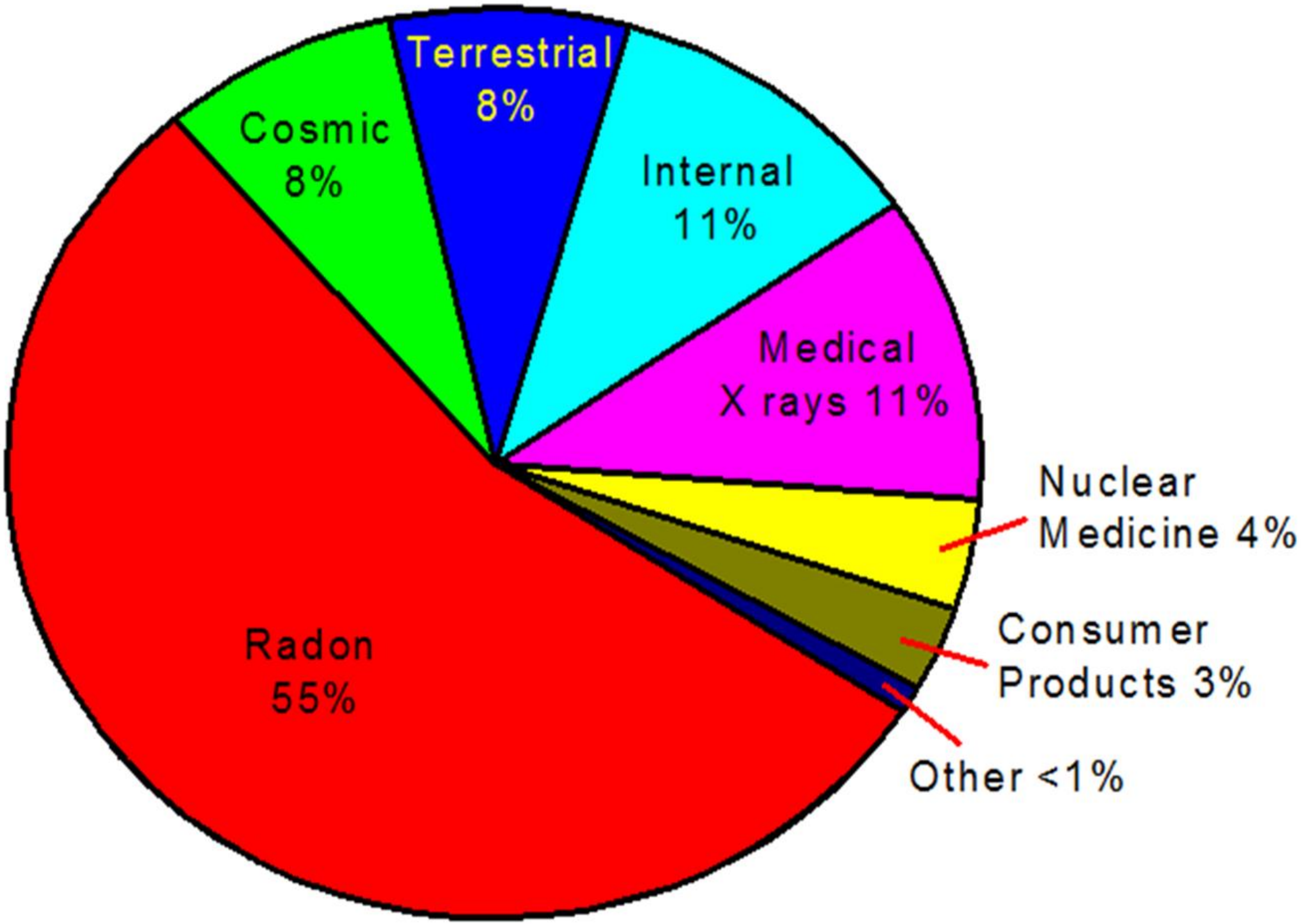
1. Introduction

- Nuclear decay or radioactivity, is the process by which a nucleus of an unstable atom loses energy by emitting ionizing radiation.

- The most important radionuclides of radiological concern are ^{238}U, ^{235}U, ^{232}Th, ^{40}K and ^{87}Rb which are the main contributors to external exposure from gamma-radiation (Bashir et al, 2013).

- Environmental radioactivity depends on the soil type, geographical location and topography (Habshi et al, 1980).

