Radon and its Decay Products in the Main Campus of Qassim University, Saudi Arabia, and its Radiation Hazards

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Abstract: Rn-222 is the most important source of natural radiation and is responsible for approximately half of the received dose from all sources. Most of this dose is from inhalation of the Rn-222 progeny, especially in closed atmospheres. Portable devices, Alpha Guard and RAD 7 were used for Rn-222 measurements inside the main campus of Qassim University at Saudi Arabia in order to estimate the effective dose to the occupants from ^{222}Rn and its progeny. At the same time, meteorological variables, such as temperature and humidity were observed. The values of annual effective doses for radon inhalation by the inhabitants were found to vary in the range 0.2–0.6mSv/ y, with a mean of 0.38mSv /y^{1}. These results are lower than the value 1 mSv/y recommended by ICRP, 1990. The variation of dose relationship from indoor radon in lung tissue are calculated and tabulated. The investigation shows that the levels of indoor radon are well within acceptable values in main campus of Qassim University at Saudi Arabia. The Quality level parameters of the water used in the campus are measured and compared with the recommended levels of World Health Organization, WHO. In addition to environmental value of the present survey, the results are considered to be essential in analyzing any data for future activities in this field.

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1.Introduction

Radon is a naturally occurring, chemically inert, alpha particle emitting radioactive gas. This colorless, tasteless and odorless gas is produced by natural radioactive decay of uranium, radium and thorium found in trace amounts everywhere in the rocks and soils of the Earth's crust. The most stable and abundant isotope of radon is ^{222}Rn which has a half-life of 3.8 days. It decays by emitting an α particle of 5.49 MeV and creates radioactive daughters. In nature, radon is found in the air and being soluble in the water in all the water sources on the Earth including lakes, rivers, oceans, underground waters, springs and even in atmospheric precipitation. Radon is a player of a dual role in man's life. On one hand its presence in soil, waters and rocks has greatly facilitated the humanity in identification and prediction of earthquake occurrence, volcanic activities, fault dislocation and in hydrological research, while, on the other hand its presence in high level in indoor environment and drinking water constitutes a major health hazard for mankind because of its carcinogenic effects (1).

Human beings are exposed to radon in two ways, either through inhalation, or ingestion. Radon can enter into the indoor environment of our houses through cracks and openings in the floor and walls. Ground water constitutes an additional source of delivery of radon to the indoor environment. Radon and its short-lived decay products like ^{218}Po, ^{214}Po and ^{214}Bi etc. at indoor places have been pointed out to be the major sources of public exposure from the natural radioactivity, contributing to almost 50% of the worldwide mean effective dose to the community (2-3). Two of the α emitting daughters of ^{222}Rn, ^{218}Po and ^{214}Po, contribute over 90% of the total radiation dose received due to radon exposure (4). When radon decays after inhalation or ingestion, it releases energy that can damage DNA in the cells of the sensitive organs like lungs and stomach and can cause cancer. According to (5)^{222}Rn is the second leading cause of lung cancer in the US, smoking being the first.

The nature of building materials and water used for drinking and other domestic applications can make variable contributions to the radon level in indoor environment (6). Domestic water with elevated level of radon can make major contribution to the indoor radon exposure (7-8).

High concentration of radon in indoor air can be health hazard to humans, primarily being a cause of lung cancer (8).However, in addition to this, a very high level of radon in drinking water can also pose a significant risk of stomach and gastrointestinal cancer (9-10). In case of ingested radon, the radiation exposure is mainly due to radon gas itself, and the contribution of its progeny is less than in the case of indoor radon (10-11). High concentration of radon in indoor air can be health hazard to humans, primarily being a cause of lung cancer (8). However, in addition to this, a very high level of radon in drinking water can also pose a significant risk of stomach and gastrointestinal cancer (9-19). In case of ingested radon, the radiation exposure is mainly due to radon gas itself, and the contribution of its progeny is less than in the case of indoor radon (10-11). The highest organ dose from ingested radon is to the stomach, which receives about 90% of the total effective dose (10).

