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Natural ventilation considerations for radon prone areas of Ramsar

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ABSTRACT

Background: In Iran, architectures are often unaware of the risk of radon inhalation and how to reduce radon levels. Furthermore, radon considerations are not implemented in construction methods, construction materials and building utilization by regulatory authorities. ***Materials and Methods:*** In this study after reviewing the meteorological changes of Ramsar over the past 50 years (1955-2005), a novel design for constructing dwellings in radon prone areas is introduced. Out of building interventions such as planting wind-tunnel -making trees will be discussed in another paper. Ramsar soil samples with 4 levels of specific activities (extremely hot, severely hot, very hot, and hot) were placed in a model house. Radon level monitoring was performed by using a PRASSI portable radon gas survey meter. ***Results:*** For extremely hot soil samples, the radon levels inside the model house when windows were closed for 24 hours were 1615 ±516 Bq/m^3. When windows which were in the wind direction or opposite the wind direction were opened for 24 h, the radon level decreased to 89 ±286 and 139 ±314 Bq/m^3, respectively. Interestingly, when crossed windows were opened for the same duration, Radon level was 144 ±92 Bq/m^3. In cold seasons, when windows are usually closed, Chimney effect reduced the radon level to 323±641. For severely hot, very hot and hot soil samples, natural ventilation-based interventions effectively reduced the radon level. ***Conclusion:*** Results obtained in this study clearly show that natural ventilation-based simple cost-effective interventions can significantly reduce the radon concentration in radon prone areas of Ramsar.

Keywords: *Radon, Ramsar, natural ventilation, house design, dwellings.*

INTRODUCTION

Although cigarette smoking is the leading cause of lung cancer, radon exposure is reported to be an important contributor to the total burden of lung cancer (1). Recent studies show that radon inhalation even at low concentrations poses a risk of developing lung cancer (2).

Furthermore, there are published reports Indicating that environmental radon exposure may be a risk factor for squamous cell carcinoma (3), or chronic obstructive pulmonary disease (COPD) mortality (4). Radon-222 (radon) and radon-220 (thoron) are the most common isotopes of radon. It has been reported that the radon health risk is proportional to its concentration, down to the Environmental Protection Agency's action level of 148 Bq m^{-3}. Although naturally occurring isotopes of radon in indoor air are identified as the second leading cause of lung cancer after tobacco smoking (5), there is no large scale data on the incidence of radon-related lung cancers in Iran. Ramsar, a northern coastal city in Iran, has areas with some of the highest levels of natural radiation measured to date. The effective dose equivalents in the high level natural radiation areas (HLNRAs) of Ramsar, in particular in Talesh-Mahalleh district, are a few times higher than the *International Commission on Radiological Protection* (*ICRP*)-recommended radiation dose limits for radiation workers (6, 7). The annual radiation absorbed dose from background radiation in HLNRAs of Ramsar is up to 260 mSv y^{-1} (6). The high background radiation in the "hot" areas of Ramsar is primarily due to the presence of very high amounts of Ra-226 and its decay products, which are brought to the Earth's surface by hot springs(6). It's worth mentioning that, radon levels in some regions of Ramsar are up to 3700 Bq m^{-3}. Mortazavi and his colleagues have previously studied the health effects of long term exposure to naturally elevated levels of ionizing radiation (6-16) and assessed the association between the radon concentration and frequency of lung cancer in Ramsar. This article intends to introduce methods for decreasing radon level in the interiors of buildings ranging from design and implementation phases to alterations in utilization. In this article, radon reduction systems which are compatible with local architectural design in north Iran are discussed. Natural ventilation is a type of ventilation that is created by the differences in the distribution of air pressures around a building. The basic element of our design is enhancement of natural ventilation by making wind and chimney effect to move fresh air through dwellings. The buoyancy effect caused by temperature differences makes air flow. The size and location of openings in each dwelling determine the extent of natural ventilation. Considering the glorious history of *natural ventilation* techniques in Iranian traditional *architecture,* this article specially focuses on the role of natural ventilation strategies adapted with environments potentials in radon reduction systems. This paper is only focused on the indoor interventions and out of building interventions such as planting different trees and shrubs which make wind tunnels to convey breezes into the house will be discussed in another paper.

