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Radon measurements by nuclear track detectors in secondary schools in Oke-Ogun region, Nigeria

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ABSTRACT

Radon measurements were performed in secondary schools in the Oke–Ogun area, South-west, Nigeria, by solid state nuclear track detectors (SSNTDs). About seventy CR-39 detectors were distributed in 35 high schools of the Oke-Ogun area. The CR-39 detectors were exposed in the schools for 3 months and then etched in NaOH 6 N solution at 90 °C for 3 h. The tracks were counted manually at the microscope and the radon concentration was determined at the Radioactivity Laboratory, Department of Physics, University of Trieste, Trieste, Italy. The overall average radon concentration in the surveyed area was 45 ± 27 Bq m^{-3}. The results indicate no radiological health hazard. The research also focused on parameters affecting radon concentrations such as the age of the building in relation to building materials and floor number of the classrooms. The results show that radon concentrations in ground floors are higher than in upper floors.

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1. Introduction

A true measure of a society's quality can be seen in the development of programs designed to protect the health of its children. Due to the fact that children spend most of their time in kindergartens and schools, a number of radon surveys have been performed in schools in many parts of the world (Poffijn et al., 1992; Kunz et al., 1996; Kullab et al., 1997; Popit and Vaupotič, 2002; Synnott et al., 2006; Oikawa et al., 2006; Papaefthymiou and Georgiou, 2007; Rahman et al., 2010; Llerena et al., 2010; Trevisi et al., 2010). Radon is a naturally occurring odourless, colourless, tasteless and chemically inert gas with a half-life of 3.8 days that is produced continuously from the natural decay of ^{238}U, which is spread all over the earth. As a consequence of this, ^{222}Rn is the main source (69%) of internal radiation exposure to human life (ICRP, 1993). Radon concentration levels are strongly affected by geological and geophysical conditions, as well as atmospheric influences such as barometric pressure and rainfall. When radon moves through soil pore spaces and rock fractures near the earth it may escape into the atmosphere. When a house or other building is present, radon may migrate into these structures and accumulate indoors in sufficient quantities to pose a health hazard. Research on natural radiation exposure has recognized ^{222}Rn and its progeny as a worldwide problem. The radiation damage caused to the lungs, due to inhalation of radon and its radioactive progeny, may cause a significant increase in lung cancer risk to the population (Darby et al., 1998; UNSCEAR, 2006; ICRP, 2007). Risk projections imply that radon is the second leading cause of lung cancer after smoking (BEIR IV, 1999; Melloni et al., 2000).

It has been recognized that an increase in radon concentration of 100 Bq m^{-3} is associated with approximately a 16% increased chance of contracting lung cancer (Darby et al., 2005) and that the risk coefficient for lung cancer is higher for children than that for adults (ICRP, 1993). Studies of radon's behaviour in the geological environment suggest that a direct relationship exists between indoor levels of radon and the concentration of gas in soil (Ball et al., 1991; Shirav and Vulkan, 1997). Hence, one of the most effective and expedient ways of reducing potential hazards posed to students in schools and other buildings would be to conduct investigations of radon concentrations at as many school and home sites as possible. To the best of our knowledge, no systematic study has been performed in Nigeria that has investigated radon level in

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schools. Together, the schools host about 5000 children 10–16 years old, where the children stay for (8–10) hours each day, five days a week.

In Nigeria, there is no public awareness and majority of the populace do not have factual knowledge about radon and its health hazards (Obed et al., 2011). Only two systematic studies have been performed in Nigeria that investigated radon levels in offices (workplaces) and dwellings (Obed et al., 2010, 2011). The aim of the present study is the determination of radon concentrations in a sample of schools located mainly in the region of Oke-Ogun, and the analysis of the main factors affecting indoor radon levels in order to achieve preliminary information.

2. Materials and methods

2.1. Study area

Oke-Ogun ($03^\circ\ 35' - 04^\circ\ 13'$ N, $008^\circ\ 05' - 009^\circ\ 08'$ E) is a large rural area located in the northwest of Oyo State, South-West of Nigeria, at an altitude of between 277 m and 456 m above sea level within the Precambrian Basement Complex of Southwestern Nigeria. The region is bounded to the West by the Republic of Benin; to the East by Atiba area of Oyo state; to the North by Kwara State and to the South by Oyo west and Ibarapa east local government areas of Oyo state. The location of Oke-Ogun region is shown in Fig. 1. Oke-Ogun region has the largest land mass in Oyo state. It covers approximately an area of 13,537square kilometers which is about 60% of the total land mass of Oyo State. It has a population of about 1.5 million http://okeogun.jawotech.com/request_for_state_creation.php#geography. The region has only 35 private secondary schools (http://h2o.law.harvard.edu/viewThread.do?postId=3615), all of which were surveyed for indoor radon concentrations in this study. This area was chosen because important archaeological sites and a National Park are situated in this area (the Ikere George Dam at Iseyin, National Park at Sepeteri, archaeological site at Igboho).

