MEASUREMENT OF RADON ACTIVITY CONCENTRATION IN WATERS FROM HOMA MOUNTAIN SOUTH WESTERN KENYA

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ABSTRACT: The activity concentration of radon in spring, river and pond waters from Homa Mountain South western Kenya was measured using liquid scintillation counting technique. The average activity concentration of radon in all water samples was 17.3 Bq/L. The maximum and minimum activity concentrations of radon were 43.9 Bq/L and 4.2 Bq/ L respectively. The activity concentration of radon from 65 % of the sampling points was above USEPA recommended contamination limit of 11.1 Bq/L. The annual dose received by individuals as a result of water borne radon was determined according to UNSCEAR reports. The average annual effective dose due to radon resulting from direct consumption of spring, river and pond waters was 46.4 μSvy^{-1}, with three samples inducing a total annual effective dose greater than 100 μSvy^{-1} recommended by WHO and EU council.

Key words: Effective dose, LSC, Radon.

1. INTRODUCTION

Radon is a radioactive inert gas produced in rocks and soils through α-decay of radium-226 which is a daughter product of uranium-238 with some atoms escaping to groundwater and air [1], [2]. It has a half-life of 3.82 days, decays by emitting 5.49 MeV α particle, and produces radioactive progeny [3]. ^{222}Rn and two of its daughters, ^{218}Po and ^{214}Po, are alpha emitters, while ^{214}Pb and ^{214}Bi are beta/gamma emitters [4]. Radon is transported mainly upwards from deep layers of the earth by underground waters and diffuses through soils and cracks of rocks under the bedrock in the ground to the surface [5]. The rate at which radon is transported is affected by the distribution of radium in the soil and bedrock, the porosity of the soil, humidity, micro cracks, granulation, surface winds, temperature, rainfall and pressure [6] – [8].

Secondary contributors of radon include natural gas, geothermal fluids, volcanic gases, ventilation from caves and mines, and combustion of coal [9]. Radon may be generated in geothermal areas due to the presence of small quantities of radioactive eruptive rocks containing uranium that lies in the path of the passage of geothermal waters and it may be transported a long with an influx of magnetic gases such as CO_2, He, H_2, Hg and CH_4 from a deeply burned magma chamber [10], [11].

Excessive radon level in water is associated with lung cancer and risk of tumors of the stomach [12] – [15]. Radon can enter the body through the gastrointestinal tract and the whole radiation dose is received by the stomach. Radon escaping from household water also supplements indoor radon source. This radon enters the body through the respiratory tract to deliver the radiation dose [16], [17].

Radon in water may be measured using several methods. Some of these methods and techniques are: Gamma ray spectrometry, Electret ion chambers based on the use of E-PERM, Radon diffusion chamber equipped with solid state nuclear track detectors (SSNTD) and Liquid Scintillation Counting (LSC) which was used in this work [16]. Liquid scintillation counting technique was used to quantify the activity concentration of radon in water because the technique has high sensitivity of 200pCi/L, requires small sample volume of 10 ml and many samples are measured within a short time [18].

Homa mountain in south western Kenya among other areas in the country such as Kerio valley is a geothermal field that is associated with elevated background radiation from naturally occurring radioactive materials (NORMs) [19]. The mountain has a series of cone sheets of carbonatite alkaline rocks and ijolite (alkaline igneous rocks) which have been documented to have high radiation levels [20]. The soils of these areas are mainly clay and in some parts clay mixed with sand.

The aim of this work was to determine the activity concentration of radon in spring, river and pond waters from Homa Mountain using LSC technique and assess the corresponding effective radiation dose received by individuals drinking these waters.

2. METHODOLOGY

Spring, river and pond waters were collected from Homa Mountain south western Kenya as indicated in figure 1. The locations of sampling points were determined using the global positioning system (GPS). Water samples from each sampling point were taken directly into EPA type water collection bottles with a volume of 100 ml. These bottles have rubber-teflon septa which prevents radon from leaking from the bottle. The water was filled to the brim to avoid partitioning of radon between water and air above the water. The samples were given identification codes and transported to the

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radiation protection board of Kenya laboratory for radon measurement.

