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Review Paper

The Need for Indoor Radon Prevention and Mitigation in Iran: A Health Policy Brief

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ABSTRACT

Background: Radon is a colorless and odorless radioactive gas that is considered a leading cause of lung cancer. Given this need, the main objective of this policy brief was to discuss the need to pay attention to the prevention and control of indoor radon (IRD) in Iran.

Materials & Methods: To prepare this policy summary, which is similar to a narrative review, scientific reports and studies conducted in Iran over the past two decades were 1st obtained by searching reliable national and international databases. Then, based on the main results of the above studies, the general level of IRD concentration in the main regions of Iran was determined. Finally, by using the experiences and measures in other countries, necessary recommendations for the prevention and mitigation of IRD were made

Results: By evaluating the findings of previous studies conducted in Iran, it was found that the level of IRD in residential and non-residential buildings evaluated in Iran, in most cases, was higher than the global average (40 bq/m^3). In addition, in some cases, it was higher than the acceptable level by World Health Organization (WHO) (100 bq/m^3).

Conclusion: Based on the findings, it can be concluded that it is very necessary to educate the public, engineers and health and municipal inspectors about the health risks of exposure to radon. In addition, it is necessary to take basic and preventive measures to mitigation radon in homes.

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Introduction

Radon is a naturally occurring radioactive gas that results from the decay of uranium and radium, found in almost all soils and rocks [1]. Due to its carcinogenic nature, measuring and monitoring indoor radon (IRD) is of utmost importance [2, 3]. The International Agency for Research on Cancer (IARC) has classified radon as a group 1 human carcinogen [4]. In addition, both the World Health Organization (WHO) and the U.S Environmental Protection Agency (EPA) have identified the radiation dose from inhaling radon and its progeny as the 2nd leading cause of lung cancer, after smoking [5, 6]. The most common cancer worldwide is lung cancer, which is the leading cause of cancer-related deaths. Additionally, radon is responsible for 2% (21,000 deaths) of cancer in Europe [7]. It has been reported that for every 100 Bq/m³ increase in the long-term average radon concentration, the incidence of lung cancer increases by approximately 16% [7]. Recent reports have also linked natural background radon to a 20% increase in cases of childhood leukemia [8, 9]. The WHO and EPA have set maximum permissible levels of IRD at 100 Bq/m³ and 148 Bq/m³, respectively [10, 11]. Furthermore, the global average IRD is reported to be 40 Bq/m³ [12].

Public awareness of radon and its associated health risks in Iran is low. It is therefore essential that environmental and health authorities take the necessary measures to raise public awareness. In addition, construction project managers, builders and engineers do not pay enough attention to the methods to prevent and contain IRD. The main objective of this policy brief is to highlight the need to focus on the prevention and control of IRD.

Materials and Methods

To compile this policy brief, we 1st conducted a comprehensive search of reputable national and international databases, including Google Scholar, Science Direct, Scopus, PubMed, Iranian Research Institute for Information Science and Technology (IranDoc), Magiran and Islamic World Science Citation (ISC). Relevant keywords such as "radon," "indoor," "Iran," "radiation," "exposure," "concentration" and others were used in the search, and they were combined (and/or) to conduct an exhaustive literature search. This search focused on scientific reports and studies conducted in Iran over the past two decades. By analyzing the main results of these studies, we determined the overall concentration of IRD in the main regions of the country. Finally, we have provided key recommendations for preventing and reducing IRD, building on successful strategies implemented in other countries.

Results

Table 1 shows the results of several important studies related to the occurrences of IRD in Iran. Of course, the number of studies is larger than these cases, but here it is limited to the report of a few. The table includes the studied region and its geographical orientation, analysis method, building type, building floor, sample size and Mean±SD and range (Bq/m³).

Numerous studies in Iran have assessed IRD levels, with many reporting concentrations exceeding both the WHO acceptable level (WHO-AL) of 100 Bq/m³ [10] and the global average (GAV) of 40 Bq/m³ [12]. For example, a study conducted in Shiraz by Hadad et al. (2011) found that IRD concentrations exceeded the GAV in all floors of the buildings examined, with levels in the basement exceeding the WHO-AL [13]. Similarly, a study by Bouzarjomehri and Ehrampoosh (2008) in Yazd showed IRD concentrations in the basement of a residential building to be higher than both the WHO-AL and GAV [14]. Research by Askari et al. (2019) in Tehran (Kahrizak) [15] and Sohrabi and Solaymanian (1998) in Ramsar, Tehran, Babolsar and Gonabad also showed that the average IRD levels were significantly higher than the GAV and WHO-AL [16]. A study by Aadelikhah et al. (2021) in Mashhad showed IRD levels exceeding the WHO-AL [17], while Fahiminia et al. (2016) found basement IRD concentrations in Qom to be above both the WHO-AL and GAV [18]. Other studies in various regions of Iran, including Tehran [19], Isfahan [20], Aleshtar [21], Khorramabad [22] and Shiraz [23], have consistently reported higher than average IRD levels in basements and ground floors.

