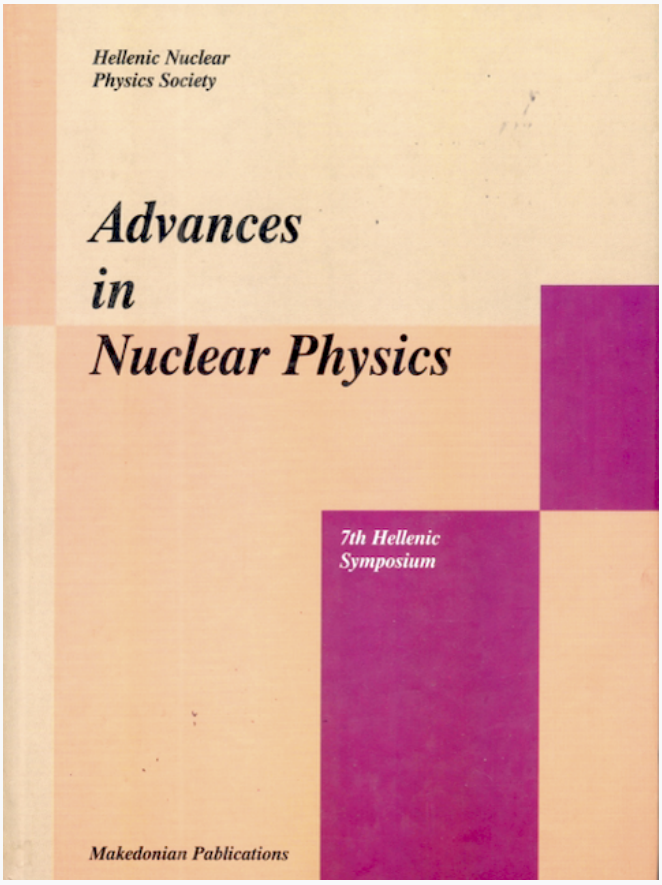
HNPS Advances in Nuclear Physics

Vol 7 (1996)

HNPS1996



Natural Radioisotopes Determination in Groundwater and Tap Water using Gamma Spectrometry

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doi: [10.12681/hnps.2415](https://doi.org/10.12681/hnps.2415)

Natural Radioisotopes Determination in Groundwater and Tap Water using Gamma Spectrometry

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Abstract

Samples of underground drinking water -tap water, water from drilled wells and springs- have been collected from selected sites in Ikaria island. Concentration levels of ^{226}Ra, ^{228}Ra and ^{222}Rn have been analysed by gamma spectrometry. The effective dose equivalents from ingestion of water are in the range 0.1-114 μSv.y^{-1} for ^{222}Rn and 25-175 μSv.y^{-1} for ^{226}Ra. The respective range from inhalation of ^{222}Rn released from water is 0.36-85 μSv.y^{-1}.

1 Introduction

Natural radioactivity in water varies greatly, depending on the geologic characteristics of the ground. ^{222}Rn is usually the main contributor to the natural radioactivity of groundwater [1]. In this study we have determined the concentration levels of ^{222}Rn in distinct samples of spring, drilled wells and tap water samples collected throughout Ikaria region. Taking into account the relationship between ^{226}Ra/^{222}Rn and ^{226}Ra/^{228}Ra, included in this study are the results from measuring the concentrations of ^{226}Ra and ^{228}Ra carried out using the same samples of water.

Ingestion of water containing ^{226}Ra and dissolved ^{222}Rn results in doses in the human body. ^{222}Rn contained in water is to some extent transferred to indoor air as a result of agitation or heating. The typical range for radon entry rate in a reference house due to water is 0.001-100 Bq.m^{-3}.h^{-1}. In conclusion, the two pathways for internal irradiation due to drinking water are ingestion and inhalation of ^{222}Rn released from water. The inhalation of ^{222}Rn and its short-lived decay products is significant in cases when the water contains high concentrations of ^{222}Rn [2].

The measurements of radioactivity in drinking water from houses, drilled wells or springs are used for the evaluation of the internal irradiation due to consumption of the water.

2 Survey Description

Ikaria island, which is mainly characterized by a mountain area, can be considered as being divided into two geological areas distinct petrologically: a) The eastern part which consists of sedimentary formations mainly metamorphosed and b) the western part which mainly consists of granitic formations [3].

In the south littoral zone of the island there are several spas and in the sublittoral zone some springs bubble up from the bottom as well. In a previous study the radiological status in areas around the springs was evaluated by measuring samples of spa water, sea water, sediment and algae. The above samples were analysed by using a high resolution gamma spectrometry system with a HpGe detector of 20% relative efficiency to a 3"×3" NaI detector [4].

In the first stage of this study samples were collected from the mineral springs of the island. In the second stage, samples were collected from other parts of the island, including drilled wells and tap water samples. Samples were collected from selected sites.

3 Materials and Methods

Water samples were transferred in: a) 1l Marinelli beakers and pH up to 1 was adjusted, adding nitric acid b) 0.93 l Marinelli beakers specially designed for ^{222}Rn measurements, in order to avoid gas losses, and made from material which permits the water sampling without acidification. The same samples were used for the measurement of the activity concentrations of ^{222}Rn, ^{226}Ra and ^{228}Ra. The concentration levels of ^{222}Rn, ^{226}Ra and ^{228}Ra were determined by the use of a high-resolution gamma spectrometry system with a HpGe detector of 20% relative efficiency to a 3"×3" NaI detector.

