Applied Radiation and Isotopes 71 (2012) 96–101

Contents lists available at SciVerse ScienceDirect

Applied Radiation and Isotopes

journal homepage: www.elsevier.com/locate/apradiso

Radon monitoring in sites of economical importance in Jamaica

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HIGHLIGHTS

- Touristic caves of economical importance shown no radon risk for workers and visitors.
- Maximum permanence time due to abnormal radon is given for caves used by speleologist.
- Despite high Rn and U in soil in bauxite areas no risk is determined in houses.

ARTICLE INFO

Available online 10 July 2012

Keywords:
Radon levels
Caves
Radon dose

ABSTRACT

The main task was to evaluate possible radon risk to the public and workers in four caves of economical importance.

Green Grotto Cave is a large labyrinthine limestone cave, open to the tourism; kept Rn concentration in the range 30–40 Bq m^{-3}. Xtabil a coral limestone sea cave is part of a beach resort resulted in very low radon concentration of 10 Bq m^{-3}.

Windsor is an intricate limestone cave system showed Rn concentration in the range 250–350 Bq m^{-3}. Whereas the Oxford caves, is situated in a region of high radioactivity in soil due to the bauxite mines, reached a maximum of 2592 Bq m^{-3}.

1. Introduction

An environmental radioactivity program carried out under a bilateral Mexican Jamaican agreement has been set in Jamaica, in order to assess the impact in three main areas of economical importance for Jamaica: Bauxite industry, Tourism and Agriculture.

The major bauxite deposits are located in the parish of St. Elizabeth at the south west of the island where high radioactivity levels permitted the association of uranium, radium and consequently radon to the presence and prospecting of this mineral (Grant et al., 2001). St. Elizabeth is also one of the most important agricultural areas in Jamaica; in addition, inside and nearby this parish there are two types of caves, those regularly visited by tourists and the ones visited by speleologists.

Therefore, it was decided to carry out a radon survey with two clear objectives; the first one being the determination of radon in four caves, two open to public tourism and two of speleologist interest for assessing the maximum occupation time in the caves. A second objective was to select some houses in St. Elizabeth parish together with others houses in a so called controlled site in Kinston, were the radioactivity levels are known to be low, to set for the first time radon indoor levels in Jamaica, which could help in a decision for more detailed studies. Further studies, not considered in this paper will consider radioactivity impact in agriculture activity.

Radon is a radioactive gas originating as an intermediate product of ^{238}U (^{222}Rn), ^{235}U (^{219}Rn) and ^{232}Th (^{220}Rn) decay series. The most abundant Rn isotope, ^{222}Rn, is released from soils and rocks depending on both the concentration and the distribution of its parent nuclide, ^{226}Ra. Soil radon gas can also be transported by advective fluxes of geogases (CO_2, H_2O, H_2S, CH_4) from deeper tectonic activity, however, our initial findings in a previous survey in central Jamaica revealed levels of soil radon gas, some of which were significant, strongly correlated ($r_2 = 0.86$) with radium content of the soil (Grant et al., 2001), indicating that most of the soil gas radon was as a direct release from the soil.

The health implications of radon inhalation have been well documented; it is considered by the World Health Organization, International Agency for Research on Cancer (WHOIARC) as a group 1 carcinogenic substance (Siemiatycki et al., 2005). In fact it has been estimated by United States Environmental Protection Agency (US EPA) that there are some 15,000–25,000 radon induced lung cancers annually in the US (Gates and Gunderson,

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http://dx.doi.org/10.1016/j.apradiso.2012.07.007

1992). National regulatory bodies in several countries have set action levels for indoor air. The ICRP has set action levels based upon an effective dose constraint of 10 mSv per year; assuming an equilibrium factor of 0.4 and 2000 h per year at work, this amounts to radon concentration of between 600 and 200 Bq m^{-3} for dwellings, with a corresponding range 1500–500 Bq m^{-3} (10–3 mSv) for the work place. (Ann. ICRP 23, 1993). The National Commission on Radiological Protection (NCRP) has set a level of 296 Bq m^{-3}, the USEPA 148 Bq m^{-3}, and the United Kingdom has set a level of 200 Bq m^{-3} for exposure at home, International Atomic Energy Agency (IAEA) set a value of 1000 Bq m^{-3} for work place exposure. Although exposure to radon is a complex problem, its restriction is often easily achieved once the problem has been identified. Simple remedial actions can often result in a significant reduction in exposures to ionizing radiation from this source.