The present work deals with the measurement of radon concentration in some offices and laboratories, stores and drinking water supplies of the Main Campus of Qassim University by using , RAD7 and Alpha GUARD in order to see if the students, teachers, employees are at any risk from radon related health hazards. Moreover, mean annual effective dose due to radon will also calculated and compared with the maximum permissible level of the world recommended value. With this project we also aim to create interest and increase public awareness about the radon hazard in the community .Furthermore, some chemical analysis of drinking water supplies of Qassim university have been performed.

Radon in Saudi Arabia

In Saudi Arabia radon concentrations have been considered by the scientists as well and measured in several parts in the Kingdom. Abu-Jard and Al Jarahhah, studied radon measurements in a total of 19 cities and discuss the first survey of this type in Saudi Arabia (12). Abu-Jard et al, monitor radon in 1200 houses in four cities Hafr Al- Batin, Khafji, Madina and Taif (13). Abu Jard et al., monitor radon in 2700 house and 98 school nine cities in Saudi Arabia seven in the eastern province Dammam, Abqaiq, Al Ahsa, Hafr Al Batin, Khafji, Qatif, and Khobar and two in western provinve Madina and Taif. The lowest average radon concentration 8 Bq m-3 was found in Ahsa while the highest acerage concentration 40 Bq m^{-3} was found in Khafi (14). Al Jarallah and Fazul-u-Rahman, measured the radon concentrations in dwellings of Al Gouf region they found that the radon concentration varied from 7 Bq m-3to 168 Bq $m^{-3}$with an overall average of 45 Bq m^{-3} for all surveyed dwellings (15). There are also other studies deals with radon in Saudi Arabia cities (16-17).

2. Materials and Methods

The study location and measurement sites

Al Qassim Province is located in the center of Saudi Arabia approximately 400 km northwest of Riyadh the capital. Qassim is the heart of the country, its population is more than a million and its area is about 65,000 km². It has more than 400 cities, towns, villages, and Bedouin settlements. Its capital city is Buraydah, which is inhabited by approximately 49% of the region's total population. Buraydah has a typical desert climate, with hot summers, cold winters and low humidity. Qassim University was established in 2004. Since the establishment of the university, it has experienced a remarkable growth in enrollment and a significant expansion of faculty and its administrative staff. At present the university encompasses 28 colleges both for male and female students. Qassim University is located in the center of the Qassim region, 4 km north of Qassim regional airport, and covers an area approximately 7.8 million square meters in total. It is 28 Km from the main city Buraydah. Our survey of radon concentration was limited to 27 offices laboratories, and stores in addition to drinking water supplies in the main campus of Qassim university by using, RAD7 and Alpha GUARD in order to estimate the effective dose to the public from ^{222}Rn and its progeny ^{222}Rn concentrations in dwellings depend on meteorological an geological conditions, lifestyle, construction materials, and ventilation (18).

3. Results and Discussion

The results of indoor radon concentrations measured in twenty seven class room, student labs, research labs, offices, stores and main halls in the campus of Qassim university are tabulated and listed in table1. Indoor radon release is affected by moisture content, temperature, air pressure and other factors, therefore these factors are also observed and listed. From table 1 we noted that the radon 222 concentrations ranged between (5±6- 14±6) Bq/m^3. The variation in the indoor radon concentration due to many reasons such as the different ventilation rate and nature of the building materials, etc. The walls of all class room, student labs, research labs, offices, stores and main halls are painting with paint covering material; the flours of all offices are covered by carpets. We noted that, moreover detected radon concentration in the rooms of the ground floor is higher than for the other floors above the ground floor. This could be attributed to the fact that the radon is heavy gas and cannot go up to higher floors. Furthermore, the radon concentrations in the rooms of higher floors have a convergence values and there is no clear relation between the reduction of radon concentration value with height of the floor above the ground floor due to the different in there ventilation rates. The main campus was well air-conditioned completely by independent air conditioner types throughout the working hours. It is widely agreed that the principal source of ^{222}Rn in houses is the soil gas in the surroundings, but it could be reduced by a high ventilation rate. Adequate supply of outside air, typically delivered through the air conditioning system, is necessary in any office environment to dilute indoor radon concentrations because less ventilation allows radon to build up.

