SOIL MOISTURE AND ITS EFFECT ON GAMMA RADIATION LEVEL AT THE AIR-GROUND INTERFACE

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ABSTRACT

Measurements of environmental gamma radiation level at the air-ground interface were made at three separate sites $L_{1,}$ [Lat N07^{o} 27' 17'' and Long E 05^{o} 43' 50'']; $L_{2,}$ [Lat N 07$^{o\ 27'}$ 56'' and Long E05^{o} 44' 09''] and $L_{3,}$ [Lat N07^{o} 28' 44'' and Long E05^{o} 45' 27''] in Adekunle Ajasin University, Akungba Akoko, Nigeria. Measurements of gamma radiation level and the water percentage of the top soil were made at each site at different times of the year. The data obtained throughout the whole year obeys a power law showing a decrease of gamma ray count per second with increase in top soil percentage water (% water). The data was discussed in terms of the solubility in water of the radioactive radon emanating from the underground geological basement. The contribution that the soil % water has on the concentration of radon in rooms with faulty and or cracked floors is also discussed.

Keywords: Percentage water, radon, gamma ray, soluble.

INTRODUCTION

The gamma radiations experienced at the air-ground interface can reasonably be associated with three types of sources: gamma rays in the cosmic radiation from the outer space, gamma rays in the radiations from the progeny of radon emanating from within the ground and in the air above the ground; and gamma rays in the radiations from the terrestrial radio-nuclides present in trace elements in the soil and rocks at the earth's surface. Some of the radon progeny in air and clouds are transferred into the rain water and are carried to the ground surface by precipitation (Whittlestone et al, 2003).

The intensity of the cosmic radiation is comparably very low since the cosmic rays are largely attenuated by the earth's atmosphere (Larmash, 1983). The radiation from the radio-nuclides in rocks and soil at a place can be constant with time depending on the intervention of man and the weathering effect. It can also vary from place to place due to the type of radio-nuclides in the soil and temporally due to changes in the weather primarily affecting the release of gaseous 222Rn from the soil [Kouzeset al, 2008].

Just as radon is produced by radioactive decay, it also disappears by radioactive decay and is constantly replenished by the decay of long lived radium in the soil and rocks. Indoor levels of radon vary, depending on the rate at which radon is leaking into the house (Brown, et al., 2000) and can pose a great threat to public health when it accumulates in poorly ventilated residential building. Inhalation is the most likely source of radon exposure in the home and exposure due to this has been known to cause lung cancer.

Nuclear radiation is present everywhere, affecting both plants and animals on the earth's surface (Martin and Harrison, 1979). The knowledge of background radiation level of any environment is of paramount importance to health (UNSCEAR-A-2000 and DREK et al, 2010), and it is therefore desirable to know the contributing factors to the level of radiation in a place in order to know how to manage it for health purposes. Thus the goal of this research is to study the variation of gamma radiation level above the ground surface due to the changes in the percentage water of the top soil. The knowledge of the variation of gamma radiation level at the ground air interface will be particularly useful in looking at emanation of radon from the ground as a health problem in houses with cracked and un-plastered floors. Determination of gamma radiation level in such houses when compared with W.H.O. standard can be used to determine the level of health risk to the inhabitant of such cracked and un-plastered house floors.

MIGRATION OF RADON IN SOIL AND WATER

The basic mechanism of radon escape from a material has been traced to its mobilization from the material due to the recoil energy of the alpha particle decay (Tanner, 1980). The large value of the recoil energy in water accounts for the solubility of radon in water. Thus the amount of radon emanating from under the ground, and as measured on the surface of the ground, depends on how humid the soil in its pathway is. Variation in moisture saturation in soils has been recognized as a cause for fluctuating radon concentration in indoor air (Brookins, 1990).

It is noted that most of the α and β emitters also emit gamma rays as part of their decay process. After the decay reaction, the nucleus is often in an excited state. Rather than emitting another α or β particle, the excess energy of the excited daughter particle is lost by emitting gamma rays. In fact, there is no such thing as 'pure gamma emitters'. Important gamma emitters include tecnetium 99 which is used in nuclear medicine and cesium137 which is used for calibration of nuclear instruments.

