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MEASUREMENT OF NATURAL RADIOACTIVITY FOR AGRICULTURAL PRODUCTS IN AL-LHIS, AL-ZUBAYR AND SAFWAN AREAS IN AL-BASRA AND EVALUATION OF RADIATION DOSES TO CONSUMERS

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Abstract

Natural radioactivity was studied in different plants species commonly consumed in Al-Basra Governorate and corresponding soil samples where the plants samples are grown using gamma-ray spectrometry system (NaI(Tl) detector) and Solid State Nuclear Track Detector (CR-39). Three cultivated areas at Al-Basra governorate (Al-Zubayr, Al-Lhis and Safwan) were investigated for determination of natural radioactivity in plants and corresponding soil samples. The average activity concentrations in investigated radish, garlic and onions samples were 17.42 ± 9.47 Bq/kg for ^{238}U, 24.32 ± 13.74 Bq/kg for ^{232}Th and 225.24 ± 100.96 Bq/kg for ^{40}K. The corresponding average activity concentrations in soil samples were 47.69 ± 20.97 Bq/kg for ^{238}U, 41.01 ± 18.43 Bq/kg for ^{232}Th and 445.79 ± 113.38 Bq/kg for ^{40}K. The mean annual effective dose to the public arising from ingestion of natural nuclides in the investigated radish, garlic and onions samples (0.23 mSv) was found to be below the annual dose limit of 0.3 mSv. ^{222}Rn activity concentrations in radish, garlic, onions, tomato, melon, watermelon, cucumber, aubergine and green pepper samples were ranged from 23.2 to 156.2 Bq/m^3, with an average value of 89.2 ± 32.1 Bq/m^3. The reported ^{222}Rn activity concentrations in investigated plants samples were far below the corresponding limit of 400 Bq/m^3. Hence, the investigated plants species in current study were considered safe for human consumption with respect to radiological hazard.

Key words: Natural radioactivity, plants, NaI (Tl) detector, CR-39 detector.

Introduction

Radionuclides of natural origin are found in the human environment, even humans have natural radioactive materials within their bodies. Naturally occurring radionuclides and their corresponding gamma-radiation exposure show geographical and geological dependence. Such radioactive materials exist at different quantities in different worldwide regions. Primordial radioisotopes of ^{40}K, ^{232}Th and ^{226}Ra represent the major sources of environmental radioactivity on the earth (Njinga *et al*., 2015). However, their activity concentrations show considerable geographical variability. The radionuclides of natural origin, as well as essential nutrients are absorbed from the soil through plant-roots and transferred to other plant parts. The presence of natural radioactivity in the plants parts consumed by human cause internal radiation exposure (Alsaffar *et al.*, 2015).

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This research work focused on measuring the activity concentrations of naturally occurring radionuclides (^{238}U, ^{232}Th and ^{40}K) in selected soil samples and selected plants species commonly used in Iraq for human consumption using NaI (Sodium Iodide) gamma-ray spectrometry system. Annual effective doses arising from ingestion of ^{238}U, ^{40}K and ^{232}Th in investigated plants species were evaluated. This study also involves measurement of Radon activity concentrations in plants samples using Solid State Nuclear Track Detector (CR-39).

Materials and Methods

Areas of the Study

Al-Basra is an Iraqi governorate located at the Shatt Al-Arab between Kuwait and Iran, more than 500 km distance to the south of Iraqi capital (Baghdad). It had an estimated population of 2.5 million in 2012. Three

Fig. 1: Investigated areas at Al-Basra Governorate.

agricultural areas at Al-Basra governorate were investigated for environmental radioactivity in plants and soil samples, namely: Al-Zubayr, Safwan and Al-Lhis (Fig. 1).

