Short Communication

Zahedan Journal of Research in Medical Sciences

Journal homepage: www.zjrms.ir

Survey of Gamma Dose and Radon Exhalation Rate from Soil Surface of High Background Natural Radiation Areas in Ramsar, Iran

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Article information

Article history:
Received: 27 Jan 2013
Accepted: 29 Feb 2013
Available online: 28 Apr 2013
ZJRMS 2013; 15(9): 81-84

Keywords:
Radon
Gamma dose
Iran

Abstract

Background: Radon is a radioactive gas and the second leading cause of death due to lung cancer after smoking. Ramsar is known for having the highest levels of natural background radiation on earth.

Materials and Methods: In this research study, 50 stations of high radioactivity areas of Ramsar were selected in warm season of the year. Then gamma dose and radon exhalation rate were measured.

Results: Results showed that gamma dose and radon exhalation rate were in the range of 51-7100 nSv/hr and 9-15370 mBq/m^{2}s, respectively.

Conclusion: Compare to the worldwide average 16 mBq/m^{2}s, estimated average annual effective of Radon exhalation rate in the study area is too high.

Introduction

Various experiments and studies done by researchers in Ramsar indicated high concentration of ^{222}Rn and its daughters in the air and soil of this region. Radon and its decay products (mainly which are alpha and beta emitter) are the main sources of exposure to radioactivity and a significant part (more than half) of the total effective dose received from natural and artificial radioactive sources [1].

Alpha particles can initiate a series of molecular and cellular events that culminates in the development of lung and other cancers [2]. Ramsar is known for having the highest levels of natural background radiation on Earth. According to the results of the surveys performed by the AEOI (Atomic Energy Organization of Iran), the radioactivity seems to be firstly due to the mineral water and secondly due to some travertine deposits having thorium content higher than that of uranium [3]. Inhabitants who live in some houses in this area receive annual doses as high as 132 mSv from external terrestrial sources and the maximum credible annual radiation exposures were up to 260 mGy [4].

One of the most important subjects which can strongly effect on radon concentration in air is its exhalation rate from soil. This type of study never has been done before in Ramsar. The main objective of this research is to estimate radon exhalation rate from soil surface but radon related measurements are usually a time consuming procedure. So instead of surveying all the area of Ramsar, we only focused on the places which have high amount of gamma dose rate. We assume that every place with high radon exhalation rate have high gamma dose rate too.

Materials and Methods

Natural Gamma dose usually in all area comes from three main natural radioactive decay series. In Ramsar many studies shows that high gamma dose rate comes from ^{238}U decay series, which at the end lead to radon and its daughters. As a result in many areas high gamma dose rate could be equal to high radon production. High radon production is not usually equals to high radon exhalation rate because it is function of many parameters which has to determine by point to point measurement.

Ramsar lies on the coast of the Caspian sea and north of the Alborz mountains, the city is located between 50º 21’ to 50º 46’E longitude and 36º 34’ to 36º 58’N latitude. [5]. This field study was performed on 50 stations in high radiation areas of Ramsar (Fig. 1) from 2012 Jun to August, so that at first, the location of each station was recorded in terms of longitude and latitude through Global Positioning System (GPS), then to perform the measurements, clearing the relevant surface of any grass, gravel and plant roots. To measure the radon exhalation rate from soil surface, AlphaGuard detection system PQ2000Pro (produced by Genitron Company, France), radon collection chamber with specified dimensions, Alpha pumps, and connecting tubes were used. The radon collection chamber was placed on the ground surface from its open side, and its surroundings were covered to prevent any air exchange with environment. Then a closed cycle was created between the air of collection chamber, the AlphaGuard and the alpha pump, which resulted in the discharge of the air from the chamber to the AlphaGuard volume with the rate of 1Lit/min for a period of 90 minutes (Fig. 1).

