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Annual effective dose from radon-222 concentration levels in underground water in bungoma south sub - county, Kenya

Abstract

This research measured the concentration levels of radon in groundwater and determined the ingestion and inhalation dose. The study used RAD7 detector with RAD7-H2O accessory from Durridge Company to determine the radon levels. Thirty water samples in granitic dominated regions were collected from various areas of Bungoma County: ten from boreholes (BH), ten from hand dug wells (WL) and ten from springs (SP). The water samples were collected in 250 ml bottles which were tightly covered with lid to avoid radon leakage. The highest value was 303±4.00 KBq/m^3 recorded in Kanduyi well and the lowest was 126±11.4kBq/m^3 from where most of the samples recorded a high radon concentration with a mean of 269±5.25 KBq/m^3 in wells, 213±7.96 KBq/m^3 in boreholes and 290±7.70 KBq/m^3 in springs. The average ingestion dose was found to be 1.5±0.07mSv/yr, 1.9±0.09 mSv/yr and 2.1±0.1 mSv/yr. The average annual effective dose rate for the samples collected were 2±0.1 mSv/yr for boreholes, 2.6±0.13 mSv/yr for wells and 2.7±0.14 mSv/yr for springs. The samples reported an average value of AED higher than the world average of 1.15 mSv/yr but below the exception limit of recommended action level of 10 mSv/yr hence the radon concentration levels in underground water in the study area has minimal health implications to the population.

Subject area: Nuclear and Radiation Physics.

Keywords: underground water, bungoma county, RAD-7 detector, dose rate, annual effective dose rate (AED)

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Introduction

Radon-222 is a gaseous highly radioactive element discovered in 1899 by Ernest Rutherford. It is a chemically unreactive colourless inert gas with a half –life of 3.82 days. It has three isotopes ^{222}Rn (radon gas),^{220} Th(thoron) and ^{219}Rn (actinone).[1] Radon-222 decays by emitting 5.49 MeV alpha particles, two of the ^{222}Rn daughters ^{214} Po and ^{218}Po are alpha emitters and contribute over 90% to the total radiation dose received due to radon exposure.[2] Radon mainly comes from the breakdown of uranium in the soil, rock and in water. It is denser than air and exist as a single atom gas thus can easily penetrate materials, paper, leather, low density plastic, most paint, sand, building materials like gypsum (sheet rock) concrete bock, mortar, wood panelling and most insulations.[3] Radon from natural sources mainly come from uranium rich minerals and soils, it can also accumulate in houses made of mud in areas such as basements. It can also be dissolved in groundwater such as hand-dug wells, boreholes, spring water and hot springs.[4]

The presence of radon in the environment and ground water is associated with presence of amounts of uranium in rocks and granitic soils. The uranium levels change from place to place since types and rocks and soils like granite, uranium-enriched phosphates' rocks and shales contain more uranium than others.[5] The quantity of radon dissolved in ground water also depends on some factors such as characteristics of the aquifer, water-rock interaction, mineral content of radium.[5] The concentration of radon level in groundwater from bedrock is high compared to surface water due to the presence of granite, sand and gravels.[4] Radon contributes approximately 55% of the total internal radiation to human beings.[6] The radioactive process that at the end radon is released and other decay products, which include polonium, lead and bismuth is also accompanied with energy. These decay products are small minute solids which have a short half-life and thus decay through ionizing radiation immediately they are formed. Therefore, if inhaled, they tend to decay before the lungs can clean themselves.[7] These daughters are also electrically charged particles and thus attach to natural aerosol and dust when inhaled, they tend to be deposited to the lungs thus exposing the cells to alpha radiation which can damage sensitive tissues.[8] Among non-smokers radon has been identified to be the number one cause of lung cancer. EPA has estimated that radon causes more than 20000 deaths from lung cancer each year.[9]

Exposure to radiation can be harmful to human. Radiation from natural sources has risen over time. Human beings are exposed to radiation mainly from either inside or outside their body. Cosmic rays and gamma ray emitters in soils and walls of buildings contribute most to radiation from outside the body. Inhaling air, ingesting food and water also expose humans to radiation by in cooperating radionuclides in the body. These radionuclides emit alpha and beta particles of low penetrating power.[10] This radiation over time are harmful to the cells and can damage the cells Studies have shown that the major contribution to internal irradiation is as a result of taking water containing high concentration levels of radon-222 and its decay products.[11] In most countries including Kenya ,most of the population depend on the ground water sources such as boreholes ,hand-dug wells and springs which have been noted to contain higher concentrations of radon-222 as compared to surface water sources like lakes.[12] The importance of ground water in Kenya cannot be overemphasized and the need for monitoring. This study is thus aimed at assessing the annual effective dose from the concentration level of radon in groundwater sources and their potential health hazards to human beings.