Sources of Background Radiation



Justification of the Study

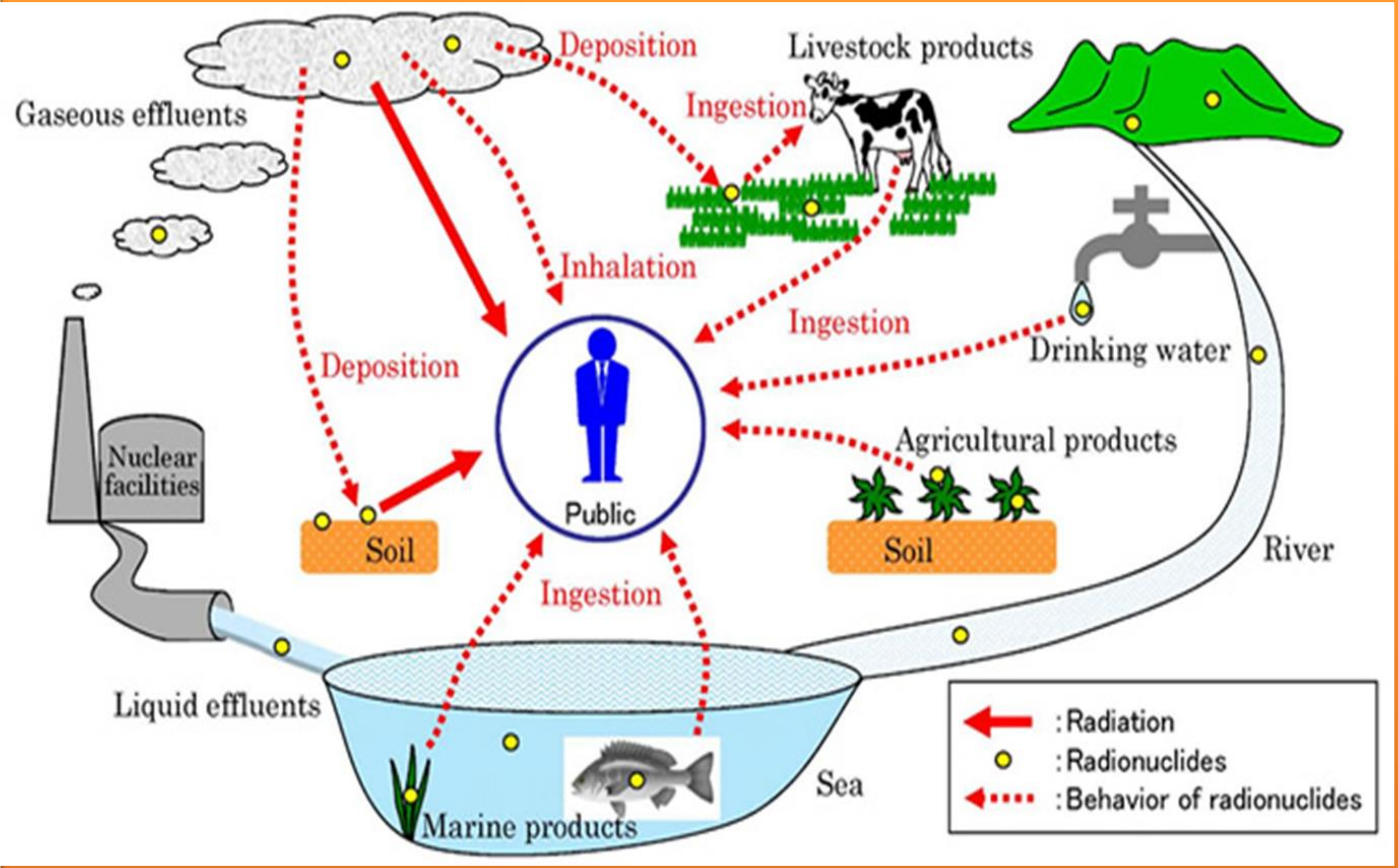
- During mineral mining and exploration, large quantities of wastes containing radionuclides and heavy metals which are discharged into the environment affecting the nearby communities.

- It is critical to evaluate soil radioactivity in order to understand background radiation concentrations.