MATERIALS AND METHODS

Meteorological studies

In the 1st step of this study, the meteorological changes of Ramsar area including alterations in temperature, humidity, wind direction and speed over the past 50 years (1955-2005), were reviewed. These data were obtained from the database of the Iranian meteorological department.

Environmental monitoring and soil sampling

Before soil sampling, environmental monitoring in Talesh Mahalleh (a well-known district in HBRAs of Ramsar) was performed using a RDS -110 (RADOS. Inc., Finland) multi-purpose survey meter. Absorbed dose rates in air were measured at one meter above the ground level. Soil was sampled in 4 areas with different dose rates, and sent to the National Radiation Protection Department (NRPD) of the Iranian Nuclear Regulatory Authority for gamma spectroscopy. Ra-226, Th-232 K-40 concentrations in each soil sample was measured. Based on specific activities, soils sampled from different areas were categorized in 4 samples; namely extremely hot (A), severely hot (B), very hot (C), and hot (D) were placed in a model house. Radon level monitoring was performed by using a PRASSI portable radon gas survey meter at Radiation Research Center of Shiraz University. The concentrations of Ra-226, Th-232and K-40 radionuclides in each sample were determined using a high purity germanium (HPGe) gamma ray spectrometer (Canberra Industries).

House model

After performing a comprehensive study on the architecture and materials which are commonly used for construction of dwellings in HBRAs of Ramsar, a wooden model house was designed (figure 1). Natural ventilation in this model could be effectively enhanced to reduce energy consumption as well as to reduce radon concentration. In the two-storey house model, wind speed and direction, relative humidity, average temperature, and especially the traditional architecture of the northern coastal part of Iran, are taken into account. Furthermore, in this model, windows and skylights, evergreen or deciduous trees and fireplace chimneys as well as construction materials and wall coverings are the key components of the natural ventilation system.

Statistical analysis

Data were analyzed by using IBM SPSS Statistics (Version 19). A value of $P<0.05$ (2-sided) was considered statistically significant.

Radon and air quality measurements

Radon level measurement was performed by using a PRASSI portable radon gas survey meter. On the other hand, for assessment of the ventilation and indoor air quality, a Testo 435-2 multi-function measuring instrument was used.

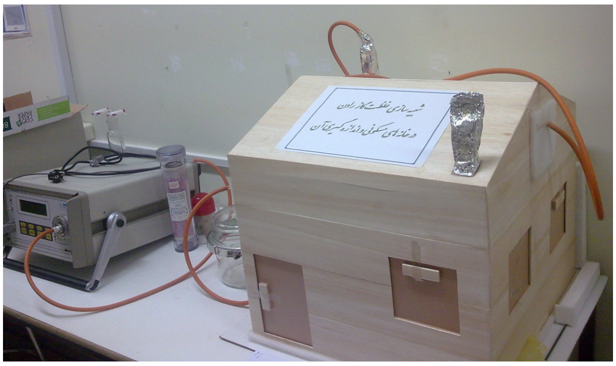

Figure 1. The wooden model house used in this study.

RESULTS

Soil sampling locations recorded by GPS and the dose rate at each location are indicated in table 1. For A samples (extremely hot soil samples), the mean (±SD) radon levels inside the model house when windows were closed for 24 hours was 1615 ±516 Bq/m^3 (table 2). When windows which were in the wind direction or opposite the wind direction were opened for 24 h, the radon level decreased to 89 ±286 and 139 ±314 Bq/m^3, respectively. Interestingly, when crossed windows were opened for the same duration, Radon level was 144 ±92 Bq/m^3. In cold seasons, when windows are usually closed, Chimney effect reduced the radon level to 323±641 Bq/m^3 (figure 2).

