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Indoor radon variations in central Iran and its geostatistical map

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HIGHLIGHTS

- A thorough 2 year indoor radon survey in central Iran (covering an area of 80,000 km^2).
- Analysis of indoor radon level variability.
- Estimation of population effective dose from radon.
- Presentation of radon geostatistical spatial distribution map for central Iran.

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ABSTRACT

We present the results of 2 year indoor radon survey in 10 cities of Yazd province in Central Iran (covering an area of 80,000 km^2). We used passive diffusive samplers with LATEX polycarbonate films as Solid State Nuclear Track Detector (SSNTD). This study carried out in central Iran where there are major minerals and uranium mines. Our results indicate that despite few extraordinary high concentrations, average annual concentrations of indoor radon are within ICRP guidelines. When geostatistical spatial distribution of radon mapped onto geographical features of the province it was observed that risk of high radon concentration increases near the Saqand, Bafq, Harat and Abarkooh cities, this depended on the elevation and vicinity of the ores and mines.

1. Introduction

The radon maps in many European countries and North America has been obtained and published (Wilkening, 1986; Crameri et al., 1989; Andam, 1992; Miles, 1998), such studies have started to pick up during past two decades in parts of Asia (Narayana et al., 1998; Mui and Wong, 2004; Singh et al., 2005; Badhan et al., 2010; Rafique et al., 2010), Latin America (Canoba et al., 2001; Magalhães et al., 2003; Espinosa and Gammage, 2003; Hadler et al., 2008) and Africa (Abo-Elmagd et al., 2007; Lindsay et al., 2008; El-Zaher, 2011; Saad et al., 2013).

Radon measurements started in Iran since 1968 (Taghizadeh and Eftekharnejad 1968). The atomic energy organization of Iran (AEOI) has developed measurement techniques since 1988 (Sohrabi and Solaymanian, 1988; Sohrabi, 1999). Indoor radon measurements have been accelerated during past two decades in Iran as well as other developing countries. The importance of indoor radon brought to the attention of local governments, have provided sufficient funds for such studies. Example of these studies are:

1 Measurement of Radon Concentration in dwellings around the hot spring in the north west of Iran was investigated using Passive method. The radon levels in the majority of measurements reported less than the lowest limit recommended action level by ICRP (Karamdoust et al., 1993).
2 The indoor radon in 1124 samplers in northern Iran were monitored using both passive and active measurements by solid state nuclear track detectors (SSNTDs) with CR-39 polycarbonate and PRASSI Portable radon Gas Surveyor. The mean value of radon level during the year in Lahijan, Ardabil, Sar-Ein and Namin were 163, 240, 160 and 144 Bq/m^3, respectively (Hadad et al., 2007).

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3 The Indoor radon concentrations in 30 homes in western Iran were measured using CR-39 alpha track-etch detectors. The average radon concentration and the effective dose equivalent were 108 Bq/m^3 and 2.7 mSv/y, respectively. They stated that the maximum radon concentration in Hamadan occurred during the winter period with lower concentrations during the autumn (Gillmore and Jabarivasal, 2010)

4 The radon level of residential dwellings in Shiraz were assessed using Solid State Nuclear Track Detectors (SSNTD), CR-39 polycarbonate films. The annual average indoor radon concentration was 94 ± 52 Bq/m^3 and annual effective doses were less than the limitation value recommended by ICRP (Hadad et al., 2011).

5 The indoor radon concentration in 150 apartments in Mashhad city were surveyed by PRASSI Portable radon Gas Surveyor. Result showed about 94.7% of apartments had radon concentration less than 100 Bq/m^3 (Mowlavi et al., 2012).

6 The radon levels in 650 homes during the year in the Sari province were obtained using dosimeters DOSEman. The amounts of radon were 28.615 Bq/m^3, 27.20 Bq/m^3, 27.07 Bq/m^3 and 36.95 Bq/m^3 in the spring, summer, autumn and winter, respectively. The study has concluded that the average radon concentration was higher in winter than other seasons (Rahimi and Nikpour, 2013).

7 Using portable radon gas surveyor, the radon level of 84 dwellings basement in the city of Yazd were measured in 15 min periods. Despite vicinity of Yazd uranium mines of Saghand (180 Km from Yazd city) the average Radon concentrations of the basements was found to be 137.36 Bq/m^3 (Bouzarjomehri and Ehrampoosh, 2008).

In the present study, the authors examine radon concentration inside dwellings of the major cities in Yazd Province. The parameters that affect radon concentration variations including building's location, age and residents literacy levels are determined. This work can help to prepare the Iran Radon Map.

