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Measurement of Radon-222 Concentration in Bottled Natural Mineral Drinking Water in Kuwait using the Nuclear Track Detector (CR-39)

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ABSTRACT

Water is the essential element in creating and sustaining conditions for human life Cell of the organism, and the medium in which we live. Water is one of the most important natural elements in our life; it is the secret of life, and is one of the most important components of living matter. Water accounts for 63% of the human body weight (Average) and human muscles contain about 83% of it. The human body needs about 5.2 liters Daily of water, and gets this quantity of water from food and drink. Water plays a key role in the chemical processes in the body, rid of waste, and contribution the regulation of body temperature and Sweating process. Due to the importance of drinking water in the preservation of life on the one hand, water is exposed to pollution by many pollutants, including microorganisms, minerals, organic substances and radioactive materials, on the other hand Which called for the issuance of standards for the acceptance of drinking water, whether global or local standards. I would highlight the radiological side on this study [1]. Although Kuwait does not have natural drinking water resources such as wells or rivers, most bottled water companies are directed to seawater in desalination, or resort to drill coastal beach wells. The coastal beach wells, are wells drilled near the coast of sea at depths of up to 50 meters, and are extracted from it salty sea water, but it is free of pollutants and impurities, or can be taken directly from the sea and thus work is a comprehensive desalination of water and adding Minerals such as magnesium and calcium, in addition to ensuring that it is free of any bacteria or viruses and detect its radioactive contamination or ensure that the concentration of natural radionuclides are not exceeded the international limit in this drinking water, after that water treatment and the addition of ozone gas for sterilization, then the final stage is manufacturing conservation bottles and bottling water in different sizes and processing for sale to the consumers. In this study, the concentration of radon gas in different samples of bottled mineral drinking water companies was measured in State of Kuwait. Concentration of (^{222}Rn) in Bottled Mineral drinking water varies from 1.02 Bq/L to 6.05 Bq/L with the average value of 2.97±1.44 Bq/L. From these results it can be concluded that the majority of drinking water is a safety potable water from the stand point of radon concentration in them. Mean values of effective dose per liter and annual effective dose from radon ingested with drinking water for an individual consumer are 29.72 nSv/L and 21.69 µSv/y, respectively. So, the level of Radon concentration in Kuwaiti bottled mineral drinking water is below the permissible limits for health purposes to drink.

1. Introduction

Mineral water is also called gaseous substances, which are water containing salts and minerals, such as salt, magnesia, iron, magnesium sulphate, and many other elements and substances and useful gases, most notably carbon dioxide. This water is found in artesian wells and mountains, and varies depending on the type of terrain in which they are found. Mineral water is formed after rainfall, as water flows through the soil to the bottom of the earth, reaching the depths and forming wells and springs. Mineral materials dissolve in water as they travel through the rocks in the ground, and the rocks that collect water high porosity to retain water inside. There are other sources of mineral water, flowing water, which is produced in the ground by the interaction of water with the magma present there, where it escalates to the location of hot springs and regular heat. But they are less pure than those formed by rainwater, because of the presence of magma containing poor substances and impurities. Mineral water can be prepared without nature, where specific proportions of salts allowed by the Ministry of Health permit are prepared and processed to become potable. Carbon dioxide is also added to make water suitable for as long as possible.

Water springs are similar to the well water (groundwater) in the formation, the formation and the specifications as a result of passage of water Rain (or any other source of water) through the pores of the soil from which it leaks containing impurities and plankton Non-biological, and as they pass

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through soil layers many salts and elements In the soil, which earns a high content of these salts so called mineral water, Hot water is also called because of its high temperature which may reach 90 °C compared with Natural water temperature ranging from (10 - 25 m). This water is characterized by its stable, non-changeable chemical composition, naturally formed in water reservoirs especially, so that they do not mix with surface water and do not need to apply any changes or add chemicals to them. It is healthier for the human body compared to normal drinking water because it contains almost all ions, and necessary elements for non-delayed the growth and protection of the human body as they maintain the presence of ions in the body. It regulates the body and purifies it from harmful substances and also maintains a balance in the amount of water that Lost by the human body during activities. Mineral water is released from underground and flows into the form Water wells or by drilling wells to extract groundwater, and the quantity and size of mineral water Vary from site to site depending on the conditions of composition and the quality of the layers of composition in which this water is stored.

