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Evaluation of background radiation dose contributions in the United Arab Emirates

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ABSTRACT

The natural background radiation consists of three main components; cosmic, terrestrial, and skyshine. Although there are currently methods available to measure the total dose rate from background radiation, no established methods exist that allow for the measurement of each component the background radiation. This analysis consists of a unique methodology in which the dose rate contribution from each component of the natural background radiation is measured and calculated. This project evaluates the natural background dose rate in the Abu Dhabi City region from all three of these components using the developed methodology. Evaluating and understanding the different components of background radiation provides a baseline allowing for the detection, and possibly attribution, of elevated radiation levels. Measurements using a high-pressure ion chamber with different shielding configurations and two offshore measurements provided dose rate information that were attributed to the different components of the background radiation. Additional spectral information was obtained using an HPGe detector to verify and quantify the presence of terrestrial radionuclides. By evaluating the dose rates of the different shielding configurations the comic, terrestrial, and skyshine contribution in the Abu Dhabi City region were determined to be 33.0 ± 1.7, 15.7 ± 2.5, and 2.4 ± 2.1 nSv/h, respectively.

1. Introduction

Measuring the dose rate contributions from background radiation is essential to the nuclear industry. For instance in the event of a nuclear incident where radiation could be released, knowing the background radiation dose rate allows for the quantification of the potential dose from the released radiation. Presently there exists methods for measuring the total background radiation dose rate, however, these methods do not identify the source of each natural background component. Rather than simply measure the total background dose rate, this analysis consists of a unique methodology that allows for the quantification of the multiple contributions within the total background dose rate.

Natural background radiation consists of three major components; cosmic (primary and secondary), terrestrial, and skyshine. The primary cosmic radiation is made up of charged particles which are mainly protons with a small fraction of heavy ions. Secondary cosmic radiation occurs when these charged particles enter the atmospheric column, interact with its components and produce high energy mesons, muons, electrons, protons, neutrons, and photons (Patrignani et al., 2016). Cosmic radiation is considered to have a hard and soft component. The hard component consists of protons, neutrons, mesons, and high energy muons. The soft component includes electrons, positrons, photons, and low energy muons (Bacioiu, 2011). The second component is terrestrial radiation, attributed to gamma rays emitted from the decay of naturally occurring radionuclides and their daughter products located in the soil and air. These radionuclides consist of ^{4}K and the ^{232}Th, ^{235}U, and ^{238}U decay chains. The final component is skyshine which represents the atmospheric reflection of radiation from terrestrial and man-made sources (Kouzes et al., 2008). Determining the natural background radiation for a location and understanding the contributions of the different components provides a baseline from which elevations in the radiation dose rate can be detected. The purpose of this experiment is to quantify the different components of the natural background radiation in the Abu Dhabi City region of the United Arab Emirates (UAE).

2. Material

2.1. Radiation detection equipment

In order to accurately quantify the dose at any location and identify possible contributors to that dose two different portable detector

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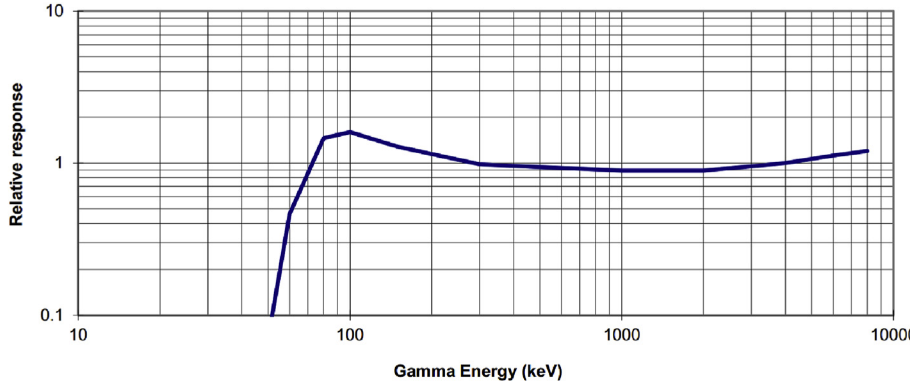

Fig. 1. HPIC relative efficiency with respect to photon energy (GE Energy, 2008).

systems were used for this project. A high-pressure ion chamber (HPIC), RSS-131, was used to quantify the dose rate while a Micro-Detective-HX HPGe detector was used to determine the terrestrial impact at different locations and shielding configurations.

