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Technical report

Natural radiation background in the ancient city of Palmyra

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HIGHLIGHTS

► This work presents natural radiation measured in the ancient city of Palmyra.
► It was found that indoor Rn and radiation exposure rates are within Syrian BG levels.
► Results showed no relation between recorded cancers and radioactivity in the city.

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ABSTRACT

Natural radiation background has been determined for the Ancient City of Palmyra and its surrounding areas. Car-borne gamma spectrometry, indoor radon gas concentration and natural radionuclides levels in environmental samples (soil, water and plants) have been determined. Two types of dwelling were involved in this study, one with cancer cases, and the others without. The results showed that indoor radon gas concentrations and radiation exposure rates are within reported mean background levels in Syria (45 Bq m^{-3} and less than 0.1 μSv h^{-1}, respectively); no differences were noticed between the dwelling groups. In addition, the results did not indicate any relation between recorded cancers and measured natural radioactivity.

1. Introduction

Natural radionuclides have existed in the earth's crust since its creation and their levels vary over a wide range from place to place. These radionuclides may be concentrated in some non-nuclear processes such as in the phosphate, oil and gas and electricity industries, and can be transported to inhabited areas. Radiation emitted by these naturally radioactive materials contribute to the natural gamma radiation background, to which people are exposed (IAEA, 1988; ICRP, 1991; Behounek, 1970). potassium-40, uranium-238 and thorium-232 are the most important nuclides that contribute radiation dose to humans (UNSCEAR, 2000).

Radon is a noble gas produced by the radioactive decay of radium-226, which, in turn, is a product of the decay series of uranium-238 and widely distributed in soils and rocks. These decay products are often referred to as radon progeny or daughters. Because it is chemically inert, most inhaled radon is rapidly exhaled, but the inhaled decay products are readily deposited in the lung, where they irradiate sensitive cells in the airways, thereby enhancing the risk of lung cancer (Kunz et al., 1979). The concentration of radon in a home depends on the amount of radon-producing uranium in the underlying rocks and soils, the routes available for its passage into the home and the rate of exchange between indoor and outdoor air. Radon gas enters houses through openings such as cracks at concrete floor-wall junctions, gaps in the floor, small pores in hollow-block walls, and through sumps and drains. Consequently, radon levels are usually higher in basements, cellars or other structural areas in contact with soil (IAEA, 1996; NCRP, 1993; ICRP, 1991).

In many countries, some homes obtain drinking water from groundwater sources (springs, wells and boreholes) (Sohrabi, 1990). Underground water often moves through fractured rocks containing natural uranium and radium that produce radon. This is why water from deep drilled wells normally has much higher concentrations of radon than surface water from rivers, lakes, and streams.

2. Study area

Palmyra was, in ancient times, an important city of central Syria (Silk Road), located in an oasis 230 km northeast of Damascus and 205 km southwest of the Euphrates. It has long been a vital caravan

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city for travelers crossing the Syrian Desert and was known as the *Bride of the Desert*. Though the ancient site fell into disuse after the 16th century, it is still known as Tadmor in Arabic, and there is a newer town next to the ruins of the same name. The Palmyrenes constructed a series of large-scale monuments containing funerary art such as limestone slabs with human busts representing the corpse body (Ministry of Tourism MOT, 2005).

The climate is dry and hot, the vegetation is typically of semi-desert type. Oases with date-palm and olive trees are centered near permanent springs of high concentrations of sulphate and chloride anions. Palmyra inhabitants receive water for drinking and other uses from deep wells and this groundwater contains sulphide.

3. Geological sitting

Palmyra town is located at the northern edge of Syrian Desert and in the northern eastern limit of the Adaww basin, filled with Neocene-Quaternary deposits. That basin divides between the northern and southern palmyrides series. Palmyra town settles on Quaternary conglomerates, where it bounded from the north and west by palmyrides mountain relief which consist of limestone, dolomite, marl clay, phosphate and glauconitic nodules and beds, sometimes farraginous sandstone gypsum belong to Jurassic, Cretaceous and Paleocene age (Technoexport U.S.S.R, 1966).

To the south, the Sabkhet El-Mouh basin bounded the study area, where it is filled by Quaternary and recent of salinized loam, clay and lesser extent by sandy loam and gypsum due to evaporation effects. Aeolian deposits are found only along the eastern edge of Sabkht El-Mouh. These deposits are the erosion products of the surrounding mountain area.