1.1. First Classification of Mineral and Hot Water

Some scientists classified mineral water on the basis of its flow and depending on the amount of salts dissolved in it to the following:

1 - Light Mineral Water: is the water containing the amount of dissolved salts ranging from 250 - 500 mg / l.

2 - Heavy mineral water: is the water containing the amount of salts salted more than 500 / mg.

3 - Water of natural eyes: is the water that flows from the underground and comes out naturally and not unstable physical or chemical properties are found in various rocky places.

It is worth noting that most of this water is suitable for drinking and does not require purification or filtration which contains natural ions that do not harm human health.

1.2. Second Classification of Mineral Water

Other scientists have classified mineral water on the basis of the concentration of certain elements in it (Calcium, Magnesium and Sulfur) Ingredients:

Calcium Water: Which contains each liter of 140 mg of calcium, it helps to growth of the human body.

Magnesium Water: Mineral water, each containing 12 mg of magnesium which strengthens the immune system and controls blood pressure.

Sulfur Water: is mineral water rich in sulfur and is used to treat rheumatic diseases, Joints, skin, and other diseases.

The third part of the scientists classified these waters on the basis of their natural flow to the Earth's surface They are often associated with trenches, deep valleys in mountainous areas, and mineral waters are found Extracted by drilling wells at depths far from sources of pollution, and related to the formation of geological layers that maintain their physical and chemical properties.

1.3. Benefits of Mineral Water

The treatment of many diseases, such as irritable bowel syndrome, rheumatism, dyspepsia and constipation, and many infections such as inflammation of the gums, arthritis and skin infections, and is useful in the treatment of kidney stones and bladder, and protects from Many types of cancer diseases. Taking into account the temperature of water when used, there are resorts, baths, and tourist and therapeutic centers for people for treatment, tourism and entertainment.

Mineral water benefits the skin due to its sensitivity and effects. There are oily skin that suffers from the presence of open pores and pimples. The magnesium and calcium elements help to renew the skin's weak cells. There are dry skin that helps moisturize, not only in the face, but in other areas of the body, such as the feet and knees and elbows. Sensitive skin is also very sensitive to environmental factors; it protects it from dehydration to a large extent, to contain the element calcium.

1.4. Radioactivity in Mineral and Hot Water

Humans are exposed to ionizing radiation from two important sources: natural radioisotopes and artificial radioisotopes. Natural radioactive isotopes are found on the surface of the earth with concentrations varying between place to place since the Earth was formed. The most important radioactive elements present in the Earth's crust are K-40, Rb-87, Uranium-238 and Thorium-232 and its derivatives.

Natural radiation is the primary responsible for radiation exposure to the general public around the world since the Earth formed, where the radiation continues to fall on its surface from outer space, in which the primary and secondary cosmic rays and gamma rays are from the earth's crust and the products of disintegration of half – life of radon and radionuclides long life half of the most important sources leading to the exposure of the human population to radiation varies from region to region. The result of the interaction of these rays is generated with the atmosphere components, and the most important radioactive elements most important in terms of human are: carbon-14, beryllium-7 and tritium-3, which are soon to fall either by rain or gravity to the surface of the earth.

1.4.1. Radioactivity in Natural Waters is Generally Formed by the Disintegration of Three Main Chains

Uranium-238 Series, Uranium-235 Series, Thorium-232 series where many products are disintegrated of semi-short-lived radioactive nuclei and the breakdown of these chains ends with isotopes pb-206 Fixed. The uranium-238 series produces the majority of the radioactive nuclei present in natural water. Play as products the disintegration of the thorium-232 series is particularly important in some areas where thorium ores are available, while the products of the disintegration of Uranium-235 (Actinium) Chain are of secondary importance due to the low availability of this analog within the uranium Natural.

The total dissolved uranium is found in natural water in many forms, including U, UO2 and U. Characterized with low solubility, while UO2 is associated with 4 + U 4 water solutions. It has the capacity to form uranium hexafluoride 6 + high acidity with relatively high solubility, and uranium hexa U in the form of a solid phase as in the rocks of the crust. The contents of the total dissolved uranium in natural water (1.0 - 10) ppm, and coincide with high concentrations of total dissolved uranium (More than 1 mg / l) in groundwater near the uranium ore deposits.

