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Natural Radioactivity and Radon Concentrations in Parenteral Nutrition Samples Utilized in Iraqi Hospitals

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ABSTRACT

Introduction: This study was conducted to measure the gamma emitters (e.g., uranium-238 [^{238}U], thorium-232 [^{232}Th], and potassium-40 [^{40}K]) and alpha emitters (e.g., radon-222 [^{222}Rn] and radium), and also to evaluate the radiation hazard indices of radionuclides in parenteral nutrition samples utilized in the hospitals of Iraq.

Material and Methods: The measurements were accomplished using gamma-ray spectroscopy with NaI (Tl) detector, solid state nuclear track detector (CR-39), and RAD-7 detector. Gamma radiation hazard indices, such as radium equivalent activity and internal hazard index, were also calculated.

Results: According to the results, the mean specific activities of the radionuclides belonging to the uranium (^{238}U) and thorium series (^{232}Th) in the parenteral nutrition samples were 1.17±0.20 and 0.185±0.026 Bq/kg, respectively (range: 0.33±0.17-1.81±0.42 Bq/kg and 0.09±0.03-0.28±0.06 Bq/kg, respectively). However, natural radionuclide (^{40}K) was not detected in all samples. Furthermore, the mean values of radon and radium concentrations were 13.77±2.84 mBq/L and 0.19±0.03 mBq/kg, respectively using CR-39 detector (range: 2.00-29.97 mBq/L and 0.03-0.41 mBq/kg, respectively). There was a significant correlation (R^2=0.91) between the concentrations estimated by the CR-39 and RAD-7 detectors. In addition, a significant correlation (R^2=0.90) was observed between ^{238}U and ^{222}Rn.

Conclusion: The comparison of the results obtained in the present study with the worldwide average revealed that all values were within the recommended range given by the United Nations Scientific Committee on the Effects of Atomic Radiation, World Health Organization, and Organization for Economic Co-operation and Development. In other words, the parenteral nutrition samples under study were safe for consumption and did not expose the citizens to any hazards.

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Introduction

According to the International Atomic Energy Agency, the main sources of radiation exposure to humans include natural radiation of terrestrial and cosmogenic origins and internal radioisotopes [1]. However, human exposure to a large dose of ionizing radiation may result in cancer development despite using a control exposure for cancer treatment. Over the history of earth, the useful or harmful radiation exposure has been an unavoidable part of the environment. The process of nucleosynthesis fabricating the elements leads to the formation of stable and unstable nuclides. Moreover, unstable nuclides with a very long half-life, along with their progeny, account for the formation of naturally occurring radionuclides on the surface of the earth [2].

Additionally, the processes taking place in the sun or elsewhere in the universe, which are characterized with violent radiation result in the bombardment of the earth with cosmic rays. Radiation has been considered as a familiar pollutant over the history [2]. The determination of 'naturally occurring radioactive material' in our physical environment facilitates the assessment of the extent of population exposure to radiation and its subsequent effects. Radiation decays either in the series, like uranium-238 (^{238}U) and thorium-232 (^{232}Th), or in singly occurring radionuclides, such as potassium-40 (^{40}K), existing within the earth and atmosphere at different levels[1].

Radon is a natural radioactive gas produced by natural radioactive decay of such elements as uranium series (^{222}Rn) and thorium series (^{220}Rn). Both uranium and thorium exist everywhere in the ground, and their important isotopes are ^{238}U and ^{232}Th, respectively [3]. The levels of uranium and thorium in each district depend on the geology of the area. The emergence of natural radionuclides mainly results from human activities, such as the use of fertilizers in agriculture [4, 5].

The surface and airborne contaminations, which are potential to enter the body, are considered as the

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sources of internal radiation exposure to the inner body tissues, resulting from food or drink ingestion [6].

