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Evaluation of Toyserkan City's Water Contamination, due to the existence of Radon, and Estimation of the annual effective dose

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ABSTRACT

The gas of ^{222}Rn is one of the natural radioactivesources which is the decay product of ^{226}Ra from ^{238}U decay chain. Based on the latest information presented bythe United Nations Scientific committee in the field of the effects of atomic radiations, the respiration of Radon and its daughters (Plutonium, Bismuth and Lead), are one of the most important factors in human radiation inhalation, since Radon and its daughters account for approximately 1.2 msv of the total of 2.4 msv (mili Sievert) annual effective dose of natural radioactive sources produced. The fluctuation in the levels of Radon resolved in water, due to the hazards caused by the emitted radiations, is considerable; because studies show that long-term exposure to Radon increases the chances of lung cancer. The amount of radon in underground waters is more than that of surface waters. If water is exposed to free air, especially when it's mixed as well, a considerable amount of its radon content is released. In this paper, Radon concentration (Bq/L) in waters of the wells and springs located in Toyserkan, is measured using Lucas chamber technique by means of a light weighted and transportable machine namely PRASSI (SFLENAmod5s). The results showed that the radon density in four measured samples in the waters of this region exceed 10 Bq/L, the allowable amount determined by the US Environmental Protection Agency (USEPA). For the cases where the concentration is high, is it proposed that drinkable water be preserved in open pools or at least waterfalls be used in order to agitate the water to release itsradon content. It is better to install a system for settling and exposing the water to air so that Radon and its decay products are dispersed and the contamination problem is solved.

Keywords

Healthy Drinkable Water 2, Radon 3, PRASSI System 4, Toyserkan Region.

INTRODUCTION

Radon with the chemical sign of Rn, is a colorless, odorless, neutral and heavy gas; which is hazardous to the human health. ^{222}Rn is the decay product of ^{226}Ra from decay chain for ^{238}U and the natural decay series of ^{238}Th [16]. According to figure 1, in which the natural isotopes of Radon are introduced, it should be stated that on average, in every 10^{21} molecules of air, there is one molecule of Radon; and in each square miles of soil with the depth of 6inches, one gram of Radium exists that is also degraded to Radon (Ferri ,2002). The regions where the Radon comes to the surface by the upstream current, it is expected that the diffusion of Radon from underground waters and soil, represent the soil structure of that region. (Adilson 2007, Vasarheli 1997). Furthermore, the measurement of the concentration of Radon in the air available in soil is of great importance in the construction of new buildings that are resistant against Radon and prevent the increase in the internal Radon level (Jonsson 1995, Theodorsson 1996).

This element has 20 isotopes, the most stable of which is ^{222}Rn with the half-life of 3.8 days and it is used in radiotherapy (Field 2001). When this gas is cooled down below its freezing point, it exhibits a brilliant phosphoric color that is changed to yellow for lower temperatures and has an orange-red color in normal temperatures [7]. This element was discovered by Ernest Radford and Fredrich Eren in 1900. Almost 50 percent of the human radiation inhalation is due to Radon, lots of people suffering from digestive and respiratory diseases lose their lives each year. This number is 21000 people only in the United States.

The main purpose of this research is to evaluate the Radon and Radium concentration in the drinking waters of Toyserkan city and other regional water resources using PRASSI system.

