

ESTIMATION OF ANNUAL EFFECTIVE DOSE DUE TO RADON AND THORON CONCENTRATIONS IN MUD DWELLINGS OF MRIMA HILL, KENYA

M. W. Chege^{1,*}, N. O. Hashim², A. S. Merenga², O. Meisenberg³ and J. Tschiersch³

¹Physics Department, Kenyatta University—Mombasa Campus, PO Box 16778, Mombasa, Kenya

²Physics Department, Kenyatta University, PO Box 43844, Nairobi, Kenya

³Helmholtz Zentrum München—German Research Center for Environmental Health, Institute of Radiation Protection, Ingolstädter Landstraße 1, 85764 Neuherberg, Germany

*Corresponding author: znimo@yahoo.com

This study presents radon and thoron concentration measurements and the corresponding effective dose rates in mud dwellings located in the high background radiation area of Mrima Hill, Kenya. Discriminative technique was used for simultaneous measurement of radon and thoron. The effective dose was evaluated based on the concentration of the isotopes and the time spent indoors. Radon concentration ranged from 16 to 56 Bq m⁻³ with an average of 35 ± 14 Bq m⁻³ and a corresponding annual effective dose of 0.67 mSv y⁻¹, while that of thoron ranged from 132 to 1295 Bq m⁻³ with an average of 652 ± 397 Bq m⁻³ and an effective dose of 13.7 mSv y⁻¹.

INTRODUCTION

The human race has been exposed to background radiation since time immemorial. Over 80 % of this radiation originates from natural sources, with radionuclides in the decay chains of ²³⁸U and ²³²Th and the singly occurring ⁴⁰K contributing the largest fraction⁽¹⁾. These primordial radionuclides are ubiquitously present in trace amounts in rock and soil. Rock and soil constitute the main building materials in most parts of the world and consequently may act as important sources of radiation dose. Inhalation of indoor air contributes ~42 % of the dose received from natural sources⁽²⁾. While radon (²²²Rn) was previously considered responsible for nearly the entire inhaled dose, recent studies have shown that thoron (²²⁰Rn) can significantly add to the dose, particularly in dwellings where the main building material is soil^(3, 4). This has been observed in parts of India and China^(5–9).

The present study was carried out in a rural village of ~3000 residents nestled on the lower slopes and the base of Mrima Hill located in Kwale County in the coastal region of Kenya. Mrima Hill is roughly located at 39° 15' 45" East, 4° 29' 18" South and has an approximate circumference of 2.5 km. Mrima Hill has among the highest background radiation levels in Kenya with some parts reporting external gamma exposure of 106 mSv y⁻¹⁽¹⁰⁾; the worldwide average natural dose to humans is ~2.4 mSv y⁻¹. The high background radiation in the region has been attributed mainly to ²³²Th⁽¹¹⁾ whose average concentration in the soil has been found to be 500 Bq kg⁻¹⁽¹²⁾. Typical to rural Kenya, dwellings in Mrima Hill region are mud-walled with bare earthen floors; untreated soil dug near the site of the proposed dwelling is usually used

for the construction. The aim of this research was to measure radon and thoron concentrations in the mud dwellings of the region and estimate the risk attributed to the isotopes in terms of annual effective dose.

MATERIALS AND METHODS

Sampling and analysis

Twin canisters fitted with CR-39 solid-state nuclear track (SSNT) detectors were used for simultaneous measurement of radon and thoron. The canister used for the measurement of both radon and thoron was fitted with a screw cap that contained several holes. That used for the measurement of radon only had a solid screw cap, with air entering the canister through the cap thread. This provided sufficient time for thoron to decay before gaining access to the detector. The discriminating devices were calibrated against a RAD7 active radon and thoron measurement device (Durrige Inc.) in a 1 m³ calibration chamber. The measurement uncertainty was estimated to be ~10 % for radon and 20 % for thoron. Each pair of the measuring devices was affixed on a paper holder and then on the wall of the dwelling under study at a height of at least 1.5 m from the floor. The paper holder maintained a constant distance of 0.2 m between the canisters' screw caps and the wall of the dwelling assumed to be a representative distance for thoron measurement^(7, 13).

Twenty dwellings were randomly selected from the sampling region (Figure 1). The selected dwellings had a similar design (of Digo subtribe): non-storied, mud-walled with bare earthen floor and thatched using dry coconut vines. In each dwelling, one pair of