Parenteral nutrition is referred to the intravenous feeding of a patient, resulting in bypassing the usual process of eating and digestion. This process facilitates the delivery of glucose, salts, amino acids, lipids, and supplementary vitamins to the patient as a nutritional formulae. Occasionally, parenteral nutrition process is exploited in order to prevent the malnutrition phenomenon in patients who do not have the ability to get adequate nutrients through oral or enteral routes [7,8]. Solutions for total parenteral nutrition may be customized to individual patient requirements, or standardized solutions may be used [9].

In many countries like Iraq, there are no studies investigating radioactive elements in parenteral nutrition products. Therefore, there is no reports on the baselines of natural and anthropogenic radioisotope concentration. With this background in mind, the present study aimed to estimate gamma ray emitters (natural radioactivity) and alpha emitters (radon concentrations) in different types of parenteral nutrition, used in the hospitals and pharmacies of Iraq using gamma spectroscopy detractor, as well as CR-39 and RAD-7 detectors for alpha particles. The estimation of radioisotope concentrations would provide a suitable original baseline for population exposure.

Materials and Methods

Sample Collection and Preparation

For the purpose of the study, 10 types of parenteral nutrition samples were collected from the hospitals and pharmacies in Iraq, as shown in Table 1. Prior to final measurement in the laboratories, the collected samples were weighed and transferred to plastic polynomial containers.

Table 1. Parenteral nutrition samples used in the present study

No.	Samples Name	Samples Code	Origin
1	Glucose water	PN1	Iraq
2	Dextrose saline	PN2	
3	Dextrose saline	PN3	
4	Ringer-Lactate	PN4	
5	Normal saline	PN5	Iran
6	Dextrose water	PN6	
7	Dextrose saline	PN7	Egypt
8	Dextrose water	PN8	
9	Normal saline	PN9	U.A.E
10	Mannitol	PN10	Kuwait

PN: parenteral nutrition

Systems of Measurement

In the current study, the measurements were accomplished using two techniques, namely the gamma spectroscopy with NaI (Tl) scintillation detector, as well as CR-39 (Polyallyl diglycol carbonate) and RAD-7 detectors for alpha particles.

Gamma-Ray Spectroscopy

The gamma-ray spectrometer used in this study was equipped with an NaI (Tl) detector with the crystal dimension of 3"×3" (ORTEC Co., provided by Alpha Spectra Inc., 12I12/3), along with a multi-channel analyzer (ORTEC, Digi Base) with a range of 4096 channels joined with Analog to Digital Convertor unit through the interface. The spectroscopic measurements and analysis were performed in MAESTRO-32 software [1]. The gamma-ray detector had a high sensitivity.

Given the presence of uranium, thorium, and potassium in the building materials, radioactive materials exist around and inside the room, as well as in the laboratory furniture and even people near or using the room. The detector surrounded by lead shield to prevent the background radiation. Regarding this, a shield of lead (mostly ^{210}Pb) with a cylinder shape with the thickness of 100 mm and a lid of the same thickness was purchased. Whether purchasing a comprehensive shield or lead bricks, it should be assured that the lead is of appropriate low-activity quality [10].

The samples were kept in containers coded with specific codes in order to distinguish between the samples. Equal volumes of 0.75 L were considered for each sample. For NaI (TI) spectrometry technique, the samples were placed in the Marnelli beakers (with size 1L) to measure the gamma-ray emitters, such as ^{238}U (^{214}Bi at gamma energy line of 1764.49 keV), ^{232}Th (^{208}Tl at gamma energy line of 2614 keV), and ^{40}K (at gamma energy line of 1460 keV). Subsequently, they were placed in front of the detector for counting to about 86,400 sec.

Alpha Particle Techniques

Alpha particles (radon concentrations) were measured using solid state nuclear track detector (SSNTD; CR-39) and RAD-7 detector (Continuous Radon Monitor, Durridge). For the SSNTD detector, 10 mL of parenteral nutrition samples were placed in a container. The CR-39 detector, made by Pershore Moulding LTD Company, U.K., had a thickness of 200 μm and density of 1.32 g/cm^3. The containers used in the present study were made of polypropylene with the diameter of 5 cm and height of 7.7 cm. They had an impermeable surface and were airtight to prevent the escape of radiogenic gases (e.g., radon).