For ^{222}Rn determination, beakers were sealed and stored for 3 h prior to measurement to ensure that ^{222}Rn and its daughters reached equilibrium. ^{222}Rn activities were derived from the analysis of the 295.2 keV, 352 keV lines of ^{214}Pb and 609.4 keV line of ^{214}Bi taking into account the correction factor for decay between sampling and counting of the sample. It is estimated that the measurements in 1l plastic Marinelli beakers have an uncertainty of 25% due to gas releases during sampling. For ^{226}Ra determination, the samples were aerated and closed after the removal of ^{222}Rn. The samples were kept sealed for at least 20 days to ensure that equilibrium was achieved between ^{226}Ra and its daughters. Because some of the ^{226}Ra and ^{228}Ra values were near the Low Limit of Detection for these nuclides (0.1 Bq l^{-1}), the results were tested by performing another method of measurement: A volume of 4-4.5 l of acidified water was evaporated at 100 °C and the residue was measured in the γ spectrometry system. The results obtained for ^{226}Ra and ^{228}Ra from this method are in accordance with the direct method.

The method described, in cases with concentrations $\geq$ LLD allows operators to use small volumes of water and non-destructive gamma spectrometry for ^{222}Rn and ^{226}Ra-^{228}Ra concentration measurements. Water sampling is carried out in a simple way and it is not needed specialists to be performed. This is quite a privilege in studies involving national surveys or periodical (e.g. seasonal) monitoring.

4 Results and Discussion

The results of gamma spectrometry measurements in drinking groundwater samples in Ikaria island are given in Table 1, together with the summarized results from other areas. These results show that elevated concentrations of ^{222}Rn and ^{226}Ra-^{228}Ra are detected in drinking spa water in comparison with the respective values in tap water and drilled well samples.

4.1 Radium-226

The activity concentrations of ^{226}Ra are in the range of <0.1-0.7 Bq.l^{-1} (Table 1). Considering a water consumption of 0.5 litres per day, per person and a conversion factor 250 μSv.y^{-1}.Bq^{-1}.l [5], the annual effective dose equivalent due to ^{226}Ra ingestion is in the range 25-175 μSv.y^{-1} (Table 2). The highest doses correspond to the drinking spa water consumption.

4.2 Radon-222

The activity concentrations of ^{222}Rn are in the range 0.1-114 Bq.l^{-1} (Table 1). Considering water ingestion of 0.5 litres per day, per person and a conversion factor 1 μSv.y^{-1}.Bq^{-1}.l [2], the annual effective dose equivalent due to ^{222}Rn ingestion is in the range 0.1-114 μSv.y^{-1} (Table 2). The highest doses correspond to the drinking spa water consumption. In case of domestic water supplies, in order to evaluate the contribution of potable water to the indoor ^{222}Rn concentration, the average value of 10^4 for the water-air transfer coefficient of ^{222}Rn is used [6]. Applying this factor, the radon concentration in indoor air due to its entry from water degassing is 0.01-2.4 Bq.m^{-3}. This corresponds to an annual effective dose equivalent range due to radon released from water 0.36-85 μSv.y^{-1}.

5 Conclusions

The survey of natural radioactivity in drinking water in Ikaria island shows that the highest concentrations are found in potable spa water. Exceptionally high concentrations in domestic water supplies have not been found. The effective dose equivalent due to the drinking spa water is enhanced when compared with respective values in the literature.

Table 1

a) Activity concentrations of natural radionuclides in drinking groundwater samples in Ikaria island (Bq·l^{-1}).

Drinking spa water

	^{222}Rn	^{226}Ra	^{228}Ra
MV±SD	45±38	0.2±0.2	0.5±0.5
Min	19±3	0.1±0.2	<0.1
Max	114±9	0.7±0.3	1.5±0.7

Domestic water supplies (Tap water-Drilled wells)

	^{222}Rn	^{226}Ra	^{228}Ra
MV±SD	8.8±9.3	0.1±0.4	0.4±0.5
Min	0.1±2	<0.1	<0.1
Max	24±3	0.2±0.2	1.3±0.7

b) Summarized results of measurements in drinking water from other areas in Greece and other countries (Bq·l^{-1}).

^{222}Rn	^{226}Ra	^{228}Ra
	$(10\text{-}130)\times10^{-3}$ [7]	$(30\text{-}300)\times10^{-3}$ [7]
25-269 [8]	$(4.1\text{-}89)\times10^{-3}$ [8]	
17 ± 0.7 [9]	0.140 ± 0.004 [9]	
600 [10]	1 [10]	
3 [10]	0.02 [10]	
0.15-13 [11]		

Table 2

Annual effective dose equivalents due to ^{222}Rn and ^{226}Ra ingestion and ^{222}Rn inhalation from drinking water ($\mu Sv\cdot y^{-1}$).

a) Annual effective dose equivalents due to the ingestion of drinking water

^{222}*Rn*	
This study	(0.1-114) $\mu Sv.y^{-1}$
Other areas	(1.8-1300) $\mu Sv.y^{-1}$
^{226}*Ra*	
This study	(25-175) $\mu Sv.y^{-1}$
Other areas	(0.5-120) $\mu Sv.y^{-1}$

b) Annual effective dose equivalents due to the inhalation of ^{222}Rn released from water:

(0.36-85) $\mu Sv.y^{-1}$

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