

# Radon in water in the qanats of the Province of Shahrood

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## Abstract

According to WHO statements, radon is the second most important cause of lung cancer, after cigarette smoking. Thus, it is mandatory to evaluate the radon indoor and radon in water concentration in areas where there is a large population. Few studies were performed on this topic, apart from those concerning the Province of Ramsar (a northern coastal city in Iran), which has some of the highest levels of natural radiation measured to date.

For these reasons we are performing within a larger research study on qanats a specific study on radioactivity in drinking water coming from the qanats of the province of Shahrood. The very first results obtained are really encouraging: we sampled the water coming from some qanats near Shahrood, Torud and Biarjomand and the concentration levels are very low and do not represent any hazard for the population. More measurements will be done in the next future also in other drinkable water supply systems.

## 1. Introduction

Radon is a colourless, odourless gaseous radioactive element having the symbol Rn, the atomic number 86, an atomic weight of 222, it is the daughter of Ra-226 (Radium), coming from U-238 decay chain and it has 25 isotopes already known. It is present in the earth and rock beneath homes; well water; building material. Volcanic areas are usually rich of radon. It is the major contributor to the environment ionising radiation dose: present estimates published by UNSCEAR [1] indicate that approximately half of the natural-origin radiological dose to humans originates from inhalation of the short-lived progeny of radon isotopes. Such estimates are based upon data from the numerous radon surveys which are carried out in several States all over the World.

Rn-222 has a 3,82 days half-time and it decays in lead-210 (which has higher half-life -22,3 years-) via three alfa and two beta decay processes realised within 4 days from the first decay. When Rn-222 arise after radium decay in the earth, it can reach the surface, as it is a gas; an estimation shows that the continental surface produces  $8,9 \times 10^{19}$  Bq per year [2]. It is highly soluble in cold water and this makes easy the transportation also to long distances from the original source. In particular EPA (Environmental Protection Agency) evaluates [3] that 1% of radon induced deaths come from the use of drinkable water with huge radon concentration; 89% of them are caused by lung cancer, 11% of them by stomach cancer. The main contribution of radon to health diseases comes from radon indoor concentration if it is not monitored and mitigated. Since the Eighties there is a growing attention in several countries to the control of radon concentration in houses and working places and in the houses, after the ICRP recommendations [4].

Radon-222 is an extremely toxic gas: the World Health Organization (WHO) and the US Department of Health and Human Services, as well as EPA, have classified it as a "Class A" known human carcinogen, because of the wealth of biological and epidemiological evidence and data showing the connection between exposure to radon and lung cancer in humans, in fact almost all the absorbed radon is transmitted to lung tissues [5]. In particular, according to WHO statements [6], radon is the second most important cause of lung cancer, after cigarette smoking. It gives no immediate symptoms. The only health effect which has been definitively linked with radon exposure is lung cancer. Lung cancer would usually occur years (5-25) after exposure. There is no evidence that other respiratory diseases, such as asthma, are caused by radon exposure and there is no evidence that children are at any greater risk of radon induced lung cancer than adults. Smokers are at higher risk of developing Radon-induced lung cancer.

In Iran there are some areas famous for their high natural radiation concentration: i.e. the maximum radon levels in some regions of Ramsar are up to  $3700 \text{ Bq m}^{-3}$  [7], but few studies were performed on the problem of radon, i.e. the one on the North-West area of Iran, namely in the cities of Ardabil and Lahijan [8], only one on radon in water [9], where 8 springs, deep wells and rivers water sources of Mashhad region were measured with PRASSI system. No studies on the possible presence of radon in water in the region of

Shahrood were performed till now. In order to realize radiation protection plans, where they are needed, it is mandatory to evaluate radon concentration in drinkable water, where it is predictably present. For these reasons we are performing, within a larger research study on qanats, a specific study on radioactivity in drinking water coming from some of the qanats of the province of Shahrood (North-East of Iran).

## 2. Rationale

A joint project started on January '09 in order to study some qanats in the Province of Shahrood. It is performed by CNR – Institute of Chemical Methodologies, in collaboration with the University of Technology of Shahrood, Department of Earth Sciences, Iran and the University of L'Aquila, Italy, according to the Memorandum of Understanding signed on June 16, 2008. The project has three tasks: a) to realize a better definition of hydrologic and hydro-geological of the area; b) to study the possible presence of radon in the water; c) to contribute to a better definition of qanats (Fig. 1) in the economic and social context of the region.