The SSNTD was cut into pieces of 1×1 cm^2. A piece of CR-39 detector was fixed at the top of the container. For the samples subjected to NaI (TI) detector, each sample was coded with a specific code in order to be distinguished. The containers were left at ambient temperature for the exposure time of 70 days. These detectors were etched with sodium hydroxide solution at 60^{o}C for 6 h, solution of (6.25) N [11]. Then, the etched track counting were carried out using the Novel optical microscope made in China (microscope N-120A). The magnification used was up to 400X. For RAD-7 radon detector, parenteral nutrition samples were taken in a radon-tight reagent bottle of 250 ml capacity. The RAD-7 detector uses a solid state

detector (silicon ion-implanted detector). Radon concentration was estimated using RAD-7, which is an electric detector, connected to RAD-H_2O accessory (Durridge Co,USA, 2010) for one month. RAD-7 detector was used to evaluate radon in water by connecting it to a bubbling kit facilitating the release of the gas from water sample to the air through a close loop. For a period ranged from 5 min to 10 min, air was circulated through a close circuit until the achievement of a uniform mix of radon and air, while alpha activity was recorded. This allowed for the direct measurement of the radon concentration [12].

Calculation

Specific activity

The specific activity (A) of each radionuclide can be calculated using the following equation [13, 14]:

$$A\left(\frac{Bq}{Kg}\right) = \frac{C}{t\varepsilon I_\gamma M} \quad (1)$$

where, C is the net area of the photo peaks, t is detecting time, ε is energy efficiency, $I\gamma$ is the percentage of gamma-emission probability, and M is the weight of samples under study.

Radium Equivalent Activity

The significance of ^{226}Ra, ^{232}Th, and ^{40}K concentrations was outlined in terms of equivalent activity determined using the following equation [13]:

$$Ra_{eq}\left(\frac{Bq}{kg}\right) = A_{Ra} + 1.43A_{Th} + 0.077A_K \quad (2)$$

Where, A_{Ra}, A_{Th}, and A_K are the activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K, respectively.

Internal hazard index

Internal hazard index (H_{in}) is defined as follows [15, 16]:

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad (3)$$

Radon Concentration

Track density of α-particles (ρ) in parenteral nutrition samples can be calculated according to the following formula [17]**:**

$$\rho\left(\frac{Track}{cm^2}\right) = \frac{Number\ of\ Track}{Area\ of\ view} \quad (4)$$

The value of radon concentration (C_{Rn}) can be obtained using the following equation [18]:

$$C_{Rn}\left(\frac{Bq}{m^3}\right) = \frac{\rho}{k\,t} \quad (5)$$

Where, t is the irradiation time, and k is the calibration coefficient of CR-39 detectors in tracks/cm^2.d per Bq/m^3, which is equal to 0.029±0.0002 [19].

Effective Radium Content (Radium concentrations)

The evaluation of the radium concentration for parenteral nutrition samples was performed using the next equation [20]:

$$C_{Ra}\left(\frac{Bq}{kg}\right) = \frac{\rho ha}{KT_eM} \quad (6)$$

Where, h is the distance between CR-39 detector and parenteral nutrition sample, a is the surface area of parenteral nutrition sample, M is the weight of the sample, and T_e is the effective exposure time, which is calculated by [21]:

$$T_e = t - \frac{1}{\lambda(1 - e^{-\lambda t})} \quad (7)$$

Results

The detection of gamma emitters (i.e., ^{238}U, ^{232}Th, and ^{40}K) and alpha emitters (i.e., ^{222}Rn and ^{226}Ra) in 10 samples of parenteral nutrition available in Iraq hospitals was accomplished using two techniques described in the following sections.

