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Radon activity measurements in irrigation water from Qassim Province by RAD7

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Abstract

The present study deals with investigating radon level in groundwater, which is being used for irrigation in the environs of Qassim province, Saudi Arabia. 99 samples of groundwater were collected from eight cities in Qassim province. Radon concentrations in the collected water samples were measured with RAD7 electronic radon detector connected to RAD- H2O accessory (Durridge Co., USA). The concentration of ^{222}Rn in 99 irrigation groundwater samples ranged from 1.20 to 15.43 Bq l^{-1}Radon level in 5 samples 2 from Al-Asyah, 2 from Al shamasia and one sample from Al Moznib exceeded the permissible level of radon 11 Bq l^{-1} in groundwater. The total annual effective dose varied with increase in radon concentration. The calculated effective dose per liter (EDL) and annual effective dose (AED) ranged from 6.1 to 77.15 nSvL^{-1} and 4.45 to 56.16 μSv y^{-1}, respectively. It was evident that the total annual effective doses resulting from radon in 95% from groundwater in Qassim area were significantly lower than the permissible limit of 1 mSv y^{-1} for the public.

Key words

RAD7, Irrigation water, Aeration, Purging, Qassim province

Introduction

Radon and its short-lived decay products in the environment play an important role to human exposure from natural sources of radiation. Radon is an important natural source and is the largest contributor to the effective dose received from natural sources. It has been estimated that radon and its progeny contribute 75% of the annual effective dose received by human beings from natural terrestrial sources and are responsible for about half of the dose from all sources. Water is the most important source of life and makes up 70-75% of total body weight. While 70% of the world's surface is covered by water, only 0.3 % of the total water resources on earth are suitable for drinking and daily use. Human being provides their water needs from surface water and ground water resources. Ground water has more radioactive contents than surface water since it passes through rocks and soil formations, dissolves many compounds, minerals and radioactive materials (UNSCEAR, 2009; El-Taher and Madkour, 2011 ; 2014; Madkour *et al.*, 2012; 2015; El-Taher., 2012; El-Taher and Al Ashrah, 2015).

There is no evidence that exposure to naturally present levels of radium has harmful effects on human health. However , exposure to higher levels of radium may result in health problems, such as teeth fracture, anemia and cataract. If the exposure lasts for a long period of time radium may even cause cancer, and the exposure may eventually lead to death These effects may take years to develop. They are usually caused by gamma radiation of radium, which is able to travel fairly long distances through air .Therefore, contact with radium is not necessary for causing health effect (EPA, 1999).

In recent years, a great interest has arose towards natural radioactivity in water (Schwartz, 2003; Snow and Spalding, 1997; Bem *et al.,* 2014). Activity concentration of ^{222}Rn radionuclide was determined in drinking water samples from the Sothern Greater Poland region by liquid scintillation technique. The measured values ranged from 0.42 to 10.52 Bq l^{-1} with geometric mean value of 1.92 Bq l^{-1}. The calculated average annual effective doses from ingestion with water and inhalation of this radionuclide escaping from water were 1.15 and 11.8 μSvy^{-1}, respectively. Wen *et al.* (2014) measured ^{222}Rn in groundwater and surface seawater during a full tidal period and estimated ^{222}Rn activity along the coast of Xiangshan, Zhejiang, China. ^{222}Rn activity in Xiangshan coast was in range of 2.4 ×10^4 - 1.7 × 10^5Bqm^{-3}, with an average of 9.6 × 10^4Bqm^{-3} for groundwater; 0.2 × 10^2 - 2.8 × 10^2Bqm^{-3} with an average of 1.1 × 10^2Bqm^{-3}, for surface seawater. Ravikumar and Somashekar (2014) studied distribution of radon in ground and surface water samples in Sankey Tank and Mallathahalli Lake areas, and reported mean radon activity of 7.24 and 11.43 Bq l^{-1}, in surface water, and 11.6 to 381.2 Bq l^{-1} and 1.50 to 18.9 Bq l^{-1} in ground water respectively. About 70% of water samples from monitored wells presented ^{222}Rn concentration values above the limit of 11.1 Bq l^{-1} recommended by the United States Environmental Protection Agency USEPA (Correa *et al.*, 2014). (Voltaggio and Spadoni, 2013). The efficiency of ^{222}Rn gas accumulators made of polydimethylsiloxane (PDMS) mixed with activated Carbon (AC) for sampling Rn in water was studied high Rn volumetric enrichment factor in PDMS–AC disks with respect to water resulted in about 206:1, lowering detection limits for ^{222}Rn in water to 20 Bq/m^3, when total activity of Rn progeny in disks was measured by high resolution gamma-ray spectrometry. Radon concentration in groundwater samples of different areas of Sri Ganganagar, Hanumangarh, Sikar and Churu districts in northern Rajasthan was assessed and radon concentration was well below the allowed maximum contamination level (MCL) of radon concentration in water of 11 Bq l^{-1}, as proposed by (USEPA).

