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Influence of chimney effect on the radon effective dose of the lung simulated for radon prone areas of Ramsar in winter season

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***Abstract**: One of the well-known radon prone areas of the world is Ramsar in Iran, which is surrounded by the Alborz Mountain in its southern part and Caspian Sea on the north. The annual effective dose in the district of Talesh-Mahalleh is higher than the annual dose limits for radiation workers. In this study, the indoor radon level and effective dose of the lung were estimated using a Prassi portable radon gas survey meter in a model house containing top soil samples from different parts of Ramsar. For the extremely hot samples, the effective dose of the lung in winter season was 27.75±2.55mSv, when the windows and exhaust part of chimney were closed. However, when the chimney was turned on and the exhaust part of chimney was open, the effective dose of the lung was reduced to 1.27±0.23mSv. Also the seasonal radon effective doses of the lung with other samples were reduced to low values. The results suggest by using chimney effect and chimney heaters a significant lessening of the radon seasonal effective dose in dwellings of Ramsar can be achieved.*

***Key words:** radon gas, seasonal effective dose, chimney effect, Ramsar, Iran*

I. Introduction

Radon gas from the terrestrial radionuclides ^{238}U and ^{232}Th are transported through the subsoil pore spaces and, while an amount of them will decay, the rest will be released into the atmosphere[1] and in the case of a closed area in our daily life will accumulate and increase its concentration. The silent gas of Radon is recognized to present a lung cancer risk when it, or rather its decay products, is inhaled [2]. Exposing to this natural gas is the second main significant causes of lung cancer after cigarette smoking [3]. It has been reported that, the effective dose of lung, is proportional to radon level, above to the Environmental Protection Agency's action level of 148 Bqm^{-3}. The ICRP recommendation dose limit for radon is 2.5 mSv y^{-1}. High background radon concentration radiation is primarily because of the presence of very high amounts of ^{226}Ra isotope and its decay products, which are brought to the Earth's surface by hot springs[4]. It is mostly accepted that the human activity modifies the Earth's surface and therefore the radiation exposure may be considered as an ever-changing parameter [5]. A measurement of radon level in soil air is a valuable tool in the planning and construction of new buildings in order to avoid high indoor radon concentration received by the residents [6]. Latest studies show that radon inhalation even at low levels poses a risk of increasing lung cancer [7]. Additionally, there were published reports indicating that the environmental radon exposure is the also causes larynx cancer, and Chronic Obstructive Pulmonary Disease (COPD) [8]. About 2,000 inhabitants in the high level natural radiation areas (HLNRAs) of Ramsar, a littoral city in northern Iran were exposed to ionizing radiation of annual absorbed dose of 260 mSv y^{-1} [4]. The annual radiation absorbed dose in HLNRAs of Ramsar, in particular in Talesh-Mahalleh district, is about 13 times higher than the ICRP-recommended radiation dose limits for radiation workers [9]. The high background radiation in the hot areas of Ramsar is primarily due to the presence of very high amounts of ^{226}Ra isotope and its decay products, which are brought to the Earth's surface by hot mineral water fountains [4]. Because of local geology, which includes high concentrations of radium in rocks, soils, and water, the people in Ramsar are also exposed to high levels of alpha particles in the form of ingested radium and its decay progenies as well as very high radon levels in their dwellings, over 3000 Bq m^{-3} in some cases [10]. Much the radon largest doses to human organ are in the respiratory tract, that is to lung and to the extra-thoracic part of the respiratory tract [11] especially for the winter season that, all windows and openings are completely closed to save the energy and provide suitable indoor air which is causing to higher indoor radon concentration for inhabitants. The indoor radon level in some regions of Ramsar is higher than the recommendation of W.H.O (2.5 mSv y^{-1} or 6 mSv annual effective doses for the lung) especially for the winter season, when all the openings must be closed to keep the indoor air in warm condition and there is no choice to open the windows. The reason for this high indoor radon levels, is the presence of many hot springs, and also local building materials which were used in the buildings. Moreover, the chimney effect caused by temperature differences makes a variation in radon concentration due to air flow in winter season. During the cold season using chimney effect to provide suitable indoor air is preferred to other heater systems such as chauffage, electrical heaters, gaseous heaters and other devices and methods, and this important effect could reduce the radon levels and consequently the radon effective dose of the lung is reduced to acceptable levels in HLNRAs of Ramsar. This article discusses the chimney effect on the reduction of radon annual effective dose of the lung in HLNRAs of Ramsar during the winter season.