The alpha beam emissions are mainly derived from the dissociation of radium-226 and radium-228 resulting from the disintegration of the uranium and thorium chains. Beta and gamma radiation also results from the breakdown of the nuclides which is formed by the disintegration of the two chains. Potassium-40 and rhubidium-87 represent the most important isotopes exporting beta and gamma rays. From a geochemical perspective, we mention a number of important isotopes such as: Sr-89, Sr-90, I-131, P-32, and Co-60, which have been observed in natural waters since the 1920s.

Radium is one of the most important natural radioisotopes found in water, in the form of four isotopes Radium-232, Radium-224, Radium-226, Radium-228, of these Isotopes in natural water due to the relative length of half the age of its decomposition (1620 years) Radium in its chemical properties with the barium element, but the degree of dissolved salts is lower than Barium salts solubility in thermodynamic conditions. Radium is found in natural waters generally with weak activity not exceeding 1 picocurie, high radium activity is observed in aquatic pregnant women deep or near the uranium and phosphate rock mines, the maximum limit of the radium-226 and radium-228 allowed in drinking water is about 5 pieco curie according to the Environmental Protection Agency [2].

United States of America Common radioisotopes, found in natural waters, include radon isotopes formed from the dissociation of isotopes Radium-226, radium-224 and radium-223. The radon-222, which is half the age of 3.82 days and is made up of the breakdown of radium-226, is one of the most important radon isotopes in natural water. Radon is often found insoluble in this water; it can also be transferred to the gas phase when leaving the solution. The high frequency of radon-222 is associated with elevated events of radium-226 in solid form in wetland rock marshes.

The radon-222 breaks down with lead-210, with an equal half-life of 21.8 years. A number of scientists have tried to link hot water content with volcanic movements. Japanese scientists measured radon concentration in hot springs immediately after the USU surge in 1977, and the results did not indicate, which have a direct relationship with the effectiveness of the volcanoes, but radon concentration changes suggest a potential A relationship with the mixing of groundwater. Another study indicated that radon concentrations during one the volcanic eruptions (Karyn in Russia) were consistent with seismic movements recorded in Earthquake monitoring station in Raya Karyn. As for health effects, many researchers have investigated the effect of radioactivity in water and radon, which are naturally around us.

1.4.2. Radon Gas

Radon is one of the products of the decomposition of the element of radioactive uranium in the natural radiation chain, the radioactivity The radon is automatically decomposed into other radioactive elements that can stick to dust particles in the atmosphere The human breathes and attaches inside the lungs and in turn decomposes to other elements, during this decay radiated Alpha rays (helium atom nuclei), which are ionizing rays and ionizing radiation causing ionization of living cells leading to Chemical changes in the cell are either permanent changes and thus a genetic defect or late interference such as Cancers or damage that leads to cell death and then organ death of the organism.

During the past decade Scientists have unanimously agreed that radon is the probable cause of cancer in humans. But fortunately, such a type of alpha-ray radiation which is relatively heavy particles, so it can cross short distances in the human body (skin only in the case of external exposure) and that is it, it cannot reach other cells of other organs to destroy them; thus lung cancer is an important and known danger So far that accompanies radon. It is estimated to cause between 15,000 and 22 deaths in the United States alone as a result of lung cancer.

Radon cannot be detected by human senses because it is a colorless and odorless gas. Radon is heavier than air seven times and half of what always leads to its bottom but it is about 1 in 1020 of the air is not it forms a layer close to the surface of the earth, but is almost homogenously mixed with the internal air of the homes where it is Radon concentrations in homes generally are 2 to 10 times higher than abroad, so it is often which neglects exposure to radon outside homes [3,4]. The physical properties of radon are shown in Table 1.

Table 1. Shows some physical properties of radon.

