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Soil radioactivity levels, radiological maps and risk assessment for the state of Kuwait

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HIGHLIGHTS

- Measurements made using high-resolution gamma-ray spectrometry for activity concentrations of ^{238}U, ^{232}Th and ^{40}K involving 184 analysed soil samples.
- The distribution of ^{40}K is observed to remain rather constant across the entire region of Kuwait.
- Results obtained indicate higher ^{238}U/^{232}Th ratio in the northern region relative to southern one.
- Measured radiological risk factors across the wider Kuwait environment are below world mean values.

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ABSTRACT

An evaluation of the radioactivity levels associated with naturally occurring radioactive materials has been undertaken as part of a systematic study to provide a surface radiological map of the State of Kuwait. Soil samples from across Kuwait were collected, measured and analysed in the current work. These evaluations provided soil activity concentration levels for primordial radionuclides, specifically members of the ^{238}U and ^{232}Th decay chains and ^{40}K which. The ^{238}U and ^{232}Th chain radionuclides and ^{40}K activity concentration values ranged between 5.9 ↔ 32.3, 3.5 ↔ 27.3, and 74 ↔ 698 Bq/kg respectively. The evaluated average specific activity concentrations of ^{238}U, ^{232}Th and ^{40}K across all of the soil samples have mean values of 18, 15 and 385 Bq/kg respectively, all falling below the worldwide mean values of 35, 40 and 400 Bq/kg respectively. The radiological risk factors are associated with a mean of 33.16 ± 2.46 nG/h and 68.5 ± 5.09 Bq/kg for the external dose rate and Radium equivalent respectively. The measured annual dose rates for all samples gives rise to a mean value of 40.8 ± 3.0 μSv/y while the internal and internal hazard indices have been found to be 0.23 ± 0.02 and 0.19 ± 0.01 respectively.

1. Introduction

Anthropogenic radioactivity comes in different forms and arises from a range of applications, including nuclear medicine, energy production, and industrial and agricultural applications. Anthropogenic radionuclides are released into the environment due to nuclear weapon tests, effluent discharges from nuclear facilities, and reactor accidents. Man-made radioisotopes discharged from such sources can be retained in environmental materials including soil. However, even with this artificial utilization of radioactivity, up to 85% of the typical human annual exposure dose received by the world population arises from naturally occurring radioactive material, NORM (UNSCEAR, 2000). Industrial processes involving NORM can also carry an associated radiological risk and therefore identifying, quantifying, evaluating and managing any such risks are important (Baeza et al., 2011; G. Xhixha et al., 2015; IAEA, 2003).

The State of Kuwait lies between longitude 46–48° east and latitude 28–31° north, is located in the Middle East at the tip of the Persian Gulf, bordered by Iraq and Saudi Arabia (Fig. 1) and covering a land mass area of 17,820 km^2 (UN, 2010). According to a recent estimate, it has a population of about 4 million (Government of

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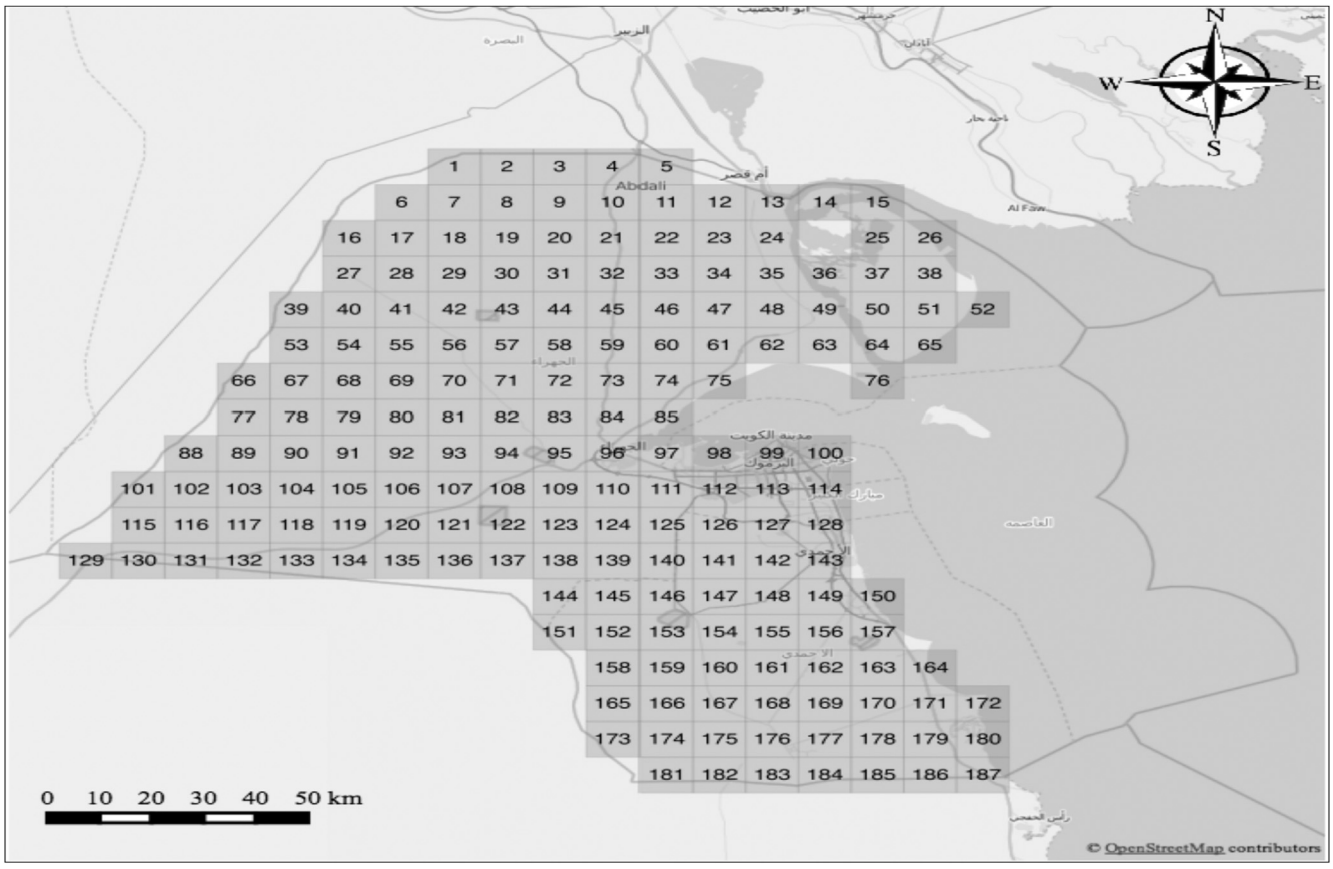