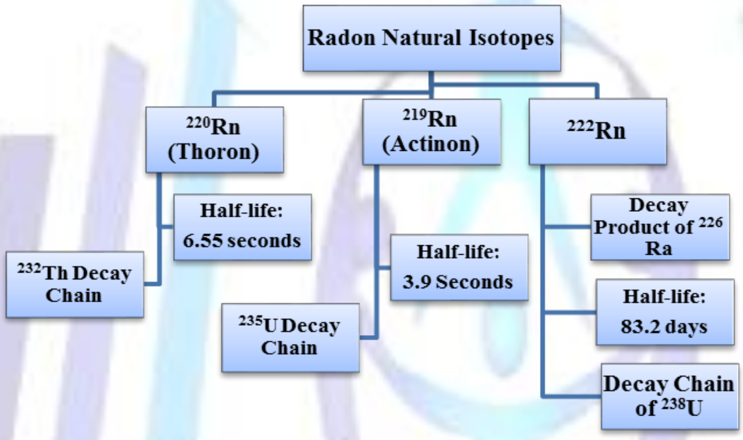
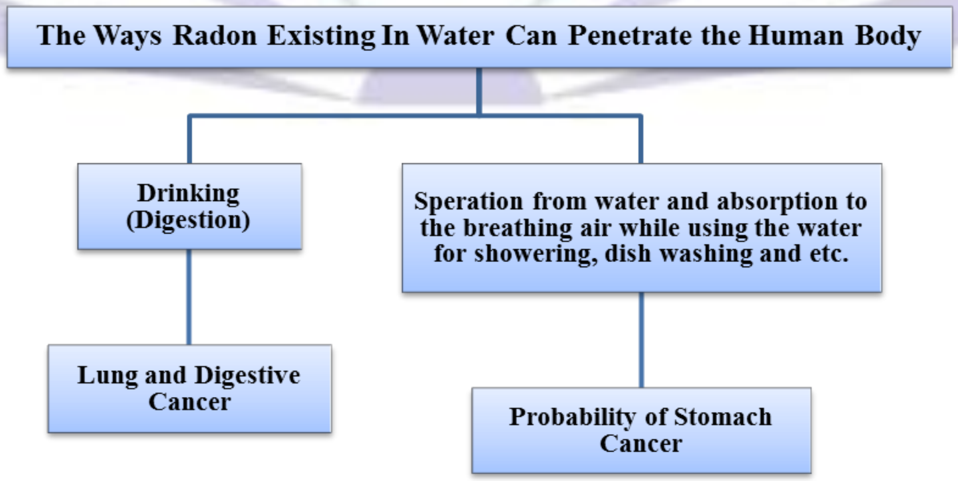


Figure 1: Different isotopes of Radon and its properties

.RADON IN WATER AND ITS HAZARDS

A part from respiration, Radon can enter the human body by digesting, drinking and showering which is illustrated in figure 2. The amount of Radon existing in underground and static waters, especially deep wells, is more. In the United States of America, deaths due to cancers caused by Radon in drinking waters are estimated about 180 persons per year [9].



. **Figure 2:** The ways Radon existing in water can penetrate the human body

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It should be noted that if only 40-50 percent of the Radon in water is decreased prior to entering households, the number of people suffering from respiratory and digestive diseases is decreased by 30-35 percent which is very effective in the long-term reduction in the medical costs. Since one of the major water pollutants that plays an important role in the drinking water health is Radon, and according to recent reports regarding the pollution of the waters in the city of Toyserkan leading to the increase in the lung cancer, therefore in this research, the authors have the intention to measure the concentration of Radon gas in water resources by means of the PRASSI device.

.RADON MEASURMENT IN WATER SAMPLES

The amount of Radon in springwaters, deep wells and especially in underground waters is more. Also, the more the water is agitated, the more the amount of Radon is decreased. Therefore, the water samples were collected from the entrance of the springs, in the lowest depth in a 25cm distance from the free water surface and reverse pressure conditions. The samples were then transferred to the measuring site while kept cool and in the least time possible (Figure 3).

In this research, the PRASSI system, model 5S, was utilized for the purpose of measuring the Radon gas concentration. This system has special features for measuring the concentration of Radon in water and air such as high sensibility, high memory capacity, short response time and large LCD screen which has the capability of monitoring the Radon density diagrams.

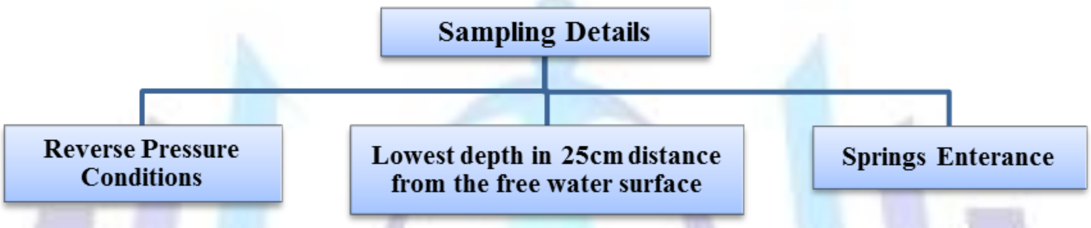

Figure3:How the sampling was done

In figure 4, the design and the measurement method of Radon in water samples using the PRASSI device is illustrated.The device's built-in detector is made of a 1830 cm^3 chamber whose internal walls are coated with ZnS(Ag). This device is suitable for closed-cycle measurements. The pumping cycle of PRASSI functions with the constant speed of 2 Liter per second in this research [11].