Gamma-Ray Spectroscopy

The specific activity values (activity concentrations) of ^{238}U, ^{232}Th, and ^{40}K are presented in Table 2. According to the results, the mean specific activities of ^{238}U and ^{232}Th were 1.17±0.20 and 0.185±0.026 Bq/L, respectively (range: 0.33±0.17-1.81±0.42 and 0.08±0.04-0.28±0.06 Bq/L, respectively). However, regarding the value of specific activity for ^{40}K, this radioisotope was below the limit of detection in all samples (Table 2). Figure 1 displays a summary of the average activity concentrations of all samples for ^{238}U and ^{232}Th, including the liquefied parenteral nutrition samples that are made in Iraq, Iran, Egypt, U.A.E., and Kuwait. The Iraq samples had the highest value of ^{238}U and ^{232}Th, while the lowest value of ^{238}U and ^{232}Th were observed in the samples made in Egypt.

Table 2. Activity concentrations of gamma emitters in the parenteral nutrition samples

No.	Sample Code	Activity concentrations (Bq/L)		
		U-238	Th-232	K-40
1	PN1	1.00±0.30	0.24±0.08	BLD
2	PN2	1.81±0.42	0.27±0.08	BLD
3	PN3	1.70±0.40	0.21±0.07	BLD
4	PN4	0.87±0.26	0.21±0.05	BLD
5	PN5	1.76±0.41	0.28±0.06	BLD
6	PN6	0.33±0.17	0.09±0.03	BLD
7	PN7	1.10±0.33	0.20±0.07	BLD
8	PN8	BLD	0.16±0.04	BLD
9	PN9	0.86±0.29	0.08±0.04	BLD
10	PN10	1.13±0.33	0.11±0.05	BLD
Mean±S.D		1.17±0.20	0.185±0.026	BLD

PN: parenteral nutrition, BLD: bellow the limit of detection

Based on Figure 2, the mean radium equivalent value was 1.317±0.22 Bq/L, ranging from 0.23 (in PN10) to 2.2 Bq/L (in PN4). In addition, the mean internal hazard index was 0.006±0.001, which ranged from 0.011 in sample PN4/PN7 to 0.001 in sample PN10 (Figure 3).

Solid state nuclear track detector

In this study, 10 samples of PN were analyzed using the CR-39 detector. Table 3 illustrates the values of radon and radium concentrations. As the results demonstrated, radon concentrations and effective radium content (radium concentrations) in collected samples varied from 2.00 to 29.97 mBq/L and 0.03 to 0.41 mBq/kg with the mean values of 13.77±2.84 mBq/L, and 0.19±0.03 mBq/kg, respectively.

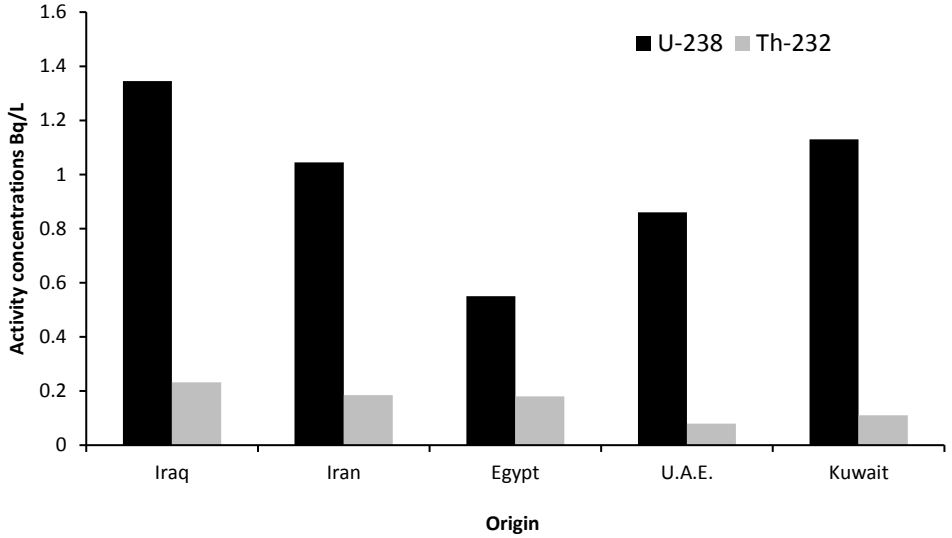

Figure 1. Relationship of uranium-238 and thorium-232 activity concentrations with the origin of parenteral nutrition samples