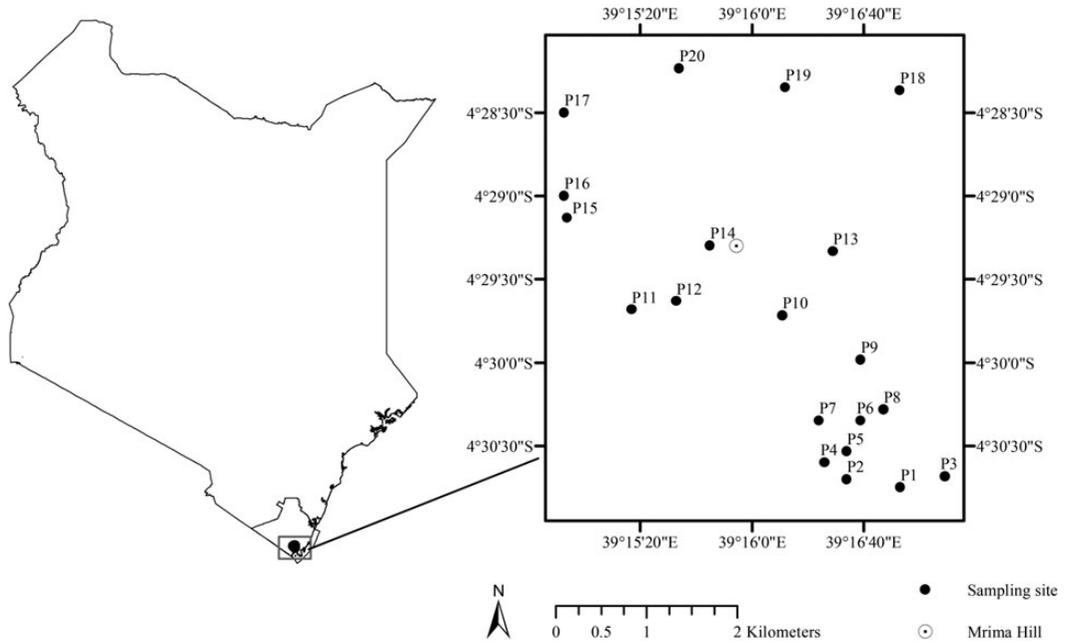


Figure 1. Sampling sites in Mrima Hill region.

the discriminating devices was used. The devices were left on site for ~ 3 months (2280 h). At the end of the exposure period, the SSNT platelets were removed from the canisters and etched in NaOH solution at 94°C for 4 h. The concentrations of radon C_R (Bq m^{-3}) and thoron C_T (Bq m^{-3}) were then evaluated based on the number of damage tracks caused by the isotopes' progeny on the SSNT detectors, calibration factors relating the track densities to known isotope concentration, and time of exposure of the measuring devices using the equations,

$$C_R = \frac{(N_R - N_B) \times CF_R}{t} \quad (1)$$

$$C_T = \frac{[(N_{RT} - N_B) \times CF_R - C_R] \times CF_T}{t} \quad (2)$$

where N_R is the number of tracks in the radon platelet, N_B the number of tracks in the blank/control platelet, N_{RT} the number of tracks in the radon/thoron platelet, CF_R (kBq h m^{-3} per track) and CF_T (kBq h m^{-3} per track) the calibration factors for radon and thoron, respectively, and t (h) the exposure time.

Estimation of annual effective inhaled dose

The health risk due to radon and thoron exposure, quantified in terms of the annual effective dose E

(mSv y^{-1}), was evaluated using the relation⁽¹⁾,

$$E = C \times F \times Q \times t \quad (3)$$

where C (Bq m^{-3}) is the concentration of isotope of interest, F ($\text{nSv per Bq h m}^{-3}$) the dose conversion factor (9 nSv per Bq h m^{-3} for radon and 40 nSv per Bq h m^{-3} for thoron), Q the equivalent factor taken as 0.4 for radon and 0.1 for thoron⁽⁶⁾ and t (h y^{-1}) the indoor occupancy. In Kenya, indoor occupancy per day is $\sim 60\%$ ^(14, 15).

RESULTS AND DISCUSSION

Figure 2 shows the concentration of radon and thoron in the dwellings sampled. All the dwellings had detectable concentration of both isotopes, although the concentration of thoron was higher than that of radon. Radon concentration varied from 16 to 55 Bq m^{-3} with an average of $35 \pm 14 \text{ Bq m}^{-3}$, while that of thoron varied from 132 to 1295 Bq m^{-3} with an average of $653 \pm 397 \text{ Bq m}^{-3}$. The main source of thoron and radon is usually the soil. In most modern houses, higher radon concentration is normally found in the basement where radon enters from the underlying soil by diffusing through the foundation, or through cracks and crevices. The presence of thoron in such dwellings is detected mainly near the cracks and crevices, as it is otherwise suppressed by the solid foundation, given its relatively short half-life. Unlike

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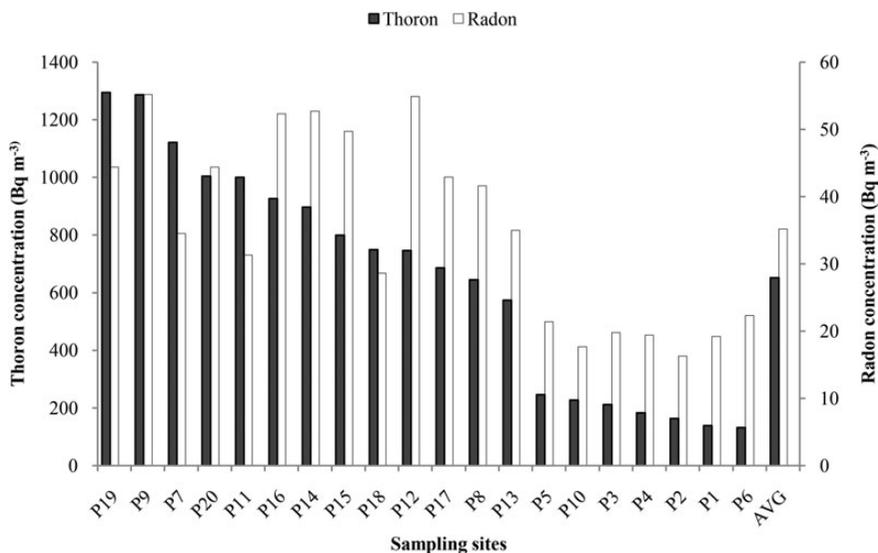