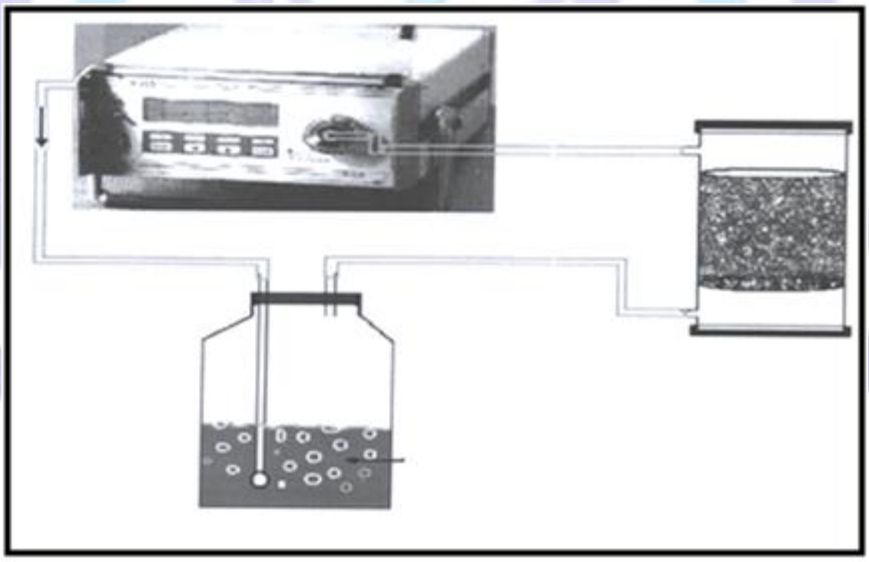

Figure 4: PRASSI Model 5S Device and its belongings

.RESULTand DISCUSSION

In the current research, the concentration of Radon gas was determined in 15 samples from the water resources in Toyserkan region. The sampling locations are marked in the city plan shown in figure 5.

Figure 5: Plan of Toyserkan City and sampling locations

In table 1 the Radon gas density of each sample in terms of Bq/L calculated by equation 1, is shown.

$$Q_{Rn}\left(\frac{Bq}{Lit}\right) = Qprassi \times \frac{V_{tot}(m^3)}{V(lit)} \quad \text{(eq. 1)}$$

Where:

Q_{Rn}: the real amount of radon gas concentration (Bq/L)

Q_{PRASSI}: the amount of radon gas measured by PRASSI device (Bq/L)

V_{Tot}: the total volume of the work cycle, in this case: 2.4×10^{-3} m^3.

V: the sample volume, in all cases approximately: 0.15×10^{-4} m^3.

Furthermore, figure 6 shows the histogram graph of the radon gas density in the evaluated samples. The results determine that the amount of radon in 4 samples is more than 10 Bq/L.

Table 1: Measures Radon concentration results from 15 samples in the Toyserkan region

Sample No.	Water Type	Sampling Time	Measurement Time	Correction Factor	Q_{PRASSI} (Bq/L), (∓ 0.004)
1	Drinking water of Ghaem town, retrieved from the faucet	10:35	14:15	1.033	7.1952
2	Drinking water inside the house (boiled)	12:10	16:46	1.035	5.9712
3	Drinking water in the city	12:15	17:05	1.037	6.776
4	The outlet water of Mobarak-Abad well	12:20	17:40	1.041	10.9424
5	Drinking water of Sorkan City	11:35	15:05	1.027	14.7408
6	Outlet water of the Qanat of Emamzadeh Naser	11:40	15:00	1.026	9.11424
7	Drinking water of Taleghani Town	11:50	14:50	1.023	6.6720
8	Drinking water of Feresfej City	11:57	15:30	1.027	5.96
9	Mirage water of Emamzadeh Zeid Town	11:55	15:25	1.027	5.9152
10	Qanat[1] water of Farhangian Town (10 m of the qanat entrance with 10cm depth)	12:00	15:45	1.029	6.5824
11	Mirage water of reservoir dam	12:05	15:50	1.029	12.1843
12	Drinking water of Eslam-Abad Region	11:44	16.37	1.038	6.7456
13	Qanat water of Emamzadeh Abdollah Shahr	11:51	15:55	1.031	10.7456
14	Drinking water of Police Town	11:39	17:15	1.043	6.0624
15	Drinking water of Shohada Town	11:39	16:54	1.041	6.6752