Physical Properties of Radon	Physical Value
Boiling degrees	- 61.80 C
Fusion degree	- 71 C
Limit temperature	104 C
Metric pressure	62 atm
Density at normal pressure and temperature	9.96 kg/m^3
Volume (27.03pCi) when the pressure and normal temperature	$1.6\times10^{-20}m^3$

Radon is highly soluble in coloring. So that, coloring is often used to extract radon Dissolved in water samples in order to measure radon concentration. It is worth mentioning, that radon Solubility is average in water and some other fluid [4].

2. Materials and Methods

A total of 10 different Famous models of bottled natural mineral drinking water were collected from the local market in the State of Kuwait and are widely traded. After the collection process, a constant weight of all samples (70 gm) was taken from each sample, and the Sensitive balance was used to calculate the weight of the samples. The samples were then placed in a plastic cylindrical irradiation chambers, which are 20 cm cylindrical test tubes with a diameter of 2.5 cm and length of air in the plastic cylinder 13 Cm as shown in Figure 1.

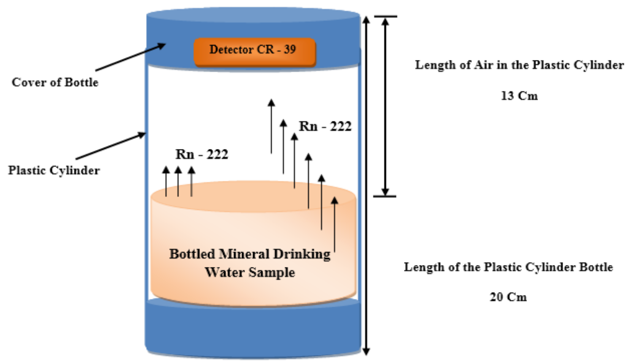

Figure 1. A Schematic Diagram of the Sealed-Cup Technique in bottled natural mineral drinking water sample with Nuclear Track Detector (CR – 39).

The cylindrical tubing was sealed tightly and a layer of silicone was put around the cover of the cylindrical tube to prevent leakage and to ensure that the models were not contaminated from external sources, taking into account that the distance between the sample surface and the surface of the inner cover fitted with the CR-39 was fixed by 13 cm. The samples and the nuclear reagents were then left exposed for 52 days to reach the ideal state of balance between radium and their wolves from radon isotopes. The nuclear track detector was used in thickness (1000 μm) and with an approximate area (1 x 1 cm^2).

After the end of the period of radiation balance and exposure, the seals and reagents of the sample containers are removed. To begin the stage of showing the Nuclear Tracks using the chemical etching technique, a sensitive balance German-made is used with the accuracy of 0.01gmto calculate the weight of the sodium hydroxide used in the preparation of the skimming solution. Nucleic reagents for chemical scavenging using NaOH and BN (7N). In order to perform the chemical scaling process; the straw solution container is placed in a water bath for heating at 70 °C. To heat the skimmer solution, a German-type of water bath is used.

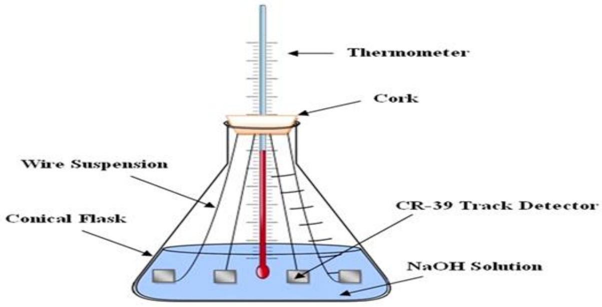

Figure 2. A Schematic Diagram of the Chemical Etching Technique for the Nuclear Detector (CR – 39).

Its temperature ranges from 0-100 °C, at a precision of 1 °C, a CR-39 detector is attached to be placed inside the etching solution as in Figure 2. For 7 hours, the chemical etching solution attacks the affected area of the detector and dissolves, leaving the soluble material in the container containing the straw solution. After that, the track detector was washed with distilled water and dries.

At this stage, the Tracks are detected by using a microscope with a precision camera and by selecting the appropriate magnification of (×400) and then counting the Tracks of the area unit using a special lens divided into several boxes according to the average number of Tracks. Example 20 fields for each nuclear track detector. A special gradient is placed on a glass slide in front of the objective lens of the microscope. A microscope from Olympus-Bausch Lomb-Japanese made, was used. It is equipped with optical lenses of different magnification power (×10, ×20, ×40, ×100) and two eyesight with a magnification of (×10) Intensity of effects.