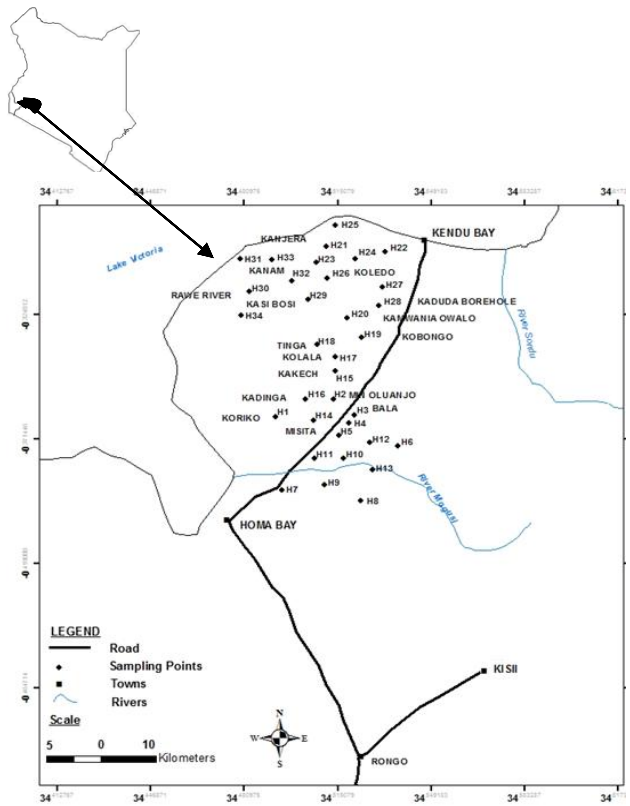

Figure 1: A section of the Homa mountain region in Kenya showing the sampling points in this work.

2.1 Liquid scintillation counting analysis

10 ml of Ultima Gold™ cocktail was measured and placed in 24 ml plastic vials. A needle of a 20 ml hypodermic syringe was inserted below the water surface and several milliliters of water withdrawn and discarded. This rinse was repeated several times. 12-15 ml of water was withdrawn slowly to minimize air bubbles. The syringe was inverted to eject any air bubbles and retain 10 ml of water. The syringe needle was placed under the surface of 10 ml of Ultima Gold™ cocktail contained in a plastic scintillation vial and water ejected slowly from the syringe into the cocktail [21]. The vial was tightly capped and vigorously shaken. During shaking almost all ^{222}Rn is extracted from water to the cocktail, while other radionuclides, elements or minerals remained in the water [22]. The above procedure was repeated three times for each sample. The prepared samples were left for at least three hours for radon to equilibrate with its daughter nuclide before they were analyzed by LSC [22], [23] – [26].

2.2 Activity concentration of radon

The radon partition coefficient for water : Ultima Gold™ cocktail : air is 1 : 48 : 4 [22], [26]. The activity concentration of radon in water was calculated according to equation 1.

$$\text{RnC} = \frac{100(N)\exp(\lambda t)}{60\times5\times0.949} \qquad (1)$$

where RnC is ^{222}Rn concentration at the time of sample collection (Bq L^{-1}); N is the sample total count rate (count $min.^{-1}$); t is the elapsed time between sample collection and counting (min.); λ is ^{222}Rn decay constant (1.26×10^{-4} $min.^{-1}$); 100 is a conversion factor of 10 ml to per liter (L^{-1}); 60 is conversion factor from min. to sec. (s. $min.^{-1}$); 5 (500 %) is the number of emissions per disintegration of ^{222}Rn (3α and 2 β, assuming 100 % detection efficiency for each); and 0.949 is the fraction of ^{222}Rn in 10ml of Ultima Gold™ cocktail in a vial of 24 ml total capacity.

2.3 Effective dose due to radon

The radiation dose resulting from waterborne radon enters the body through ingestion and inhalation. The adults' annual effective doses due to ingestion and inhalation were calculated according to UNSCEAR parameters [27]. The equations used to calculate the adults' annual effective doses due to ingestion and inhalation are:

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

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

where ^{222}RnC is the measured activity concentration of radon in water.