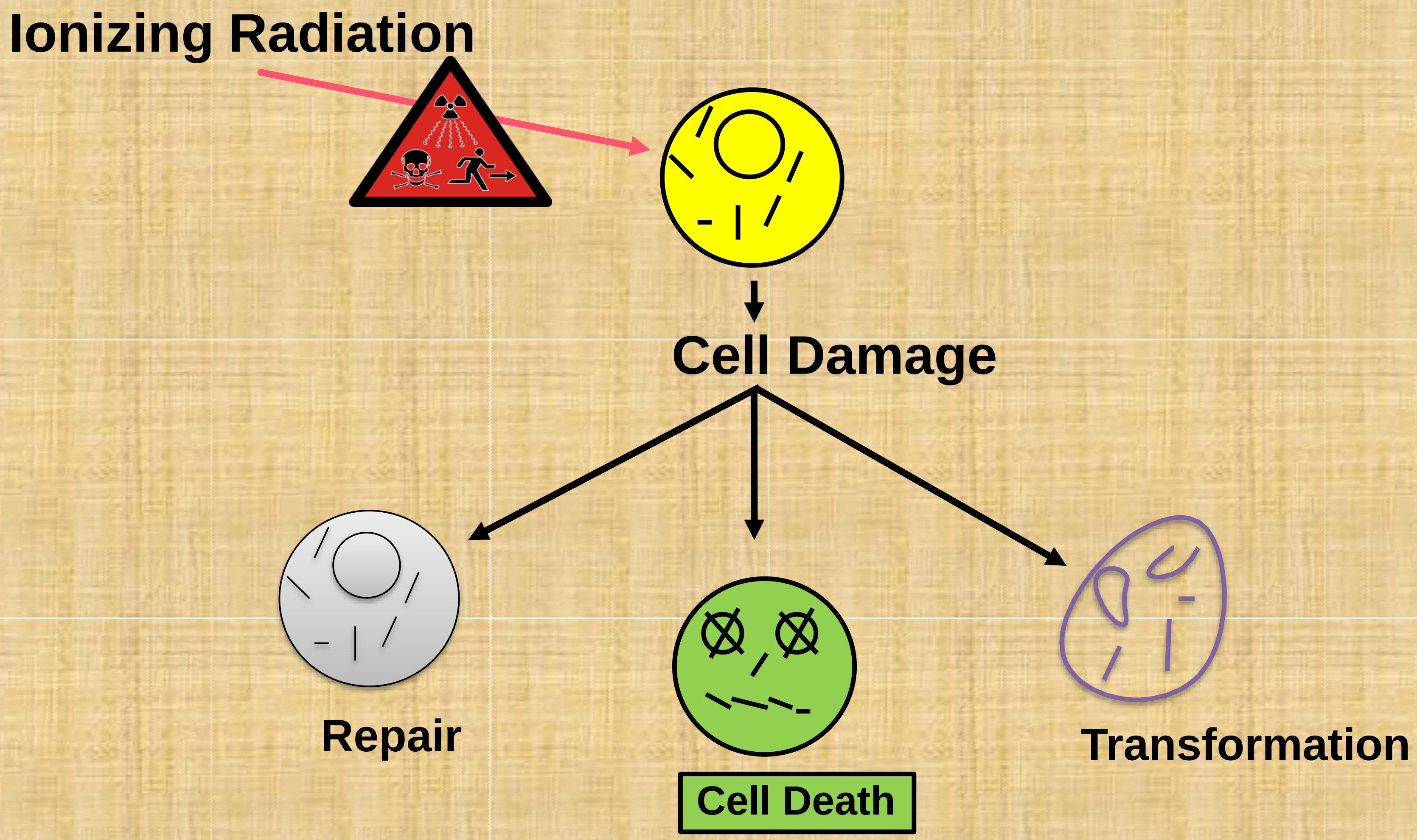
- In Namibia, they are few studies related to soil radioactivity

- The studies are limited to radon concentrations and lifetime cancer risk in the mining environments.

Exposure Pathways



Biological Effects: Mechanism of cell damage



2. Material and Methods
Study area

"Map of the town of Karibib showing the sampling points(Google earth. Com)

Activity measurements in soil and indoor radon measurements

- A total of thirty surface soils samples were collected and twenty radon gas monitors were deployed in selected houses within the town of Karibib.

- The soil samples were investigated for their radioactivity using a well calibrated HPGe gamma-ray spectrometer while radon gas monitors (CR-39) were analysed for indoor radon concentrations.

- This was followed by assessment of radiological hazards and estimation of excess lifetime cancer risk to the general public.