Sampling

Total of 3 of surface soil and 12 plants samples were collected in 2018 for gamma-ray spectroscopy analysis from investigated areas shortly before harvest. The various plants species considered are: radish, garlic and onions. 20 plants samples were collected randomly from investigated locations in the Al-Basra Governorate for ^{222}Rn activity measurement. Radish, garlic, onions, tomato, melon, watermelon, cucumber, aubergine and green pepper samples were chosen for present study since these plants species are the most popular food to Al-Basra and Iraqi people. The samples labeled with unique codes were transferred into polyethylene bags, washed carefully with tap water and dried on trays for a period of 7 days before they were placed in labeled polyethylene bags to the laboratory for analysis. The three surface soil samples (depth: 10 cm) were collected by using trowel, then labeled and placed in plastic bags.

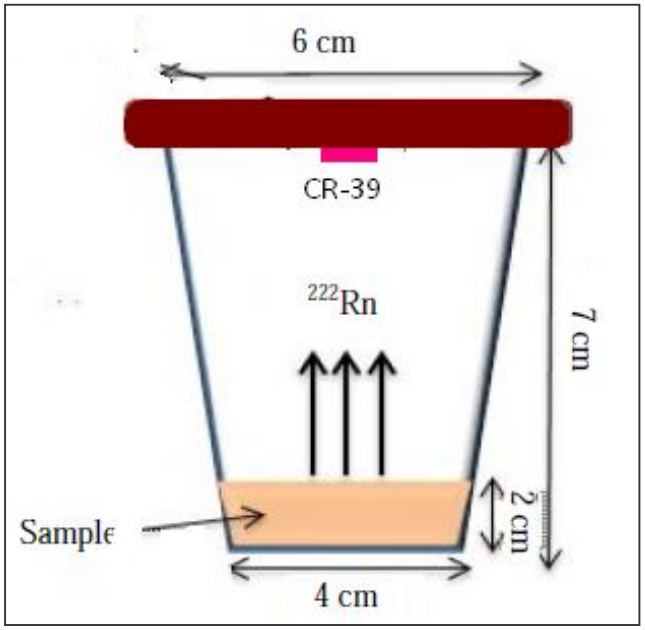

Fig. 2: Sample in container.

The plants and soil samples were adequately dried at the analytical laboratory using electric oven at temperature of 110°C for 1 hour to remove the humidity, then crushed to fine powder and filtered using a sieve of 2 mm mesh size in order to obtain uniform sample matrix. The samples were then transferred into cylindrical plastic containers of known weight. The weight of the container and the sample were measured using micro-balance. The weight of the sample was calculated through subtracting the weight of the empty container from the weight of the sample and the container. The outer portion of the plastic container lid was then coated with tape to avoid or at less minimize escape of radon gas (^{222}Rn). The sealed containers were then kept for a period of 30 days to attain secular equilibrium between ^{226}Ra and its progeny in the uranium decay series (Njinga *et al*., 2015).

Radiometric Analysis of the Samples

Gamma-ray spectrometry system was used for the measurement of activity concentrations. The detector assembly used consisted of a 7.62 × 7.62 cm NaI(Tl) detector, housed in a 6 cm thick lead-shield, cadmium-lined assembly with copper sheets for the minimization

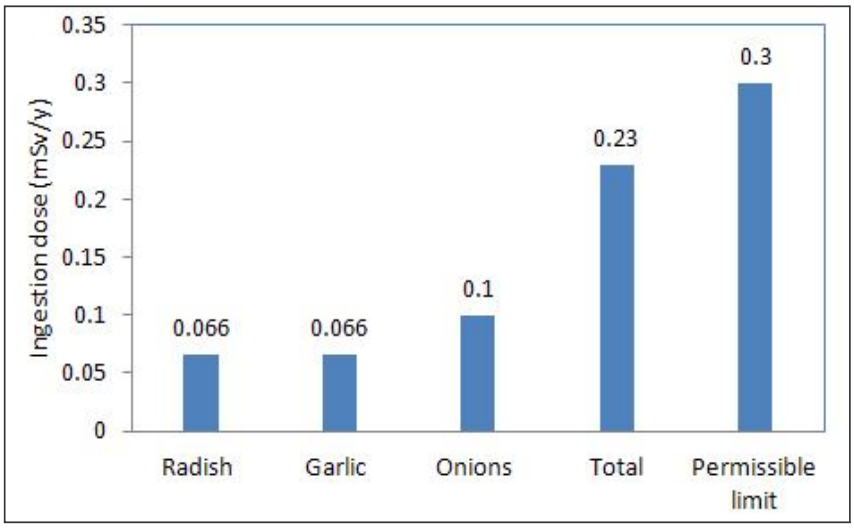

Fig. 3: Estimated AACED due to ingestion of investigated plants species.