Materials and methods

Study area

Bungoma County is one of the 47 counties in Kenya that borders Uganda to the western part of the country. Its headquarters is in Bungoma town which is located 00 34'N 34 34'E. The County has a population of 1375063 people and 2206.90km2 in size (KNBS, 2019). Bungoma County is divided into South, North, Central, West, Kimilili, Cheptais, Mt. Elgon, Bumula, Webuye East and Webuye West Sub-Counties. The areas of concern for the study were as shown in Figure 1. Lack of adequate water for use by people is a growing concern for the people living in this county. This has been brought about by climate change that is being experienced all over the world. People in this region rely on groundwater as their main source of water.

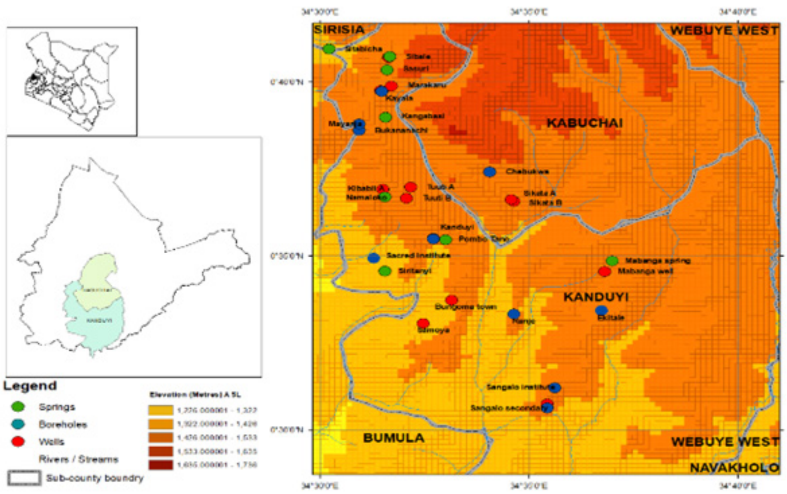

Figure 1 Map of Bungoma County. (KNBS, 2019).

Sample collection and preparation

A total of 30 water samples were collected in this study. Samples were collected from these areas Sang'alo, Musikoma, Marakaru, Tuuti, Namaloko, Sasuri, Siaka, Siritanyi, Bwema, and Bungoma town. The water was collected in a pail with minimal air contact and the vial placed at the bottom of the pail and allowed to fill. The 250ml vial was capped while still under the water and was ensured that there were no bubbles in the vial. The cap was tightened, removed from the bail, dried and labelled ready for measurements.[13]

Experimental method

RAD-7 detector was used for the measurement of radon concentration in underground water. RAD-7 uses silicon as semiconductor material which converts the alpha radiation into electrical energy.[14] The detector inside the RAD-7 distinguishes the alpha particles from ^{218}Po and 214Po with an energy range of 6.0 MeV and 7.9 MeV, respectively, into their respective windows (Figure 2). Radon concentration in the underground water in this study was determined by using RAD H_2O was used.[15] A watt-250 protocol along with Grab mode was chosen on the RAD-7 for 250 ml samples. The internal pump was used to obtain radon from the water sample and it circulates the gas to the counter for measurement.

Annual effective dose estimation

Radon assessment of drinking water is extremely important because of the recognized health risks associated with radon.[14] Committed annual effective dose from in gestion and inhalation was calculated using the equation 2.1.[15]

$$AED_{ing=}C_W \times D_W \times DCF \times T \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2.1)}$$

Figure 2 Rad7 detector and a printer.[13]

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Where C_W is the mean radon activity concentration in water, D_W the weighted estimate of water consumption (2L/day), DCF is the ingestion dose conversion factor of radon and its progeny (10^8 Sv/Bq) T-365 days/y. The annual inhalation dose from the water was calculated using the equation 2.2.[16]

$$E_{Wih}(mSv/y) = C_{RnW} \times R_{aW} \times F \times O \times DCF \ldots\ldots\ldots\ldots\ldots (2.2)$$

Where, R_{aW} is the ratio of radon in air to radon in drinking water 10^{-4}, C_{RnW} is concentration of radon in water , F the equilibrium factor between radon and its decay Products (0.4), O the average indoor occupancy time per person (7000h/y) and DCF is the dose conversion factor for radon exposure 9nSv/h (Bq/m³).[15]