In this method, changes in the radon concentration in the chamber were used as a function of time to estimate the exhalation rate from the ground surface. AlphaGuard device continuously records the concentration in the chamber every ten minutes. Radon exhalation rate from surface is obtained from the following equation as an estimation of radon level changes in the collection chamber related to the time which is increasing as an exponential function:

$$\emptyset = \frac{\Delta C}{\Delta t}.\frac{V}{S} \quad \rightarrow \text{P}.\frac{V}{S} = \text{P}.\omega \text{ with } \omega = \frac{V}{S}$$

It is noteworthy that the reverse release and air movement have been neglected in this equation [6].

$\emptyset$: Radon Surface exhalation rate, Bqm^{-3}

Δc: Variation in radon activity concentration during the time interval, Bqm^{-3}

V: Useful volume, m^3

S: Useful surface, m^2

P: slope of the straight line fixed to the increasing radon concentration points in the exhalation box.

Δt: Period in which the radon concentration changes were occurred, per second

Besides measuring radon, the gamma dose rate was measured by a portable gamma spectrometer GR-130 Mini spec (produced by Exploranium Company, Canada) at one meter height from ground level. To evaluate gamma dose rate in each station and to determine the risk level, the system was set in dose meter and by setting at average of 5 second, a mean of 5 data (one data per second) is achieved in this interval. Finally, the average of 15 data was considered as gamma dose rate as n.sv per hour [7]. Furthermore, some environmental parameters such as temperature, pressure, relative humidity, soil moisture status and also weather conditions at the time of measurement were recorded. After all we use SPSS-20 for statistical analysis.

Results

Figure 2 shows frequency distribution graph of each element separated by station, depicts gamma dose rate and radon exhalation rate in stations where their levels were above 300 mBq/m^{2}s. Radon Exhalation rate ranged 9-15370 mBq/m^{2}s with a highest level of 15370 mBq/m^{2}s in station 34. Gamma dose rate ranged 58-7100 nSv/hr with a highest level of 7100 nSv/hr in station 1. Relative humidity was less than 40% in only 2% of the studied stations, while in 36% of the stations it was above 70% and in the rest it ranged 40-70%. At measurement day, the soil was dry in 52% of stations, semi-moist in 38% of stations, and wet in only 10% of stations. Weather conditions on the day of measurement were partly cloudy for 50% of the stations, sunny for 40% of the stations and cloudy for 5% of the stations. Due to severe skewness of radon exhalation rate variables and gamma dose rate and to eliminate the effect of large outlying values of these two variables, we used base-10 logarithm change of variables, through with the normality of radon exhalation rate and gamma dose changed variables was established and radon exhalation rate and gamma dose in new scale were obtained 2.5±0.7 and 2.3±0.5, respectively.

Table 1 represents Spearman's correlation between radon exhalation rate in the first scale and Pearson correlation of this variable in the new scale with other variables measured on a quantitative scale.

Based on the conducted studies, it is observed that with reduced soil moisture and weather conditions changing into sunny, radon exhalation rate increases. Although the negative correlation between radon exhalation rate and the distance from hot springs is significant (i.e. with increasing distance from hot springs, radon exhalation rate decreases), but the correlation level is low. To simplification and eliminating the effects of temperature and humidity on radon exhalation from soil, we did the experiment in days with approximately same weather conditions. As the climate of Ramsar is moderate and we did the experiments in one season with the approximately same pressure, temperature and humidity conditions. We could not find any strong correlation between these three parameters and radon exhalation rate from soil surface.

