Journal of University of Babylon for Pure and Applied Sciences, Vol. (28), No. (1): 2020
Online ISSN: 2312-8135, Print ISSN: 1992-0652
The First International Scientific Conference for Pure and Human Studies, University of AL-HAMDANIYA, 20-21 November 2019

Long-lived alpha emitters concentrations in the spices consumed in Iraq using CR-39 detector

Malik H. Kheder[1] **Laith A. Najam**[2] **Hana N. Azeez**[3]

1. Physics Department, College of Education, AL-Hamdaniya University, Iraq malik.19732013@yahoo.com
2. Physics Department, College of Science, Mosul University, Mosul, Iraq prof.lai2014@gmail.com
3. Physics Department, College of Education, AL-Hamdaniya University, Iraq. akrawyhana@gmail.com

Article Information
Submission date: 5 /11 / 2019
Acceptance date: 21 /5/ 2020
Publication date: 31/ 5 / 2020

Abstract

Spices are mainly used as additives to diets in different countries, including our country, so it is necessary to ensure that they are free of radioactive substances harmful to human health. This research aimed to measure the concentrations of alpha emitters, and measure the annual effective dose AED resulting from the intake of radon. The CR-39 detector used to measure radon, radium, and uranium concentrations in the 24 spices samples selected from markets. In this work the radon concentrations in the samples were found to vary from 65.102 to 195.30 Bq/m^3 with 126.47 Bq/m^3 a mean value, this mean value is a small amount over 100 Bq/m^3 the reference level limits of the World Health Organization (WHO), below 200 Bq/m^3 of the UK Board of National Radiation Protection (NRPB) limits and below the level of the European Recommendation Commission. The annual radon effective dose varied between 1.642-4.927 mSv/y which is within the range of 0.2-10 mSv/y of (UNSCEAR). Radium contents vary between 0.446-1.367 Bq/Kg with 0.943 Bq/Kg as a mean value. The range of uranium activity concentrations is between 4.408-13.520 Bq/Kg with a mean value of 9.322 Bq/Kg. This work identified and measured the specified concentrations of radionuclide present in spices showed that spices are safe for consumption.

Keywords: Radium content, radon Dose effective, CR-39 detector, spices, Uranium.

Introduction

Spices refer to products that are added to the food in order to give it a flavor, taste, and smell delicious and likable to everyone, as it opens appetite and there are many benefits the human body and protect people from most diseases, which is the fruits of some food grains and also some herbs, stems, bark and leaf trees Grain and seeds some flowers and cut from the roots of some trees. They are often dry and are very good sources of antioxidants. They are used in most foods. They also help to kill microbes and fungi. They also resist food poisoning. Spices are mainly used as additives to diets in different countries, including our country, so it is necessary to ensure that they are free of radioactive substances harmful to human health

Journal of University of Babylon for Pure and Applied Sciences, Vol. (28), No. (1): 2020
Online ISSN: 2312-8135, Print ISSN: 1992-0652
The First International Scientific Conference for Pure and Human Studies, University of AL-HAMDANIYA, 20-21 November 2019

The radioactive materials are the unstable element nuclei, were exposed the nucleus to corrosion by emitting radiation types such as alpha, beta and gamma particles, and sooner or later becomes more stable element nuclei. This process is called radioactivity or radiation decay [1]. Human exposure to radioactive elements faces a high risk, which has health risks that affect their lives and maybe reflected in future generations. The damage to the human body from the radioactive elements depends on certain factors, the nature of the radioactive material and the type of radiation and the time the body is exposed to these radiations [2]. Radioactive substances when they enter the body of any pathway, are absorbed and introduced into biochemical basic processes and access to blood circulation and body fluids, to all body tissues are distributed according to the properties of the element [3]. The control of the effects of exposure to internal radiation depends on many factors, the most important of which is the slow development and appearance of radiation effect, the heterogeneity of radiation dose absorption in tissues with the time required for the degradation of radioactive material to give cumulative dose over time, the chemical toxicity level of the radioactive element itself, On the human body with self-injurious physical effects or effects on cells of body, symptoms or same organism appeared effects when exposed to radiation, the genetic effects of radiation, and the effects that appear in the offspring of an organism due to damage Genital organ exposed to radiation. [4], [5]. In living organisms radioactivity is due to the presence of several radioactive elements in the organism's body, such as radium, uranium, and radon. These elements fatal if consumed. They may lead to damage and malfunction in the bones, kidneys, the radon is an important element that can cause lung cancer as in the case of dissolved solubility or inhalation in a gaseous form. [6]. The passive sealed can with the CR-39 detector technique used in radioactive measure uranium and radium and the spice samples.