Figure 2. Concentration of radon and thoron in mud dwellings of Mrima Hill region (P1–P20) and average values (AVG).

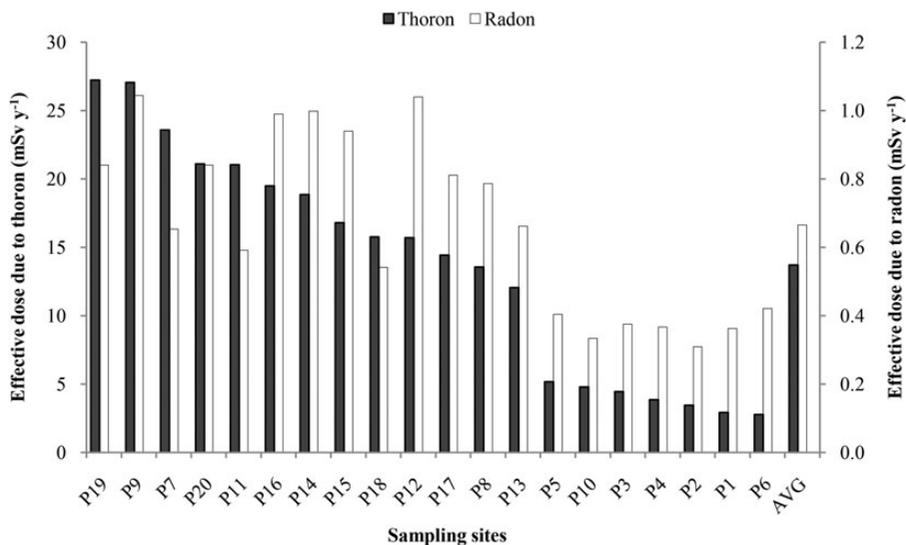


Figure 3. Annual effective dose attributable to the indoor radon and thoron in mud dwellings of Mrima Hill region (P1–P20) and average values (AVG).

modern houses, all the dwellings sampled in this study had earthen walls and floor and therefore offered little hindrance to the exhalation of both radon and thoron into the indoor air.

Radon is a recognised carcinogen and for this reason, agencies and countries the world over have come up with reference levels beyond which radon mitigation measures are recommended. The majority of these reference levels are within the range of 200–600 Bq m^{-3} .

All the dwellings sampled registered radon concentration lower than 200 Bq m^{-3} . Thoron concentration in excess of 300 Bq m^{-3} was observed in 65 % of the dwellings; of which, 25 % had concentration exceeding 1000 Bq m^{-3} . While the high thoron concentration may be attributed to high concentration of ^{232}Th in soil from the hill region^(11, 12) and which the residents use to construct their dwellings, the influence of ventilation rate occasioned by the living habits of the dwellers

cannot be ruled out. This may explain the unexpected low concentration of the isotopes in Sample P10.

Figure 3 shows the annual effective dose attributable to the isotopes. The dose due to radon ranged from 0.32 to 1.04 mSv y⁻¹ with an average of 0.67 mSv y⁻¹, while that due to thoron ranged from 2.78 to 27.2 mSv y⁻¹ with an average of 13.7 mSv y⁻¹, resulting in a total inhaled dose of 14.4 mSv y⁻¹. The effective dose is in the same order of magnitude as that reported in cave dwellings of the Chinese loess plateau (12.13 mSv y⁻¹) calculated using the same UNSCEAR formula⁽⁶⁾. The ICRP recommends effective dose action levels of 3–10 mSv y⁻¹⁽¹⁶⁾. While the estimated average annual effective dose attributable to radon was below the ICRP recommended action level, that due to thoron was higher than the ICRP upper action level by 37%. Furthermore, the dose rate due to thoron was higher than the 10 mSv y⁻¹ reference level in 65% of dwellings sampled.

CONCLUSION

There exists significant radiation exposure due to inhalation of indoor air in Mrima Hill region. Significant amount of the inhaled dose came from thoron, contributing an average effective dose of 13.7 mSv y⁻¹. Sixty-five per cent of the dwellings sampled had thoron concentration exceeding 300 Bq m⁻³ with 25% of them having concentrations of over 1000 Bq m⁻³. The high thoron concentration may be attributed to elevated concentration of ²³²Th in the building materials.

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