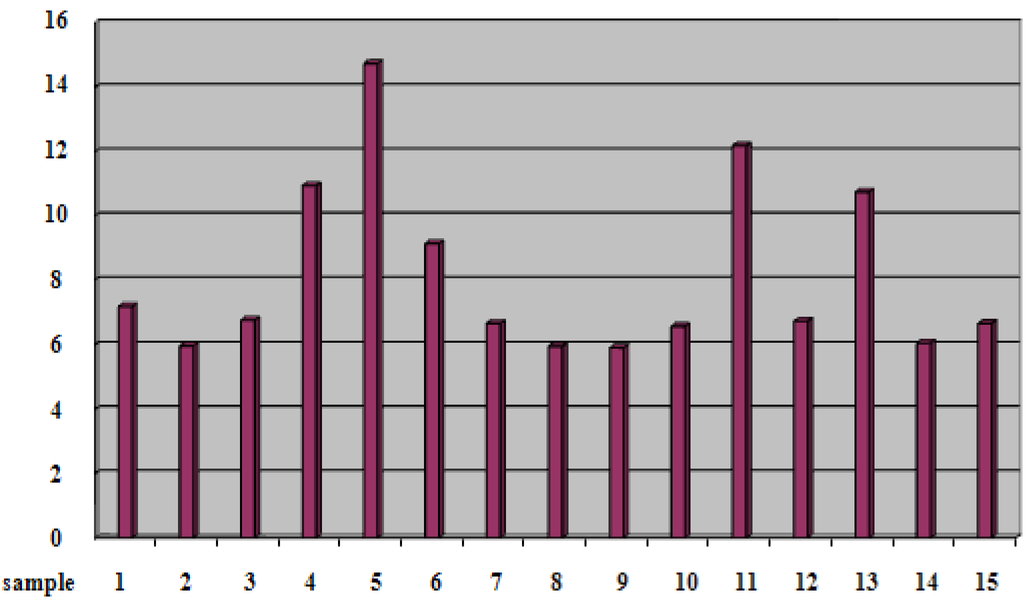

Figure 6: Plan of Toyserkan City and sampling locations

[1] Subterranean Canal

. A Comparison between the Current Sampling and a Sampling Done in Covalency City Campus, Swaziland

The results from the measured radon concentration in Covalency city are shown in table 2 and the related diagram and histogram graphs are illustrated in figures 7 and 8, respectively.

Table 2: Measured Radon concentration results from 9 samples in Covalency City, Swaziland**.**

Sample No.	Well Depth (m)	Temperature (Centigrade)	Radon Concentartion, (Bq/L)
1	**50**	**19**	**0.857**
2	**N/A**	**19**	**2.376**
3	**N/A**	**21**	**2.452**
4	**80**	**21**	**2.949**
5	**120**	**21**	**3.656**
6	**N/A**	**18**	**4.678**
7	**140**	**19**	**4.888**
8	**180**	**19**	**6.345**
9	**100**	**23**	**3.456**