Material and Methods

Twenty four samples were collected from most used spices, these samples are different weights because their density is different, but they have the same volume, filled inside a plastic sealed-can cylindrical container (diffusion chamber 4 cm in diameter, 10.5 cm in length) CR-39 track detector facing, 7.5 cm is the sample to the detector surface distance, 3 cm is the sample thickness. The detectors after 60 days etched by NaOH at 6.25 N normality and heat 70 C^{o} for 8 hours in a water bath. The detectors dried after washing in water, by a microscope at 400x a magnification tracks counted.

المؤتمر الدولي العلمي الأول للدراسات الصرفة والإنسانية للمدة 20-21 تشرين الثاني 2019 / جامعة الحمدانية

https://www.journalofbabylon.com/index.php/JUBPAS, info@journalofbabylon.com, jub@itnet.uobabylon.edu.iq
+9647823331373 (Viber and Telegram)

Journal of University of Babylon for Pure and Applied Sciences, Vol. (28), No. (1): 2020
Online ISSN: 2312-8135, Print ISSN: 1992-0652
The First International Scientific Conference for Pure and Human Studies, University of AL-HAMDANIYA, 20-21 November 2019

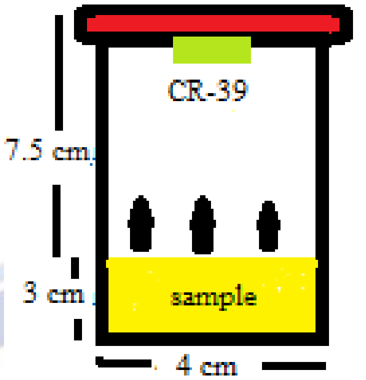

Figure 1. The schematic diagram of a sealed-can technique for spice samples.

The spice samples radon gas concentration calculated using the equation [7], [8].

$$\rho = \frac{Total\ number\ of\ tracks}{Area\ of\ the\ field\ of\ view} \qquad (1)$$

The radon activity concentration C_{Rn}(Bq/m^3) related to the density of tracks ρ(Track/cm^2) and the exposure time T (days) by equation [9].

$$C_{Rn} = \rho/KT \qquad (2)$$

Where CR-39 calibration factor is K, its value (0.04965 Traks.cm^{-2}.day^{-1} / Bq.m^{-3}) calculated by the equation [10], [11].

$$K = \frac{1}{4}\, r \left(2cos\theta_c - \frac{r}{R_i}\right) \qquad (3)$$

Where θ_c is the critical angle of CR-39 which equals 35°, r is the radius of the sealed can (2 cm), R_i is the range of alpha in the air (4.09 cm for radon) calculated by [12].

$$R_i = 0.318\, E_i^{3/2} \qquad (4)$$

Where E_i is the alpha particle emitted energy from radon 5.49 MeV. The concentration of radon in the samples calculated using the equation [13].

$$C_s = \lambda_{Rn}\, C_{Rn}\, H\, T/L \qquad (5)$$

Where C_s is the concentration of radon in the spices sample (Bq/m^3), C_{Rn} is the concentration of air space Radon (Bq/m^3), λ_{Rn} is the constant of decay for Radon (0.1814 day^{-1}), in the can the height of air space is H (7.5 cm), the time of exposure is T (60 days), and the thickness of the sample is L (3cm) in the can.

المؤتمر الدولي العلمي الأول للدراسات الصرفة والإنسانية للمدة 20-21 تشرين الثاني 2019 / جامعة الحمدانية

Journal of University of Babylon for Pure and Applied Sciences, Vol. (28), No. (1): 2020
Online ISSN: 2312-8135, Print ISSN: 1992-0652
The First International Scientific Conference for Pure and Human Studies, University of AL-HAMDANIYA, 20-21 November 2019

The sample effective Radium content calculated by formula [14], [15].

$$C_{Ra}(Bq.Kg^{-1}) = \left(\frac{\rho}{KT_e}\right)\left(\frac{HA}{M}\right) \qquad (6)$$