1.1. Study area, geographic and historic features the Yazd area

The province is located in the central part of Iran, and covers an estimated area of 80,000 km^2. It consists of ten townships, 21 cities, 19 districts and 51 villages. Neighboring the important provinces of Fars, Isfahan, Khorasan and Kerman make the province a major cross road in central Iran. The bordering deserts of Kavir-e-Loot, Kavir-e Namak and Dasht-e Kavir, as well as a scanty rainfall give the province a dry climate. The existence of deserts and floating sand are the main geographical features of this province. The inexplicable silence of the desert attracts those who love profound beauties of nature.

Yazd province holds a diversity of geodynamic environments like volcanic arcs, metamorphic complexes, and plutonic bodies with their associated hydrothermal mineralization. Therefore, the amount of geological and exploration studies on this province are very high and considerable. This province is one of the exceptional areas on which systematic studies are conducted in both regional and thematic ones. The existence of basement rocks (Bafq-Posht-e-Badam zone), volcanic arc (Urumiyah-Bazman zone), and rift zones (Bafq-Posh-e-Badam zone) created a high mineral resource potentials for this province. Exploration studies are conducted in two regional and thematic ways.

In this paper we present the results of 24 months radon measurements in dwellings of Yazd province. 10 major cities whose populations exceeded 50,000 were surveyed. Fig. 1 shows the location of Yazd in Iran.

2. Material and method

2.1. Annual radon concentrations

Indoor radon sampling was carried out in 10 cities of Yazd province during two years. The map of this region is shown in Fig. 1. Sampling stations were chosen to be able to analyze the radon variation with population density, building age and elevation from see levels. Solid State Nuclear Track Detectors (SSNTD) with Lexan™ polycarbonate films was used as passive sampling instrument. The sampler consists of a 2.5 × 2.5 cm film placed inside a plastic diffusive holder. The sampler has been developed by Atomic Energy Organization of Iran (AEOI) and the detection, chemical etching and track density measurements and calibration have been fully explained in previous works in Ramsar (Sohrabi, 1999), Ardabil (Hadad et al., 2007), Shiraz (Hadad et al., 2011). The sensitivity of Lexan polycarbonate detector is 0.016 (tracks cm^{-2}/Bq m^{3}day) and based on background counts, a minimum detection level (MDL) of 6 Bq/m^3 was achievable (Hadad and Doulatdar, 2008).

Houses in 10 major cities in Yazd province were chosen in random to include different geological structures. In the Yazd city,

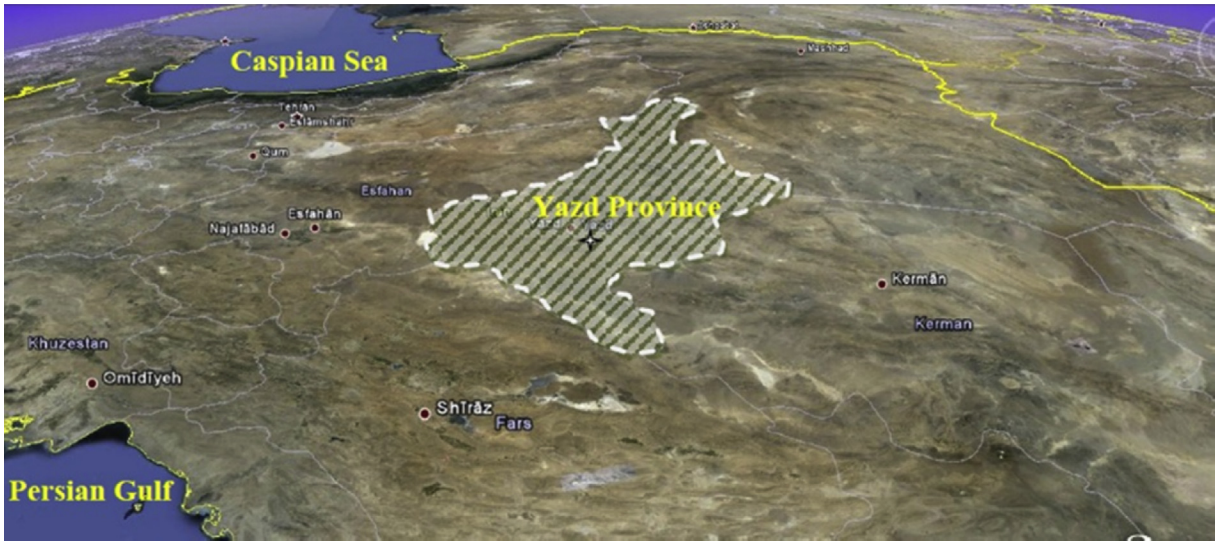

Fig. 1. Location Of Yazd province in central Iran.