II. Materials and Methods

2.1 Environmental Monitoring and Soil Sampling: earlier to soil sampling, environmental dose monitoring in Talesh Mahalleh (a well-known district in Ramsar) was performed using a RDS-110 (RADOS Inc, Finland) multipurpose survey meter. The absorbed dose rates in air were measured at one meter above the ground to find the hot radiation areas. The top soils were sampled in four areas with different dose rates, and were analyzed using gamma spectroscopy system. ^{226}Ra, ^{232}Th and ^{40}K concentrations in each soil sample were measured and according to their specific activities. The soil samples from different areas were categorized as extremely hot (A), severely hot (B), very hot (C), and hot (D). These samples were placed in a model house one after the other. Radon concentration monitoring was performed using a Prassi portable radon gas survey meter and the radon annual effective dose of lung organ was calculated according to two modalities, the first monitoring was carried out in a completely closed model house and second one using chimney effect and opening the exhaust part of chimney on top of model house. The specific activities of ^{226}Ra, ^{232}Th and ^{40}K in each sample were determined using a high purity of germanium (HpGe) gamma-ray spectrometer (Canberra).

2.2 Model house: A wooden model house of 65×65×60 cm^3 was designed to simulate the Ramsar dwellings (Fig 1). There were windows on the four sides, each with the dimension of 15×15 cm^2 and this model house was including two chimneys with exhaust part which were 15 cm upper than the top of the roof of model house. Using chimney in this model could be effectively enhanced to reduce radon concentration and radon effective dose of lung also as a result reduces the ratio of lung cancers however we lose a fraction of produced thermal energy by the exhaust of chimney. Traditional architecture of the northern coastal part of Iran is taken into account.

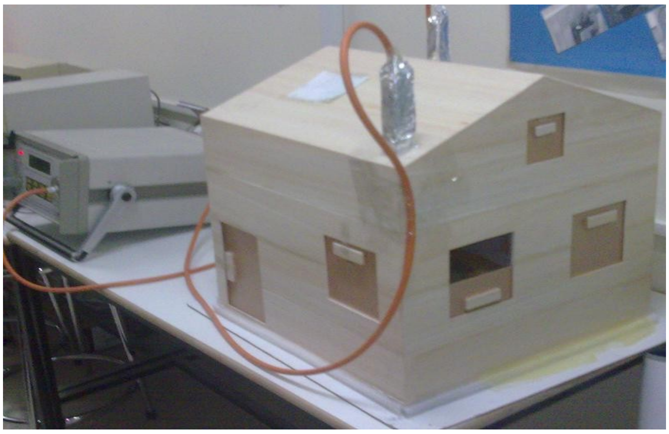

Figure 1 model house

2.3 Radon level measurements: Optimization of radiological protection points to keeping doses as low as reasonably achievable[12]. Radon level measurement in soil air is a valuable tool in the constructing of new buildings in order to avoid high indoor radon levels [6]. The radon hazards usually are stated in unit of Bq m-^{3}. However, this value cannot be applied as the absorbed dose or radon effective dose, so we need to define the radiation exposures to individual or a critical organ such as lung, based on units and quantities. The radon absorbed dose of the lung calculated based on UNSCEAR 2000 suggestion using the equation of:

D_{Rn} (mSv y^{-1}) = C_{Rn}.D.H.F.T

Where;

C_{Rn} is the measured Rn-222 concentration (in Bq/m^3)

F is the Rn-222 equilibrium factor indoors (0.4)

T is the indoor occupancy time (80%) =7000h/y (yearly)

H is the indoor occupancy factor (0.4), and

D is the dose conversion factor (9.0×10^{-6} mSv/h per Bq/m^3)

The annual absorbed dose to lung at a radon concentration of 100 Bq/m^3 will be 2.5 mSv during of 7000 hours yearly (an occupancy factor of 80%) and according to an equilibrium factor of 0.4 as used in ICRP publications

[13]. Having the $D_{Rn,}$ and using the equation below, the radon effective dose of the lung in using chimney effect in model house was calculated from:

H_E (mSv y^{-1}) = $D_{Rn} . W_R . W_T$

Where:

D_{Rn} =Annual absorbed dose

W_R =Radiation weighting factor for alpha particles 20

W_T =Tissue weighting factor for the Lung 0.12

The obtained values of annual effective dose were multiplied to a coefficient of ¼ (one season) to obtain the fairly accurate seasonal effective dose of lung organ during the winter season.

