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Outdoor dose rate mapping in Kuwait

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ABSTRACT

As part of ongoing efforts to develop the data base required for the gamma dose rate baseline in Kuwait, a survey of ambient outdoor gamma-ray dose rates was carried out in 112 locations within the country. Measurements were performed, during the period from August 2013 to March 2016, in various undisturbed open areas in the desert using a NaI dosimeter/spectrometer. The dose rates were recorded along with the corresponding gamma-ray spectra for in-situ relative contribution of the primordial radionuclides and ^{137}Cs in the outdoor environment. Soil samples were also collected from the surface layers in a few locations for laboratory gamma spectrometric analysis and dose rate calculations. The dose rates obtained range from 31 to 59 nSv/h with a mean value of 46.5 nSv/h. There was no anomaly in the relative contributions of the primordial radionuclides to the dose rate values, while ^{137}Cs was not detected within the investigated locations. The significance of using the NaI-based dosimeter in the present survey is discussed in the paper.

1. Introduction

Some countries in the Arabian Gulf region are considering embarking on Nuclear Power Programme (NPP). The anticipated NPP in the region will require corresponding expansion in the national and regional capacities to develop data for estimating the potential radiological environmental impacts of the NPP. Well-documented baseline information on the pre-operational background radiation levels in the relevant countries will also be indispensable. Baseline gamma dose rates can be used as early warning and/or remedial actions references in the event of an environmental contamination (Maiello, 1997). Experience from other parts of the world, e.g. Finland (Koivukoski and Paatero, 2013), suggests that baseline information may be constructed by assembling different data sets generated from different projects using different devices and procedures.

In Kuwait, a number of background radiation and environmental radioactivity measurements have been carried out in the last two decades, some of which are potentially relevant for baseline determination. In 2002, following the Gulf War and the concerns of possible contaminations of the environment by “Depleted Uranium” (DU), scientists from the International Atomic Energy Agency (IAEA) carried out measurements and sampling at sites where DU munitions were used and where DU residues were stored (IAEA, 2003). The background radiation levels in Kuwait were found to be generally normal except at battle sites and the areas used as stores, which were reported to have elevated levels. Access to such areas remains restricted. Other scientific reports (Bou-Rabee, 1997; Bem and Bou-Rabee, 2004; KISR, 2008) also indicated no areas of anomalous background radiation in Kuwait. Recent measurements of dose rates along the roads and streets in Kuwait were carried out using a GM-dosimeter with GPS information also show normal levels (Al-Azmi, 2014).

As part of a national project on background environmental radiation monitoring a NaI-dosimeter/spectrometer was used in the present work to measure the terrestrial gamma dose rates in outdoor locations, including a future designated residential area in Kuwait.

2. Materials and methods

2.1. Measurement and sampling sites

Kuwait is located on the north-western coast of the Arabian Gulf. It is a flat desert-type country with relatively uniform sandy areas with altitudes reaching about 300 m in the west. 112 sampling sites were randomly selected within the entire country for dose rate measurements in undisturbed locations outside the residential areas, in the desert of Kuwait whenever accessible, as well as in two

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locations in the Failaka island. The sampling points also covered the Mutlaa area in north-central part of Kuwait due to its importance as a planned residential area. Although the results of some soil samples which were collected by the IAEA team within two nearby locations in the Mutlaa area showed normal levels (IAEA, 2003), the public are still concerned about the radiation hazards/levels in the area, thus this survey was expanded to include more locations within such an area.

In addition to the direct measurements of the dose rates using a portable dosimeter/spectrometer, 13 soil samples were also collected from the surface layer in some locations for laboratory analysis for their primordial radionuclide contents, which are intended for dose rate calculations.

