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MEASUREMENT OF RADON ACTIVITY CONCENTRATION IN UNDERGROUND WATER OF BURETI SUB-COUNTY OF KERICHO COUNTY KENYA

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The activity concentration of radon in underground water of Bureti sub-county was measured using liquid scintillating counter device. The average radon activity concentration in all the water samples was 12.41 Bql^{-1}. The maximum and minimum activity concentrations of radon were 22.5 and 4.57 Bql^{-1}, respectively. In total, 53% of the total samples analysed had radon concentration levels above the US Environmental Protection Agency-recommended limit of 11.1 Bql^{-1}. The annual dose received by an individual as a result of waterborne radon was determined according to the United Nations Scientific Committee on the Effect of Atomic Radiation reports and was found to be 33.23 µSvy^{-1}. All the samples recorded a value <100 µSvy^{-1} recommended by the World Health Organization and the European Union council.

INTRODUCTION

Radon is a noble gas that is produced by the radioactive decay of ^{226}Ra found in uranium ores, phosphate rocks and a number of common minerals(1). It is an invisible, odorless and tasteless gas that seeps up through ground and diffuses into the air(1,2). The rate of radon transportation depends on radium distribution in both the soil and rocks, soil porosity, granulation, microcracks, temperature, surface winds, humidity and pressure(2). Because it is inert, radon itself does not pose a hazard but instead undergoes a radioactive decay producing a series of short-lived progeny that can emit alpha, beta or gamma. Radon is classified as group one carcinogen by International Agency for Research on Cancer and World Health Organization as a result of direct evidence from human exposure studies that support the link between exposure to radon and induction of lung cancer(3,4).

The most abundant form of radon is ^{222}Rn with a half-life of 3.82 d, and this is the type that was analysed in this work. Natural gas, volcanic gases, geothermal fluids, combustion of goal, ventilation from caves and mines are considered the secondary contributors of ^{222}Rn(5,6). Radon gas can also be generated from geothermal areas due to existence of small quantities of radioactive rocks containing uranium that lies in the path of the passage of geothermal waters and it may be transported along with an influx of volcanic gases. These gases include CO_2, He, H_2, Hg and CH_4 from a deeply burned magma(7,8). Underground uranium miners exposed to radioactive radon and its decay products have been found to be at increased lung cancer risk(9). The risk increased with estimated cumulative exposure and decreased with attained age, time since exposure and time since cessation of exposure(9–11). Radon escaping from household water can also enrich indoor radon source and this can access the body through respiratory tract hence delivering radiation dose(12–15). The concentration of waterborne radon can be determined using a variety of measuring devices that include: radon diffusion chamber coupled with solid state nuclear tract detector, liquid scintillating counting device and electret ion chambers based on the use of Electret Passive Environmental Radon Monitor. Liquid scintillating counting device was employed in this work(16,17) owing to its high sensitivity of about 200 pCiL^{-1} and its ability to measure many samples within a shorter time interval(17).

METHOD

In total, 15 sampling sites were randomly identified in Bureti sub-county of Kericho county as shown in Figure 1. In each site, water samples were collected from five different bore holes and mixed to form a representative sample and the same procedure was extended to the rest of the sites. A total of 75 Water samples collected were carefully transferred into well-labelled Environmental Protection Agency (EPA) bottles of capacity 100 ml. After mixing, the representative samples were eventually transferred into another set of 15 EPA bottles capped tightly using rubber Teflon to avoid radon leakage. During sampling, the water samples were filled to the brim to rule out any chances of partitioning of radon gas between air and water(18). The samples were handled carefully during transportation to the

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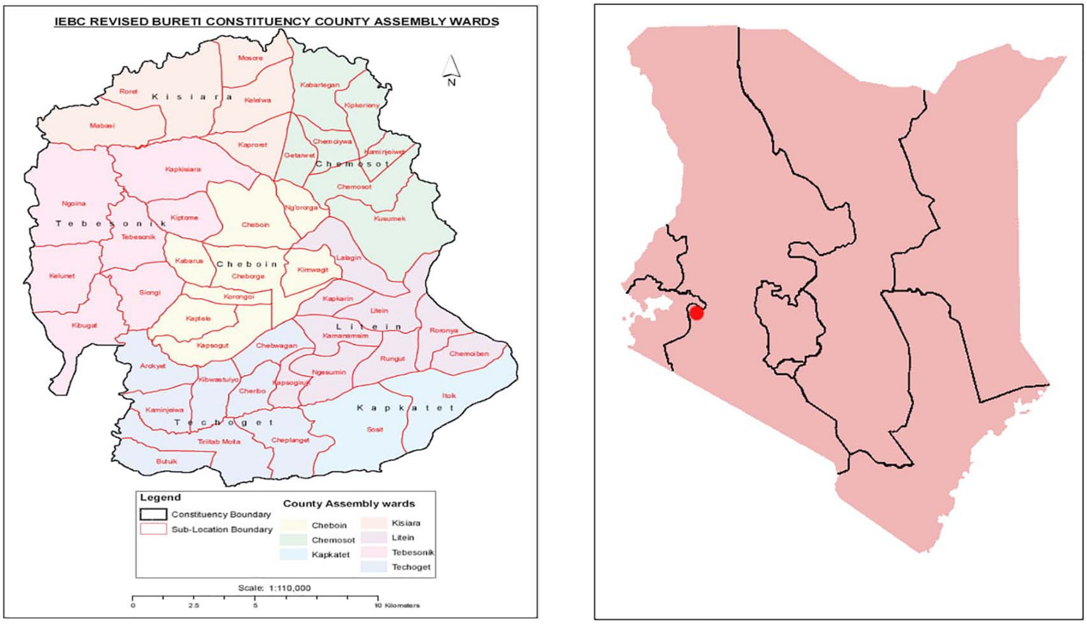

