MEASUREMENT OF RADON LEVELS IN WATER IN ARAR CITY, SAUDI ARABIA

H.M. DIAB

Physics Department, Faculty of Science, Northern Border University, Arar, Kingdom of Saudi Arabia
E-mail: hdiab2003200327@yahoo.com

Abstract. Exposure to radioactive elements or having them through drinking water causes many biological risks. Therefore, it is important to investigate the drinking water especially in regions where people depend on well water for drinking. Concentrations of radon in Arar city of Saudi Arabia were measured by using RAD7 and RAD H_2O accessories. Concentrations of radon were measured in three types of drinking water: mineral water, tap water and bottled drinking water coming from wells. The results showed that the average values of radon concentrations of all three water types under study were in the internationally permissible range. Results therefore showed that there were no indications of hazard in water samples and the investigated wells from which the water was taken are suitable for drinking concerning the measured radon. The work recommends more studies to investigate other radionuclide elements that might be present in the drinking water.

Key words: radon, water, RAD7, RAD H_2O accessories, environment.

INTRODUCTION

Natural environmental radioactivity and the associated external exposure due to gamma radiation depend mainly on the local geological and geographical conditions and appear at different levels in each region in the World [20]. Radon is released from the decay of uranium in soil and rocks and its concentration in particular geological materials and locations is different [4]. Abnormal changes in radon levels in many areas have been identified by active faults [22]. The occurrence of high levels of radon in drinking water represents a potential health risk due to human exposure through inhalation on account of exhalation of radon and its decay products from water into household air and through direct ingestion of radon in drinking water [21, 23]. An evaluation of international research data,

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United Nations Scientific Committee on the Effects of Atomic Radiations [20] has concluded that, on average, 90% of the dose attributable to radon in drinking water comes from inhalation rather than ingestion. The exposure of the population to high concentrations of radon and its daughters nuclei for a long period lead to pathological effects such as the respiratory functional changes and the occurrence of lung cancer [3]. However, a very high level of radon in drinking water can lead to a significant risk of stomach and gastrointestinal cancer [9]. Humans are also exposed by contamination of the food chain which occurs as a result of direct deposition of radionuclides on plant leaves, root uptake from contaminated soil, sediment or water [2], and from direct ingestion of contaminated water [16].

The radon issue has become one of the major problems of radiation protection. Radon exposure occurs when using water for showering, washing dishes, cooking and drinking water [13]. Long half-life of Radon is formed in the ground or building materials [14].

Radon is the second most important cause of lung cancer after smoking. Lower concentrations of radon – such as those found in homes – also contribute to the occurrence of lung cancers worldwide [5, 11, 12]. RAD7 detector is used to measure concentration of radon in water [17]. The distribution of radon (^{222}Rn) in groundwater samples and their annual effective dose exposure in some areas were studied using Durridge RAD7 radon-in-air monitor, by RAD H_2O technique with closed loop aeration concept [18]. To measure radon on the surface, in the underground water and in the oil-produced water separated from oil in Basra Governorate in Iraq, there were used fast electronic techniques RAD7 and the passive method with the solid state nuclear track detectors CR-39 and L115-II [8]. RAD7 detector was also used for measuring the concentration of radon in drinking water supplies in Palestine [1].

In this study, three types of drinking water in Arar using RAD7 and RAD H_2O accessories were investigated, which were well water, tap water and bottled mineral water. Bottled mineral water was bought from the nearest supermarket, while tap water and well water were taken from selected areas of Arar city. Total 12 samples were taken with 4 samples for each type of water. The radon values reported in this study were considered as a baseline for radon level in the Arar city as no such radon study in drinking water had been carried out in this area before.