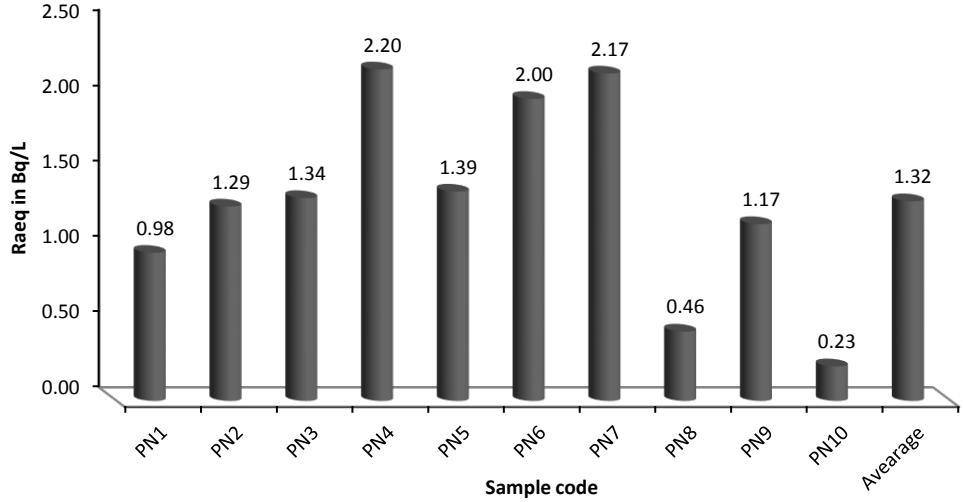

Figure 2. Results of radium equivalent in parenteral nutrition samples

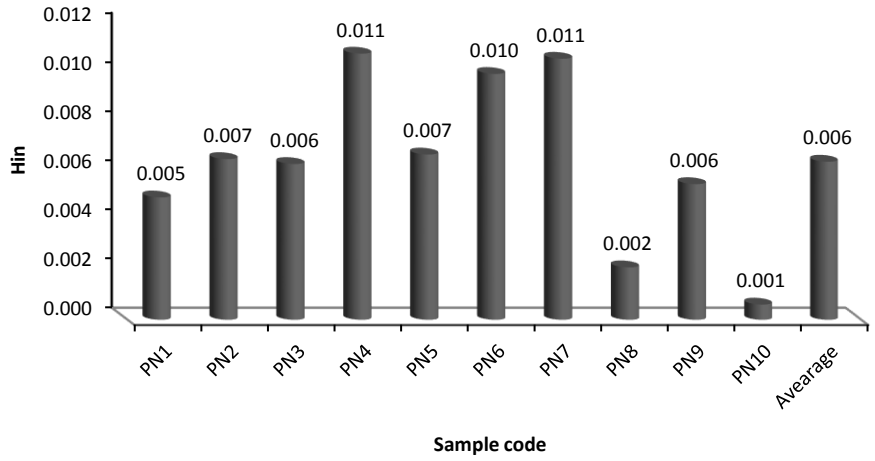

Figure 3. Results of internal hazard indices in parenteral nutrition samples

Table 3. Radon and radium concentrations in the parenteral nutrition samples

No.	Sample Code	C_{Rn} (mBq/L)	C_{Ra} (mBq/kg)
1	PN1	11.99	0.16
2	PN2	29.97	0.41
3	PN3	19.98	0.27
4	PN4	7.99	0.11
5	PN5	21.98	0.30
6	PN6	3.33	0.05
7	PN7	12.99	0.18
8	PN8	2.00	0.03
9	PN9	12.49	0.17
10	PN10	14.99	0.20
Mean±SD		13.77±2.84	0.19±0.03

PN: parenteral nutrition, C_{Rn}: concentration of radon, C_{Ra}: concentration of radium

Figure 4 depicts the comparison between the results obtained by CR-39 and RAD-7 detectors regarding the mean radon concentrations in the parenteral nutrition samples under study. As displayed in Figure 5, there was a significant linear correlation (R^2=0.91) between these data.

