COMPLEMENTARY MEASUREMENTS OF RADON CONCENTRATION IN WATER SOURCES AND NATURAL EXPOSURE IN DWELLINGS IN THE VICINITY OF THE RAMSAR HLNRA, IRAN

by

Mehrdad AMIRZADI [1], ***Seyed Mahdi HOSSEINI POOYA*** [2, 3*], ***Mehran TAHERI*** [2], ***and Asad BABAKHANI*** [2, 3]

[1]Department of Physics, Faculty of Basic Sciences, Azad University – Tehran Branch, Tehran, Iran
[2]National Radiation Protection Department, Iran Nuclear Regulatory Authority, Tehran, Iran
[3]Radiation Application Research School, Nuclear Science and Technology Research Institute, Tehran, Iran

Technical paper
DOI: 10.2298/NTRP1204399A

Tonekabon is a big city in the vicinity of the high level natural radiation area of Ramsar, Iran. Natural exposure due to gamma and radon concentration in 100 dwellings in the city has been measured using a thermoluminescent dosimeter and a radon diffusion chamber, respectively, over four seasons. Using active and passive methods (*i. e.* ZnS scintillation detectors and homemade radon diffusion chambers), the concentration of dissolved radon in water sources has been measured in both cities and frequency distributions of doses studied for radon measurements.

Results show a daily average gamma dose of 4.2 0.8 μSv and an average radon concentration in air of 232.5 187 Bq/m^3 in dwellings. Frequency distributions show that 85% of the dwellings have an average radon concentration of 100 to 300 Bq/m^3 per year and that 80% have a maximum seasonal radon concentration of up to 400 Bq/m^3. The maximum concentrations of dissolved radon in water in Ramsar and Tonekabon have been measured as 198 30 and 109 16 BqL^{-1}, respectively.

Key words: radon, high level natural radiation area, passive measurement

INTRODUCTION

High level natural radiation areas (HLNRA) in the world are numerous. Such areas are well known in states like Kerala in India, [1], cities like Yangjiang in China [2], Ramsar in Iran [3], Niška Banja in Serbia [4], as well as the Flinders Ranges in Australia and the town of Guarapari in Brazil.

Ramsar, a city in the north of Iran, near the Caspian Sea, is a world-famous HLNRA. In the past, many studies on the indoor and outdoor exposure in the area have been carried out [3, 5]. The reason for the high exposure in the area is the high concentration of ^{226}Ra in water sources, as well as in natural building materials, so that the annual natural exposures may reach up to 100 mSv [3-5].

On the other hand, the extent of the HLNRA has not yet been fully examined. Tonekabon is a big city 30 km away from Ramsar, with many natural water sources and ancient houses.

In this research, the indoor gamma/radon exposures in Tonekabon, along with their frequency distributions, have been investigated in a year-long seasonal survey. In both cities, concentrations of dissolved radon in water have been measured for some water sources such as rivers, spa pools, natural sources and fish pools, as well.

* Corresponding author; e-mail: mhosseini@aeoi.org.ir

MATERIALS AND METHODS

Area of measurement

Figure 1 shows the area maps of measurements for both the city of Ramsar and that of Tonekabon. Approximate sampling points of water sources, along with their local names, are also shown.

Type of used detectors

In this research, both active and passive methods of measurement have been used for gamma dose and radon measurements, as:

– LiF: Mg, Cu, P, TLD, for passive gamma ambient dose measurements,
– a type of a calibrated diffusion chamber based on a solid-state nuclear track detector (SSNTD), for