2.1.1. High-pressure ion chamber

The HPIC is a sensitive detector for gamma radiation measurements (Accuracy of ± 5% at 10 μR/h). While extreme temperature environments, such as the United Arab Emirates, can affect the performance of radiation detectors, the HPIC has been designed to minimize its sensitivity to temperature fluctuations. The photon energy response range of the HPIC spans roughly 70 keV to several MeV, with a mostly flat response curve across this range, as seen in Fig. 1. One of the advantages of the HPIC is its spherical design, allowing a uniform angular response to incident photons (GE Energy, 2008).

2.1.2. High purity germanium Micro-Detective-HX

The Micro-Detective-HX is a mechanically cooled portable HPGe detector. The detector crystal consists of P-type HPGe with a diameter of 5 cm and a length of 4 cm. The full width half maximum (FWHM) is 1.33 keV at 122 keV and 2.04 keV at 1332 keV. In addition to the intrinsic temperature stability of HPGe detectors, the Micro-Detective-HX uses an automatic gain stabilization technique that utilizes the naturally occurring ^{4}K 1461 keV photoelectric peak when present (ORTEC, 2012).

3. Experimental and methods

3.1. Experimental measurements

A set of six different measurements were made, two offshore on a small boat and inflatable raft and four on flat vegetation free rural land each in a different shielding configuration. Considering the background radiation measured is made up of multiple components, each measurement was configured such that the components of the background radiation could be separable. For example, offshore measurements do not contain the terrestrial of skyshine components and on land measurements in certain shielding geometries can remove the terrestrial component while keeping the cosmic and skyshine components unaltered. These measurements were taken in the Abu Dhabi City region at approximately sea level elevation. Although not all the measurements were performed on the same day, they were within the same season and took place under approximately the same environmental conditions. The temperature during the measurements was moderate (30° Celsius) with minimal cloud cover and dust in the air. For all the measurements (except for the offshore inflatable raft) both the HPIC and HPGe detectors were used to collect data. Both detectors collected data for approximately one hour per measurement with the HIPC using an integration time of one minute.

3.1.1. Offshore measurements

The offshore measurements were conducted on a small boat and an inflatable raft. On water far enough from the shore, the contribution from skyshine and terrestrial can be assumed to be negligible. Thus these measurements isolate the cosmic component. However, the measurement on the small boat includes a slight contribution from the boat, its fuel, its cargo, and the large heavy metal battery power supply system. The measurement on the small boat occurred on March 27, 2016, during the morning hours. The location of the measurement was 2 km offshore of Abu Dhabi New Mina Port (N24.54389, E54.33614) at a water depth greater than 10 m. Fig. 2 shows a satellite image of the measurement location and surrounding area. This measurement location was selected because the distance from the shore and depth of the water should remove all land based terrestrial and skyshine components of background radiation (Mitchell et al., 2009). Fig. 3 shows a picture of the measurement configuration for the HPIC. The offshore measurement using the inflatable raft, shown in Fig. 4, was taken at approximately the same location and time of day on April 25, 2016. The inflatable raft with the HPIC detector in it was located approximately 25 m from the small boat during the measurement. No HPGe measurements were made in the inflatable raft.

3.1.2. Land measurements

In order to isolate each source of background radiation multiple measurements were made using four different shielding configurations. These configurations consisted of:

1 Unshielded – the detector was placed directly on the ground with no shielding materials near or around the detector. This configuration

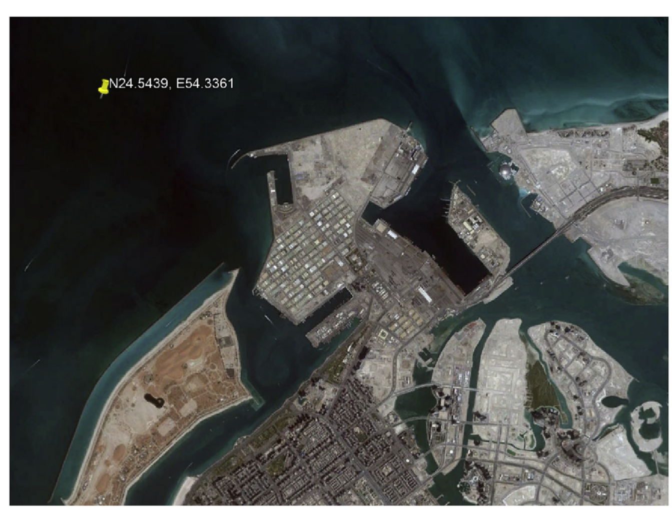

Fig. 2. April 2017 Google Earth image of offshore measurement location.

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