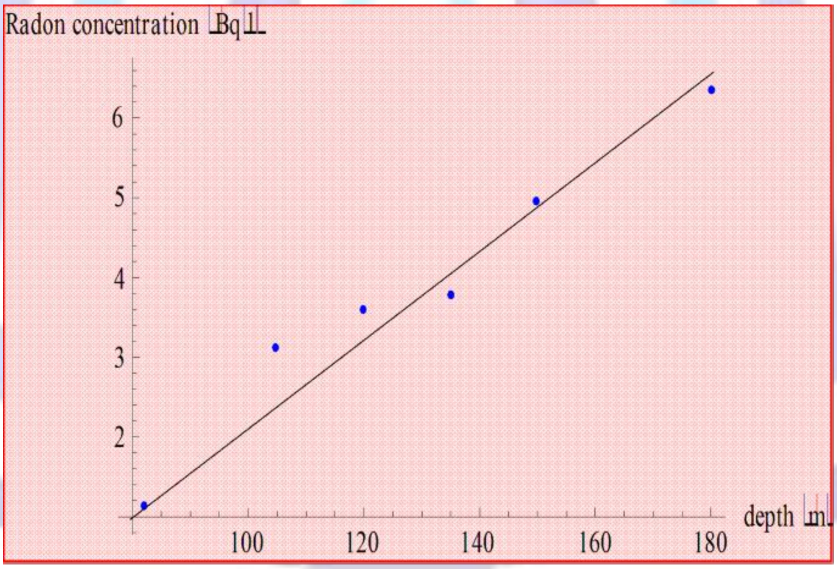

Figure 7: the amount of Radon concentration in samples to the wells depth and the best fit

According to the results, for both case studies (Toyserkan and Covalency Campus), radon gas concentration in the water samples is less than the proposed amount by USEPA which is 10 Bq/L. Therefore the radon concentration in the regional waters of Toyserkan and Covalency Campus is not hazardous to the human health

. Calculation of the Annual Effective Adsorbed Dose of Radon in the Region

The effectivedose in every material includes the direct and indirect ionizing radiations which can be easily measured and is defined by the following equation

$$D = \frac{dE}{dm} \qquad \text{(Eq.2)}$$

In order tocalculate the annual effective dose, it is assumed that each inhabitant of the Toyserkan region daily consumes 2.5 liters of water. Based on the results found in table 1 and the calculations regarding the effective dose of stomach and lung, the correction factor for the stomach and lung were found as follows, respectively: 2.628 and 2.79

[EPA, 1998]. Using these factors, the effective dose for the regional water samples of Toyserkan were determined and are presented in table 3 [2].

Table 3: The Annual Effective Dose of Radon in

Sample No.	**Radon Concentration, Bq/L**	**Annual Effective Dose,** (μSvy^{-1})		
Sample No.	**Radon Concentration, Bq/L**	**Annual Effective Dose,** (μSvy^{-1})		
		Stomach	**Lung**	**The Whole Body**
1	**7.1952**	**18.9089**	**20.0747**	**38.4836**
2	**5.9712**	**15.6923**	**16.6596**	**32.3519**
3	**6.7776**	**17.8115**	**18.9095**	**36.721**
4	**10.9424**	**28.7566**	**30.5292**	**59.2858**
5	**14.36**	**34.7380**	**40.0644**	**77.8024**
6	**9.1424**	**24.0262**	**25.5027**	**49.5334**
7	**6.672**	**17.5340**	**18.6148**	**36.1488**
8	**5.96**	**15.6628**	**16.6284**	**32.2912**
9	**5.9152**	**15.5451**	**16.5034**	**32.0485**
10	**6.5824**	**17.2985**	**18.3648**	**35.6633**
11	**12.1843**	**33.7545**	**33.9939**	**67.7484**
12	**6.7456**	**17.7274**	**18.8202**	**36.5476**
13	**10.7456**	**28.2394**	**29.9802**	**58.2196**
14	**6.0624**	**15.9319**	**16.9140**	**32.8459**
15	**6.6752**	**17.5424**	**18.6238**	**36.1662**

. CONCLUSION

. Since almost 50 percent of the human radiation inhalation is due to Radon gas, which is one of the main causes of the annual death due to respiratory and digestive cancers, and according to the fact that the most Radon intake is from drinking water and respiration while showering and etc., the measurement of the Radon gas concentration in the regional underground waters of Toyserkan was carried out [10]. The results found in this research show that the radon concentration in 4 samples of the consumed water by the inhabitants exceeds the allowable limit proposed by USEPA which is 10 Bq/L. (Samples numbers 4, 5 11 and 13)

However, currently, no serious hazard threatens the consuming water of Toyserkan regarding its Radon content [12]. Therefore, in order to improve the water health and to decrease the potential hazards due to Radon, it is proposed that the drinking waters settle in open pools for a while, before distribution or at least waterfalls for agitation and removal of the gas, be used [5].

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