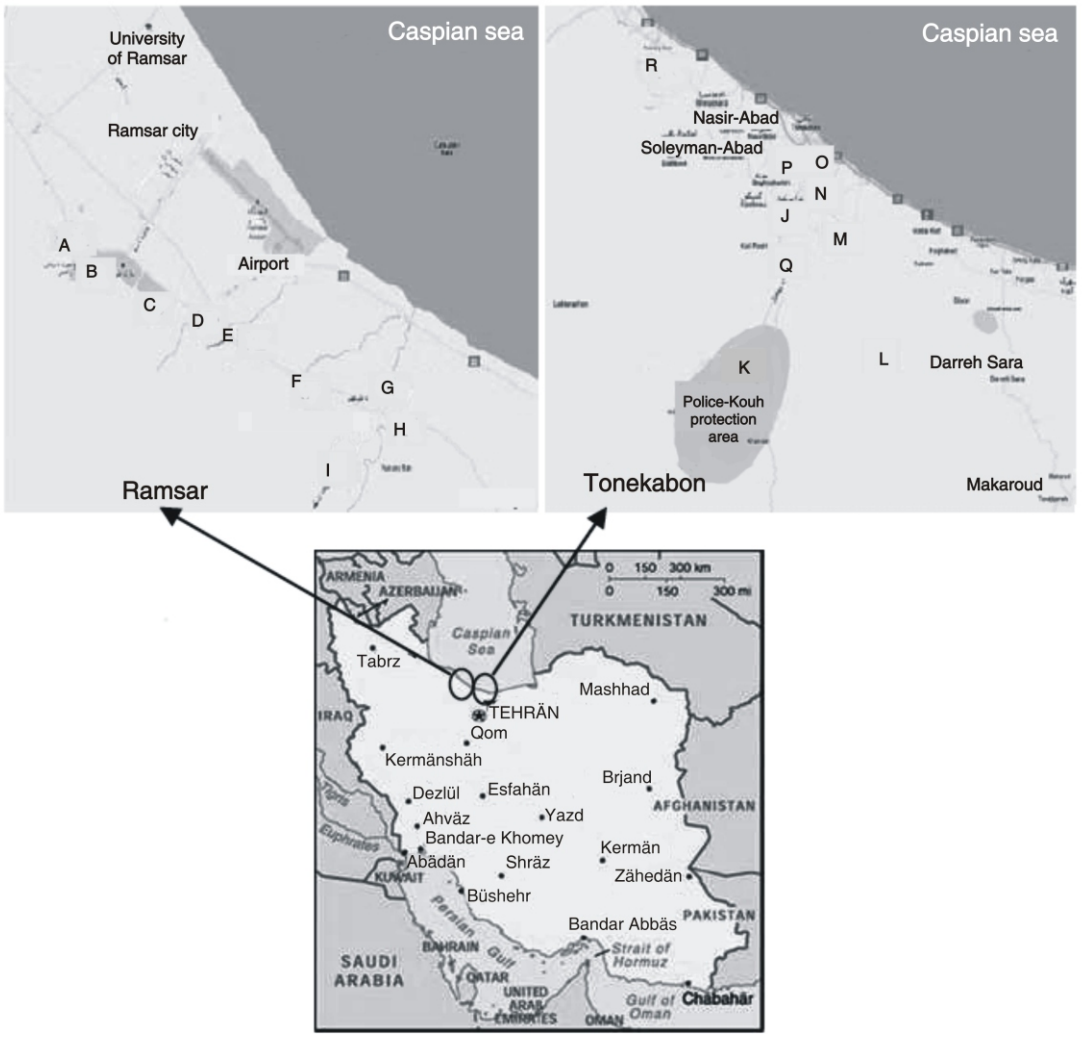

Figure 1. Area maps of measurements for cities of Ramsar and Tonekabon. The approximate positions of water sources with their local names are as follows:
A – Hotel Ramsar, B – Hotel spa (Madar-shah), C – Sakht-sar spa, D – Talesh-mahalleh river, E – Talesh-Mahalleh natural source, F – Khak-sefid natural source, G – Sadat-shahr spa, H – Eshger spa, I – Sang-boneh spa, J – Kenar-jouibar fish pool, K – Do-hezar natural source, L – Falakdeh natural source, M – Mian-nahieh fish pool, N – Akbar-abad fish pool, O – Shirij-mahalleh fish pool, P – Khorram-abad fish pool, Q – Kal-poshteh natural source, R – Baramsar fish pool

passive radon measurements in air and in dwellings [6],
– a calibrated ZnS scintillation cell of a Pylon AB-5 model, for active measurements of radon in water (see fig. 2), and
– a diffusion chamber, for passive measurements of radon in water. The method is schematically shown in fig. 3.