Figure 6 illustrates the correlation between the mean radon concentrations in parenteral nutrition samples using CR-39 detector and activity concentrations of uranium-238 using the NaI (Tl) detector.

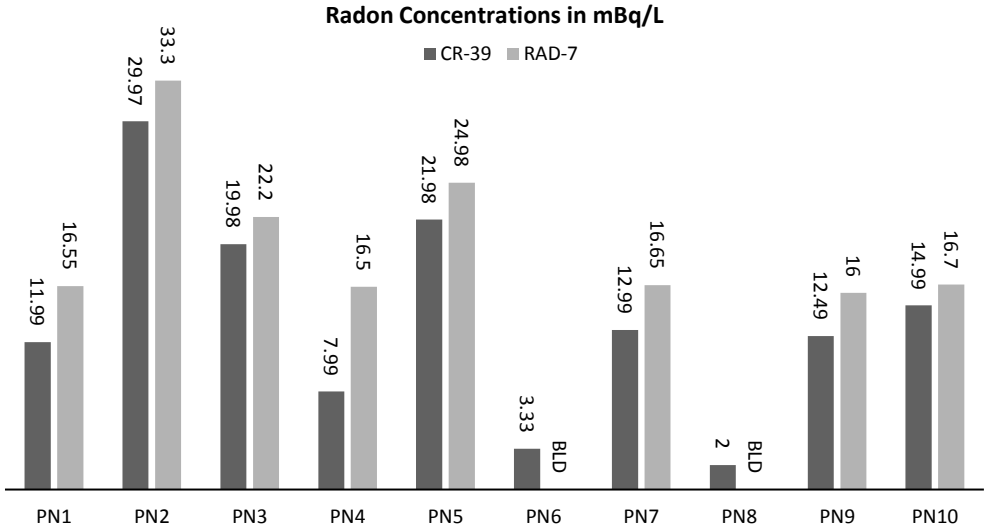

Figure 4. Mean radon concentrations using CR-39 and RAD-7 detectors

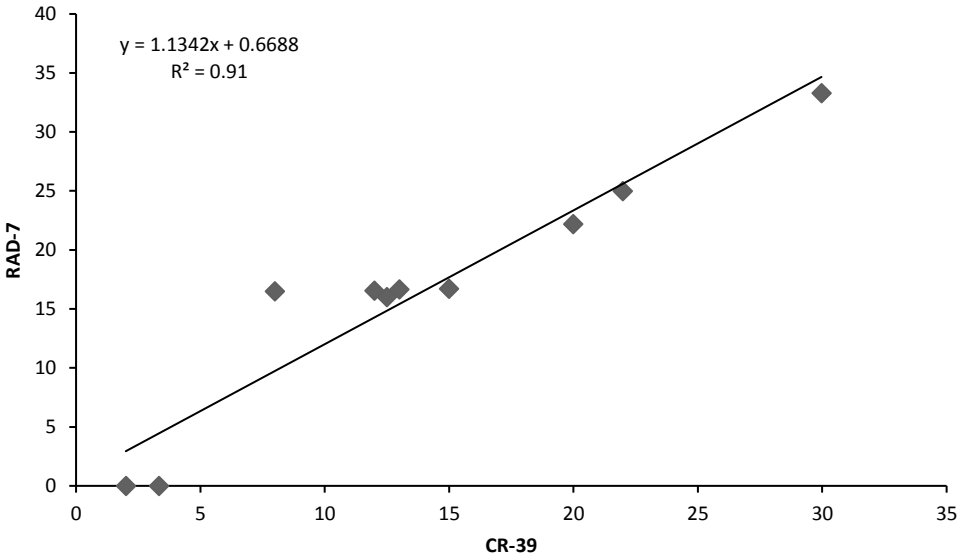

Figure 5. Correlation of the mean radon concentrations obtained by CR-39 and RAD-7 detectors