MATERIALS AND METHODS

SAMPLE COLLECTION AND PREPARATION TECHNIQUES

A total of 12 samples of water from three types of common drinking water were concerned in this study and 250 mL of water sample were used in each study. These three types of drinking water were taken into account: a) well water coming from different wells inside Saudi Arabia; b) tap water coming from reservoirs through pipes after water desalination process in General Organization for water desalination; c) bottled mineral water with different branding was bought from the nearest supermarket. The samples of tap water were taken from different districts inside Arar city, Saudi Arabia: Khaledya, Mossaedya, Faysalya, Salheya. Other four samples of well water were collected from Alshark, Alsahab, Ghadeer, Katr Elnada companies which seal water for a public. Because of improving the sensitivity and precision of measurements at low radon concentrations, a larger sample size was chosen. Water was allowed to flow about 10 minutes to ensure an accurate radon content of water can be collected from the underground water supplies [13]. Then, the bottles were closed rapidly and tight to avoid radon leakage. The samples taken were analyzed in the radiation Physics Laboratory, Northern Border University, Arar, Kingdom of Saudi Arabia.

THE RAD7 SYSTEM

The RAD7 (manufactures by Durridge Company) with RAD H_2O accessory was used to measure radon in water from the concentration range less than 10 pCi/L up to greater than 400 000 pCi/L. The RAD H_2O always requires the desiccant in order to dry the air stream before it enters the RAD7. For water sample analysis, the small drying tubes are necessary to avoid using the large drying tube as its much larger volume would cause improper dilution of the radon. Humidity reading for RAD7 has to remain below 10% and must be free of radon and dry before starting the measurement. A drying unit during the initial purging process should be found to save the small drying tubes and for the actual measurement, in water, in order to assure a suitable argued system, a source of inert gas is required [6, 9].

CALCULATION OF RADON DOSE

RAD7 calculates radon concentration in water samples by multiplying the air loop concentration by a fixed conversion coefficient that depends on the sample size. Conversion coefficient is 4 for a 250 mL sample volume and it is assuring the accuracy for the larger sample volume (250 mL), but not the reading difference in the smaller sample volume. The results of the sample were corrected from the time the sample was drawn to the time it was counted. Decay correction can be used for samples counted up to 10 days after sampling, though analytical precision will decline as the sample gets weaker and weaker.

$$DCF = \exp\,(T/132.4) \tag{1}$$

where T is the decay time in hours and DCF is the decay correction factor.

Based on the table with the decay correction factors, decay times less than three hours require very small correction. The decay factor can be neglected for the samples counted quickly. Thus, the actual radon concentration for each sample was calculated as below:

$$\textit{Concentration in water (corrected)} = \textit{radon concentration} \times DCF \tag{2}$$

There is no correction for the temperature of the water sample. Also the background of RAD7 is less than one count per hour, so there is no need for measuring the background of RAD7 because it is very low. For stabilization, the RAD7 was purged for 30 minutes to remove the old radon from the machine and purged again for 15 minutes between the measurements [6].

RESULTS AND DISCUSSION

Table 1 represents four different types of drinking water (coming from different four companies) and their radon concentration was measured using RAD7. These samples were named A, B, C, D. The temperature during the measurement of the sample was between 24 °C and 25 °C and relative humidity is from 5 to 11%. As can be seen from Table 1, brand A has the highest radon concentration with 16±4 pCi/L. Brand B has the second highest concentration, 12±3 pCi/L followed by 8±6 for brand D. The lowest radon concentration in drinking water is brand C, where 2.9 ± 2.9 pCi/L.

Table 1

Radon concentration for different samples of drinking water coming from wells

Number of the sample	Name of stations (Bottled wells water)	Radon concentration (pCi/L)
A	Alshark	16±4
B	Alsahab	12±3
C	Ghadeer	5±2.8
D	Katr Elnada	8±6

Table 2 summarizes the radon concentration for different samples of bottled mineral water coming from supermarkets. Temperature during measurement was 24 °C to 25 °C and relative humidity was between 7 and 11%. There were four different sources of bottled mineral water. Sample C has the highest radon concentration with 10±1.9 pCi/L, followed by the sample A with 9±1.5 pCi/L and sample D with 8±2.3 pCi/L The lowest radon concentration was detected in sample B: 5±1.7 pCi/L.