Measurement process

Seasonal measurements of both the gamma ambient dose and radon concentration in air have been carried out in 100 dwellings in Tonekabon over a year.

For this purpose, two TLD pellets were placed inside each radon chamber, under its SSNTD film, so that the gamma dose and radon concentration for the

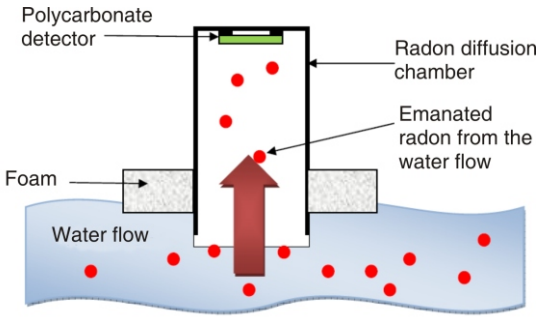

Figure 2. Passive measurement method of the dissolved radon in water. The radon emanates from the water into a floating diffusion chamber and then starts to decay. The produced alpha particles may affect the polycarbonate on the SSNTD

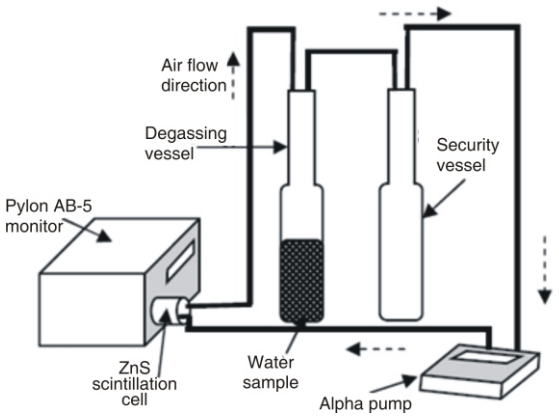

Figure 3. Active measurement method of the dissolved radon in water. The radon emanates from the water sample into a degassing vessel and then flows into a scintillation ZnS cell via an air pump. The Pylon monitor then counts the emitted alpha particles

same sampling point could be simultaneously determined.

The dissolved radon concentrations of selected water sources in Ramsar and Tonekabon have been measured during the rainy seasons (*i. e*. autumn and winter), when the level of water in natural water sources is appropriate for this type of measurements.

RESULTS AND DISCUSSION

The average value of gamma ambient doses and radon concentrations in the 100 dwellings in Tonekabon city are shown in tab. 1. As can be seen in the figure, the measured values for both gamma dose and radon concentration are highest in spring. Although the ambient gamma dose value is generally not so high in the area, its higher value in spring is meaningful in comparison with that of the related value for radon.

Frequency distributions of radon concentration in dwellings are shown in fig. 4. The distribution of annual radon concentration fig. 4(a) shows that 85% of the total number of selected dwellings have an average radon concentration value between 100 to 300 Bq/m^3, whereas 3% have values over 500 Bq/m^3, placing them in the range of high concentrations. In addition, the distribution of seasonal radon concentration fig. 4(b), shows that 80% of the total numbers of selected

Table 1. Average values of gamma ambient doses and radon concentrations in 100 dwellings of Tonekabon city in different seasons

	Spring	Summer	Autumn	Winter
Ambient daily gamma dose [μSv]	5.7 0.8	3.9 0.9	4.1 0.9	3.0 0.7
Radon concentrations in air [Bqm^{-3}]	279.1 204	224.3 219	221.2 191	206.9 135