Qassim University with indoor surveys in dwelling reported worldwide is given in Table 2. It is clear that the detected concentration values of ^{222}Rn in the main campus of Qassim university are lower than those values reported in otherworld wide locations, see table 2 and also lower than the median values 46Bq m^{-3}, reported by UNSCEAR 2000 Report (3). On the other hand, it was found that the detected concentration values of ^{222}Rn in the main campus of Qassim university are in agreement with those reported in some other countries such as, Egypt, Japan, Syria, Cyprus and Australia.

Table1. Indoor Radon Concentrations radon-222 in the main campus of Qassim University.

Sample No.	*Location*	*Rn-222 Bq/m³*	*Temperature °C*	*Humidity %*	*Pressure mbar*
1	Nuclear physics Student Lab	14	26	28	934
2	Nuclear physics research Lab	11	24	23	936
3	Radiology lab (AMS)	12	23	22	937
4	Main Hall of the university	14	24	23	936
5	Analytical chemistry Student lab	11	23	26	936
6	101 Phys Student lab	11	24	21	933
7	Staff member office (1)	11	27	25	933
8	X-ray Lab	8	25	19	933
9	Electromagnetic Student Lab	9	18	27	937
10	Class room (1) 207 C	11	21	26	937
11	University Ceremony Hall A	9	20	30	937
12	Class room (2) 204 A	11	23	26	936
13	Administration office(1)	9	23	21	936
14	Employee office 1	10	24	21	935
15	Store (1)	9	23	22	933
16	Nanotechnology research lab	9	19	29	942
17	Staff member office (2)	9	24	25	911
18	101 chem. Student lab	5	21	28	941
19	Staff member office (3)	8	23	24	940
20	Main Hall Faculty of Science	9	22	24	939
21	Food Research lab	11	22	29	934
22	Main Hall Computer Science	8	27	22	939
23	Employee office (2)	9	24	21	935
25	Store 2	10	23	22	933
26	Class room (3)	10	24	21	935
27	Administration office (2)	8	22	29	934

Estimate of the radon exposure and radiation hazards

When exposure to radon (and radon progeny) is to be compared to the exposure from other radiation sources, it is necessary to estimate the effective dose per unit radon gas exposure. In the past this has predominantly been done by using the dosimetric evaluation of the absorbed dose to basal cells of the bronchial epithelium and applying the ICRP convention for calculating effective dose (effective dose equivalent). The indoor radon concentration is expressed in terms of equilibrium-equivalent radon concentration ($EECR_n$) by using the following relation: $EECR_n = F \times AR_n$ (1)
where F is the equilibrium factor (F=0.45) and ARN is the measured indoor radon activity. The equivalent dose received by bronchial pulmonary regions of human lungs has been calculated using a conversion factor 1.0 x10-5 mSv per Bq.h/m3.

Table3 shows the equilibrium-equivalent concentration (EEC) and the annual effective dose (Ann. eff. Dose) of indoor radon-222 from air in the main campus of Qassim University. Figure 1 shows, the concentration of radon and equilibrium-equivalent concentration in (Bq/m3) with location site.