Activity Measurements …

Gamma Spectrometry

Nuclear data of radionuclides used in the analysis

Parent nuclide	Daughter nuclide	Gamma Energy (KeV)	Gamma Ray Abundance (%)
^{238}U	^{214}Bi	1120.27	15.0
	^{214}Bi	609.31	46.10
	^{214}Pb	295.2	19.7
	^{214}Pb	351.9	38.9
^{232}Th	^{212}Pb	238.63	44.6
	^{228}Ac	338.3	11.4
	^{228}Ac	911.21	26.60
^{40}K	-	1460.83	10.67

Activity Measurements …

- The activity concentrations of each of the radionuclides was divided by the mass to express the results in Bq kg^{-1}.

- The energy and efficiency of the detector was performed using IAEA composite standards of Cadmium 109, Strontium 85 and cobalt-60 before sample measurements.

- The sample were counted for 12 hours.

- The background radiation was determined using an empty Marinelli beaker under identical conditions.

- The output of the detector was analysed using Canberra Genie 2000 software

Measurements of Radiological parameters in soil

Absorbed Dose (D_R)

D_R = ($0.462C_U + 0.604C_{Th} + 0.047C_K$) nGy/h (Eq.1.0)

where A_k , A_u and A_{Th} are the activities of ^{40}K, ^{238}U and ^{232}Th in Bq kg^{-1} respectively.

Annual Effective Dose Equivalent (AEDE)

AEDE (mSv/yr) = D_R x T x F (Eq. 2.0)

where, AEDE is the annual effective dose (mSv/y), D_R is the absorbed dose rate ($nGyh^{-1}$), T is the outdoor occupancy time (365 days x 24h x 0.2) and F conversion factor (0.7 x 10^3 mSv/10^9nGy).

Measurements of Radiological parameters in soil

Radium Equivalent (Ra_{eq})

Ra_{eq} (Bq/kg) = $A_U + 1.43A_{Th} + 0.077A_K$ (Eq. 3.0)

where A_k , A_u and A_{Th} are the activities of ^{40}K, ^{238}U and ^{232}Th in Bq kg^{-1} respectively (Ibrahiem, 1999).

Internal and External hazard indices (H_{in} and H_{ex})

$$H_{in} = \frac{A_U}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \leq 1 \qquad \text{(Eq. 4.0)}$$

$$H_{ex} = \frac{A_U}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \leq 1 \qquad \text{(Eq. 5.0)}$$

Measurements of Radiological parameters in soil

Excess Lifetime Cancer Risk (ELCR)

$$\textbf{ELCR = AEDE x DL x RF} \qquad \text{(Eq.6.0)}$$

where, AEDE = annual effective dose (mSv/y), DL = is the life expectancy (70) and RF = is risk factor (0.05), (ICRP, 1993).

Indoor Radon Concentration and Associated Doses

Radon Concentration

$EECR_n = F \times CR_n$ (Eq. 7.0)

$\text{Equivalent Dose} = EECR_n \times DCF$ (Eq. 8.0)

$$\mathbf{H_E = C_{Rn} \times F \times DCF}$$ (Eq. 9.0)

where, C_{Rn}= is the concentration of radon (Bq/m3), F = is the equilibrium factor (0.4), T= is the indoor occupancy time (7000 h) and DCF = is the dose conversion factor (9 $\times 10^{-6}$ mSv/h per Bq/m3)

3. Results: Activity concentrations and radiological parameters

Table 1.0 Activity concentration and radiological parameters (Absorbed dose (D), Annual Effective dose Equivalent (AEDE), Radium equivalent (R_{eq}), External hazard index (H_{ex}), Internal Hazard Index (H_{in}) and Excess Lifetime Cancer Risk (ELCR) in soils samples collected from town of Karibib.