III. Results and Discussion

The average annual effective dose to population through natural radiation is equal to 2.4 mSv y^{-1}. Out of 98% of radiation doses received to human is from natural sources, and 52% of this amount is due to radon inhalation of thoron and radon progenies inside of closed areas such as dwellings and workplaces [14], The background radon concentration in the closed lab was measured prior to measuring the radon levels in model house which had an average value of 19.95 ±7.78 Bq/m^3 that corresponds the lung effective dose of 1.19± 0.46 mSv y^{-1} and will be equal to 0.29±0.11mSv per season. Based on soil analysis, the most significant detectable radionuclide element in the collected soil samples was ^{226}Ra. For A samples (extremely hot soil samples), the mean (±SD) seasonal effective dose of the lung inside the model house when the windows and all openings were closed and chimney was turned off, was 27.75 ± 2.55mSv (Table 1). When the chimney was turned on and the exhaust part on top of roof also was open, the radon effective dose of the lung decreased to 1.27 ± 0.23mSv (Fig 2). The reason for these value reductions is due to differential temperature between indoor and outdoor air which results to reduce the values at the time of measurement. So when there is a relation between indoor and outdoor air, it can be assumed as the presence of fresher outdoor air inside of dwellings and sending out the lighter warm air including indoor radon to the outdoor space, it can be so effective and useful tool to dilute the indoor radon levels and its benefits will be the reduction of indoor radon hazards especially for the radon related critical organ of the lung. For B samples (severely hot soil samples), the mean (±SD) radon effective dose of the lung when the windows and all openings were closed, was 2.61 ± 0.31mSv (Table 1). When the chimney was turned on and the exhaust part on top of roof also was open, the effective dose of the lung decreased to 0.40 ±0.05 mSv (Fig 2).

Moving to C samples, the mean (±SD) radon effective dose of lung when the windows were closed and also chimney was turned off, was 0.81 ± 0.15mSv (Table 1). When the chimney was turned on and the exhaust part on top of roof also was open, the radon effective dose of the lung decreased to, 0.38± 0.12 mSv (Fig 2). And finally for D samples, the mean (±SD) radon seasonal effective dose of lung when chimney was turned off and all windows were closed was 0.64 ± 0.14 mSv (Table 1). When the chimney was turned on and the exhaust part on top of roof also was open, the radon effective dose of the lung decreased to 0.34 ± 0.05 mSv (Fig 2).