2. Sites of study

The parish of St. Elizabeth, which has approximately 6% of the islands population, was selected to be the first study area because of the relatively high levels of radioactivity previously noted (Grant et al., 2001). The parish has an area of 1215 km^2. The most extensive lithological unit in the parish is Tertiary White Limestone Formation, which covers over half the parish and occurs at elevations ranging from below sea level to over 762 m high. It forms the cap of the great Limestone Plateau of Jamaica, thickening with dips in some areas to the south. The St. Elizabeth Plains divides it into two main masses, the northern limestone region has been weathered to produce typical karst country with sinkholes, and dry valleys in abundance, the southern plateau region is heavily dissected by faults. Seven homes were selected within the study area, these included four homes (1, 2, 3, 4) of contemporary design made from concrete and steel having running water and tiled concrete floors, and three homes (A, B, C) constructed from Wattle and daub a woven latticework of wooden stakes called wattles daubed with a mixture of clay and sand and straw to create a structure. These homes carefully selected cover areas of low, medium and high soil radon concentrations.

A control area selected for this study was the Liguanea Plains situated in the heart of Kingston Metropolitan area, Jamaica's largest urban area with approximately 28% of the islands population. Previous studies (Grant et al., 2001) had identified the Kingston Metropolitan area as a region of low radioactivity. The Liguanea Plains, which is an old alluvial Holocene fan, consists of a thick series of sand, gravel and clay deposits bordered on the north and the east by predominantly Tertiary limestone hills. The offices (O1, O2) and control home one (C1) were located in the plain, control homes two (C2) and three (C3) were located on the surrounding northerly and easterly limestone hills respectively. Homes of Wattle and daub or buildings constructed in similar manor were not identified in the control area.

Four caves were selected, two in regions of elevated radioactivity and two in a region low radioactivity but of great importance to the tourist industry.

In the low radioactivity area the Green Grotto Cave, located in the parish of St. Anne at the north central part of Jamaica, is one of the Islands major tourist attraction, it consist of a 1525 m long labyrinthine limestone cave system and a subterranean lake (Fincham, 1997). The Green Grotto Cave was the first attraction of its kind in the world to be awarded Green Globe 21 Certification in 2003. Also in low radioactive area, the Xtabi cave in Negrils West End is part of a beach resort and restaurant; the cave is visited regularly by guest and visitors who use the cave as a route to seashore some 10 m below; this type of coral limestone sea cave is believed to have been started by joints and fractures that have been widened initially by fresh-water solution; their subsequent enlargement is believed to be the result of stopping and wave action more than by salt-water solution (Aley, 1964)

In the elevated radioactivity area the Oxford Caves, located on the boarder of the parishes of Manchester and St. Elizabeth, is a fossil stream passage with a muddy floor, 10–15 m wide, 10–12 m high, and 765 m long that eventually ends in a mud choke (Aley, 1964). It has been reported that a great deal of damage has been done to this cave due to unsupervised visits and vandals. A second cave in an elevated radioactivity area is Windsor Cave, located in the parish of Trelawny, is one of the better-known caves on the island. This is a complexed limestone cave system almost 3 km in length and 20 m deep (Fincham A., 1997). It has seen much visitation over the years, has been mined for guano, and continues to experience tourism.

Locations of homes, caves and offices in study and control areas are displayed in Fig. 1.

3. Experimental method

3.1. Radon measurements

Two methods were used to assess radon concentration: an Alpha GUARD detector (Balcázar, 2008), which is capable of measuring environmental radon concentration in situ every 10 min simultaneously with temperature and humidity was used for the measurements of the control homes, offices and caves.

For the study area, which included many remote sites with difficult access, Kodak LR115 nuclear track etch detector film was used for home radon measurements. The measurement times were typically around 2 months; this ensured sufficient response on the film to provide an accurate radon reading. A detailed description of the measurement equipment and film processing has been given elsewhere (Grant et al., 2001).

3.2. Soil gas radon from radium

Approximately 1/2 kg, was collected from each of the home sites in the study area and control area as well as soil from University Campus (Offices site), obvious pieces of rock and vegetation were removed, and the samples were placed in double strength labelled plastic bags, and returned to the laboratory. The bulk soil samples were then dry sieved through 2 mm and then through 150 μm nylon sieves. Each fraction was placed in Kraft paper bags, air dried at an ambient temperature of about 30°C and subsequently oven-dried at approximately 45 °C for 12 h. The dried samples were then ground and homogenized in a Fritsch mortar-grinder and stored in polyethylene containers prior to analysis.

The soil gas radon concentration was estimated using a previously established relationship between soil gas radon and radium soil content over white limestone lithologies in Jamaica (Grant et al., 2001). Approximately 35 g of sample were placed in a 30 cm^3 plastic vial, the lid put firmly in place and sealed with paraffin film to prevent the leakage of radon gas. The vials were then left for a period of at least thirty days, for radon to reach secular equilibrium with radium, before measuring the activity of ^{214}Bi ($E\gamma = 609$ keV and $E\gamma = 1.76$ MeV) and ^{214}Pb ($E\gamma = 351.9$ keV). These isotopes are intense gamma emitters and rapidly reach secular equilibrium with radon. Each sample was counted for 50,000 s on a Canberra reverse electrode germanium photon detector with an efficiency of 15% at 1332.5 keV gamma rays. The detector was shielded with 0.5 cm of copper sheet surrounded by a 10 cm thickness of lead bricks. In addition to