Because of their different physical properties, radon gas and radon decay products are considered separately. Inhaled radon, being a noble gas, is constantly present in the air volume of the lungs at the concentration in air (XRn,air) and is partly dissolved in soft tissues. Taking the solubility factor for soft tissues to be 0.4 and assuming that the short-lived decay products decay in the same tissue as radon gas, the following relationship for soft tissues other than the lungs was derived from (49).

$$\dot{D}_{soft\ tissues}\ (n\,Gy\,h^{-1}) = 0.005\ \chi_{Rn,air}\ (Bq\,m^{-3}) \quad (2)$$

In the case of the lungs, in addition to the dissolved radon, the radon content of air in the lungs must be taken into account. Assuming the air volume in the lungs to be $3.2 x 10^{-3}$ m^3 for the 'Reference Man' and assuming further that the short-lived decay products will stay in the lungs, the dose rate due to alpha-radiation was determined as (49).

$$\dot{D}_{lung}\ (n\,Gy\,h^{-1}) = 0.04\ \chi_{Rn,air}\ (Bq\,m^{-3}) \quad (3)$$

Taking a quality factor of 20 for alpha-radiation and applying a weighting factor of 0.12 for the lungs and of 0.88 for other tissues, the effective dose equivalent rate was calculated as

$$\dot{H}_{eff}\ (n\,Sv\,h^{-1}) = 0.18\ \chi_{Rn,air}\ (Bq\,m^{-3}) \quad (4)$$

Table 4shows Variation of dose relationship from radon measurements from indoor air in the main campus of Qassim university. Figure 2 shows the variation of the indoor dose and the annual effective dose (mSv/y) with location site. and the annual effective dose ranged between 0.2- 0.6 mSv/y, with a mean value 0.38 mSv/y. These results are lower than the value 1 mSv/y recommended by ICRP report.

Table 2: Arithmetic mean of Radon concentrations in dwelling in indoor surveys

Region	***Country***	***Radon concentrations Bq/m^3***	***Reference***
Africa	**Algeria**	30	(19)
	Egypt	9	(20)
America	**Canada**	34	(21)
	United State	46	(22)
	Argentina Chili	37	(23)
	Paraguay	25	(24)
East Asia			
	China	24	(25)
	Hong Kong	41	(26)
	India	57	(27)
	Japan	10	(28)
	Pakistan	30	(29)
West Asia			
	Iran	82	(30)
	Syria	10	(31)
	Kuwait	14	(32)
	Qassim, SaudiArabia	9.5	This work
North Europe			
	Estonia	120	(33)
	Finland	120	(34)
	Sweden	108	(35)
West Europe			
	Austria	48	(36)
	France	62	(37)
	Switzerland	70	(38)
	United kingdom	20	(39)
South Europe	**Cyprus**	7	(40)
	Greece	73	(41)
	Italy	75	(42)
	Portugal	62	(43)
Eastern Europe			
	Czech Republic	140	(44)
	Hungary	107	(45)
	Poland	41	(46)
Oceania			
	Australia	11	(47)
	New Zealand	20	(48)
Median	**UNSCEAR**	46	(3)

Table 3: EEC and Ann. eff. Dose of indoor radon-222 from air in the main campus of Qassim university.

Sample No.	*Location*	*Radon-222*	*EEC*	*Annual effective Dose*	*Indoor Dose*
		Bq/m^3	Bq h /m^3	mSv/y	mSv/y
1	Nuclear physics Student Lab	14	6.3	0.6	0.4
2	Nuclear physics research Lab	11	5.0	0.4	0.3
3	Radiology lab (AMS)	12	5.4	0.5	0.3
4	Main Hall of the university	14	6.3	0.6	0.4
5	Analytical chemistry Student lab	11	5.0	0.4	0.3
6	101 Phys Student lab	11	5.0	0.4	0.3
7	Staff member office (1)	11	5.0	0.4	0.3
8	X-ray Lab	8	3.6	0.3	0.2
9	Electromagnetic Student Lab	9	4.1	0.4	0.2
10	Class room (1) 207 C	11	5.0	0.4	0.3
11	University Ceremony Hall A	9	4.1	0.4	0.2
12	Class room (2) 204 A	11	5.0	0.4	0.3
13	Administration office(1)	9	4.1	0.4	0.2
14	Employee office 1	10	4.5	0.4	0.3
15	Store (1)	9	4.1	0.4	0.2
16	Nanotechnology research lab	9	4.1	0.4	0.2
17	Staff member office (2)	9	4.1	0.4	0.2
18	101 chem. Student lab	5	2.3	0.2	0.1
19	Staff member office (3)	8	3.6	0.3	0.2
20	Main Hall Faculty of Science	9	4.1	0.4	0.2
21	Food Research lab	11	5.0	0.4	0.3
22	Main Hall Computer Science	8	3.6	0.3	0.2
23	Employee office (2)	9	4.1	0.4	0.2
25	Store 2	10	4.5	0.4	0.3
26	Class room (3)	10	4.5	0.4	0.3
27	Administration office(2)	8	3.6	0.3	0.2