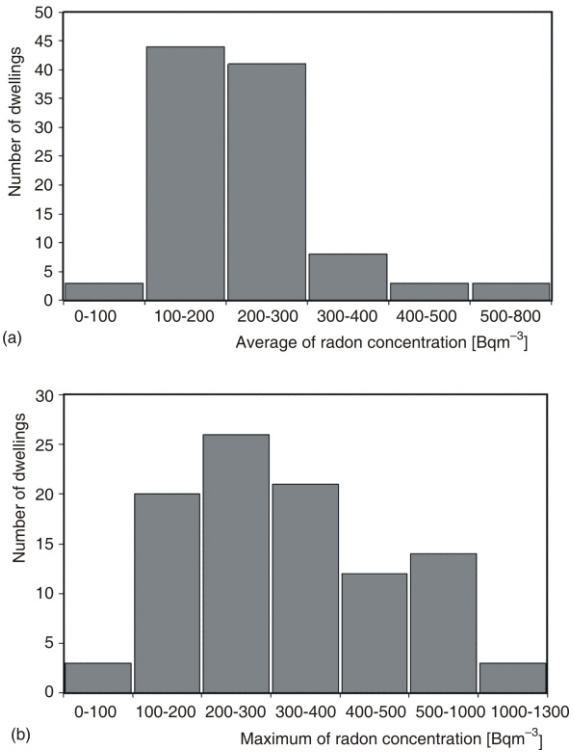

Figure 4. Frequency distributions of radon concentration in dwellings: (a) average values of annual radon concentration, (b) maximum values of seasonal radon concentration

dwellings have a maximal radon concentration of 100 to 400 Bq/m^3. However, 17% of them have a value over 500 Bq/m^3, which is a considerable value for dwellings [4].

The average annual effective dose from inhaled radon progeny in dwellings, *E*, is

$$E \quad C \quad F \quad DCF \quad OF \quad 8760 \qquad (1)$$

where *C* is the radon concentration, *F* – the equilibrium factor of radon which is 0.4 for indoors, *DCF* – the dose conversion factor which is 9 nSv per hour in the equilibrium equivalent concentration (*EEC*) condition, and *OF* – the occupancy factor, which is 0.8 for indoors [7]. Since the average value of radon concentration in Tonekabon is 232.5 187 Bq/m^3, the approximate average annual dose from radon progenies inhalation is given as 5.8 4.7 mSv. Considering the total annual gamma dose of 1.5 0.3 mSv from tab. 1, the average of total natural exposure in Tonekabon could be 7.4 5.0 mSv, three times the world wide average natural exposure value by UNSCEAR-2000 (*i. e*. 2.4 mSv per year) [7].

The values of dissolved radon concentrations in water which have been measured by the active method for both cities are shown in tab. 2.

In order to verify these measurements, the passive method has also been used for the selected points, shown in tab. 2.

Table 2. The value of dissolved radon concentrations in water sources which have been measured by the active and passive methods in both Ramsar and Tonekabon. (Measurement points are shown in fig. 1)

Point of measurement/type of water source	Radon concentrations in water in autumn [BqL^{-1}]		Radon concentrations in water in winter [BqL^{-1}]	
	Active method	Passive method	Active method	Passive method
A/spa	57.1	50.2	87.9	90.1
B/spa	91.3	–	51.4	–
C/spa	107.6	122.6	49.2	61.5
D/river	16.3	–	15.4	–
E/natural source	167.4	–	198.6	–
F/natural source	12.1	–	12.9	–
F/spa	1.1	–	24.2	–
H/spa	55.6	–	24.3	–
I/spa	13.0	–	23.4	–
J/fish pool	18.1	–	*	–
K/natural source	1.1	–	1.4	–
L/natural source	9.8	13.8	109.5	61.8
M/fish pool	2.3	–	1.8	–
N/fish pool	5.9	–	9.4	–
O/fish pool	33.1	–	35.5	–
P/fish pool	27.0	–	5.5	–
Q/natural source	29.6	20.8	*	*
R/fish pool	14.6	17.6	*	*

*not accessible at the time of surveying

The compatibility of the results for both active and passive methods shows the accuracy of these measurements (except that of the L point in winter, which is related to measurements at different sampling times and points).

Since there are no internationally accepted criteria for radon concentration in water, we can compare the results with those of the Environmental Protection Agency (EPA), USA, for drinking water. According to the said criteria, standard concentration values less than the 300 pCi/L (10 Bq/L) do not call for treatment of water for radon. Concentration values over the 4000 pCi/L (150 Bq/L) standard need some mitigation programs so as to reduce the concentration of radon [8]. Fortunately, most of the water sources in tab. 2 are not drinking waters and their radon concentrations are less than the EPA criteria. But, particular attention should be paid to swimming pools in spas and similar water areas with a high level of radon concentration, since no criteria for cases such as these are in existence.