Table 2

Radon concentrations for different sample of bottled mineral water

Number of the sample	Name of bottled water companies	Radon concentration (pCi/L)
A	Qassim	9±1.5
B	Nestla	5±1.7
C	Helwa	10±1.9
D	Nova	8±2.3

In Table 3 is presented radon concentration for the samples of tap water from different districts inside Arar city. The temperature during the measurement of radon concentration of the sample is between 24 °C and 29 °C. Relative humidity was between 4 and 9 %. Mossaedya has the highest radon concentration with 44±2.3 pCi/L, followed by Khaledya with 43±1.4 pCi/L and Faysalya 35± 3.1 pCi/L. Salheya had only 29±1.7 pCi/L, which is the lowest radon concentration.

Table 3

Radon concentration of tap water from different districts in the Arar city

Number of the sample	District in the Arar city	Radon concentration (pCi/L)
A	Khaledya	43±1.4
B	Mossaedya	44±2.3
C	Faysalya	35±3.1
D	Salheya	29±1.7

In the Kingdom of Saudi Arabia, the workers obey the safety reports series No.67-IAEA publications concerning water quality standards but no special regulation for radon gas. Some research indicated that radon in drinking water may affect the stomach as well as other organs, once the radon was detected in the bloodstream [15]. Although the radon concentration in drinking water is not regulated by legislation, The US Environmental Protection Agency (EPA) has proposed a maximum contaminant level (*MCL*) for drinking water equal to 300 pCi/L or 11.1 Bq/L.

This study showed that all the water is safe to use for various purposes, because most of samples do not exceed the value of radon concentration recommended by EPA. Four different types of drinking water were measured and displayed in Table 1. The results of this study show that sample A has the highest radon concentration compared to other types. Sample C showed the highest radon concentration for mineral water as presented in Table 2. These results may be explained as water coming from different sources. Each source has a different geological element and compound. This is supported by the idea of [8] that radon concentration varying from a region to another depended on the variation of the geological structure of the source of drinking water.

The possible reason regarding the reduction of radon concentration may be due to radon decay process during the water treatment including the procedures of mixing, flocculation/coagulation, sedimentation and filtration before it was bottled [19]. Besides this, another possible reason for low concentration of radon in all types of water might be the long time between the dates of bottling and the measurements.

Based on Table 3, the tap water at Mosaedya had the highest concentration of radon compared to Faysalya, Khaledya, and Salheya. These samples are below *MCL* recommended by US EPA. It might be possible, since all of tap water comes from a surface water source such as a reservoir. It is due to no underground water contribution to this surface water [7]. Plus, radon concentration in surface water decreases very fast because of the escape of radon from water into atmosphere before reaching water supplier or home. Thus, tap water is safe to be used for domestic purpose.

Relative humidity inside the measuring instruments during measurement is another factor that contributes to radon concentration. This was supported by other studies [19] which reported that relative humidity had the greatest impact. Relative humidity should be below 10% for the entire 30 minutes of measurements. However, during the measurements, the humidity exceeds more than 10% in most of cases. High humidity reduces the efficiency of collection of ^{218}Po atoms. Under these circumstances, a low level of radioactivity can be detected. RAD7 detector has unusual ability to inform about the difference between new radon daughter nuclei and old radon daughter nuclei left from the previous test. The higher radon concentration and the longer previous samples were held in the cell, the more daughter nuclei activity was left behind. In order to remove the background, the detector is purged and the background activity that was left in the detector is flushed from the chamber.

CONCLUSIONS

In this work the natural radioactivity levels of radon have been measured in water samples using RAD7 and RAD H_2O accessories. The activity profiles of the radon have clearly shown low activity concentrations across the study area. Radon concentration in drinking water should not exceed 300 pCi/L in US EPA recommendations. According to this work, three types of samples which are well water, bottled mineral water and tap water have a level of the concentration of radon below *MCL* which was recommended by US EPA. The mean activity concentrations of radon were 10.3±3.95, 8±1.85 and 37.8±2.13 pCi/L respectively. Therefore, the water of the area has no immediate health risk for the inhabitants and it can be used, without posing any significant radiological threat to the population. However, further studies might be necessary to estimate the external and internal doses from other suspected radiological sources within Saudi Arabia.

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