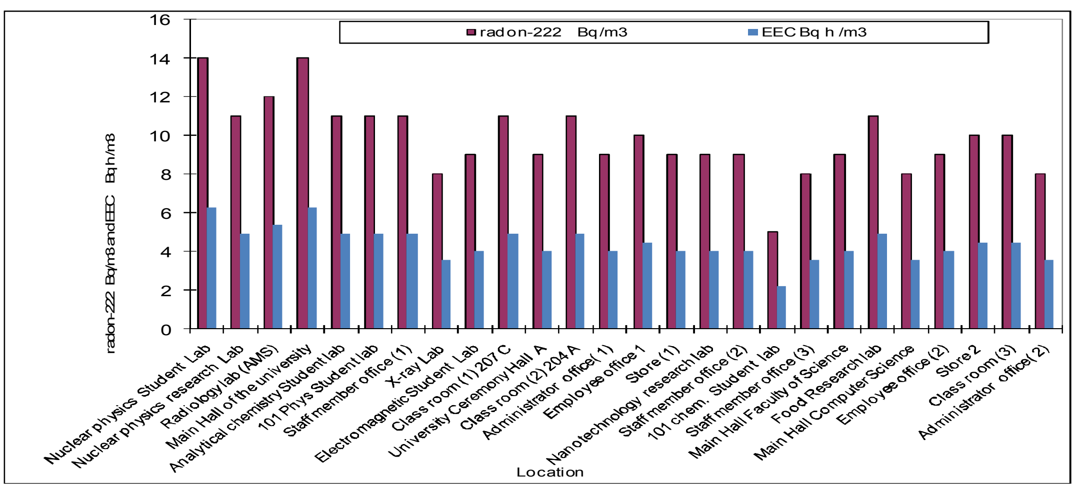

Fig 1.The concentration of radon and equilibrium-equivalent concentration in (Bq/m^3) with location.