The commonest of the primordial radio-nuclides which give rise to radon as their bye-products and occurring naturally in minor concentrations in soil and rocks are ^{40}K, ^{238}U and ^{232} Th and their progenies. ^{222}Rn is the alpha decay product of ^{226}Ra in the ^{238}U series decay chain, while ^{220}Rn is the alpha decay product of the ^{226}Ra in the ^{232} Th series decay chain. The half life and associated energy of the decay series are as follows: ^{222}Rn decays with a half life of 3.825 days into ^{218}Po, and continues in a chain reaction by decaying into ^{214}Pb with a half life of 3.05min and then into ^{214} Bi with a 26.8 min half life. ^{214}Bi decays with a half life of 19.7m, emitting gamma rays of 607 KeV. It is here noted that the half lives of ^{218}Po and ^{214}Pb are so short that the incidence of the 607 KeV gamma rays from ^{214}Bi will imply the presence of radon above the soil (Tsukuda, 2008).

MATERIAL AND METHOD
Measurement Area

Measurement of gamma radiation level at the air-ground interface was carried out between 10 am and 11 am at three randomly selected locations in Adekunle Ajasin University, Akungba Akoko, Nigeria. Since the average life span of radon is approximately 5.5 days, no measurement was taken within six days after a rainfall in order to eliminate the effect of radon progeny pulled down to the ground surface by precipitation. The sites of measurements were L_1 [Site1: Lat N07^o 27' 17'' and Long E 05^o 43' 50'']; L_2 [Site2: Lat N 07^o 27' 56'' and Long E05^o 44' 09''] and L_3[Site3: Lat N07^o 28' 44'' and Long E05^o 45' 27'']. The location at site 2 is about 1m away from a river bed while the other locations are far away from any river. Fig 1.0 shows the topographical map of the measurement area.

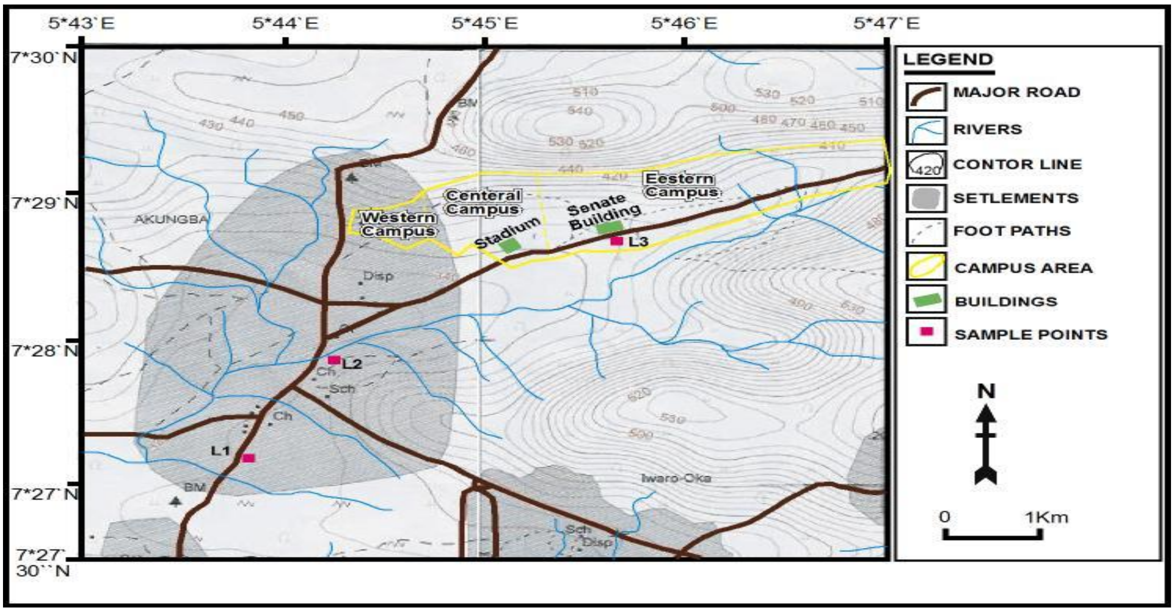

Fig 1.0 The topographical map of Akungba Akoko. The sites of measurements are L1, L2 and L3

Instrument

Measurements were carried out using sodium iodide Nal (T1) scintillation counter which reads in counts per second (cps). The meter is a Scintrex instrument of model BGS – ISL, with s/n 8001089 and works with four UM1 Size 'D' R20 1.5V batteries for its dc power supply.