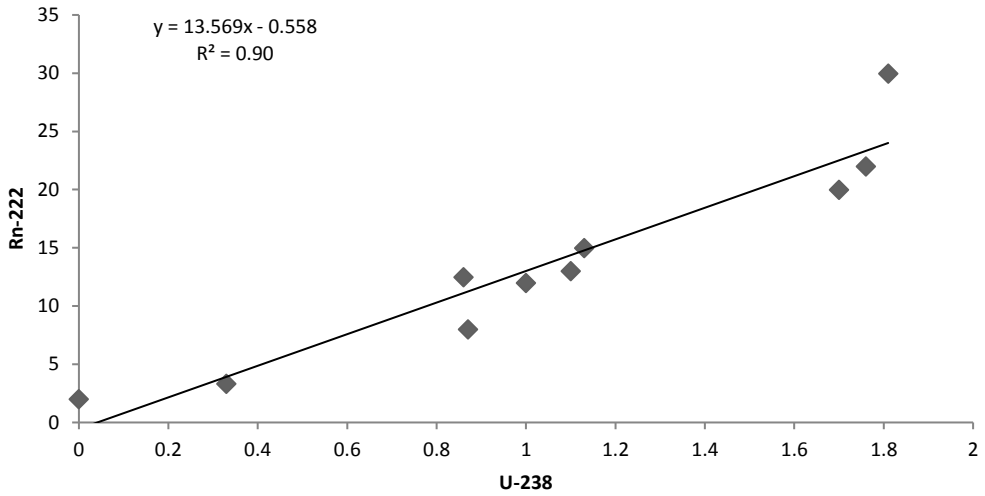

Figure 6. Correlation between uranium-238 and radon-222 concentrations in parenteral nutrition samples

Discussion

The results of specific activity revealed that sample PN2 (made in Iraq) had the highest value of ^{238}U, while sample PN9 (made in Iran) was detected with the lowest value in this regard. On the other hand, the highest specific activity of ^{232}Th was recorded in sample PN5 (made in Iran), whereas the lowest was observed in sample PN6 (made in U.A.E.). The comparison of the specific activity values for ^{238}U, ^{232}Th, and ^{40}K in the present study with the world wide average values recommended by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) (2000) revealed that the values obtained in the current study were lower than the specified limits [16].

Furthermore, the radium equivalent activity values obtained in this study were below the values suggested by the Organization for Economic Co-operation and Development (OECD) for all parenteral nutrition samples [22]. Additionally, all values of internal hazard index for the studied samples were lower than the permissible safety limit advised by UNSCEAR (2000) [16]. The concentrations of radon values in the measured samples were within the safe limit determined by the World Health Organization (WHO) [23].

The values of effective radium content (Table 3) were also less than the permissible value recommended by the OECD [22]. These results indicated that the parenteral nutrition samples were safe as far as the health hazards of radon and radium concentrations were concerned. Most of the samples have been successfully completed in term of measurements of activity concentrations of ^{238}U with specific activity of ^{222}Rn. As can be seen in Figure 6, a good linear correlation (R^2=0.90) was observed between the activity concentrations of ^{238}U and ^{222}Rn in the parenteral nutrition samples.

Conclusion

As the findings of the present study indicated, three radionuclides of ^{238}U, ^{232}Th, and ^{40}K were lower than the allowed limit specified by the UNSCEAR. Moreover, radon and radium concentrations were within the safe limit determined by the WHO and OECD. Additionally, radium equivalent activity and internal hazard indices were lower than the worldwide average. There was a significant correlation between the data obtained by CR-39 and RAD-7 detectors regarding the uranium-238 and radon-222 concentrations in all samples. The results of gamma-ray spectroscopy and SSNTD investigations revealed that the parenteral nutrition samples utilized in the hospitals of Iraq were safe in terms of contamination with radionuclides.