of background radiation. The entire assembly was connected to computer-based Multichannel Analyzer (MCA) card system programmed used for the spectra analysis and data acquisition. The activity concentrations of gamma-emitting radionuclides in the soil and plants samples were estimated using the following expression (Njinga *et al*., 2015):

$$C_i = \frac{N_i}{I_\gamma \times \varepsilon \times M \times T} \quad \ldots 1$$

where C_i is the activity concentration of a certain radionuclide (Bq/kg), N_i is the net peak area count of the sample (background subtracted), ε is the absolute efficiency of the detector, I_γ is the emission probability of a specific energy photo-peak, T is the counting time (3600 s) and M is the weight of the sample (kg). The activity concentrations of ^{238}U and ^{232}Th were estimated by the gamma-lines of their progeny: ^{208}Tl (2614 KeV) and ^{214}Bi (1760 KeV), respectively. The activity concentrations of ^{40}K were estimated from gamma line (1460 KeV).

A CR-39 detector (chemical composition $C_{12}H_{18}O_7$, density 1.32 g/cm^3, thickness 200 μm, area 1 cm^2) was used for measuring radon levels in soil and investigated plants samples. 100 gram of plants and 1 kg of soil samples were placed into the container and then sealed for 60 days as shown in fig. 2. These detectors were placed at the closed top end of a plastic cup of diameter (4 cm), length (7 cm) and volume (130 mL). The CR-39 detectors were etched in sodium hydroxide (NaOH) solution (Hady *et al*., 2016) in water bath (type Labsco) at 65°C for 2.5 hours. The numbers of tracks per unit area were then counted using an optical microscope (type Motic) of 100X magnification power. Radon activity concentration (C_{Rn}) in (Bq/m^3) for plants samples was calculated using the following expression (Hady *et al*., 2016):

$$C_{Rn} = \frac{\rho}{K \times t} \quad \ldots 2$$

where ρ is the radon track density (track/cm^2), K is the calibration factor (0.0092 track/cm^2)/(Bq hr m^{-3}) and t is the exposure time (60 days, 1440 hr).

Dose Assessment

The Mean Annual Committed Effective Dose (MACED in mSv/y) for intake of radionuclides in the plants species investigated in the current study was calculated using the following expression (Njinga *et al*., 2015; Larbi *et al*., 2013):

$$MACED = C_i \times DCF_i \times A \quad \ldots 3$$

where C_i is the activity concentration of radionuclide i in plant (Bq/kg), DCF_i is the dose conversion coefficient for ingestion (4.5×10^{-5}, 2.3×10^{-4} and 6.2×10^{-6} mSv / Bq for ^{238}U, ^{232}Th and ^{40}K respectively for an adult) (Njinga *et al*., 2015; UNSCEAR, 2000) and A is the consumption rate of plants (27.9 gram per capita per day, equivalent to 10.18 kg per capita per year (Van *et al*., 2018)).