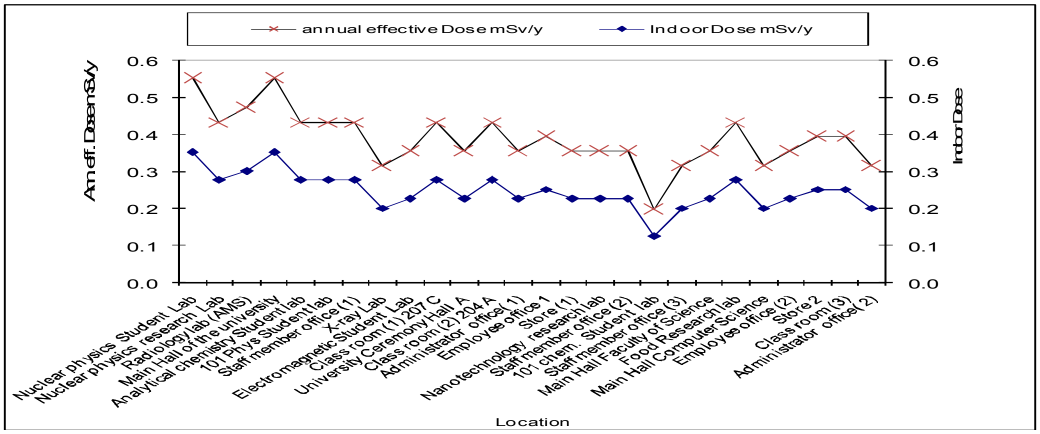

Fig 2: The indoor dose and the annual effective dose (mSv/y) with location

Table 4 :Variation of dose relationship from indoor radon measurements from air in the main campus of Qassim university.

Sample No.	*Location*	*Radon-222*	*D soft tissues*	*D Lung*	*H eff*
1	Nuclear physics Student Lab	14	0.07	0.56	2.5
2	Nuclear physics research Lab	11	0.06	0.44	2.0
3	Radiology lab (AMS)	12	0.06	0.48	2.2
4	Main Hall of the university	14	0.07	0.56	2.5
5	Analytical chemistry Student lab	11	0.06	0.44	2.0
6	101 Phys Student lab	11	0.06	0.44	2.0
7	Staff member office (1)	11	0.06	0.44	2.0
8	X-ray Lab	8	0.04	0.32	1.4
9	Electromagnetic Student Lab	9	0.05	0.36	1.6
10	Class room (1) 207 C	11	0.06	0.44	2.0
11	University Ceremony Hall A	9	0.05	0.36	1.6
12	Class room (2) 204 A	11	0.06	0.44	2.0
13	Administration office(1)	9	0.05	0.36	1.6
14	Employee office 1	10	0.05	0.40	1.8
15	Store (1)	9	0.05	0.36	1.6
16	Nanotechnology research lab	9	0.05	0.36	1.6
17	Staff member office (2)	9	0.05	0.36	1.6
18	101 chem. Student lab	5	0.03	0.20	0.9
19	Staff member office (3)	8	0.04	0.32	1.4
20	Main Hall Faculty of Science	9	0.05	0.36	1.6
21	Food Research lab	11	0.06	0.44	2.0
22	Main Hall Computer Science	8	0.04	0.32	1.4
23	Employee office (2)	9	0.05	0.36	1.6
25	Store 2	10	0.05	0.40	1.8
26	Class room (3)	10	0.05	0.40	1.8
27	Administration office (2)	8	0.04	0.32	1.4

Calculation the concentration of radon in tap water used in Qassim university campus

The concentration of radon in the tap water used in Qassim University has been carried out for using RAD 7. It can be seen that radon activity varies from $1.15 BqL^{-1}$ to $4.49 BqL^{-1}$.Although, all the samples are within the maximum contaminant level (MCL) of 11.1 Bq L^{-1}(5).When the measured radon concentration values are compared with the allowed maximum contamination level for radon concentration in water (which is 11 BqL^{-1}), proposed by the US Environmental Protection Agency, (5), it can be seen that the present values are below this recommended value. Also, when the measured values for radon concentration are compared with the European Commission Recommendations on the protection of the public against exposure to radon in drinking water supplies which recommends action levels of 100 BqL^{-1} for public water supplies, it can be seen that the levels we measured were below these limits. In Table 5, the values obtained here are compared with those of reported in the literature from other countries.

Table5: Range of radon concentrations in various types of water worldwide

Water type	Country	Range Bq/l	Reference
Drinking	India	0.87-32.10	(50)
Ground	Brazil	0.95-36.00	(51)
Well	Turkey	0.70–31.70	(52)
Well	Mexico	1.78–39.75	(53)
Ground	Italy	1.80–52.70	(54)
Tap	Qassim university, Saudi Arabia	1.15- 4.49	Present work

Quality levels of water used in Qassim university campus

Water is the basic necessity and an essential element for life. It can play an important role in human nutrition. The quality of drinking water is a universal health concern and access to safe water is a fundamental human right. To ensure the quality of water used in the main campus of the Qassim University, the tap and drinking water in addition to bottled water and underground water samples were collected and analyzed. The quality level parameters were analyzed using portable meters for pH, EC and TDS; spectrophotometer for SO_4, NO_2 and NO_3 and Atomic Absorption Spectrometry for elemental analysis of Pb, Cu, Mn and Zn. Table 6, shows the levels of the determined parameters. The obtained results has been compared with the recommended levels of The World Health Organization, WHO (55).