People in Palmyra claimed to have cancer cases higher than usual which could be due to the existence of a high natural background. Therefore, the aim of this work is to determine natural radiation levels inside and outside dwellings of Palmyra city and its surroundings. Gamma radiation, dose rates, radon concentrations in air and drinking water in addition to gross alpha and beta in drinking water and natural radionuclides in environmental samples were measured.

4. Methods and measurements

Car-borne gamma spectrometry was used to map the gamma radiation levels in the new town of Palmyra. Gamma-ray spectrometry is an important remote sensing technique for detecting the apparent concentration of potassium, uranium, thorium and total radioactivity in the earth's surface (Aissa and Jubeli, 1997). Variations in the radioactivity of rocks may be useful for acquiring information on the distribution of radiation exposure rates (Raghuwanshi, 1992), as well as, for environmental monitoring (Tauchid and Jubeli, 1991).

The gamma-ray spectrometer system comprised a four-channel gamma-ray spectrometer (GAD-6, Scintrex, Canada) with a GSA-61 NaI(Tl) crystal contained in a thermally insulated case (1.852 L). It was mounted on an extended iron frame beyond the top of the vehicle, to reduce the attenuation caused by the metallic body of the vehicle. Distance-measuring equipment was connected to the speedometer of the vehicle to mark the location (fiducial-marks). Also a global position system (GPS) was used to mark the location of the start and end of the survey line. The vehicle moved at typically 15 km h^{-1} on the survey line.

Potassium, uranium, thorium, total gamma-ray counts and fiducials, were recorded cumulatively over 30 m count intervals by the four energy windows shown in Table 1, and stored on disk in real time, along the all survey tracks in Palmyra town and adjacent area. One clearly marked base station was established and it was measured at least twice or three times every day (morning, noon, and afternoon) throughout the survey period. This procedure aimed to monitor the daily variation of atmospheric radioactivity which is mainly caused by radon in air. The data obtained indicate that no significant variations were recorded. Processing of the carborne raw-data was done with the help of a PC, using modular software for the subtraction of the background count rates owing to the contributions of non-terrestrial sources. The background values were obtained by measurements over the Euphrates River.

Table 1
Specification of the counting windows.

Designation	Window setting (MeV)	Principal radioisotope detected
Potassium	1.38–1.56	^{40}K
Uranium	1.66–1.90	^{214}Bi
Thorium	2.44–2.77	^{208}Tl
Total-count	0.40–2.77	–

In addition, indoor radon concentrations in Palmyra town were investigated using passive integrating method, based on track detectors and called the passive radon diffusion dosimeter system (Othman et al., 1996; Shweikani and Raja, 2005). About one hundred radon diffusing chambers were distributed inside houses in Palmyra and its surrounding. Also TLD detectors were mounted on outside surface of these chambers to measure the gamma dose rate. Simultaneously, gamma dose rate and radiation survey were carried indoors and outdoors during the distribution of radon chambers using a portable instrument (RADOS RDS-110).

Two combined soil samples were collected from the Al Bayarat area (each sample is a combination of 9 samples collected from an area of 100 m^2), where people plant their crops. Gamma spectroscopy (HPGe detector) was applied to determine the natural radioactivity of the soil samples (Al-Masri et al., 2008).

Finally, radon in drinking water supplies and in tap water was measured. The emanation technique was used, where radon is extracted from water by degassing and collection in a scintillation cell (Lucas cell) (Othman and Yassine, 1996). The cell was left for 3 h to obtain equilibrium between radon and its daughters and counted. Also samples of drinking water were collected to measure the total alpha and beta concentration using a liquid scintillation counter (Al-Masri et al., 2007).

5. Results and discussion

5.1. Gamma radiation map

Fig. 1 shows the gamma contour of Palmyra city in which the total gamma counts were plotted against the measurements positions. It is clear that the highest values were obtained in the Al-Byarat area. These high counts were due to the irrigation process from wells with high radiam-226 activity concentration as discussed further below. The map shows also, that there were no high count rates in the whole area due to artificial sources.

About 100 homes were studied for γ exposure by direct measurement and by TLD dosimeters. Fig. 2 shows the results of measurements by the two methods. The results showed that the measured doses by electronic dosimeter were lower than the doses measured by cumulative dosimeter (TLDs). The mean dose rate with TLD measurements was 0.12 $\mu Sv\ h^{-1}$ with SD 0.03 $\mu Sv\ h^{-1}$ and this value fall within the average terrestrial exposure levels in Syria (about 0.1 $\mu Sv\ h^{-1}$) (Othman and Yassine, 1996). The difference in the results of the two measurements could be attributed to fact that the cumulative method (TLD) is more accurate than that of the electronic