Where the mass of sample M is in Kg, A in m^2 is the cross-section area of the sealed can, the distance between the detector and top surface of spices sample is H in meter, T_e is time effective exposure in day calculated by the formula:

$$T_e = \left[T - \lambda_{Rn}^{-1}\left(1 - e^{-\lambda_{Rn}T}\right)\right] \qquad (7)$$

The spices radon activity A_{Rn} calculated through relation [16], [17].

$$A_{Rn} = C_s\, V \qquad (8)$$

Where A_{Rn} the radon activity, V the spices volume $(V = \pi r^2 L)$ = 37.68 X 10^{-6} m^3, r is a radius of the can. The atoms number of the radon N_{Rn} determined by the relation:

$$A_{Rn} = \lambda_{Rn}\, N_{Rn} \qquad (11)$$

By the secular equilibrium (the activity of radon equal the activity of uranium) uranium atom number in the samples can be calculated N_U from:

$$\lambda_U\, N_U = \lambda_{Rn}\, N_{Rn} \qquad (12)$$

Where λ_U is the decay constant of uranium (4.883 X 10^{-18} sec^{-1}), then the weight of uranium in the spices samples calculated from:

$$W_U = N_U\, a_U\, / N_{avo.} \qquad (13)$$

Where a_U is the mass number of uranium ^{238}U, $N_{avo.}$ Avogadro constant (6.02 X 10^{23} atom/mol). The concentration of uranium, then calculated by

$$C_U = W_U\, / W_s \qquad (14)$$

Where C_U is the concentration of uranium in (ppm) unit, the sample's mass W_s is used in gram (differ from sample to another listed in table 1.).

The activity concentration of uranium in units of (Bq.Kg^{-1}) will be.

$$Ac_U = \lambda_U N_{avo.} [a_U]^{-1}\, C_U \qquad (15)$$

Where C_U must be in units of (g/Kg) (since 1ppm=10^{-6}g/g = 10^{-3}g/Kg).

The annual radon effective dose D_{eff} (mSv/y) calculated from [18].

$$D_{eff} = C_{Rn} OFT_y D \qquad (16)$$

Where C_{Rn} the concentration of radon (Bq/m^3), F is an equilibrium factor 0.4, and O is the occupancy factor its value 0.8, T_y (8760 h.y^{-1}) hours is a time of one year, and D is the conversion factor (9×10^{-6}mSv.h^{-1}(Bq.m^{-3})$^{-1}$) [19].

Results and Discussion

The results of the measurements are listed in (Table 1).

Table 1. Samples, samples weight, track density, Radon concentration, radon annual effective dose, radium concentration, and uranium activity concentration.

No.	Samples	Samp. weight gm	ρ Track /cm^2	C_{Rn} Bq/m^3	$Rn\ D_{eff}$ mSvy^{-1}	C_{Ra} Bq/kg	C_U Bq/kg
1	Latency	14.81	581.81	195.30	4.927	1.367	13.520
2	Ginger	17.14	363.63	122.06	3.079	0.738	7.301
3	Lemon Dozy	28.21	424.24	142.41	3.592	0.523	5.175
4	Curry	15.16	327.27	109.85	2.771	0.751	7.429
5	Coriander	11.25	400	134.27	3.387	1.238	12.236
6	Darcin	16.51	424.24	142.41	3.592	0.894	8.843
7	Turshi Spices	12.67	460.60	154.61	3.900	1.265	12.511
8	Black pepper	14.27	533.33	179.03	4.516	1.301	12.862
9	Paprika	14.14	303.03	101.72	2.566	0.746	7.375
10	Hill	11.09	387.87	130.20	3.284	1.217	12.037
11	Anba Spices	21.95	315.15	105.79	2.669	0.499	4.941
12	White pepper	18.64	460.60	154.61	3.900	0.860	8.504
13	Sweet pill	14.45	290.90	97.653	2.463	0.701	6.928
14	Turmeric	16.02	315.15	105.79	2.669	0.684	6.770
15	Red pepper	12.82	484.84	162.75	4.106	1.316	13.016
16	Black pill	15.51	436.36	146.47	3.695	0.979	9.682
17	Anise	15.14	193.93	65.102	1.642	0.446	4.408
18	Oregano	10.6	351.51	117.99	2.976	1.154	11.413
19	Summak	13.8	375.75	126.13	3.182	0.948	9.371
20	Rosemary	8.73	230.30	77.308	1.950	0.918	9.079
21	Saffron	9.48	278.78	93.584	2.361	1.023	10.121
22	Hawaij Clegga	15.06	363.63	122.06	3.079	0.840	8.310
23	Basra num	11.58	327.27	109.85	2.771	0.984	9.726
24	Chicken Spices	11.65	412.12	138.34	3.490	1.231	12.174
	Min			65.102	1.642	0.446	4.408
	Max			195.30	4.927	1.367	13.520
	Mean			126.47	3.190	0.943	9.322