To evaluate the quality level parameters of the water used in the campus, the parameters were classified as following:

I. Parameters and substances affect the quality of water (pH, EC, TDS, HCO3, NO_3 and SO_4).
II. Micronutrients – trace elements (Pb, Zn and Cu)
III. Potentially essential elements that have some beneficial health effects (Mn).

From Table 6, we may conclude that, the physical and chemical properties of drinking and tap water collected from the same source in the campus passes through a same purification process do not have any preference for drinking used than other purposes in the labs. The reference sample (Bottled water) pass through high purification process is in well agreement with the stander specification of drinking water. However, the measured concentration of ions in the underground waters found to be very high. The depth of the well is about 90 m from the sea level which is used in irrigation. This type of wells can easily polluted by agricultural fertilizers and various human activities. The investigation reveals that the water taken from such kind of well contain high concentration of prevalent cautions (e.g. calcium and magnesium) as well as the prevailing anions (e.g. chloride, sulfate, bicarbonate). Consequently, one may conclude that the underground well water is not suitable for drinking completely.

Table 6: Quality levels parameters of the water used in the main campus of Qassim University compared to bottled and underground well water.

Water parameter	Drinking water	Tap water	Bottled water	Underground well water	Limits for drinking water in WHO, 2006 (55)
PH	7.67	7.57	7.33	6.99	
EC (µS)	645µS	649 µS	203 µS	6832 µS	
TDS (mg/l)	300	324	101	3400	
Turbidity (NTU)	0.39	0.38	0.30	0.71	
Bicarbonate Alkalinity as $CaCO_3$	127	90	55	193	600
Total Hardness as $CaCO_3$	130	120	21	2561	
Ca Hardness as $CaCO_3$	84.66	73.66	7.66	1522	
Mg Hardness as $CaCO_3$	45	46	15	1040	
Cl^- (mg/l)	89	88	32	1352	250
NO_3^- (mg/l)	2.85	2.84	0.807	37.61	
NO_2^- (mg/l)	NIL	NIL	NIL	NIL	0.2
SO_4 (mg/l)	150	152	19	3118	500
Pb (mg/l)	Nil	Nil	Nil	Nil	0.01
Cu (mg/l)	Nil	Nil	Nil	Nil	2
Mn (mg/l)	Nil	Nil	Nil	Nil	0.4
Zn (mg/l)	Nil	Nil	Nil	Nil	

Conclusion

Uranium and thorium are widely distributed in rocks and soils of the earth's crust. Thus, parent materials for radon daughter isotopes are also available worldwide. The most important radon isotope from a health viewpoint is Rn-222. Its decay products, especially ^{218}Po and ^{214}Po, can have a pronounced adverse effect on lung tissues, leading to lung cancer in many cases. Radon entry into dwellings usually occurs through cracks, joints, pipe fittings in walls, loose sealants or caulking around windows, and so on. Based on the portable device Alpha Guard and RAD 7, Rn-222 was measured in air inside the main campus of Qassim University at Saudi Arabia. The Arithmetic mean of radon concentrations was 9.5 Bq/m3 and the annual effective dose ranged between 0.2- 0.6 mSv/y, with a mean value 0.38 mSv/y. These results are lower than the value 1 mSv/y recommended by ICRP,1990. On the basis of the current results, we may conclude that in main campus of Qassim University at Saudi Arabia, the levels of indoor radon are well within acceptable values.

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