The Concentration of Radon-222 measured by using the following equations:

The density of the tracks (ρ) of the samples were obtained according to the following relation [5]:

$$\textbf{Tracks density } (\rho) = \frac{\text{Average number of total pits (track)}}{\text{Area of field view}}.$$

The radon gas concentrations in water samples were obtained by the comparison between track densities registered on the detectors of the samples and that of the standard water samples, which are shown in Figure 3, using the relation [6]:

$$(\mathbf{Cx}) = \rho\mathbf{x}.(\mathbf{Cs}/\rho\mathbf{s})$$

Where :

CX: is the radon gas concentration in the unknown sample.

CS: is the radon gas concentration in the standard sample.

ρX: is the track density of the unknown sample (track/mm^2).

ρS: is the track density of the standard sample (track/mm^2).

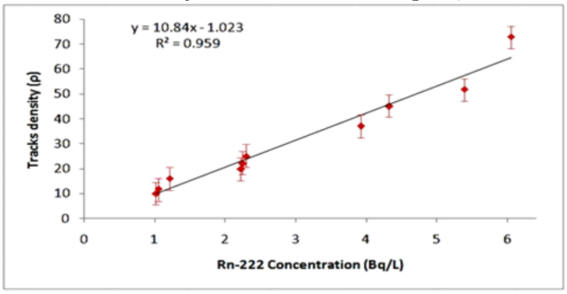

Figure 3. The relation between radon gas concentration and track density in standard water samples.

The Figure 3 shows the relation between radon gas concentration and track density in standard water samples.

The following below tables (2), (3), (4), (5) shows us the Criteria for mineral waters in accordance with the EU mineral water directive, (WHO and Dutch) drinking water standards & its Number of times drinking water standards are exceeded, and International Comparison for Chemicals (Maximum Allowable Concentration) [7,8].

Table 2. Criteria for mineral waters in accordance with the EU mineral water directive.

Mineral water type	Criterion
Very low mineral concentration	Mineral content (TDS) < 50 mg/l
Low mineral concentration	TDS 50 - 500 mg/l
Intermediate mineral concentration	TDS 500 - 1500 mg/l
High mineral concentration	TDS > 1500 mg/l
Containing bicarbonate	Bicarbonate > 600 mg/l
Containing sulphate	Sulphate > 200 mg/l
Containing chloride	Chloride > 200 mg/l
Containing calcium	Calcium > 150 mg/l
Containing magnesium	Magnesium > 50 mg/l
Containing fluoride	Fluoride > 1 mg/l
Containing iron	Bivalent iron > 1 mg/l
Acid	Carbon dioxide > 250 mg/l
Containing sodium	Sodium > 200 mg/l
Suitable for low sodium diets	Sodium < 20 mg/l

Table 3. WHO and Dutch drinking water standards.

Drinking water standards (mg/l)	Cl	Ca	Mg	Ca+Mg min.	K	Na	NO_3	SO_4	F
WHO	300	-	50	-	-	175	50	250	1.5
Netherlands	150*	150*	50*1	60*2	12*1	120*1	25*3/50*1	150*1	1.1*

* may only be exceeded in circumstances out of the waterworks' control

*1 may only be exceeded if the responsible minister grants dispensation

*2 this value may not be lower (calculated as Ca + 1.66 Mg (mg/l))

*3 target value based on 4th Dutch memorandum on water management.

Table 4. Number of times drinking water standards are exceeded.

Drinking water standards (mg/l)	Cl	Ca	Mg	Ca+Mg min.	K	Na	NO_3	SO_4	F
WHO	4	-	16	-	-	16	0	11	10
Netherlands	9	16	16	33	19	20	1/0	14	17

Table 5. International Comparison of Drinking Water Quality Standards and Guidelines for Chemicals (Maximum Allowable Concentration). All standards and guidelines in mg/L [9].