Fig. 1. The map of Kuwait, showing the sampling collection sites used in the current work.

Kuwait, 2014). According to Saad and Al-Azmi (2002) and Jallad (2013), the geological topography of Kuwait is relatively uniform, with smooth sand-sheets and having relatively consistent concentrations of radionuclides of natural origin.

The aim of this study is to produce a comprehensive radiation map of the State of Kuwait that is intended to serve as a reference for future radiological evaluations of the region. This is achieved by determining the levels of radioactive concentrations from the ^{238}U (^{226}Ra) and ^{232}Th (^{228}Ac) decay series, along with ^{40}K, using high resolution γ-ray spectrometry with a hyper-pure germanium detector retained in a low background configuration. Values from the measured activity concentration can be used to characterise the radiological risk associated with these sample locations. Results obtained from the analysis of 181 samples from across Kuwait are presented in this paper. There is a growing interest across the world to establish national baseline terrestrial radiation levels (Al-Jundi et al., 2008; Al-Sulaiti et al., 2011; Saad and Al-Azmi, 2002; Al-Hamarne and Awadallah, 2009; Dawood and Issa, 2011), intended to be of utility in evaluation and provision of future baseline values associated with other locations from the particular regions.

2. Material and methods

2.1. Sample collection and preparation

The 181 separate soil and sand samples that were collected from a wide variety of locations in Kuwait were shipped to the University of Surrey for further analysis, based on techniques that have been outlined in Santawamaitre et al. (2014). The samples were taken to the Environmental Radioactivity Laboratory at the University where they were sieved using a 2 mm sieve to remove any unwanted impurities such as twigs, vegetation and glass. After sieving, the samples were dried in a drying oven to remove any moisture present in the soil. Additional sieving using a 500 μm sieve was then performed to produce uniform and homogeneous samples. The sieved soil was put into Marinelli beakers and sealed with tape to be air tight, to prevent escape of gaseous decay progeny (eg.^{222}Rn). The beakers were then stored for a minimum of 1 month to achieve secular equilibrium between ^{226}Ra and ^{222}Rn.

2.2. Instrumentation and calibration

Two independent HPGe detectors were used for the gamma-ray spectrometric measurement of the samples. These systems both had measured FWHM energy resolutions of 0.8 keV and 2.0 keV for the 122 keV (^{57}Co) and 1332 keV (^{60}Co) lines respectively. Prior to beginning the measurements, both the detectors underwent full energy and full-energy peak total efficiency calibration procedures using four standard reference sources, viz, ^{226}Ra, ^{232}Th ^{152}Eu, and an NG3 mixed source containing ^{57}Co, ^{60}Co, ^{85}Sr, ^{88}Y, ^{109}Cd, ^{137}Cs, ^{139}Ce, ^{203}Hg and ^{241}Am. These gave accurate representations of the efficiency of the counting systems for soil samples. The standard sources were measured for 48 h and results were used for determination of the efficiency curve. Each of the sources was contained in a 550 ml Marinelli beaker of the same geometry as those used in the sample measurements.