For B samples (severely hot soil samples) the mean (±SD) radon levels when the windows in the wind direction opened for 24 hours was 149±40 Bq/m^3 (table 2). When windows which were in the wind direction or opposite the wind direction were opened for 24 h, the radon level decreased to 42±27 and 62.24±27 Bq/m^3, respectively. Interestingly, when crossed windows were opened for the same duration, Radon level was 50± 34 Bq/m^3. In cold seasons, when windows are usually closed, Chimney effect reduced the radon level to 46.74±51 Bq/m^3. Moving to C samples (very hot soil samples) the mean (±SD) radon levels when the crossed windows opened for 24 hours was 53±18 Bq/m^3 (table 2). When windows which were in the wind direction or opposite the wind direction were opened for 24 h, the radon level decreased to 34±10 and 35±10 Bq/m^3, respectively. Interestingly, when crossed windows were opened for the same duration, Radon level was 34±10 Bq/m^3. In cold seasons, when windows are usually closed, Chimney effect reduced the radon level to 33±18 Bq/m^3. wind direction or opposite the wind direction were opened for 24 h, the radon level decreased to 34±10 and 35±10 Bq/m^3, respectively. Interestingly, when crossed windows were opened for the same duration, Radon level was 34±10 Bq/m^3. In cold seasons, when windows are usually closed, Chimney effect reduced the radon level to 33±18 Bq/m^3.

And finally for D samples (hot soil samples), the mean (±SD) radon levels when there was chimney effect for 6 hours was 42±10 Bq/m^3 (table 2). When windows which were in the wind direction or opposite the wind direction were opened for 24 h, the radon level decreased to 27±8 and 35±10 Bq/m^3, respectively. Interestingly, when crossed windows were opened for the same duration, Radon level was 32±8 Bq/m^3. In cold seasons, when windows are usually closed, Chimney effect reduced the radon level to 31±8 Bq/m^3.

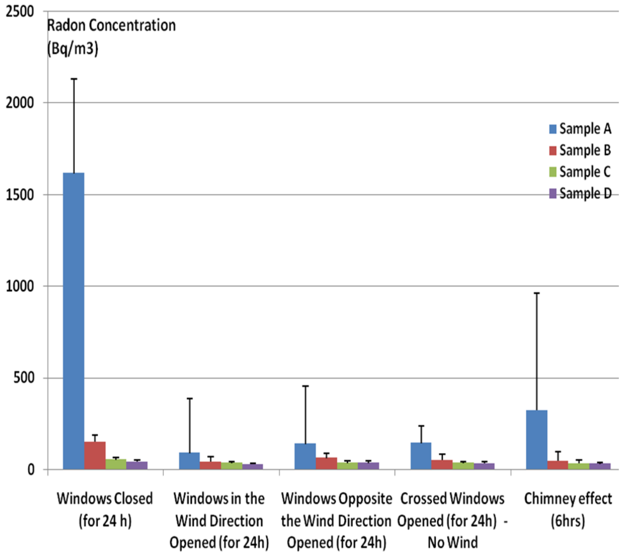

Figure 2. Radon Concentration in Model House using Soil Samples with Different Levels of Specific Activities after Some Natural Ventilation-Based Interventions.

DISCUSSION

World Health Organization (WHO) reports that the main health hazard from high radon exposure is an increased risk of lung cancer (17). Based on the findings of this study, it can be concluded that for extremely hot, severely hot, very hot and hot soil samples, natural ventilation -based interventions can effectively reduce the radon level. This effect was especially prominent for extremely hot soil samples. After reviewing the meteorological alterations of Ramsar over the past 50 years (1955-2005), it was revealed that the most common direction of wind was 315 degree (direction of wind in 26 out of 50 years). In this light, construction of the houses toward the wind direction and selection of proper size and orientation of windows is the best solution to control radon level in radon prone areas of Ramsar.

Table 1. Soil sampling locations recorded by GPS and the dose rate at each location.