Journal of University of Babylon for Pure and Applied Sciences, Vol. (28), No. (1): 2020
Online ISSN: 2312-8135, Print ISSN: 1992-0652
The First International Scientific Conference for Pure and Human Studies, University of AL-HAMDANIYA, 20-21 November 2019

The calculated concentration of radon activity values are in the range 65.102-195.30 Bq/m^3, a mean value of 126.47 Bq/m^3. The concentration of radon mean value is a small amount over the reference level of the World Health Organization (WHO) limits of 100 Bq/m^3, below 200 Bq/m^3 limits of the UK Board of National Radiation Protection (NRPB) and below the level of the European Recommendation Commission. The annual radon effective dose varied between 1.642-4.927 mSv/y, which is within the range 0.2-10 mSv/y of (UNSCEAR) with 3.190 mSv/y of a mean value. Radium contents vary between 0.446-1.367 Bq/Kg with 0.943 Bq/Kg as a mean value, comparing with the other available researches its agreement with the results of 0.81 Bq/Kg in Ghana estimated in reference [22]. The range of uranium activity concentrations is between 4.408-13.520 Bq/Kg with a mean value of 9.322 Bq/Kg its in the range when compared with a mean value of 2.19 Bq/Kg in Nigeria from reference [23]. The minimum values in the sample no. 17 Anise was found, and max values in sample no. 1 Latency. (Figure. 2) Represents the effective radon annual dose with the sample variance.

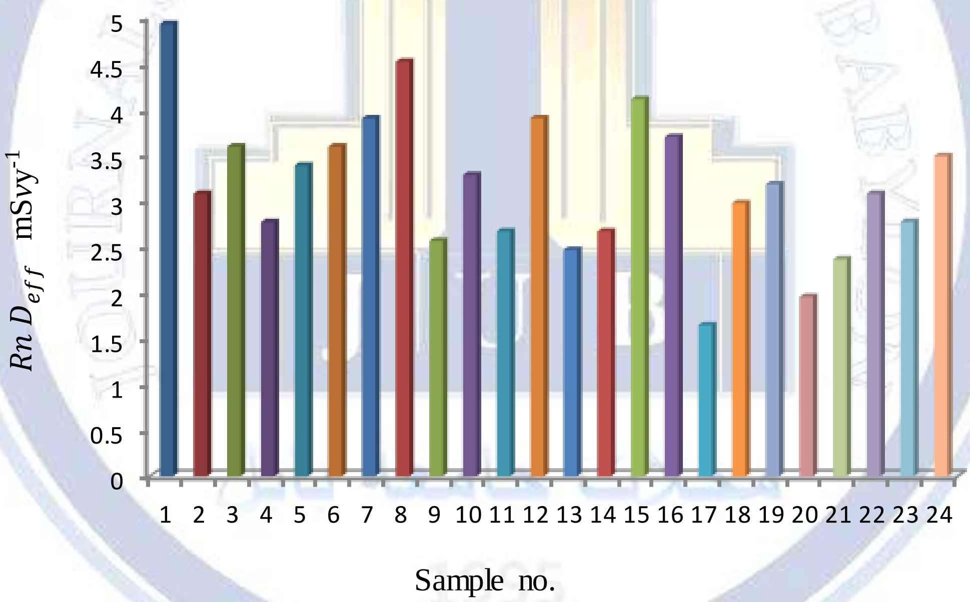

Figure 2. Samples radon annual effective dose.

The variance of uranium concentration with the samples in (Figure 3).