Discussion

Results from studies conducted across Iran indicate that the average IRD concentration in most areas exceeds the GAV [10, 12-23] and even the WHO-AL in some regions. Given these findings, it is imperative to highlight the significant health risks that IRD poses to the Iranian population. To address this issue, it is important to raise awareness among the general public, health authorities, regulators and contractors of the health risks associated with IRD. This increased awareness may lead to a change in attitudes and ultimately lead to the adoption of preventive measures against IRD. Therefore, various educational methods should be used to improve

Table 1. General results of several articles on IRD assessment in Iran

City/Geographical Orientation	Analysis Method	Building Type	Building Floor	Sample Size	Radon Concentration (Bq/m³)		Reference
					Mean±SD	Range	
Shiraz/south of Iran	SSNTDs	Residential	Basement	35	108.6±55	42.9-245.1	[13]
			Ground floor	46	87.2±54.6	32.5-280.7	
			1st floor	26	62.8±38.7	17.4-116.6	
			2nd floor	24	60.5±23.7	30-146.7	
Yazd/center of Iran	RAD7 (portable surveyor)	Residential	Basement	84	137.36±149.48	5.55-747.4	[14]
South of Tehran (Kahrizak)/north of Iran	SSNTDs	Residential	Not reported	37	60.3±19	25.1-130.2	[15]
Ramsar/north of Iran	Passive radon diffusion dosimeters	Residential	Not reported	85	578±677	NR	[16]
Tehran/north of Iran		Residential		80	80±84	NR	
Babolsar/north of Iran		Residential		14	88±35	NR	
Gonabad/north of Iran		Residential		27	84±31	NR	
Mashhad/northeast of Iran	NRPB and RADUET	Residential	Not reported	78	115±51	50.8-305.2	[17]
				78	150±62	75.3-376.6	
Qom/center of Iran	ATDs	Residential	Basement	35	123.43±50.02	48.85-259	[18]
			Ground floor	40	87.94±26.4	43.41-141.99	
			1st floor	21	63.72±24.02	19-141	
			2nd and upper floors	27	40.69±23.46	15-94	

Abbreviations: RADUET: Radon monitoring device; ATDs: Alpha track detectors; SSNTDs: Solid-state nuclear track detectors.

public knowledge about IRD, an area that does not receive enough attention in Iran. Mass media, particularly television, can play an important role in raising public awareness and empowering individuals to take simple and practical measures to prevent radon from entering their homes or workplaces.

To prevent and reduce IRD, health and regulatory authorities should establish structural and technical protocols and criteria that contractors must follow when constructing residential and public buildings. In addition, it is important to plan regular IRD measurements, provide the necessary equipment and create conditions to identify high-risk areas at city, regional and national levels.

Methods for reducing radon in homes vary significantly in complexity, long-term effectiveness and cost. Which method is best depends on the specific characteristics of the home, the radon concentration, and the pathways through which radon enters the building. A combination of methods may be necessary to achieve optimal results, especially at high radon levels. Involving experts in the field is critical to creating a radon-safe environment [24-26]. However, homeowners can often take initial, cost-effective steps to reduce radon levels in their homes [25].

Studies on IRD in Iran have shown that radon concentrations are generally higher in basements and 1st floors than on upper floors [13, 14, 21, 27]. This is because these lower levels are closer to the ground where radon is created. Therefore, building occupants, contractors and health inspectors should pay particular attention to these areas and implement stricter radon reduction and prevention measures.

The most important measures to reduce radon include both minor (simple and quick) and major (basic) mea-

sures [25]. Some of the smaller things homeowners can do with minimal cost include sealing cracks and openings in the building. Cracks and gaps in the building structure can allow radon to penetrate, but these can be sealed with foam sealant. In addition, wall and floor joints can be made radon-resistant by sealing them with polyurethane [28]. Opening windows on lower floors allows for ventilation and helps remove radon from the indoor environment. Ventilation is a key element in reducing radon exposure. Opening windows on upper floors also contributes to air circulation and radon removal. Although mechanical ventilation systems can reduce IRD, they consume energy [29, 30]. Installing ceiling fans promotes air circulation and reduces IRD. Combining ceiling fans with positive ion generators can ionize radon gas, causing it to stick to walls or ceilings and prevent it from being inhaled. It is important to note that ventilation fans can create negative pressure inside the building, which can draw in radon. When using ventilation fans, it is important to open multiple windows to allow air circulation [31].

Other major radon reduction measures include: soil suction, creating positive pressure in the home, using a small sump pit under the building connected to a pipe and a low-power exhaust fan, painting walls with impermeable paint, using polyethylene plastic floor coverings, and passing incoming water through a filtration unit containing activated carbon granules [29, 30].

Conclusion

Based on the results of previous studies, it can be concluded that IRD levels of residential and non-residential buildings assessed in Iran are in most cases above the GAV and in some cases even above the acceptable level established by the WHO. Given these findings, it is imperative that Iran takes comprehensive measures to prevent and control IRD in existing and newly constructed buildings. The 1st step in this regard is to educate the public, health officials, municipal inspectors, engineers and contractors through various media (especially mass media such as television) about the health risks of radon and the need for preventive measures. In addition, as a next step, it is necessary for building users and developers of residential buildings and public places to take preventive measures to reduce IRD in accordance with acceptable guidelines.

Ethical Considerations

Compliance with ethical guidelines

This study was approved by the Ethics Committee of Kermanshah University of Medical Sciences, Kermanshah, Iran (Code: IR.KUMS.REC.1402.279).

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Authors' contributions

Conceptualization and supervision: Kiomars Sharafi and Tooraj Massahi; Methodology: Kimya Parnoon, Tooraj Massahi, and Foad Valikhani; Data collection: Kimya Parnoon, and Jalil Jaafari; Data analysis: Kiomars Sharafi and Ali Almasi; Investigation and writing: All authors; Funding acquisition and resources: Kiomars Sharafi.

Conflict of interest

The authors declared no conflict of interest.

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