CONCLUSION

In the city of Tonekabon, situated near the HLNRA of Ramsar, exposure to both the natural gamma dose and radon inhalation may well be approximately three times that of the worldwide average. The value of dissolved radon in water sources in both cities can be expected to reach approximately 200 Bq/L. However, most of these waters are not used as sources of drinking water. Nevertheless, special care should be taken even in cases of alternative usage.

AUTHOR CONTRIBUTIONS

Practical measurements were carried out by M. Amirzadi and M. Taheri. The analysis of results was carried out by S. M. Hosseini Pooya. Manuscript was written by S. M. Hosseini Pooya, and the advisors of this work were M. Taheri and A. Babakhani.

REFERENCES

[1] Krishnan Nair, M., *et al*., Population Study in the High Natural Background Radiation Area in Kerala, India, *J. Rad. Res., 152* (1999), pp. S145-S148
[2] Morishima, H., *et al*., Dose Measurement, Its Distribution and Individual External Dose Assessments of Inhabitants in the High Background Radiation Areas in China, *J. Rad. Res., 41* (2000), Suppl., pp. 9-23
[3] Sohrabi, M., Solaymanian, A. R., Indoor Radon Level Measurements in Some Regions of Iran, *Nucl. Tracks. Radiat. Meas., 15* (1988), pp. 613-616
[4] Žunić, Z. S., A Comparison of Retrospective Radon Gas Measurement Techniques Carried Out in the Serbian Spa of Niška Banja, *Nucl Technol Radiat, 24* (2009), 2, pp. 94-99
[5] Sohrabi, M., *et al*., Determination of ^{222}Rn Levels in Houses, Schools and Hotels of Ramsar by AEOI Passive Radon Diffusion Chambers, *Proceedings*, International Conference, High Levels of Natural Radiation, Ramsar, Iran, 1990, pp. 365-375
[6] Sohrabi, M., Solaymanian, A. R., Some Characteristics of the AEOI Passive Radon Diffusion Dosimeter, *Nucl. Tracks. Radiat. Meas., 15* (1988), pp. 605-608
[7] ***, UNSCEAR- United Nations Scientific Committee on the Effect of Atomic Radiation, 2000
[8] ***, EPA-Environmental Protection Agency, Technical Fact Sheet: Proposed Radon in Drinking Water Rule, 1999

Received on May 14, 2012
Accepted on October 11, 2012

**Мердад АМИРЗАДИ, Сејед М. ХОСЕИНИ ПУЈА,
Мехран ТАХЕРИ, Асад БАБАКАНИ**

КОМПЛЕМЕНТАРНА МЕРЕЊА КОНЦЕНТРАЦИЈЕ РАДОНА У ВОДИ И ПРИРОДНОГ ИЗЛАГАЊА У ОБЈЕКТИМА У ОКОЛИНИ РАМСАРА, ОБЛАСТИ ВИСОКОГ НИВОА ПРИРОДНОГ ЗРАЧЕЊА У ИРАНУ

Тонекабон је велики град у близини области Рамсар у Ирану која има висок ниво природног зрачења. У 100 градских објеката мерено је природно излагање услед гама зрачења и концентрације радона, коришћењем термолуминисцентног дозиметра и радонске дифузионе коморе, у току четири годишња доба. Концентрација раствореног радона у води измерена је пасивним и активним поступцима (цинксулфидним сцинтилационим детекторима и ручно израђеним дифузионим коморама), при чему је проучена и расподела доза код мерења радона. Дневна просечна доза за гама зрачења износила је 4.2 0.5 Sv, док је у објектима просечна концентрација радона у ваздуху била 232.5 187 Bq/m^3. Расподела показује да 85% објеката има просечну концентрацију радона од 100 до 300 Bq/m^3 у току године, а да 80% има максималну концентрацију до 400 Bq/m^3 у сезони. Максимална концентрација радона у води у Рамсару и Тонекабону износила је 198 30 и 109 16 BqL^{-1}, респективно.

Кључне речи: радон, област високог нивоа природног зрачења, пасивно мерење