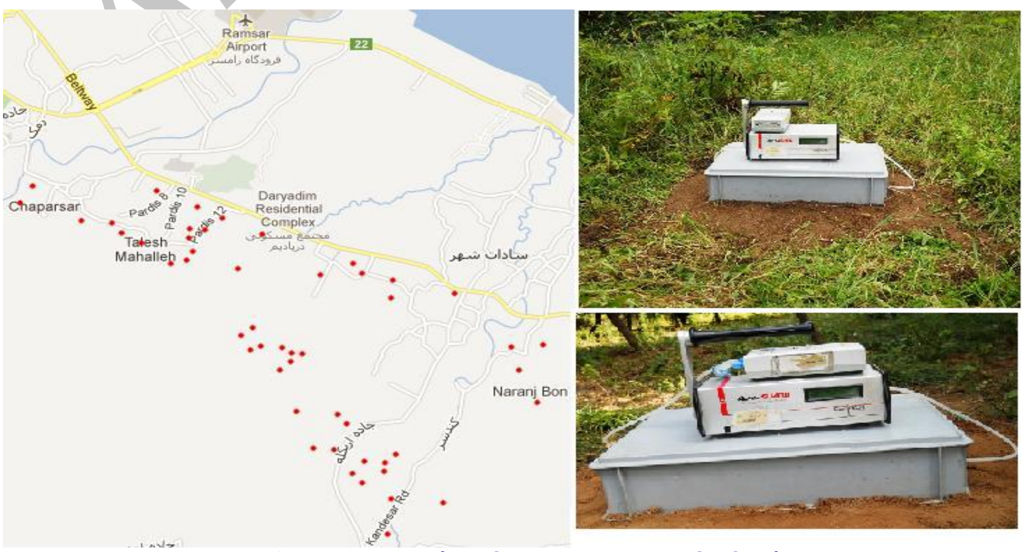

Figure 1. Position of sampling stations on map and soil surface

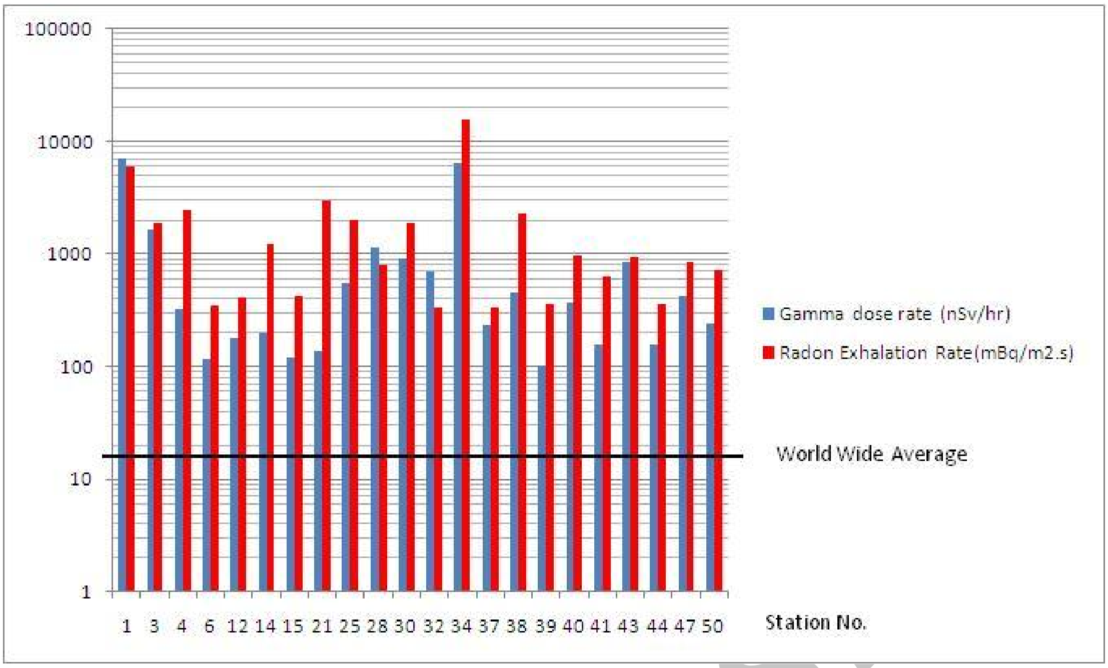

Figure 2. Frequency distribution graph of stations where their radon exhalation rates levels were above 300 mBq/m^{2}s

Table1. Represents Spearman's correlation between radon exhalation rate in the first scale and Pearson correlation of this variable in the new scale with other variables measured on a quantitative scale