Soil Sample

The soil sample from each site was taken from 5 cm below the ground surface at each time of measurement. The sample was kept inside a tin container and immediately taken to the laboratory for the determination of its water content. The percentage water content (% water) of each sample was calculated from the equation:

$$\% \text{ water} = \frac{Wc - Wd}{Wd - Wb} \text{ x } 100 \text{ ,}$$

where Wb = mass of empty petri-dish, Wc = mass of petri-dish and wet soil sample, Wd = mass of petri-dish and dried soil sample.

Measurement

The sodium iodide Nal (T1) scintillation counter used for the measurement was placed on the ground surface to measure the maximum gamma radiation level arising from the progenies of radon which diffuses into the air after emanation from the ground.

The counter was switched to the appropriate range and the dead time interval of 60 seconds for stability was observed before the reading was recorded. The contribution to the gamma radiation level at the ground surface by the radon molecules that were washed down from the air by precipitation to the ground were avoided, by not taking measurement during rainfall and within 6 days after it.

RESULTS AND DISCUSSION

The gamma radiation above the ground is associated with three sources: radiation from space, radiation from the surface materials in the environment and radiation from the radon molecules emerging from the overburden and the basement rock of the earth. At a stable environmental condition, the level of gamma radiation from the environment at a single site on the ground is constant.

Radon is an inert radioactive gas emitted by rocks and sediments. It is produced by decay of radium which is present in trace quantities throughout the earth's crust. After production, it may diffuse through air-filled pores in the sediment by virtue of the inherent kinetic energy of its atoms and migrate in the dry sediment, but in a much less way in water filled pores (Tanner, 1980), making the quantity of radon reaching the surface of the ground to depend on how humid the intervening medium is. At small soil moisture levels, water exists in thin coatings on soil grains and absorbs some of the recoil energy of the radon atoms as they escape, preventing them from burying themselves in adjacent soil grains and thus increasing the chance that the recoil path will terminate in a pore space (Tanner,1964). At higher levels of soil moisture, the thicker liquid coating on soil grains will trap the radon atoms and reduce the gas permeability of the soil.