Results and Discussion

The activity concentrations of natural radionuclides in radish, garlic and onions commonly used in Iraq have been estimated and listed in table 1. As shown in table 1, the activity concentrations of ^{40}K in the investigated plants species ranged from 88.76 ± 4.61 Bq/Kg to 382.64 ± 3.66 Bq/Kg with mean value of 225.24 ± 100.96 Bq/Kg. The greatest activity concentration of ^{40}K was found in garlic roots sampled from Safwan area while garlic leaves sampled from Al-Zubayr area had the lowest activity concentration. ^{238}U activity concentrations varied from 4.32 ± 1.12 Bq/Kg to 31.72 ± 2.61 Bq/Kg with mean value of 17.42 ± 9.47 Bq/Kg. The lowest concentration was found in garlic roots sampled from Al-Zubayr area while the greatest concentration was recorded for onions roots sampled from Safwan area. For the activity concentrations of ^{232}Th, it ranges from 6.78 ± 1.42 Bq/Kg to 47.66 ± 3.24 Bq/Kg, with an average value of 24.32 ± 13.74 Bq/Kg. The lowest activity concentration was recorded for garlic leaves sampled from Al-Zubayr area, while the highest activity concentration was recorded for onions roots sampled from Safwan area. Based on the results listed in table 1, the activity concentrations of ^{40}K were relatively high in all the investigated plants samples followed almost by ^{232}Th. ^{238}U was generally low across the three analyzed plants. Generally, it was noticed that roots of each studied plant

Table 1: Results of radioactivity measurement for plants samples using gamma-ray spectrometry system (NaI (Tl) detector).

Agricultural product	Sampling location	Activity concentration (Bq/kg)		
		^{238}U	^{232}Th	^{40}K
Radish roots	Al-Zubayr	17.61 ± 1.02	24.62 ± 0.87	287 ± 3.22
Radish leaves	Al-Zubayr	6.67 ± 0.45	16.72 ± 2.21	120.12 ± 5.21
Garlic roots	Al-Zubayr	4.32 ± 1.12	9.69 ± 1.78	96.91 ± 2.45
Garlic leaves	Al-Zubayr	4.62 ± 0.87	6.78 ± 1.42	88.76 ± 4.61
Onions roots	Al-Lhis	23.32 ± 3.37	30.08 ± 2.11	296.12 ± 10.12
Onions leaves	Al-Lhis	16.92 ± 2.41	14.27 ± 3.17	210.4 ± 7.61
Garlic roots	Al-Lhis	19.11 ± 3.62	16.76 ± 0.76	292.76 ± 2.07
Garlic leaves	Al-Lhis	8.76 ± 1.22	11.86 ± 1.78	232 ± 4.22
Onions roots	Safwan	31.72 ± 2.61	47.66 ± 3.24	367.22 ± 4.61
Onions leaves	Safwan	24.62 ± 4.5	38.79 ± 2.08	161.32 ± 8.66
Garlic roots	Safwan	29.64 ± 4.11	42.76 ± 3.42	382.64 ± 3.66
Garlic leaves	Safwan	21.73 ± 2.33	31.96 ± 2.34	167.72 ± 5.22
Average ± σ		17.42 ± 9.47	24.32 ± 13.74	225.24 ± 100.96
Minimum ± σ		4.32 ± 1.12	6.78 ± 1.42	88.76 ± 4.61
Maximum ± σ		31.72 ± 2.61	47.66 ± 3.24	382.64 ± 3.66

show relatively higher activity concentrations for investigated natural radionuclides than the leaves of the same plant. Data shown in table 1 clearly indicate that the activity concentrations of natural radionuclides in investigated plants samples varies considerably from sample to sample, which could be due to the difference in the level of radionuclides activity concentrations in the soil where the samples are grown or due to the difference in the mechanism of radionuclides adsorption and transmission to plants samples under study. On the basis of the analytical results presented in this study and as reported in some previous similar studies (Alsaffar *et al*., 2015; Hady *et al*., 2016), it was concluded that there are differences in the degree of transportation of radionuclides from soil to plants depending upon physiological characteristics of the plants and the radionuclides itself. These analytical results also indicated that the uptake of the investigated natural radionuclides depend on plants compartments, reflecting their mobility and accumulation in each plant part.