In addition, this area was chosen because hundreds of mineralized veins of varying grades and sizes had been located within this region and these veins include schists, gneisses and granodiorite assemblage: tantalite mines at Atisbo, Iwajowa, Iseyin and Itesiwaju districts and marble mines at Igbeti. Notable mineralized pegmatites also occur in this region.

2.2. Geologic, hydrogeologic and geographic frameworks

Geologically, the study area is underlain by Precambrian basement complex composed of magnaties, gneiss and schist, which extend from Iseyin to the far north Kisi. The major rock unit in the study area is the undifferentiated meta-sediments in addition to granite, granite-gneiss and porphyritic granite. However, syenites are common and well exposed within and around Saki East, Saki West and Kajola districts of the study area, while there are occurrences of several pegmatite veins, as intrusion into the undifferentiated crystalline basement rocks, most of which are in gem stones, especially tourmaline (Tijani and Abimbola, 2003). Apart from the small hills and inselbergs, the bedrocks are generally covered by the weathered regolith usually composed of clay and sandy soils, which are lateritised in places, depending on the underlying bedrock types. The mineral deposits in the region include tantalite in Atisbo, Iwajowa, Iseyin and Itesiwaju districts, amphibolities in Atisbo, Kajola, Saki East and Saki West, Kaolin in Iseyin, Saki East and Saki West, gem stones in Saki West, Saki East, Atisbo, Itesiwaju and Kajola districts, Granites, sand and gravel in all the districts. These stones are of granite type and may contain a relatively high concentration of natural radioactivity.

Hydrogeologically, the groundwater system in the study area is greatly controlled by the bedrock geology. However, the system has been discovered to occur in localized and disconnected weathered regolith aquifers, essentially as unconfined to semi-confined, underground water table conditions (Tijani and Abimbola, 2003).

Geographically, Oke-Ogun region falls within the transitional zone between the rainforest in the south and the tropical savannah zone in the north. The vegetation is typically savannah woodland with scattered trees and grasses (Iloeje, 1981), while the topography is characterized by gentle undulating terrain with isolated inselbergs and small hills typical of a Basement complex terrain. There are two distinct seasons: dry and wet with relatively high humidity (60–80%). Temperature is high (25–32 °C) throughout the year with a mean value of about 27 °C. The region has an average atmospheric pressure of 1011 mb.

2.3. Radon measurements in schools

Radon concentrations in 35 schools distributed all over the Oke-Ogun area were determined using solid state nuclear track detectors (SSNTDs) technique (CR-39, poly allyl diglycol carbonate, named PADC). The trade name of the CR-39 were RADOSYS (http://www.radosys.com) manufactured by Radosys Ltd., Hungary. The detector is a membrane permeation sampler that excludes unwanted ^{219}Rn (half-life, $T_{1/2} = 3.96$ s) and ^{222}Rn (half-life, $T_{1/2} = 3.82$ d), along with the daughters that are produced after ^{222}Rn enters the detection space. The dosimeter gives a highly reproducible and unambiguous measure of ^{222}Rn (Durrani and Ilić, 1997).

The measurements were carried out during the rainy season from May to July 2008. During the rainy season, radon tends to be higher because it is confined underground by a layer of water-saturated surface soil which has much reduced gas permeability. So for a site that has a relatively low permeability, the wet layer becomes thinner than the monitoring depth and capping effect causes higher radon value during the rainy season. The period between May and July is characterized with heavy rainfall in south-western, Nigeria and during this period, windows and doors are usually closed and the radon readings are expected to be at their highest. It is normal to have more open windows in summertime (dry season) and consequently a lower indoor radon level than in the wet season (Durrani and Ilić, 1997).

The detectors were packaged in a cylindrical exposure chamber (Radopot), 23 mm × 40 mm in dimension, which provides a discriminative measurement of radon and thoron. Individual exposure chambers were sealed in an aluminium plastic bags to prevent extraneous exposure before deployment. The CR-39 detectors are square in shape, 10×10 mm^2 in size, 0.8 mm thick and have a density of 1.30 g cm^{-3}. About seventy detectors were distributed in the schools of Oke-Ogun area, which was divided into 7 districts (sites) namely: Iseyin, Itesiwaju, Saki-west, Kajola, Iwajowa, Atisbo and Saki-east as shown in Fig. 1. The detectors were exposed for a period of 3 months in classrooms used daily during normal school activities, at a height of about 1.5 m above the floor as representative of breath height inside the classrooms. After the exposure, the detectors were etched in 6 N NaOH at 90 °C for 3 h at the Radiation and Health Physics Laboratory, Department of Physics, University of Ibadan, Nigeria. Thereafter, the radon concentration was determined at the Radioactivity Laboratory, Department of Physics, University of Trieste, Trieste, Italy. Alpha-tracks caused by radon were counted under an optical microscope connected to a microcamera which was connected to a personal computer. The observed track densities (T_D) were converted into radon concentrations (R_n) in Bq m^{-3} using the calibration factor (CF) supplied by the manufacturer divided by the exposure time (Δt). That is:

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