3. RESULT AND DISCUSSION

The results of the activity concentration of radon in waters from Homa Mountain south western Kenya are reported in table 1. The results indicate that 65% of the samples have radon concentration levels that exceed the USEPA limit of 11.1 Bq/L [1]. However, the radon levels obtained are below the alternative contamination limit of 150Bq/L recommended by EPA. Remedial actions to reduce radon levels are required if the contamination levels are above the alternative contamination limit [28], [29].

The annual effective dose due to waterborne radon to individuals living in Homa Mountain was calculated and the result is shown in table 1. It was observed the total annual effective dose of adults due to radon in water is less than the recommended limit of 100 µSv/y [9], [18]. The annual effective dose of adults due to waterborne radon as a result of

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drinking water from H12, H27 and H29 sampling points were above 100 μSvy^{-1}. This indicates that there is radon problem for these three sources. Therefore, there is need to either aerate, boil or mix water from these sources with surface water in order to remove some radon before public consumption [30].

Table 1: radon concentration in water and the corresponding annual effective dose received by individuals in Homa Mountain.

Samples	^{222}RnC (Bq/L)	Annual effective dose of adults (μSvy^{-1})		
		Stomach (Ingestion)	Lung (Inhalatio)	Whole body
H1	13.8 ± 0.7	2.5	34.5	37.0
H2	11.8 ± 0.7	2.1	29.5	31.6
H3	31.7 ± 1.9	5.7	79.3	85.0
H4	9.5 ± 0.7	1.7	23.8	25.5
H5	25.5 ± 1.9	4.6	63.8	68.4
H6	10.3 ± 0.7	1.9	25.8	27.7
H7	29.3 ± 0.7	5.3	73.3	78.6
H8	25.6 ± 1.7	4.6	64.0	68.6
H9	9.5 ± 0.7	1.7	23.8	25.5
H10	20.2 ± 0.7	3.6	50.5	54.1
H11	9.1 ± 0.7	1.6	22.8	24.4
H12	39.7 ± 1.2	7.1	99.3	106.4
H13	8.3 ± 0.7	1.5	20.8	22.3
H14	13.3 ± 0.7	2.4	33.3	35.7
H15	12.5 ± 1.3	2.3	31.3	33.6
H16	12.1 ± 0.7	2.2	30.3	32.5
H17	10.5 ± 0.7	1.9	26.3	28.2
H18	11.1 ± 0.8	2.0	27.8	29.8
H19	14.0 ± 1.3	2.5	35.0	37.5
H20	14.4 ± 0.7	2.6	36.0	38.6
H21	17.5 ± 1.9	3.2	43.8	47.0
H22	15.3 ± 0.8	2.8	38.3	41.1
H23	15.3 ± 0.8	2.8	38.3	41.1
H24	9.4 ± 0.4	1.7	23.5	25.2
H25	4.2 ± 0.7	0.8	10.5	11.3
H26	21.3 ± 0.8	3.8	53.3	57.1
H27	43.0 ± 2.5	7.7	107.5	115.2
H28	21.0± 0.9	3.8	52.5	56.3
H29	43.9 ± 0.8	7.9	109.8	117.7
H30	10.9 ± 0.8	2.0	27.3	29.3
H31	21.3 ± 1.7	3.8	53.3	57.1
H32	8.7 ± 0.8	1.6	21.8	23.4
H33	14.8 ± 1.9	2.7	37.0	39.7
H34	9.6 ± 0.7	1.7	24.0	25.7

4. CONCLUSION

The result of this study shows 65% of measured samples have the activity concentration of radon which is above USEPA contamination limit. However, their levels are below proposed alternative contamination limit. Sources H12, H27 and H29 induced annual effective dose which is greater than 100 μSvy^{-1}. These sources require some remedial action to reduce radon concentrations consumed by people. Therefore there is need for the individuals using water from source H12, H27 and H29 to boil water before they drink, and ensure that their houses are well ventilated. Boiling of water is necessary because increasing the temperature of water increases the rate of out-gassing of radon [31], [32]. For individuals who drink more than 0.5 l of water per day, infants and children, the effective dose is expected to be higher per unit intake. Children and infants are more vulnerable to the health hazards as a result of ingestion of radon due the fact that they drink more raw water in proportion to their body mass compared to adults [10].

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