**Fig. 1** Shafts sequence of a qanat in the Province of Shahrood – photo coming from: <http://www.qanatproject.com>

Using recent techniques, after the suggestions of EU recommendation [10] and of Unsear report [11] on the importance of radon in water measurement in the areas where the people use ground water for drinkable purposes, we started the monitoring of the radon content inside a certain number of qanats (ancient management systems used to provide a reliable supply of water to human settlements in arid and semi-arid climates, which are still in function in many semi-arid areas in Iran) and in particular the qanats of Shahrood, Torud and Biarjomand, all interesting and populated cities and villages on the North-East border of the Kavir desert. The radon concentration will be detected both in the air (for the workers safety) and in the water using at first a short-time monitoring system and then a long-time one.

Radon in water exposure is a phenomenon similar to radon indoor for houses; therefore it is suggested to use the same radiation protection criteria. Taking into account both ingestion and inhalation, the effective dose per year given by water containing 1000 Bq/l of radon, according to present knowledge, is comparable to the effective dose per year given by an indoor radon concentration of  $200 \text{ Bq m}^{-3}$ . This is the design level established in Recommendation 90/143 Euratom [10]. The Recommendation 01/928/Euratom [12] suggests that for water destined for human consumption the radon concentration has to be lower than 100 Bq/l and not higher than 1000 Bq/l.

## 3. Material and Equipment

For radon measurement we use the simple system of electret ion chambers (E.I.C.). It is a lightweight, affordable, passive charge integrating device for accurate measurement of different radiation. An E.I.C. for

monitoring radon comprises a base having the electret holder and a chamber (different if it is performing a short term or a long term measure). The electret itself is realised in two different types in order to be used in short term or long term monitoring. After the exposure the electret voltage decreases for the ionising events and calculating the voltage difference and the exposure time it is possible to estimate the radon concentration in the site.

We use E-Perm electrets and chambers in order to monitor the radon concentration in the qanats and in the qanat water, reading the results with SPERM 1 Electret's voltage reader and calculating the environmental ionizing radiation contribution with a PM5-ID gamma monitor. In particular radon in water was calculated using an E-Perm Radon in Water system.

The monitoring strategy was to measure the radon concentration in the water (taking the water from each qanat and measuring it with the E-Perm (short-term) Radon in Water system, in order to understand if the deep wells that supply population with drinking water may also contain a large amount of radon. In the meanwhile a long-time monitoring of radon concentration in the air in the three above mentioned qanats was performed using the E-Perm E.I.C. system and leaving *in situ* several sensors to be counted after 6 and 12 months. During the first visit in January '09, in each qanat the environmental gamma contribution was analyzed using the above mentioned portable gamma monitor.

At the end of the monitoring campaign all the data will be given (in a suitable data-base) to Local Authorities in order to allow them to realize possible radon mitigation activities (if needed). Moreover we will provide the University of Shahrood colleagues with all information, data comparisons and technical details in order to enable them to reproduce in a consistent way these analyses in different qanats. Then the radiation protection expert will provide them with suggestions and recommendations in order to minimize radon impact on the population.

#### **4. First results**

During January '09 we performed five radon in water tests in four different qanats. The results are reported below.

I test – Shahrood qanat. Water sample was collected at the end of the underground pipeline (Shahrood outskirts) which connects the former qanat to the city.  
Radon Concentration: 5,79 Bq/l

II test – Biarjomand qanat. Water sample was collected directly from one of the shafts of the qanat branch running parallel to the main road entering the village.  
Radon Concentration: 9.49 Bq/l

III test – Biarjomand qanat. Water sample was collected from one of the shafts of one of the two branches (water temperature approx. 22° C) flowing into the perpendicular branch to the main road entering in the village.  
Radon Concentration: 13.69 Bq/l

IV and V tests – Torud qanat. Water samples were collected at the end of the qanat course, before the area used by ladies for clothes washing, near the public bath building.  
Average Radon Concentration: 0.96 Bq/l

We have not yet results for radon concentration in air in the qanats, as the E.I.C. we installed at approx. 2 meters from the water level in several shafts of the Biarjomand and Torud qanats will have to be measured during the next mission in Iran. In Fig. 2 is possible to understand the system we used to suspend the electrets inside the shafts.



**Fig. 2 E.I.C. system suspended in a shaft of Biarjomand qanat – photo coming from: <http://www.qanatproject.com>**

## 5. Conclusion

It is important to stress that these results are the first of a larger monitoring campaign to be performed during the next months. But it is also important to say that these results are really encouraging, as in all the four positions we find values largely inferior to the World average. Water-saturated soil with a porosity of 20 % and a radium concentration of 40 Bq/kg, which is the world-wide average in the earth's crust, causes at equilibrium a radon concentration in ground water of the order of 50 Bq/l [12].

In particular Shahrood qanat value is highly interesting as the water is largely used for drinking purpose and it is important that the consumers are confident that the water does not pose any risk to human health.

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