In view of the above, the present work deals with estimating radon level and its radiation hazards in groundwater, which is being used for irrigation in the environs of Qassim province, Saudi Arabia.

Materials and Methods

A total of 99 groundwater samples from eight cities (Buraydah, Oniza, Al-Badayia, Al-Bakria, Al Jawaa, Al Asyah, Al-Shamasia and Al- Moznib) in Qassim area, Central Saudi Arabia were selected for investigation. The wells were purged through pumping for 10 min to ensure sample quality. Radon concentrations in these samples were measured with RAD-7an electric radon detector connected to RAD-H_2O accessory (Durridge Co, USA, 2010) for a period of one month.

RAD-7 detector was used for measuring radon concentration in water by connecting it with a bubbling kit, which enables to degas radon from water sample in air in a closed loop. A sample of water was taken in a radon – tight reagent bottle of 250 ml capacity, connected in a close circuit with zinc sulphide coated detection chamber which acted as scintillator to detect alpha activity and a glass bulb containing calcium to absorb the moisture. Air was then circulated in a close circuit for a period of 5-10 min until radon was uniformly mixed in air, and the resulting alpha activity was recorded which directly gave radon concentration (Althoyaib and El-Taher., 2015 ; 2016).

Calculation of annual effective dose : The annual effective dose of an individual consumer due to intake of radon from drinking water was evaluated by the following formula

$$D_W = C_W C_{RW} D_{CW} \quad (1)$$

where, D_w is the annual effective dose (Sv y^{-1}) due to ingestion of radio-nuclides; C_w is the concentration of ^{222}Rn in the ingested drinking water (Bq l^{-1}); C_{RW} isthe annual intake of drinking water (L y^{-1}); D_{CW} is the ingested dose conversion factor for ^{222}Rn (Sv Bq^{-1}). For calculating effective dose, a dose conversion factor of 5 x 10^{-9} Sv Bq^{-1}, suggested by the United Nations Scientific Committee on the Effects of Atomic Radiation,was used. Annual effective dose due to intake of ^{222}Rn from drinking water was calculated considering that an adult (Age >1 8 year), on average, drinks 730 l water annually (UNSCEAR, 1993).

Results and Discussion

The average radon concentrations in 99 irrigation groundwater samples from eight cities of Qassim, Saudi Arabia are presented in Table 1. The radon concentrations ranged from 1.20 to 15.43Bq l^{-1}. The obtained results in 95% of the samples were far less as compared to radon level measured by Eleftheriou *et al.* (2013); Küsters and Schraven (2009); Mauring and Gäfvert (2013); Wójcik and Zuzel (2013).

Only 5 samples, two from Al-Asyah, two from Al Shamasia and one sample from Al-Moznib exceeded the recommended level of radon in groundwater. Hence, an attempt was made in the current study to estimate the total annual effective dose resulting from radon in the sampled groundwater, and it was noticed that the annual effective dose-rate (AED) and effective dose-rate per liter (EDL) varied with increase in radon concentration. The calculated effective dose per liter (EDL) and annual effective dose (AED) ranged from 6.1 to 77.15 nSv l^{-1} and 4.45 to 56.16 □Sv y^{-1}, respectively (Table 1). It was evident that the total annual effective doses resulting from radon in groundwater from Qassim area were significantly lower than the recommended limit 1 mSvy^{-1} for public (UNSCEAR, 2009; WHO, 2012).