Figure 1: Map of Bureti sub-county where sampling was done.

laboratory to avoid cross-contamination and sample mixed up[19,20].

Liquid scintillation counting analysis

Prior to the samples analysis, 10 ml of Perkin Elmer's Ultima Gold™ cocktail was measured and put in a vial of 24-ml capacity. In total, 20-ml hypodermic syringe was inserted deep below the water surface and several millimeters of water removed and ejected. This procedure was repeated several times to rinse the syringe. About 15 ml of the water sample was removed and the syringe was inverted to get rid of any air molecules that may be present in the samples and ~10 ml of the water was retained. The 10 ml of the water was transferred into the 10 ml of the Ultima Gold™ cocktail contained in the plastic vials[21]. Each vial was tightly capped and shaken vigorously to facilitate the extraction of ^{222}Rn from the samples into the cocktail with other elements and radionuclides remaining in the water[22]. Before analysis, the samples were allowed to sit for a period of 3 h to allow radon and its short-lived decay products to equilibrate[23].

Calibration of the counting device was determined by counting ^{226}Ra standard solution over a period of 60 min using ^{218}Po, ^{214}Po alpha energies and ^{214}Pb, ^{214}Bi beta energies. Each vial was counted using the calibrated alpha window for ~5000 s using liquid scintillating counter belonging to the National Radiation Protection Board laboratory in Nairobi. For background counts, a vial containing 10-ml scintillant and 10 ml of deionised distilled water was counted over the same length of time. The actual counts for used in activity concentration of ^{222}Rn in water were obtained by subtracting background counts per minute from total counts per minute.

Activity concentration of radon in underground water

The activity concentration of waterborne radon was determined using Equation (1)[24,25].

$$\mathrm{RnC} = \frac{100(N)\exp(\lambda t)}{60 \times 5 \times 0.949} \tag{1}$$

Where RnC is the radon concentration ($\mathrm{BqL^{-1}}$) in water samples at the time of sample collection.

100 is the conversion factor of 10 ml of the sample to per litre.

60 is the conversion factor from minutes to seconds.

5 is the number of emissions per disintegrations of ^{222}Rn.

λ is ^{222}Rn decay constant i.e. $1.26 \times 10^{-4}\mathrm{min.}^{-1}$

0.949 is the fraction of ^{222}Rn in 10 ml of ultima Gold™ cocktail in a vial of 24-ml capacity,

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Table 1. Radon concentration in underground water and the effective dose received by an individual in Bureti sub-county.

Location	Annual effective dose due to waterborne radon absorbed by a resident in μSvy^{-1}			
	Radon conc. (Bql^{-1})	Dose due to ingestion (stomach)	Dose due to inhalation(lungs)	Whole body
S1	13.22 ± 0.7	2.34	33.05	35.39
S2	5.26 ± 0.2	0.95	13.15	14.10
S3	14.92 ± 0.8	2.69	37.30	39.99
S4	7.68 ± 0.4	1.38	19.20	20.58
S5	9.37 ± 0.5	1.69	23.43	25.12
S6	8.23 ± 0.4	1.48	20.58	22.06
S7	**4.57 ± 0.2**	**0.82**	**11.43**	**12.25**
S8	17.23 ± 0.9	3.10	43.08	46.18
S9	15.26 ± 0.8	2.75	38.08	40.83
S10	6.73 ± 0.3	1.21	16.83	18.04
S11	18.15 ± 0.9	3.27	45.38	48.65
S12	**22.56 ± 1.1**	**4.06**	**56.40**	**60.46**
S13	20.27 ± 1.0	3.65	50.68	54.33
S14	16.28 ± 0.9	2.93	40.70	43.63
S15	6.56 ± 0.3	1.17	16.30	17.47
Average	**12.41 ± 0.7**	**2.23**	**31.00**	**33.23**

The average values for the three radionuclides.
Values obtained from the regions with enhanced activity concentration for the three radionuclides.
Values obtained from the regions with low levels of activity concentration for the three radionuclides.