Sample ID	Activity concentration (Bq. kg^{-1}) ^{238}U	^{232}Th	^{40}K	D (nGy^{-1})	AEDE (mSvh^{-1})	R_{eq}	H_{ex}	H_{in}	ELCR (10^{-3})
K1	54.94±0.04	61.42±0.04	1260±0.17	115.02	0.14	239.61	0.65	0.80	0.49
K2	66.82±0.06	89.72±0.06	887±0.12	122.05	0.15	263.22	0.71	0.89	0.52
K3	58.02±0.04	51.76±0.03	900±0.12	95.60	0.12	201.19	0.54	0.70	0.41
K4	43.55±0.06	34.59±0.08	226±0.15	50.44	0.06	110.35	0.30	0.42	0.22
K5	78.62±0.07	80.06±0.05	1310±0.17	139.31	0.17	293.76	0.79	1.01	0.59
K6	40.90±0.03	45.16±0.03	1280±0.17	99.55	0.12	203.88	0.55	0.66	0.42
K7	60.58±0.05	75.86±0.05	1210±0.16	124.26	0.15	262.03	0.71	0.87	0.53
K8	49.32±0.04	31.94±0.02	395±0.05	58.55	0.07	125.33	0.34	0.47	0.52
K9	63.46±0.05	64.80±0.04	1330±0.17	123.92	0.15	258.34	0.70	0.87	0.53
K10	50.88±0.04	56.58±0.04	1260±0.17	110.22	0.14	228.63	0.62	0.76	0.47
K11	67.52±0.05	70.20±0.04	1320±0.17	128.64	0.16	269.34	0.73	0.91	0.55
K12	53.63±0.96	56.68±0.60	215±0.14	68.10	0.08	151.43	0.41	0.55	0.29
K13	85.12±0.16	95.30±0.15	1258±0.89	149.37	0.18	318.09	0.86	1.09	0.64
K14	55.82±0.04	45.06±0.02	1400±0.18	111.39	0.14	227.88	0.62	0.77	0.47
K15	55.76±0.05	79.40±0.05	881±0.12	110.46	0.14	236.96	0.64	0.79	0.47
K16	57.20±0.05	77.66±0.05	957±0.17	113.24	0.14	241.76	0.65	0.81	0.48
K17	29.26±0.02	14.93±0.04	245±0.03	32.75	0.04	69.43	0.19	0.27	0.14
K18	70.48±0.05	39.62±0.03	484±0.06	76.68	0.09	164.31	0.44	0.63	0.32
K19	56.86±0.05	71.56±0.05	901±0.12	107.06	0.13	228.40	0.62	0.77	0.46
K20	36.54±0.03	33.38±0.02	1040±0.14	80.41	0.10	164.23	0.44	0.54	0.34
K21	46.72±0.04	84.28±0.05	937±0.17	115.56	0.14	239.20	0.65	0.77	0.47
K22	75.08±0.07	101.48±0.06	837±0.11	130.88	0.16	284.44	0.77	0.97	0.56
K23	38.86±0.03	36.32±0.02	685±0.09	68.46	0.08	143.44	0.39	0.49	0.29
K24	45.10±0.04	42.24±0.03	1080±0.14	91.39	0.11	188.52	0.51	0.63	0.39
K25	90.80±0.07	73.86±0.05	804±0.11	120.09	0.15	258.16	0.70	0.94	0.51
K26	49.94±0.04	58.22±0.04	1060±0.14	102.44	0.13	214.65	0.58	0.72	0.44
K27	60.90±0.05	49.80±0.02	931±0.12	96.60	0.12	202.63	0.55	0.71	0.41
K28	100.72±0.02	99.12±0.06	1490±0.20	168.53	0.21	356.94	0.96	1.24	0.72
K29	59.76±0.05	61.56±0.04	1060±0.14	108.99	0.13	229.24	0.62	0.78	0.46
K30	47.36±0.04	79.90±0.04	921±0.17	108.55	0.13	232.35	0.63	0.76	0.46
Max	100.72±0.02	101.48±0.06	1400±0.18	168.53	0.21	356.94	0.96	1.24	0.72
Min	29.26±0.02	31.94±0.02	215±0.14	32.75	0.06	69.43	0.19	0.27	0.14
Mean	58.35±0.10	62.06±0.06	952±0.16	104.15	0.13	220.26	0.60	0.75	0.44

Results: Indoor radon concentrations and associated doses

Table 2.0: The indoor radon concentrations(C_{Rn}) and associated doses received due to radon and its short-lived progeny exposure i.e. Equilibrium-Equivalent dose (EEC_{RN}), Equivalent Dose (D_{RN}), Effective indoor dose rate (H_E) and total inhalation dose (TID_{RN}).