Results and discussion

Table 1 shows the average radon concentration, ingestion dose, inhalation dose and the annual effective dose rate in underground water of areas within Bungoma County. The underground water radon concentration varied from 126±11.40 KBq/m³ to 303±4.00 KBq/m³ with a average mean of 213±7.96 KBq/m³ for boreholes, 269±5.25 KBq/m³ for wells and 290.75±7.70 KBq/m³ for springs. The radon concentration in the underground water was above the recommended concentration level of 11 Bq/L proposed by the US Environmental Protection Agency, USEPA. The measured values for radon concentration were also compared with the European Commission Recommendations on the protection of the public against exposure to radon in drinking water supplies (2001/928/Euratom), which recommends action levels of 100 Bq/L for public water supplies and exceptional level of 100011 Bq/L, it can be therefore be deduced that the levels were below the criterion limit.[17] To determine the health implications of the measured radon concentration, the concentration values were converted into annual effective dose rate by using equation 2.1 and 2.2 (Table 2). From Table 2, the average annual effective dose rate was 2±0.1mSv/y, 2.6±0.13 mSv/y and 2.8±0.14 mSv/y. These values were less than the recommended limit range of 3 to 10 mSv/y for action.[18] Figure 3 shows the average values of AED of underground water. This value was found to be higher than the world permissible limit of 1.15 mSvy[1](19) above which the populace can be exposed to high levels of radiation but below the action range limit of 3 to 10 mSv/y and thus posing minimal health-related risks. The average effective dose was higher in samples from springs with an average of 2.853 mSv/y. Township region had higher averages as deduced from the graph with hand dug wells having high annual effective dose. This can be attributed to the shallowness of the well and granitic rocks which were seen from the walls and base of the well that are associated with high levels of radon concentration.[20]

Table 1 Average radon concentration values of underground water in Bungoma County

Region	Borehole	Well	Spring
Sang'alo	259±8.29	245±5.25	294±9.67
Mayanja	223.33±6.32	272.67±4.60	280.5±10.64
Township	245±5.87	303±4.00	293±5.62
Tuuti/Bwema	126±11.40	257.33±7.16	296±4.88
Average	213±7.96	269±5.25	290.75±7.70

Table 2 Average annual effective dose rate values

Region	Borehole	Well	Spring
Sang'alo	2.5±0.12	2.4±0.12	2.8±0.14
Mayanja	2.1±0.1	2.7±0.13	2.7±0.13
Township	2.4±0.12	2.9±0.14	2.8±0.14
Tuuti/Bwema	1.2±0.06	2.5±0.12	2.9±0.14
Average	2±0.1	2.6±0.13	2.8±0.14

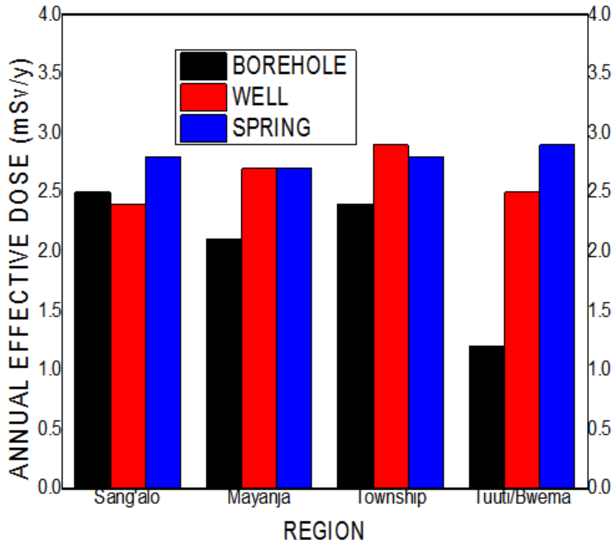

Figure 3 A Graph of Average Annual Effective Dose Rate.

Conclusion

The high concentrations are as a result of the granitic soil formations in the region. Radon-222 diffuses from the bedrock into the underground water which contributed to the high radon concentrations. The geology of this area mainly consists of igneous and metamorphic rocks. This comprises of the gneiss, schist, quartz and granite rocks. The natural weathering of rocks such as granite dissolves the natural radon which goes into groundwater by leaching and precipitation called illumination process. The use of phosphate fertilizers and other human activities such as combustion from coal or other fuels contribute to the concentration of radon in ground water which led to high radon concentration levels. However, the obtained AED values were below the action range criterion hence underground water in the study area poses minimal health threats to the general population.

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Conflicts of interest

The author declares no conflict of interest regarding publication of this paper.

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