Results of measurements of activity concentrations of natural radionuclides (^{238}U, ^{232}Th and ^{40}K) in analyzed soil samples sampled from Al-Zubayr, Al-Lhis and Safwan areas are listed in table 2. The mean activity concentrations of ^{238}U, ^{232}Th and ^{40}K were recorded to be 47.69 ± 20.97, 41.01 ± 18.43 and 445.79 ± 113.38 Bq/kg, respectively. Analytical results for ^{238}U, ^{232}Th and ^{40}K in soil samples are compared with worldwide mean values (35, 30 and 400 Bq/kg [6, 8], respectively). Generally, ^{238}U , ^{232}Th and ^{40}K in investigated soil samples showed average activity concentration values higher than worldwide average activity concentrations. However, the presented results indicate that the studied areas are situated in an area of normal background radioactivity.

Table 2: Results of radioactivity measurement for soil samples using gamma-ray spectrometry system (NaI (Tl) detector).

Sampling location	Activity concentration (Bq/kg)		
	^{238}U	^{232}Th	^{40}K
Al-Zubayr	30.96 ± 3.22	20.72 ± 1.72	340.76 ± 4.77
Al-Lhis	40.91 ± 0.72	45.61 ± 2.82	430.61 ± 11.44
Safwan	71.22 ± 2.32	56.72 ± 3.72	566 ± 8.66
Average ± σ	47.69 ± 20.97	41.01 ± 18.43	445.79 ± 113.38
Minimum	30.96 ± 3.22	20.72 ± 1.72	340.76 ± 4.77
Maximum	71.22 ± 2.32	56.72 ± 3.72	566 ± 8.66

The mean annual committed effective dose (MACED) was estimated using Eq. 3 to be ranged from 0.023 mSv/y for consumption of garlic to 0.14 mSv/y for the consumption of onion with an average of 0.079 mSv/y. Total dose from ingestion of radish, onion and garlic was estimated in Fig. 3 to be 0.23 mSv/y. The total MACED arising from ingestion of the naturally occurring radionuclides in the investigated plant is less than the world mean annual committed effective dose limit of 0.3 mSv for intake of natural radionuclides specified in the UNSCEAR, 2000 report (Njinga *et al.*, 2015; UNSCEAR, 2000). ^{40}K, ^{232}Th and ^{238}U contributed about 19.3, 71.3 and 9.4% of the total estimated dose, respectively.

From table 3, it was found that ^{222}Rn activity concentrations in plants samples varies from a minimum value of 23.2 Bq/m^3 for green pepper sampled from Al-Zubair area to a maximum value of 156.2 Bq/m^3 for watermelon sampled from Safwan area. It was noticed that ^{222}Rn activities are clearly different in the investigated plants species collected from various places. ^{222}Rn activity concentration values for all investigated plants samples were lower than the natural limits for public (400 Bq/m^3) given by the ICRP (International Commission on Radiological Protection) (Hady *et al*., 2016; ICRP, 1987).

Table 4 presents ^{222}Rn activity concentrations for soil samples collected from different areas in Al-Basra Governorate. Analytical data listed in table 4 show that the lowest value of ^{222}Rn activity concentration was found in Al-Zubayr area sample, which was (511.2 Bq/m^3), while the highest value was found in Safwan area sample, having value of 726.6 Bq/m^3.

Table 3: Results of ^{222}Rn radioactivity measurements for plants samples using CR-39 detector.

Sampling location	Agricultural product	^{222}Rn level (Bq/m^3)
Al-Lahis	Garlic	68.6
Al-Lahis	Onions	87.8
Al-Lahis	Tomato	44.6
Al-Lahis	Melon	112.2
Al-Lahis	Watermelon	124.6
Al-Lahis	Cucumber	109.7
Al-Lahis	Aubergine	77.6
Al-Zubair	Garlic	92.2
Al-Zubair	Tomato	72.4
Al-Zubair	Watermelon	111.4
Al-Zubair	Radish leaves	42.2
Al-Zubair	Radish roots	87.6
Al-Zubair	Green pepper	23.2
Al-Zubair	Cucumber	82.2
Safwan	Tomato	68.6
Safwan	Garlic	96.4
Safwan	Melon	113.4
Safwan	Aubergine	82.2
Safwan	Onions	132.2
Safwan	Watermelon	156.2
Average ± σ		89.2 ± 32.1
Minimum		23.2
Maximum		156.2