Sample ID	Conc. Radon (C_{Rn}) (Bq/m^3)	EEC_{RN}	Equivalent Dose	H_E (mSv/y)	TID_{RN}
RK1	81.30±6.62	36.56	3.66E-03	2.34E-03	2.40
RK2	81.81±6.62	36.65	3.97E-03	2.54E-03	2.61
RK3	74.00±6.71	33.29	3.33E-03	2.13E-03	2.19
RK4	85.80±6.80	38.63	3.86E-03	2.47E-03	2.54
RK5	83.60±7.26	37.60	3.76E-03	2.41E-03	2.47
RK6	84.50±6.85	38.01	3.80E-03	2.43E-03	2.50
RK7	73.10±6.30	32.88	3.29E-03	2.10E-03	2.16
RK8	73.50±6.76	33.08	3.31E-03	2.12E-03	2.17
RK9	80.80±6.89	36.37	3.64E-03	2.33E-03	2.39
RK10	70.80±6.48	31.85	3.18E-03	2.04E-03	2.09
RK11	82.60±6.58	37.19	3.72E-03	2.38E-03	2.44
RK12	76.70±7.21	34.52	3.45E-03	2.21E-03	2.27
RK13	84.90±6.39	38.22	3.82E-03	2.45E-03	2.27
RK14	74.00±6.80	33.29	3.33E-03	2.13E-03	2.51
RK15	72.10±6.89	32.47	3.25E-03	2.08E-03	2.19
RK16	80.80±6.94	36.37	3.64E-03	2.33E-03	2.13
RK17	85.40±6.48	38.42	3.84E-03	2.46E-03	2.39
RK18	73.50±6.48	33.08	3.31E-03	2.12E-03	2.53
RK19	74.40±6.16	33.49	3.35E-03	2.14E-03	2.17
RK20	86.30±6.44	38.84	3.88E-03	2.49E-03	2.20
Min	70.80±6.48	31.85	3.18E-03	2.04E-03	2.09
Max	86.30±6.44	38.84	3.88E-03	2.49E-03	2.54
Mean	79.30±6.68	35.69	3.57E-03	2.28E-03	2.35

4. Discussion

- The activity concentrations vary from 29.26 ±0.02 to 100.72±0.02 $Bq.kg^{-1}$, 31.94±0.02 to 101.48±0.06 $Bq.kg^{-1}$ and 215.00 ±0.14 to 1400.00 ±0.18 $Bq.kg^{-1}$ with an average of 58.35 ±0.10 $Bq.kg^{-1}$, 62.06 ± 0.06 $Bq.kg^{-1}$ and 952.13 ±0.16 $Bq.kg^{-1}$ for ^{238}U, ^{232}Th and ^{40}K respectively.

- In general, the soil samples collected have an equal proportions of activity concentrations for ^{238}U and ^{232}Th and a higher concentration of ^{40}K.

- The outdoor terrestial gamma dose rates were higher compared to the permissible limits receipted by UNSCEAR, in most of the soil samples with an average of 168.53 $nGyh^{-1}$. This value is 3.0 times higher than the world average value of 51.00 $nGyh^{-1}$

Discussion…

- The present mean value of annual effective dose equivalent (AEDE) is 0.13 mSv/y which is lower than 1.0 mSv/y recommended for the members of the public by ICRP and this value is lower than the average world value of 0.48 mSv/y.

- The calculated values of hazard indices for soil samples ranged from 0.19 to 0.96 with an average of 0.60 and from 0.21 to 1.24 with and average of 0.75 for the external hazard (H_{ex}) and internal hazard (H_{in}) respectively.

- The excess lifetime cancer risk (ELCR) ranges from 0.14 x10^{-3} in sample K17 to 0.72 x 10^{-3} in sample K28 with an average of 0.45 x10^{-3} as shown in Table 1.0. This average value of ECLR is 1.5 times higher than the world average of 0.29x 10^{-3}

Discussion...

- Radon concentrations and its progeny in the selected residential homes ranges from 70.80$\pm$6.48 to 86.30$\pm$6.44 Bq/m^3 with an average of 79.30$\pm$6.68 Bq/m^3 which slightly higher than the indoor radon level emanation but lies within the reference level of 300 Bq/m^3

- The indoor radon effective dose rate varies from 2.04x 10^{-3} to 2.49x10^{-3} mSv/y and the average were found to be 2.28x10^{-3} mSv/y, which are significantly lower than the safe limits .

5. Conclusion

- The average radiological parameters i.e. radium equivalent, radiation indices and lifetime cancer risk were significantly higher than the world values.
- The annual effective dose is lower than 1.0 mSv/y the recommended safe limit for members of the public. The indoor radon concentrations and its progeny are within the recommended action levels of 300 Bq/m^3 for residential places
- The indoor effective annual dose and total annual inhalation dose due to radon and its progeny are within the safe limit as recommended by UNSCEAR.

Thank you for your attention

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