Sample	Longitude	Latitude	Elevation (m)	Wind speed (km/h)	Dose Rate (µSv / hr) (Mean±SD)
A (extremely hot)	E 50.683990	N 36.884670	17	1	31.82±4.0
B (severely hot)	E 50.683529	N 36.885471	13	0.2	18.37±2.9
C (very hot)	E 50.683594	N 36.885623	11	2.7	13.92±20
D (hot)	E 50.683662	N 36.885967	10	0.1	2.77±0.9

Table 2. Radon Concentration in Model House using Soil Samples with Different Levels of Specific Activities after Some Natural Ventilation-Based Interventions.

Samples	Mean (±SD) Radon Concentration (Bq/m3) Range (min-max)				
	No Intervention	Intervention for Hot Seasons			Intervention for Cold Seasons
	Windows closed for 24 hrs	Windows in the wind direction opened for 24 hrs	Windows opposite the wind direction opened for 24 hrs	Cross windows opened for 24 hrs (no wind)	Chimney effect
Sample A (extremely hot)	1615±516 (56-2123)	89.42±296 (28-2430	139±314 (32-2376)	144±292 (40-2299)	323±641 (71-2279)
Sample B (severely hot)	149±40 (19-209)	42±27 (16-198)	62.24±27 (27-203)	50± 34 (22-193)	46.74±51 (16-210)
Sample C (very hot)	53±18 (18-86)	34±10 (16-69)	35±10 (19-78)	34±10 (21-88)	33±18 (20-89)
Sample D (hot)	42±10 (15-67)	27±8 (15-61)	35±10 (18-76)	32±8 (15-62)	31±8 (20-63)

Results obtained in this study are in line with investigations performed in some other countries (18) and clearly show that natural ventilation-based simple cost-effective interventions can significantly reduce the radon concentration in radon prone areas of Ramsar. Anderson *et al.* have previously reported that despite large house-to-house variability of radon entry rates, that natural ventilation had a significant effect on the indoor radon concentration (18). However, it should be noted that US (EPA) believes that natural ventilation should be considered a temporary radon reduction approach (19). On the other hand, according to EPA, the cost of radon reduction system which strongly depends on the characteristics of the house and choice of radon reduction methods is up to $ 2500 (the average cost of a radon reduction system is reported to be about $1,200)(20). In this light, as there are no mass produced radon reduction instruments and authorized experienced companies in Iran, we estimate that the cost of a common radon reduction system in Iran is ranges from $1000 to $3000. It is worth reminding that the residents of radon prone areas of Ramsar are not usually rich enough to install radon mitigation systems. However, as discussed before, factors such as the main characteristics of the house and selection of radon reduction methods affect the cost of radon reduction systems. Therefore, natural ventilation- based interventions can be a major part of radon reduction systems in these areas.

At the present time, there are no national radon mitigation strategies for radon prone areas. However, National Radiation Protection Department of the Iranian Nuclear Regulatory Authority has started preliminary studies for developing a national radon mitigation system. It has been reported that the vast majority of radon induced lung cancers are caused by exposure to low and moderate radon concentrations (21). EPA believes that radon causes about 20,000 cases of lung cancer annually (22) but there is no currently any data on radon inhalation caused deaths. WHO recommends that countries perform national programs to reduce the population's radon risk, as well as reducing the risk for individuals exposed to higher than population-average levels of indoor radon. In this light, special codes for construction of building should be implemented to reduce radon levels in homes. WHO recommends a national reference level of 100 Bq/m^3. WHO believes that if this level cannot be reached under the prevailing country-specific conditions, the reference level should not exceed 300 Bq/m3 (17). In this light, most countries have adopted a radon concentration of 200–400 Bq m^{-3} for indoor air as an action or reference level.

CONCLUSION

Natural ventilation is a major component of home ventilation in which outside air enters the house through windows and other openings. Altogether, findings of this study show that cost-effective natural ventilation-based interventions can significantly reduce the radon concentration in radon prone areas of Ramsar. In this study, the remarkable influence of factors such as building orientation toward wind direction and the size and direction of windows were confirmed.

Conflict of Interest

None

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