Variable	Spearman 's rho (*p*-Value)	Pearson's 's correlation (*p*-Value)
Temperature (ºC)	0.159(0.27)	0.175(0.23)
Pressure (m.bar)	-0.04(0.78)	0.036(0.8)
Humidity	-0.16(0.27)	-0.13(0.36)
Distance from mineral springs (m)	-0.27(0.06)	-0.32(0.025)
Gamma dose rate (n.sv/hr)	0.71(<0.001)	0.75(<0.001)

Discussion

Results showed that gamma dose and radon exhalation rate were in the range of 51-7100 nSv/hr and 9-15370 mBq/m^{2}s, respectively. In this study only gamma dose rate and soil type are effective on radon exhalation rate. Generally wherever the gamma dose rate was high, the exhalation rate of radon at that station was a relatively high number.

Based on the results of 50 measurement stations,the highest level in Khak-Sefid region (15370±1780 mBq/m^{2}s) and next in Talesh Mahalleh region (5998±709 mBq/m^{2}s) which were critical areas of Ramsar in terms of radiation. Radon exhalation rate from soil surface reported from different areas are 3-37 mBq.m^{-2} s^{-1} in Japan [8], 1.1-41.9 mBq.m^{-2}s^{-1} in North-West of Slovenia [9], 20.71-72.51 mBq.m^{-2} s^{-1} in China and the maximum observed exhalation rate is 620.76 mBq.m^{-2} s^{-1} in Zhuhai area [10], 114-416 mBq.m^{-2}s^{-1} in Pakistan [11], and 3.92-16.51 mBq.m^{-2} s^{-1} in southern Egypt [12]. Global mean of radon exhalation rate is 16 mBq.m^{-2}s^{-1} [13]. Comparison of radon exhalation rate obtained in Ramsar with other countries shows the special status of this region in terms of high levels of radon exhalation rate. 84% of points had a rate of more than 100 mBq/m^{2}s and 20% of points had a rate more than 1000 mBq/m^{2}s. Radon concentration varies widely from place to place.

Thus, due to high level of natural radioactivity in some areas of this city, necessary provisions should be considered for construction in these areas to avoid radon entrance into residential buildings. Nowadays, various methods are used to reduce its risks in different countries and regions of the world, such as reducing radon entry from the soil surface into the building through making radon wells, sealing of building floors and walls, increasing under building ventilation, installing a positive pressure system, improving building ventilation, and use of PVC flue pipe for transmission of gas from the base of the building to the roof [14].

Since radon is highly soluble gas in the water, it can also reach to houses through ground waters and surface waters. In addition, since warming and creating turbulence in the water, and retention time can help the gas to exit the water, it is proposed to use surface waters which have less radon gas due to turbulence and required retention time, instead of underground waters [15]. However, due to the relatively long history of investigation of radon gas by Iranian researchers, optimization of local methods, enforcement of construction laws and closely monitoring their performance, and use of alternative building materials can reduce the probable risks of radon gas in this high-risk area.

Acknowledgements
This research project approved by the Msc student research projects No. 9135 the environmental health engineering, which has been implemented in the Ramsar area. The author of this paper is expressing his deep sense of gratitude to kashan university of medical sciences, and National Radiation Protection Department, Iran Nuclear Regulatory Authority that the credit facilities were provided and the Help and support of Research Center of Ramsar.

Authors' Contributions
All authors had equal role in design, work, statistical analysis and manuscript writing.

Conflict of Interest
The authors declare no conflict of interest.

Funding/Support

Kashan university of medical sciences, and National Radiation Protection Department, Iran Nuclear Regulatory Authority.

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Please cite this article as: Dehghani R, Fathabadi N, Kardan M, Mohammadi M, Atoof F. Survey of gamma dose and radon exhalation rate from soil surface of high background natural radiation areas in Ramsar, Iran. Zahedan J Res Med Sci (ZJRMS) 2013; 15(9): 81-84.