2.2. Measurements of dose rates and acquisition of energy spectra

The ***identiFINDER 2*** scintillation dosimeter, which can be used as field gamma spectrometer for finding and identifying radionuclides, as well as to record the ambient gamma dose rates has been used throughout this survey for the in-situ measurements of dose rates. It has a 35 mm × 51 mm NaI(Tl) crystal with a sensitivity of about 9.5 cps/10 nSv/h within the energy range 20–3000 keV, allowing short-time sampling measurements to be performed with an acceptable accuracy. The energy discrimination against high-energy signals above 3000 keV makes this dosimeter capable of delineating a substantial part of the cosmic components of background radiation. However, the dose rate recorded by this instrument includes very small contribution (about 2–5%) from the cosmic dose rate component in a typical environment (Nagaoka, 1987). It may be noted that, the majority of the other gamma dosimeters (e.g. GM counter based dosimeters) where no energy-discrimination is used, the dose rate recorded is inclusive of that due to cosmic radiation. In such cases, the total dose rate readings constitute a significant component, particularly when the dose due to terrestrial sources are low (<100 nSv/h). Therefore, when surveys in regions which exhibit low levels of gamma dose, such as Kuwait, it is appropriate that recording the dose due to terrestrial sources only so that variations in the dose rate values in different places within the region of the study are better illustrated.

Many trips were made for measuring the dose rates in undisturbed areas. All the measurements were carried out on the afternoon/night time to avoid the direct sunlight on the measuring device. However, the dosimeter has a LED stabilization technique to avoid energy shift due to changes in ambient temperature, and re-calibration may be performed with a ^{40}K source, when necessary. The coordinates of the locations were recorded using GPS.

Gamma-ray energy spectra (20–3000 keV) were also acquired at the investigated locations for 2000 s and the spectra were analyzed with the objectives to find:

i) possible presence of artificial radionuclides in the environment, and
ii) relative contributions of the primordial radionuclides on the recorded dose rates.

During the field measurements, the ***identiFINDER 2*** was placed on a tripod stand at 1-meter height above the ground, Fig. 1.

2.3. Data logging and statistical analysis

Proper measurements of the dose rates in the field, as in surveys, based on manual read out of the dosimeters require sufficient measuring time to avoid statistical fluctuations and obtain values with acceptable accuracy. Thus, many researchers carry out their measurements using relatively long-time sampling intervals; alternatively, short-time measurements are repeated to obtain a representative mean value which appears to be more statistically correct than the individual readings. The more sensitive the dosimeter (such as those based on scintillation crystals), the shorter the time sampling intervals are required for the measurements (Goddard, 2002; Papachristodoulou et al., 2010; Yoshimura et al., 2004).

In an earlier study (Al-Azmi, 2013), an investigation was initiated to find out the appropriate time sampling interval and the minimum number of repeated readings that are required to obtain a representative mean for the gamma dose rate with a desired accuracy. Using a Geiger-Muller (GM) dosimeter, it was shown that the required number of repeated readings depends on the length of time sampling intervals used and the strength of the radiation field.

This finding was expanded further in the present work using a scintillation-based dosimeter that is much more sensitive than the GM-type dosimeters. Using the scintillation-based ***identiFINDER 2*** dosimeter (used in this survey), some radiation measurements were carried out to evaluate the use of short-time sampling intervals in radiation fields of various dose rate strengths. Therefore, a number of dose rate data-sets (each of 100 data points) were collected for sampling intervals of 1, 2, 5 and 10 min in different radiation field strengths covering the expected range of natural background radiation levels, from 5 nSv/h inside the lead shield to ~270 nSv/h for high dose rates when placing radioactive sources next to the dosimeter. The results are presented in Table 1, where it can be seen that the range of data becomes more confined (reduced deviations) for longer time sampling intervals and higher dose rate values.

Performing a statistical analysis, it is possible to construct a 95% confidence interval for the average (mean) μ using the formula:

Fig. 1. The handheld NaI dosimeter/spectrometer "***identiFINDER 2"*** on a tripod at the height of 1-meter in one of the northern locations in the desert of Kuwait.