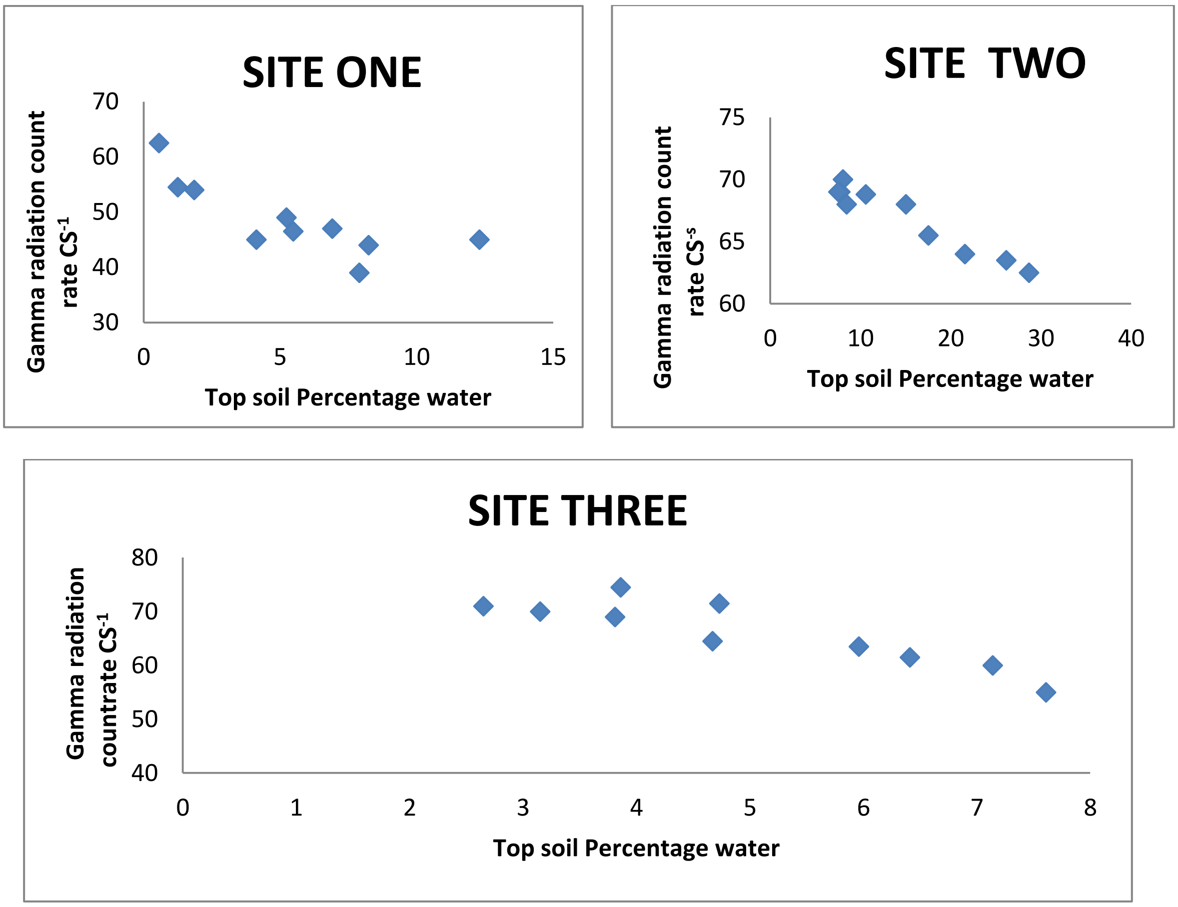

Fig. 2. The variation of top soil % water with gamma radiation level at the air ground interface at Sites 1, 2 and 3.

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The most important physical factor affecting gamma ray attenuation is the soil density which varies with soil types and soil packing (Reginato and van Bavel, 1964). The presence of water in the soil effectively increases the density of the soil by filing the pores in the soil.

Fig 2.0 shows that as the water content of the top soil increases, the radiation level at the air ground interface decreases, and this supports the observation of the earlier workers (Tanner, 1980; Nielson et a, l984; Schery et al, 1989) that the water in the overburden is a major factor governing the movement of radon through it.

Table 1.0: Variation of Top Soil % Water with Gamma Radiation Level at the Air – Ground Interface at the three sites

DATE	SITE 1		SITE 2		SITE 3	
	Mean count rate CS^{-1}	Top soil % water	Mean count rate CS^{-1}	Top soil % water	Mean count rate CS^{-1}	Top soil % water
27- 02- 2014	54.0	1.85	68.0	15.05	71.5	4.73
07-03-2014	54.5	1.25	60.0	21.59	74.5	3.86
13-03-2014	62.5	0.56	62.5	28.69	61.5	6.41
16-04-2014	45.0	12.30	64.5	26.17	69.0	7.14
29-09-2014	39.0	7.90	65.0	8.48	55.0	7.61
21-11-2014	44.0	8.24	70.0	8.07	63.5	5.96
27-11-2014	48.0	4.13	65.5	17.54	67.0	2.65
04-12-2014	46.5	5.48	59.0	7.78	66.5	3.81
12-12-2014	49.0	5.23	69.0	7.56	66.0	3.15
09-01-2015	47.0	6.91	66.5	10.60	64.5	4.67

It may be seen in Table 2.0 that the radiation level differs from one place to another. This difference may be associated with the type of overburden and basement rock in each place and the attenuation coefficient of the radon transportation in the ground.

CONCLUSION

When climatic factors such as pressure and precipitation are removed, solubility of radon in water in the overburden is suggested to explain the decrease of gamma ray level at the air-ground interface as the % water of the top soil increases.

Radon gas from the ground can enter houses through any openings, cracks in concrete floors and walls, through gaps between the floor and slab, and around drains and pipes, and through pores of hollow-block walls. In order to reduce the efflux of radon into the house especially for houses on dry land, it is therefore suggested that the foundation blocks of the house should have no holes and the concrete flooring of the house must be properly done and must have no cracks.

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