المؤتمر الدولي العلمي الأول للدراسات الصرفة والإنسانية للمدة 20-21 تشرين الثاني 2019 / جامعة الحمدانية

Journal of University of Babylon for Pure and Applied Sciences, Vol. (28), No. (1): 2020
Online ISSN: 2312-8135, Print ISSN: 1992-0652
The First International Scientific Conference for Pure and Human Studies, University of AL-HAMDANIYA, 20-21 November 2019

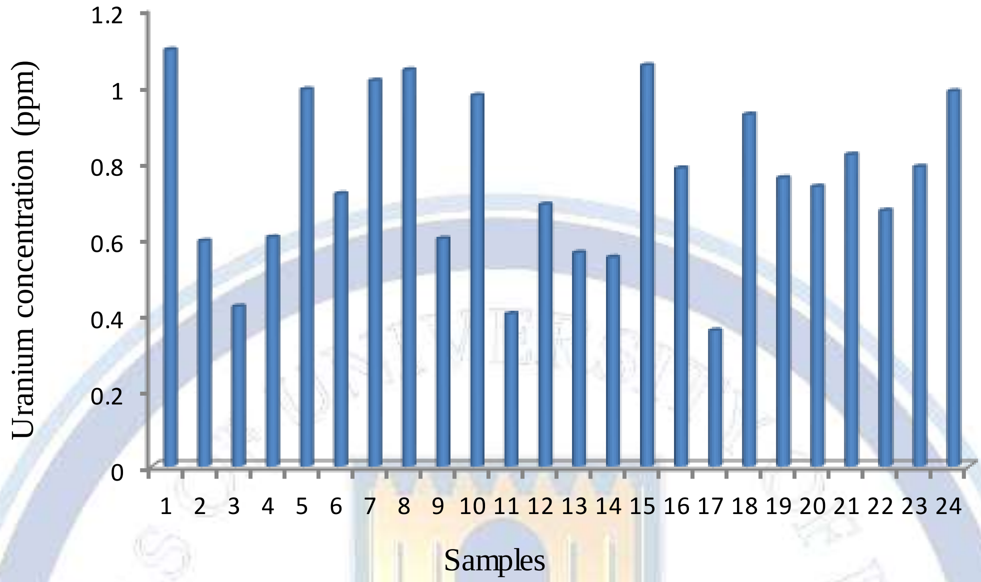

Figure 3. Uranium concentrations in samples.

The results show the sample's radiation concentrations are low and within the low radiation background limit. The important contributors corresponding to other radionuclides occurring naturally, such as ^{226}Ra isotopes, ^{238}U being lower magnitude an order. For this decay-series radionuclide, the series of uranium, isotopes of the radium are the dietary contamination source and the serious internal radiation to man. In the uranium series, most of the particles of alpha are from radium emitted and its daughter, spices all the samples have a high contribution to the ingestion consumer doses. Uptake patterns of crops have widely different from soil to plant harvest, due to variations of the transfer factor of their radionuclide for the pathway of soil-plant-spices. Longer storage and processing times can reduce the activity contents of radionuclides in foodstuffs. The removal efficiency of the radionuclide through plant product processing varies widely and up to 99% the initial activity remove in the row of material. The surface washing efficiency or cleaning of the plant is low and gives an initial activity reduction [24].

Conclusions

The calculated concentration of radon activity values are in the range 65.102-195.30 Bq/m^3, a mean value of 126.47 Bq/m^3. The concentration of radon mean value is a small amount over the reference level of the World Health Organization (WHO) limits of 100 Bq/m^3, below 200 Bq/m^3 limits of the UK Board of National Radiation Protection (NRPB) and below the level of the European Recommendation Commission. The annual radon effective dose varied between 1.642-4.927 mSv/y, which is within the range 0.2-10 mSv/y of (UNSCEAR) with 3.190 mSv/y of a mean value. Radium

https://www.journalofbabylon.com/index.php/JUBPAS, info@journalofbabylon.com, jub@itnet.uobabylon.edu.iq
+9647823331373 (Viber and Telegram)