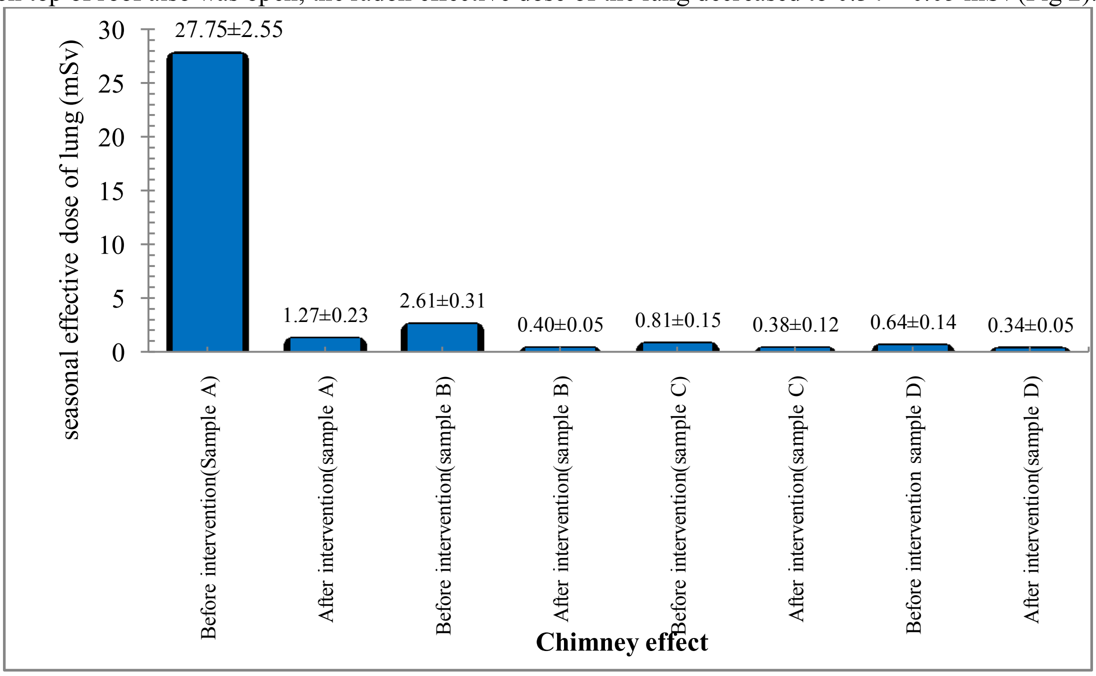

Figure 2 Influence of chimney effect on Seasonal effective doses of the lung (before and after intervention)

Table 1 seasonal effective doses of the lung with different soil samples (before and after intervention).

Samples	Effective dose(mSv) before intervention(chimney off)	Effective dose(mSv) after intervention(chimney on)
Sample A	27.75±2.55	1.27±0.23
Sample B	2.61±0.31	0.40±0.05
Sample C	0.81±0.15	0.38±0.12
Sample D	0.64±0.14	0.34±0.05

All the findings which are summarized in the Table 1 are shown the positive effect of chimney interventions on reduction of effective dose of the lung for people of HLNRAs of Ramsar during the winter season which are indicating the note that, using chimney in the dwelling will provide a good indoor air for the cold season. Much the largest radon doses are on the respiratory system, which is to the lung and to the extra-thoracic part of the respiratory tract[11]. The national cancer institute (NCI) declares, the second most important cause of lung cancer in the United States is radon gas, which is linked with 15,000 to 22,000 lung cancer deaths each year [15]. WHO recommends a national reference level of 100 Bq m^{-3} [3] which is equal to the human absorbed dose of 2.5 $mSvy^{-1}$. WHO also believes that, if this level of radon concentration cannot be reached under the prevailing country-specific conditions, the value should not exceed 300 Bq/m^{-3}. So according to our results, the chimney effect can act as a simple effective method of the reduction of lung effective dose in winter season and can be applied for the HLNRAs of Ramsar. Regarding to W.H.O reports, the main health hazard from high radon exposure is an increased risk of lung cancer [16] and as the effective dose is a factor in determining the cancer risk, according to the findings of this study, it can be concluded that for the extremely hot, severely hot, very hot and hot soil samples, chimney effect interventions for the cold season can successfully reduce the radon effective dose of the lung to lower values. This effect was especially high up in the extremely hot soil samples. Regarding to our review on meteorological factor of the Ramsar during the 50 past years, the average of minimum and maximum temperature has been 12.6 ±0.79 ^{0}C and 19.34 ±0.66 ^{0}C respectively, so that the minimum air temperature was related to the cold season and using chimney heaters for the winter season will mitigate the radon level and consequently decreases the effective dose of the lung to lowest values and in result, thus the cancer risk in this region would be reduced to the lowest values possible. One of the disadvantages of this simple technique comparing to some other heating systems such as gaseous or electrical normal heaters is its relatively high cost, and comparing to chauffage system is cheaper, but its benefits is lowering the lung cancer risk which is very important than its cost. Moreover, the people who are living at HLNRAs of Ramsar and its districts can change and renew their previous building heating systems to chimney system to obtain lower seasonal effective dose of lung in winter.

IV. Conclusion

Chimney effect is one of home freshening factors in which outdoor air enters the house through openings and burned light warm air including indoor radon gas transfers to outdoor through exhaust part of the chimney. In general, ending of this study shows, the chimney effect intervention can not only considerably reduce the radon concentration in radon prone areas of Ramsar but also its consequences are reduction of radon effective dose of lung and finally reduction of lung cancer risks for inhabitants. In this study, the influence of chimney effect on radon concentration and effective dose of lung in cold weather were set and the authors, recommends strongly using of the chimneys to the inhabitants of Ramsar to reduce unwanted indoor radon radiation hazards.

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