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References

1. Tara H, Reza M. X-Ray Safety Awareness Handbook. Canadian Air Transport Security Authority. 2010.
2. Tsoulfanidis N. Measurements and detections of radiation. 2nd edition. Taylor &Francis publisher.. USA. 1995.
3. EPA. Radiation: Facts, Risks and Realities. Office of Air and Radiation. 2012.
4. Jon R, Wenonah V, Barbara J, Navarro , Al Krause. Radiation Educator Guide. National Aeronautics and Space Administration.2012.
5. Ronnie, Lipschutz D. Radioactive Waste Politics, Technology, and Risk. CambridgeUSA. 1980.
6. Merrill E, Gressel T. Environmental Radio activity. 4thed. Academic Press. USA. 1970.
7. Linnea EW. Environmental Radiation. Health Physics Society. 2010.

8. Kozier B, Erb G, Berman AJ, Burke K, Bouchal SR, Hirst SP. Fundamentals of Nursing: The Nature of Nursing Practice in Canada. Canadian Edition. Prentice Hall Health: Toronto. 2004.
9. Yaworski JA. Total Parenteral Nutrition (TPN) Frequently Asked Questions. Children's Hospital of Pittsburgh. 2014.
10. Gordon RG. Practical Gamma-ray Spectro metry. 2nd Edition, John Wiley & Sons Ltd British. 2008.
11. Almayahi BA. Determination of Radionuclide Concentration in Human Teeth in Najaf Governorate, Iraq. Iranian Journal of Medical Physics. 2017; 14(4): 173-82.
12. Abojassim AA, Kadhim SH, Mraity A, Abid H, Munim RR. Radon levels in different types of bottled drinking water and carbonated drinks in Iraqi markets. Water Science and Technology: Water Supply. 2017; 17(1): 206-11.
13. Abojassim AA. Assessment of Radiation Hazard Indices and Excess Life time Cancer Risk due to Dust Storm for Al-Najaf, Iraq. wseas transaction on environment and development.2014; 10: 289-95.
14. Pourimani R, Mortazavi Shahroudi SM. Radiological Assessment of the Artificial and Natural Radionuclide Concentrations of Wheat and Barley Samples in Karbala, Iraq. Iranian Journal of Medical Physics. 2018; 15(2): 126-31.
15. Abojassim AA, Al-Alasadi LA, Shitake AR, Al-Tememie FA, Husain AA. Assessment of annual effective dose for natural radioactivity of gamma emitters in biscuit samples in Iraq. Journal of food protection. 2015; 78(9): 1766-9.
16. UNSCEAR. Sources and effects of ionizing radiation; United Nations Scientific Committee on the Effects of Atomic Radiation. report to the general assembly with scientific annexes. United Nations, New York. 2000.
17. Hady HN, Abojassim AA, Mohammed ZB. Study of Radon levels in fruits samples using LR-115 Type II detector. J. Environ. Sci. Technol. 2016; 9(6): 446-51.
18. El-Farrash AH, Yousef HA, El-Ala AA, Magdy A. Assessment of radon level in soil samples from Manzala Lake East Nile Delta, Egypt using passive technique. International Journal of Scientific Reports. 2016; 2(12): 312-8.
19. Almayahi BA, Tajuddin AA, Jaafar MS. Calibration technique for a CR-39 detector for soil and water radon exhalation rate measurements. Journal of Radioanalytical and Nuclear Chemistry. 2014; 301(1): 133-40.
20. Abojassima AA, Shltake AR, Najam LA, Merzaa IR. Radiological parameters due to radon-222 in soil samples at Baghdad governorate (Karakh), Iraq. Pak. j. sci. ind. res. Ser. A: phys. sci. 2017; 60(2): 72-8.
21. Abojassim AA, Najam LA, Naji D, Hussain TA. The effective radium content and radon exhalation rate in hair dyes samples. International Journal of Radiation Research. 2017; 15(2): 207.
22. Nuclear Energy Agency. Exposure to radiation from the natural radioactivity in building materials: report. OECD; 1979.
23. WHO. Guidelines for drinking water quality. 3ed. Geneva. 2008.