Chemical	W.H.O.	E.U.	Australia	U.S.A.	Canada
2.4-D	0.03	0.0001	0.0001	0.07	0.1
Aldicarb	0.01	0.0001	0.001	-	0.009
Aldrin/Dieldrin	0.00003	0.00003	0.00001	-	0.0007
Antimony	0.02	0.005	0.003	0.006	0.006
Arsenic	0.01	0.01	0.007	0.01	0.01
Atrazine	0.002	0.0001	0.0001	0.003	0.005
Azinphos-methyl	-	0.0001	0.002	-	0.02
Barium	0.7	-	0.7	2	1
Bendiocarb	-	0.0001	-	-	0.04
Benzene	0.01	0.001	0.001	0.005	0.005
Benzo[a]pyrene	0.0007	0.00001	0.00001	0.0002	0.00001
Boron	0.5	1	4	-	5
Bromate	0.01	0.01	0.02	0.01	0.01
Bromoxynil	-	0.0001	0.03	-	0.005
Cadmium	0.003	0.005	0.002	0.005	0.005
Carbaryl	-	0.0001	0.005	-	0.09
Carbofuran	0.007	0.0001	0.005	0.04	0.09
Carbon tetrachloride	0.004	0.0001	0.003	0.005	0.005
Chloramines-total	-	-	3	4	3
Chlorpyrifos	0.03	0.0001	0.01	-	0.09
Chromium	0.05	0.05	0.05	0.1	0.05
Cyanazine	0.0006	0.0001	-	-	0.01
Cyanide	0.07	0.05	0.08	0.2	0.2
Cyanobacterial toxins	-	-	0.0013	-	0.0015
Diazinon	-	0.0001	0.001	-	0.02
Dicamba	-	0.0001	0.1	-	0.12
1,2-Dichlorobenzene	1	0.0001	1.5	0.6	0.2
1,4-Dichlorobenzene	0.3	0.0001	0.04	0.075	0.005
1,2-Dichloroethane	0.03	0.003	0.003	0.005	0.005
1,1-Dichloroethylene	0.03	-	0.03	0.007	0.014
Dichloromethane	0.02	-	0.004	0.005	0.05
2,4-Dichlorophenol	-	0.0001	0.2	-	0.9
Diclofop-methyl	-	0.0001	0.005	-	0.009
Dimethoate	0.006	0.0001	0.05	-	0.02
Dinoseb	-	0.0001	-	0.007	0.01
Diquat	-	0.0001	0.0005	0.02	0.07
Diuron	-	0.0001	0.03	-	0.15
Ethylbenzene	0.3	-	0.3	0.7	-
Fluoride	1.5	1.5	1.5	4	1.5
Glyphosate	-	0.0001	0.01	0.7	0.28
Lead	0.01	0.01	0.01	0.015	0.01
Malathion	-	0.0001	-	-	0.19
Mercury	0.01	0.01	0.01	0.02	0.01
Methoxychlor	0.02	0.0001	0.0002	0.04	0.9
Metolachlor	0.01	0.0001	0.002	-	0.05
Metribuzin	-	0.0001	0.001	-	0.08
Monochlorobenzene	-	-	-	-	0.08
Nitrate	11	11	11	10	10
Nitrilotriacetic acid	0.2	-	0.2	-	0.4
Paraquat	-	0.0001	0.001	-	0.01
Parathion	-	0.0001	0.01	-	0.05
Pentachlorophenol	0.009	0.0001	-	0.001	0.06
Phorate	-	0.0001	-	-	0.002
Picloram	-	0.0001	0.3	0.5	0.19
Selenium	0.01	-	0.01	0.05	0.01
Simazine	0.002	0.0001	0.0005	0.004	0.01
Terbufos	-	0.0001	0.0005	-	0.001
Tetrachloroethylene	0.04	0.01	0.05	0.005	0.03
2,4,6-trichlorophenol	0.2	0.0001	-	-	0.005
2,3,4,6-tetrachlorophenol	-	0.0001	-	-	0.1
Toluene	0.7	-	0.8	1	-
Trichloroethylene	0.07	0.01	-	0.005	0.005
Trifluralin	0.02	0.0001	0.0001	-	0.045

Chemical	W.H.O.	E.U.	Australia	U.S.A.	Canada
Trihalomethanes	-	0.1	0.25	0.08	0.1
Uranium	0.015	-	0.02	0.03	0.02
Vinyl chloride	0.0003	0.0005	0.0003	0.002	0.002
Xylenes-total	0.5	-	0.6	10	-

Note: A dash (-) indicates that no standard or guideline has been established for a given parameter.
sources: Guidelines for Canadian Drinking Water Quality (2006). [10]
U.S. EPA National Primary Drinking Water Standards. [11]
E.U. Council Directive on the quality of water intended for human consumption [12]
Australian Drinking Water Guidelines, 2004. [13]
World Health Organization Drinking Water Quality Guidelines. [14]

Table 6. Shows measured concentrations of radon in bottled natural mineral drinking water samples collected from the local market in Kuwait.