Table 1 : Average values of radon 222 and annual effective doses for underground water fromeight cities in Qassim area, Saudi Arabia

Location	Number of samples	Rn-222 Bq l^{-1}	Annual effective dose rateEDE μSv^{-1}	Annual effective doses per literEDL nSvL^{-1}	Total annual effective dose rate mSvy^{-1}
Buraydah	**16**	5.6±1.20	307.56	429.5	0.3035
Oniza	**21**	2.92±0.60	223.71	306.85	0,2239
Badayia	**7**	4.25±1.24	108.54	148.75	1086
Bakria	**11**	4.05±0.98	162.65	222.8	0.1463
Jawaa	**14**	4.29±0.86	218.91	300	0.1946
Asyah	**18**	5.08± 1.35	332.65	456.92	0.333
Shamasia	**6**	9.49±1.14	207.14	284.1	0.2075
Moznib	**5**	6.69± 1.25	121.71	167.2	0.1221

Table 2 : Range of radon concentrations in various types of water worldwide

Water type	Country	Range (Bq l^{-1})	Reference
Tap water	India	0.87-32.10	Singh *et al.*(2009)
Groundwater	Brazil	0.95-36.00	Marques *et al.*(2004)
Well water	Turkey	0.70–31.70	Yalim *et al.*(2007)
Well water	Mexico	1.78–39.75	Villalba *et al.*(2005)

In Saudi Arabia, studies on natural radioactivity content in the environment are dispersed in last few years. (Shabana *et al.*, 2013) and analyzed for Ra contents measured Twenty-nine groundwater samples were collected from Wadi Nu'man wells, Mecca Province, Saudi Arabia and analyzed for Ra contents. ^{222}Rn concentration ranged from 10-100 Bq l^{-1} with an average value of about 40 Bq l^{-1}. Recently, Aleissa *et al.* (2013) reported ^{222}Rn radioactivity concentration level in 171 well waters located in and around the city of Riyadh in Saudi Arabia. The analyses were recently, performed by an ultra-low level liquid scintillation spectrometer equipped with ana/b discrimination device. ^{222}Rn activities of deep wells ranged from 0.34±0.05 to 3.52±0.30 Bq l^{-1} (average: 1.01±0.10 Bq l^{-1}), whereas those of shallow wells ranged from 0.72±0.08 to 7.21±0.58 Bq l^{-1} (average: 2.74±0.24 Bq l^{-1} l). Kadi (2010) found ^{222}Rn in some groundwater samples, the concentration of ^{238}U and ^{222}Rn was assessed in underground water samples collected from the Makkah Al-Mukarramah area west of Saudi Arabia.

Several national and international health organizations have determined permissible limit for radon concentration. The USEPA has defined a value of 11.1 Bq l^{-1} for radon concentration in water in its report (USEPA, 1999). United Nations Scientific Committee, on the effects of atomic radiations, has defined a value of 40 Bq l^{-1}l (UNSCEAR, 2009) while WHO has defined a value of 100 Bq l^{-1} as an action limit (WHO, 2012).

Table 1 represents the overall radon concentration and their annual effective dose exposure in groundwater. It was found that radon activity varied from 1.20 to 15.43 Bq l^{-1} although, 95% of the samples were within the maximum contaminant level (MCL) of 11.1 Bq l^{-1}(USEPA, 1999). The spatial variations in radon concentration could be a function of the geological structure of the area, depth of water source and difference in climate and geo-hydrological processes that occurs in the area. When the measured radon concentration values was compared with the allowed maximum contamination level for radon concentration in water (which is 11.1 Bq l^{-1}), proposed by USEPA (1999), it was found that 95% of the investigated samples were below the recommended value. Also, when the measured values for radon concentration were compared with the European Commission Recommendations on Protection of Public against exposure to radon in drinking water supply, which recommended action level of 100 Bq l^{-1} for public water supplies, it was found that the levels measured in most samples were below these limits. Radon concentration reported in groundwater and tap water from different countries are tabulated in Table 2.

^{222}Rn concentration in 99 groundwater samples collected, Qassim area, Saudi Arabia ranged from 1.20 Bq l^{-1} to 15.43 Bq l^{-1}. The calculated effective dose per liter (EDL) and annual effective dose (AED) ranged from 6.1 to 77.15 nSv l^{-1} and 4.45 to 56.16 μSv y^{-1}, respectively. It is evident that ^{222}Ra level in groundwater in Qassim area is significantly lower than the permissible limit 1 mSv y^{-1}.

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