T is the elapsed time from sample collection to sample analysis and N is the actual count rates in counts per minute.

Effective dose due to waterborne radon

The radiation dose due to waterborne radon enters the human body via ingestion and inhalation as shown in Equations (2) and (3), respectively[26].

$$\text{Annual effective dose due to ingestion} = 0.18\ \mu SvLy^{-1}Bq^{-1} \times {}^{222}Rn \quad (2)$$

$$\text{Annual effective dose due to inhalation} = 2.5\ \mu SvLy^{-1}\ Bq^{-1} \times {}^{222}Rn \quad (3)$$

Where ${}^{222}RnC$ is the calculated value of the activity concentration of waterborne radon.

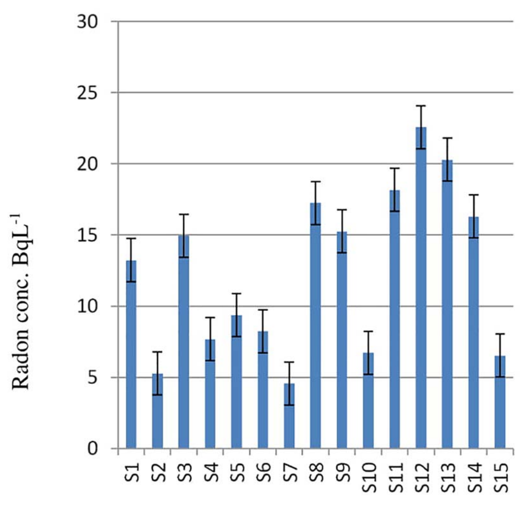

Figure 2: Variation of ${}^{222}Rn$. Activity concentration with sampling sites.

RESULTS AND DISCUSSION

The radon activity levels as well as the annual effective doses, i.e. ingestion and inhalation for underground water, are shown in table 1. The average activity concentration of radon was found to be 12.41 Bql^{-1}, which is above the world average value of 10.0 Bql^{-1} for drinking water[22,27]. The activity concentration values ranged between 4.57 and 22.56 Bql^{-1} as shown in Figure 2, with 8 sites, i.e. S1, S3, S8, S9, S11, S12, S13 and S14 out of 15 representing a total of 53% had a radon concentration levels >11.1 Bql^{-1} limit set for drinking water in 2001 by US Environmental Protection Agency (USEPA)[8]. Besides these, S12 and S13 that are neighboring sites have similar ${}^{222}Rn$ concentration in underground water and this is attributed to the same geological rock aquifers.

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The average annual effective dose due to ingestion and inhalation was found to be 2.23 and 31.0 μSvy^{-1}, respectively, and the total dose accumulated by the body was 33.23 μSvy^{-1}, which is less than the recommended maximum value of 100 μSvy^{-1} suggested by European Union (EU) council and WHO[20,28]. The total annual absorbed dose by an adult resident of Bureti ranged between 12.25 and 60.46 μSvy^{-1}. S12 and S13 underground water samples recorded an enhanced total annual absorbed dose of 60.46 and 54.33 μSvy^{-1}, respectively, which are still lower than the above recommended limit, and these are samples with enhanced radon concentration levels.

CONCLUSION

In total, 53% of the total water samples analysed had the radon activity concentration levels above the USEPA recommended contamination limit of 11.1 Bql^{-1} for drinking water. These are the sites with the lower terrains that act as sinks for the accumulation of the sediments and the terrestrial radionuclides from the higher terrain areas. Since waterborne radon can escape into indoor as well as the outdoor air, houses in these regions need to have proper ventilation to minimise its concentration in the indoor environment. For individuals' who consume >0.7 l of raw water per day are expected to have a higher radon exposure per unit intake. Consequently, infants as well as children are more vulnerable to the associated health effects of radon ingestion, since they consume higher percentage of raw water in proportion to their mass compared with their adult counterparts[29]. The residents are also advised to boil water before drinking since increase in temperature increases the outgassing of radon gas[30].

The annual effective dose due to consumption of water containing radon gas in all the sampling sites is below the WHO-recommended value of 100 μSvy^{-1}. This shows that the Bureti underground water at the moment is fit for human consumption, but those sites with radon activity concentration above the USEPA limit of 11.1 Bql^{-1} need close monitoring and if possible the residents need to be informed on the importance of boiling drinking water and the water for washing should be left in an open bucket in an open environment for some time before use to reduce radon concentration.

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