Conclusions

Natural radioactivity levels of some investigated plants species grown at Al-Basra Governorate and commonly consumed by human in Iraq were measured using gamma-ray spectrometry system. The mean activity concentrations were 17.42 ± 9.47 Bq/kg for ^{238}U, 24.32 ± 13.74 Bq/kg for ^{232}Th and 225.24 ± 100.96 Bq/kg for ^{40}K. The activity concentrations of natural radionuclides in investigated plants species were observed to be have the following order $^{40}K > ^{232}Th > ^{238}U$. Onions roots samples recorded relatively the highest activity concentrations of ^{238}U and ^{232}Th whilst garlic roots sample showed the highest ^{40}K concentration. Activity concentrations in soil samples showed wide variability with a relative elevated ^{40}K activity concentration as compared with ^{232}Th and ^{238}U.

Table 4: Results of ^{222}Rn measurement for soil samples using CR-39 detector.

Sampling location	^{222}Rn level (Bq/m^3)
Al-Zubayr	511.2
Al-Lhis	588.4
Safwan	726.6
Average ± σ	608.7 ± 109.1
Minimum	511.2
Maximum	726.6

The mean annual effective dose to the public arising from ingestion of natural radionuclides in the investigated plants (0.23 mSv per year) was found to be below the radiation dose limit of 0.3 mSv per year (Njinga *et al*., 2015; UNSCEAR, 2000). These results show that the potential radiological hazard associated with intake of the natural radionuclides in the investigated plants species is acceptable.

Radon activity concentrations in some of Al-Basra plants samples consumed in Iraq have been estimated. Radon activity concentrations in plants samples, which were collected randomly from different agricultural areas, were found to be less than the maximum permissible value of (400 Bq/m^3) as recommended by the ICRP (Hady *et al*., 2016; ICRP, 1987). Hence, the investigated plants species in current research were considered safe in terms of the radiological hazard.

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References

Gregory, A.O. and E.O. Agbalagba (2014). Assessment of natural radioactivity, associated radiological health hazards indices and soil-to-crop transfer factors in cultivated area around a fertilizer factory in Onne, Nigeria. *Environ. Earth. Sci*., **71:** 1541-1549.

Hady, H.N., A.A. Abojassim and Z.B. Mohammed (2016). Study of Radon Levels in Fruits Samples using LR-115 Type II Detector. *J. Environ. Sci. Technol*., **9(6):** 446-451.

ICRP (1987). Radionuclide Release into the Environment. Pergamum Press, Oxford, New York.

Larbi, L.T., E.O. Darko, C. Schandorf and A.A. Appiah (2013). Natural radioactivity levels of some medicinal plants commonly used in Ghana. Tettey-Larbi *et al*., *Springer Plus.,* **2:**157.

Alsaffar, M.S., M.S. Jaafar, N.A. Kabir and N. Ahmad (2015). Distribution of ^{226}Ra, ^{232}Th and ^{40}K in rice plant components and physico-chemical effects of soil on their transportation to grains. *Journal of Radiation Research and Applied Sciences.,* **8:** 300-310.

Njinga, R.L., S.A. Jonah and M. Gomina (2015). Preliminary investigation of naturally occurring radionuclides in some traditional medicinal plants used in Nigeria. *Journal of Radiation Research and Applied Sciences.,* **8:** 208-215.

Van, T.T., L.T. Bat, D.D. Nhan, N.H. Quang, B.D. Cam and L.V. Hung (2018). Estimation of Radionuclide Concentrations and Average Annual Committed Effective Dose due to Ingestion for the Population in the Red River Delta, Vietnam. Environmental Management, s00267-018-1007-8.

UNSCEAR (2000). Sources and effects of ionizing radiation. New York: United Nations Scientific Committee on the Effects of Atomic Radiation. United Nations.