contents vary between 0.446-1.367 Bq/Kg with 0.943 Bq/Kg as a mean value, comparing with the other available researches its agreement with the results of 0.81 Bq/Kg in Ghana estimated in reference [22]. The range of uranium activity concentrations is between 4.408-13.520 Bq/Kg with a mean value of 9.322 Bq/Kg its in the range when compared with a mean value of 2.19 Bq/Kg in Nigeria from reference [23]. The minimum values in the sample no. 17 Anise was found, and max values in sample no. 1 Latency. This work is to identify and to measure the radionuclide specified activity present in spices consuming in Iraq, in order to calculate their concentrations. The investigation is very useful also in ascertaining the level of risks on health that involved might be in the countries that consuming spices. The results show that radionuclides that present differently in types of the spices, due to the environments heterogeneity in which the radionuclides are deposited since it greatly influenced by the soil type, water, precipitation, and transportation by groundwater or by organic metabolism, as well as other factors. This study revealed that the public in general not been subject to radiological epidemiology until now by consuming these selected spices. Because of low concentrations activity, they not constitute any hazard to health if the general public consuming these spices.

Conflict of Interests.
There are non-conflicts of interest

References

[1] M. Askari, V. Mirzaei, and M. Mirhabibi, "Introduction to radioactive materials", International Journal of Renewable and Sustainable Energy, vol. 3, no. 3, pp. 59-67, 2014.
[2] W. H. Hallenbeck, *Quantitative Risk Assessment for Environmental and Occupational Health*, 2nd Edition, CRC Press, June 9, 1993.
[3] A. Martin, and S. Harbison, *The internal radiation hazard. In: An Introduction to Radiation Protection*, Boston, MA, Springer, 1996.
[4] E. Burgio, P. Piscitelli, and L. Migliore "Ionizing Radiation and Human Health: Reviewing Models of Exposure and Mechanisms of Cellular Damage, An Epigenetic Perspective", *Int J Environ Res Public Health*, vol. 15, no. 9, pp. 1971, 2018.
[5] F. Mettler, "Medical effects and risks of exposure to ionizing radiation", *Journal of Radiological Protection*, vol. 32, no. 1, pp. n9-n13, 2012.
[6] E. Vogiannis, and D. Nikolopoulos, "Radon sources and associated risk in terms of exposure and dose", *Front Public Health*, vol. 2, pp. 207, 2015.
[7] M. H. Kheder, "Measurement of Radon Concentration Using SSNTD in Bartella Region", *Al-Mustansiriyah Journal of Science*, vol. 29, no. 4, pp. 110-116, 2018.
[8] N. Ahmad, M. Jaafar, S. Khan, T. Nasir, S. Ahmad, and M. Rahim, "Measurement of Radon Exhalation Rate, Radium Activity and Annual Effective Dose from

Bricks and Cement Samples Collected from Dera Ismail Khan", *American Journal of Applied Science*, vol. 11, no. 2, pp. 240-247, 2014

[9] V. Hamza, and M. Mohankumar, "Cytogenetic Damage in Human Blood Lymphocytes Exposed in Vitro to Radon", *Mutation Research*, vol. 661, no. 1-2, pp. 1-9, 2009.

[10] K. Abdullah, S. Muhammed, and A. Hussein, "Assessment of Rn and U Concentrations in the Soil of Qadafery, Kalar and Zarayan Located in Sulaimani Governorate of Kurdistan Region-Iraq", *American Journal of Environmental Protection*, vol. 4, no. 1, pp. 40-44, 2015.

[11] D. Nikezic, K. Yu, and J. Stajic, "Computer program for the sensitivity calculation of a CR-39 detector in a diffusion chamber for radon measurements", *Review of Scientific Instruments*, vol. 85, pp. 022102, 2014.

[12] M. Mansy, M. Sharaf, H. Eissa, S. El-Kamees, M. Abo-Elmagd, "Theoretical calculation of SSNTD response for radon measurements and optimum diffusion chamber dimensions", *Radiation Measurements*, vol. 41, pp. 222–228, 2006.

[13] G. Somogyi, A. Hafiz, I. Hunyadi, and M. Toth-Szilagyi, "Measurement of Exhalation and Diffusion Parameters of Radon in Solids by Plastic Track Detectors", *Nucl. Track Radit. Meas*, vol. 12, no. 1-6, pp. 701-704, 1986.

[14] E. Andrade, C. Miró, M. Reis, M. Santos, and M. Madruga, "Assessment of Radium Activity Concentration and Radon Exhalation Rates in Iberian Peninsula Building Materials", *Radiation Protection Dosimetry*, vol. 177, no. 1-2, pp. 31–35, 2017.