No.	Sample Code	Rn-222 Concentration (Bq/L)	Effective dose per liter (nSv/L)	Annual effective dose (μSv/y)
1	MDW1	1.05±0.50	10.5	7.7
2	MDW2	2.25±1.15	22.5	16.4
3	MDW3	1.21±0.71	12.1	8.83
4	MDW4	3.92±1.10	39.2	28.6
5	MDW5	5.39±2.43	53.9	39.3
6	MDW6	6.05±3.11	60.5	44.2
7	MDW7	4.32±2.76	43.2	31.5
8	MDW8	2.22±1.14	22.2	16.2
9	MDW9	2.29±1.26	22.9	16.7
10	MDW10	1.02±0.20	10.2	7.5
Average		2.97±1.44	29.72	21.69

Note : nSv/L = Nano Sievert per liter , μSv/y = Micro Sievert per year

3. Results and Discussion

In the present study, radon concentrations were determined in the bottled natural mineral drinking water samples (Samples Code : MDW) collected from the local market in Kuwait.

As shown in the recorded values of radon concentration (Bq/L) for bottled Mineral Drinking Water in Table 6,

the average radon concentration in bottled mineral drinking water in Kuwait was 2.97±1.44 Bq/L. Therefore, the radon levels in Kuwaiti bottled mineral drinking water are comparatively very low since the recommended maximum level (MCL) of U.S. Environmental Protection Agency is 300 pCi/L, which is equivalent to 11.1 Bq/L [12].

3.1. Annual Effective Doses from ^{222}Rn Ingested with Water

The annual effective dose (mSv/y) was calculated by taking in account the activity concentration of radon (Bq/L), the dose coefficient (Sv/Bq) and the annual water consumption (L/y) according to equation:

$$\mathbf{D_{ing} = C_R . I_F . E_D}$$

Where $\mathbf{D_{ing}}$ is the committed effective dose from ingestion (Sv), $\mathbf{C_R}$ is the concentration of ^{222}Rn (Bq/L), $\mathbf{I_F}$ is the ingesting dose conversion factor of ^{222}Rn (10-8Sv/Bq for adults, and 2×10-8 Sv/Bq for children [15], $\mathbf{E_D}$ is the water consumption (2 L/day) [16]. For the dose calculations, a conservative consumption of 2 L/day per year for ''standard adult'' drinking the same water and directly from the source point was assumed [16,17]. The effective dose due to intake of ^{222}Rn from drinking water varied from 7.5 to 44.2 μSv/y with an average value of 21.69 μSv/y. In the present study, the effective dose from ^{222}Rn due to intake of mineral drinking water is less than the recommended value of 0.1 mSv/y [18], therefore, the contribution to the dose can be neglected.

4. Summary

1. The Concentration of Radon (^{222}Rn) in Bottled Mineral drinking water samples in Kuwait has been measured.

2. Concentration of (^{222}Rn) in Bottled Mineral drinking water varies from 1.02 Bq/L to 6.05 Bq/L with the average value of 2.97±1.44 Bq/L.

3. From these results it can be concluded that the majority of drinking water in Kuwait is a safety potable water from the stand point of radon concentration in them. Mean values of effective dose per liter and annual effective dose from radon ingested with drinking water for an individual consumer are 29.72 nSv/L and 21.69 μSv/y, respectively. So, the level of Radon concentration in Kuwaiti bottled mineral drinking water is below the permissible limits for health purposes to drink [12].

In the light of the above, I would recommend that must wait some times when opening the bottle to volatilize the very low level of radon gas (if any) from the bottle for no more than 20 seconds before drinking.

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