[15] M. Khan, A. Naqvi, A. Azam, and D. Srivastava, "Radium and radon exhalation studies of the soil", *Iranian Journal of Radiation Research*, vol. 8, pp. 207-210, 2011.

[16] M. H. Kheder, A. Ahmad, H. Azeez, M. Slewa, B. Badr, and S. Sleeman, "Radon and uranium concentration in groundwater of Nineveh plain region in Iraq", *J. Phys. Conf.: Ser.* Vol. 1234, pp. 012033, 2019.

[17] H. Cember, and T. Johnson, *Introduction to health physics*, 4th edition. McGraw-Hill, 2009.

[18] H. Azeez, M. Kheder, M. Slewa, and S. Sleeman, "Radon Concentration Measurement in Ainkawa Region Using Solid State Nuclear Track Detector", *Iraqi Journal of Science*, vol. 59, no. 1B, pp. 482-488, 2018.

[19] UNSCEAR, *Sources, effects, and risks of ionizing radiation: United Nations Scientific Committee on the Effects of Atomic Radiation*. Report to the General Assembly, United Nations, New York, 2000.

[20] WHO, *Handbook on Indoor Radon: A Public Health Perspective*, Geneva. 6, National radon programs. World Health Organization, 2009.

[21] J. Miles, D. Appleton, M. Rees, B. Green, K. Adlam, and A. Myers, *Indicative atlas for radon in England and Wales, Oxford shire (UK): Health Protection Agency and British Geological Survey*, Report No. HPA-RPD-033, 2007.

[22] C. Kansaana, E.O. Darko, O.K. Adukpo, A. Faanu, E. Shitsi, N.S. Opata, and L. Tettey-Larbi, " Measurement Of Activity Concentrations Of 226Ra, 232Th, 40K And 137Cs In Some Common SpicesConsumed By Inhabitants In Accra Metropolis, Ghana", *Int J Food Sci Nutr Diet*. Vol. 2, no. 8, pp.75-80, 2013.

[23] C.P. Ononugbo, G.O. Avwiri, and S.O. Ikhuiwu, "Estimation of Naturl Radioactivity Levels in Some Food Spices Commonly Used in Nigeria and Its Radiological Risks", *Journal of Scientific Research & Reports*, vol. 16, no. 3, pp. 1-9, 2017.

[24] A. Adeniji, O. Alatise, and A. Nwanya, "Radionuclide concentrations in some fruit juices produced and consumed in Lagos, Nigeria", *American Journal of Environmental Protection*, vol. 2, no. 2, pp. 37-41, 2013.

الخلاصة

البهارات تستخدم كاضافات على الطعام في مختلف البلدان ، من ضمنها بلدنا، لذا من الضروري التاكد من خلوها من المواد المشعة الضارة بصحة الانسان. هدف هذا البحث كان قياس تراكيز باعثات الفا ، وقياس الجرعة السنوية الفعالة AED الناتجة من تناول الرادون. استخدم كاشف CR-39 في قياس تراكيز الرادون ، الراديوم واليورانيوم في 24 عينة من البهارات المختارة من الاسواق. تراكيز الرادون وجد في هذا البحث تتغير من 65.102 الى 195.30 Bq/m^3 وبقيمة متوسطة 126.47 Bq/m^3 وهذه القيمة هي اعلى بقليل من 100 Bq/m^3 المستوى او الحدود المقبولة من منظمة الصحة العالمية (WHO) واقل من 200 Bq/m^3 التي هي حدود اللوائح البريطانية للوقاية من الاشعاع (NRPB) والاوربية. الجرعة السنوية الفعالة للرادون تراوحت بين 1.642 -4.927 mSv/y التي هي ضمن المدى 0.2 - 10 mSv/y للجنة الامم المتحدة لاثار الاشعاع الذري (UNSCEAR). تراكيز الراديوم تغيرت بين 0.446 - 1.367 Bq/Kg بمتوسط 0.943 Bq/Kg. وتراكيز فعالية اليورانيوم كانت في المدى 4.408 - 13.520 Bq/Kg وبقيمة متوسطة 9.322 Bq/Kg. هذا العمل قاس التراكيز المحددة للمواد المشعة الموجودة في البهارات وبين ان هذه البهارات امنة للتناول.

الكلمات الدالة: محتوى الراديوم، جرعة الرادون الفعالة، كاشف CR-39، البهارات، اليورانيوم.