Nuclear Technology & Radiation Protection: Year 2018, Vol. 33, No. 4, pp. 386-394

# RADIONUCLIDE AND HEAVY METAL CONTENT IN THE TABLE OLIVE (*OLEA EUROPAEA L.*) FROM THE MEDITERRANEAN REGION OF TURKEY

by

***Muhammet KARATASLI****

Department of Physics, Faculty of Science and Letters, University of Cukurova, Adana, Turkey

Scientific paper
http://doi.org/10.2298/NTRP180702007K

**This study presents the concentrations of radionuclides and heavy metals in twenty-six table olive (*Olea europaea L.*) samples, and an assessment of the health risks associated with their consumption. The samples were collected from different towns in the Mediterranean region of Turkey, one of the major olive-producing countries in the world. The average activity concentrations of $^{226}$Ra, $^{232}$Th, $^{40}$K, and $^{137}$Cs in the edible parts of the table olive samples were found as 37.9  4.1, 7.1  0.5, 274.6  14.7, and 7.2  0.7 Bqkg (dw), respectively, by using a gamma ray spectrometer. The effective radiation dose due to the intake of these radionuclides through ingestion of olive samples varied from 3.4 to 22.7  Sv with an average value of 11  1 μSv. The average concentrations of Cr, Mn, Fe, Co, Ni, Cu, Zn, Sr, and Pb in the edible parts of the table olive samples were determined as 2.04, 11.08, 166.60, 0.20, 10.29, 13.81, 14.34, 4.50, and 4.55  gg$^{-1}$, respectively, by using an inductively coupled plasma optical emission spectrometer. Based on the measured content of the radionuclides and heavy metals, the results imply that table olives are safe for human consumption.**

*Key words: table olive, radionuclide, heavy metal, annual effective dose, gamma ray spectrometry, optical emission spectrometry*

## INTRODUCTION

People have been exposed to ionizing radiation emitted from natural and artificial radioactive sources. The annual effective radiation dose per person, averaged over the world's population, is about 3.0 mSv, of which 2.4 mSv (80 %) comes from natural radioactive sources, while the remaining 0.6 mSv (20 %) is from artificial radioactive sources [1]. Natural radioactive sources are composed of cosmogenic radionuclides (*e. g.* $^{3}$H, $^{7}$Be, $^{14}$C, and $^{22}$Na) present in the Earth's atmosphere and primordial radionuclides (*e. g.* $^{238}$U series, $^{232}$Th series, and $^{40}$K) that originated in the Earth's crust. Primordial radionuclides are present everywhere in the environment, such as rock, soil, water, vegetation, and animals as well as human body tissue [2]. Artificial radioactive sources contain fallout radionuclides from nuclear explosives testing and nuclear accidents, medical and industrial sources, and medical devices. Internal exposure arises from the intake of these radionuclides by inhalation and ingestion. Inhalation exposure is mainly caused by $^{222}$Rn and its short-lived decay products ($^{218}$Po, $^{214}$Po, $^{214}$Pb, and $^{214}$Bi), while ingestion exposure is mainly caused by the $^{238}$U and $^{232}$Th series radionuclides and $^{40}$K present in food and drinking water. Ingestion of natural radionuclides depends on the consumption rates of food and water and the radionuclide concentrations [2].

Heavy metals such as chromium (Cr), manganese (Mn), iron (Fe), cobalt (Co), nickel (Ni), copper (Cu), zinc (Zn), arsenic (As), strontium (Sr), mercury (Hg), and lead (Pb) are present at various levels in soil, water, and the atmosphere. These metals can also occur as residues in food as a result of human activities such as farming and industry, or contamination during food processing and storage. Therefore, people are exposed to these metals from the environment or by ingesting contaminated food or water. Accumulation of these metals in the body can lead to harmful effects in the body and brain.

Food is required by all organisms to sustain life and its associated functions, such as growth, development and maintenance of the body [3]. It is one of the main sources of elements and radionuclides for humans. Therefore, a knowledge of radioactivity and heavy metal levels in the environment and foodstuffs is essential for assessing health risks for populations exposed to these either directly or indirectly [4]. Up to now, several studies have been performed on the deter-

* Author's e-mail: mkaratasli01@gmail.com

mination of heavy metals and nutritional elements in olive samples [5-11]. However, literature review reveals no detailed studies related to determining the concentrations of natural and anthropogenic radionuclides in table olive samples produced in Turkey. The olive (*Olea europaea L.*), which is a member of the Oleaceae family, contains beneficial and nutritive elements. The consumption of olives contributes to a long and healthy life because it boosts the immune system and protects the body from some diseases caused by undernourishment. The homeland of olives is the eastern Mediterranean coast in what is now southern Turkey, Syria, and Lebanon [12]. Table olives and olive oil are two of the most important agricultural exports of Turkey. In Turkey, the Aegean, Marmara, Mediterranean, and Southeast Anatolia regions are the major olive-producing areas. Over the past five years, about 428 000 tons of table olives have been produced [13]. In Turkey, the average annual consumption of table olives per person is about 4 kg [13].

The purpose of the study is to determine the concentrations of natural and anthropogenic radionuclides ($^{226}$Ra, $^{232}$Th, $^{40}$K, and $^{137}$Cs) and heavy metals (Cr, Mn, Fe, Co, Ni, Cu, Zn, Sr, and Pb) in the table olive samples produced in the Mediterranean region of Turkey and to assess the health risks to the population by estimating the effective radiation dose rate and daily intake of heavy metals due to ingestion of table olive samples.

## MATERIALS AND METHODS

### Sample collection

A total of 26 table olive samples were collected randomly from 26 different districts (Bahce, Hasanbeyli, Duzici, Kanligecit, Dereli, Cumhuriyet Mahallesi, Dereobasi, Akyar, Toprakkale, Mustafabeyli, Yassica, Kadirli, Sumbas, Erzin, Dortyol, Hassa, Iskenderun, Belen, Kirikhan, Kumlu, Reyhanli, Hatay Merkez I and II, Samandag, Altinozu, and Yayladag) located in the provinces of Adana, Osmaniye, and Hatay, as shown in fig. 1. The provinces of Adana, Osmaniye and Hatay belong to the Mediterranean subregion [14]. The study area

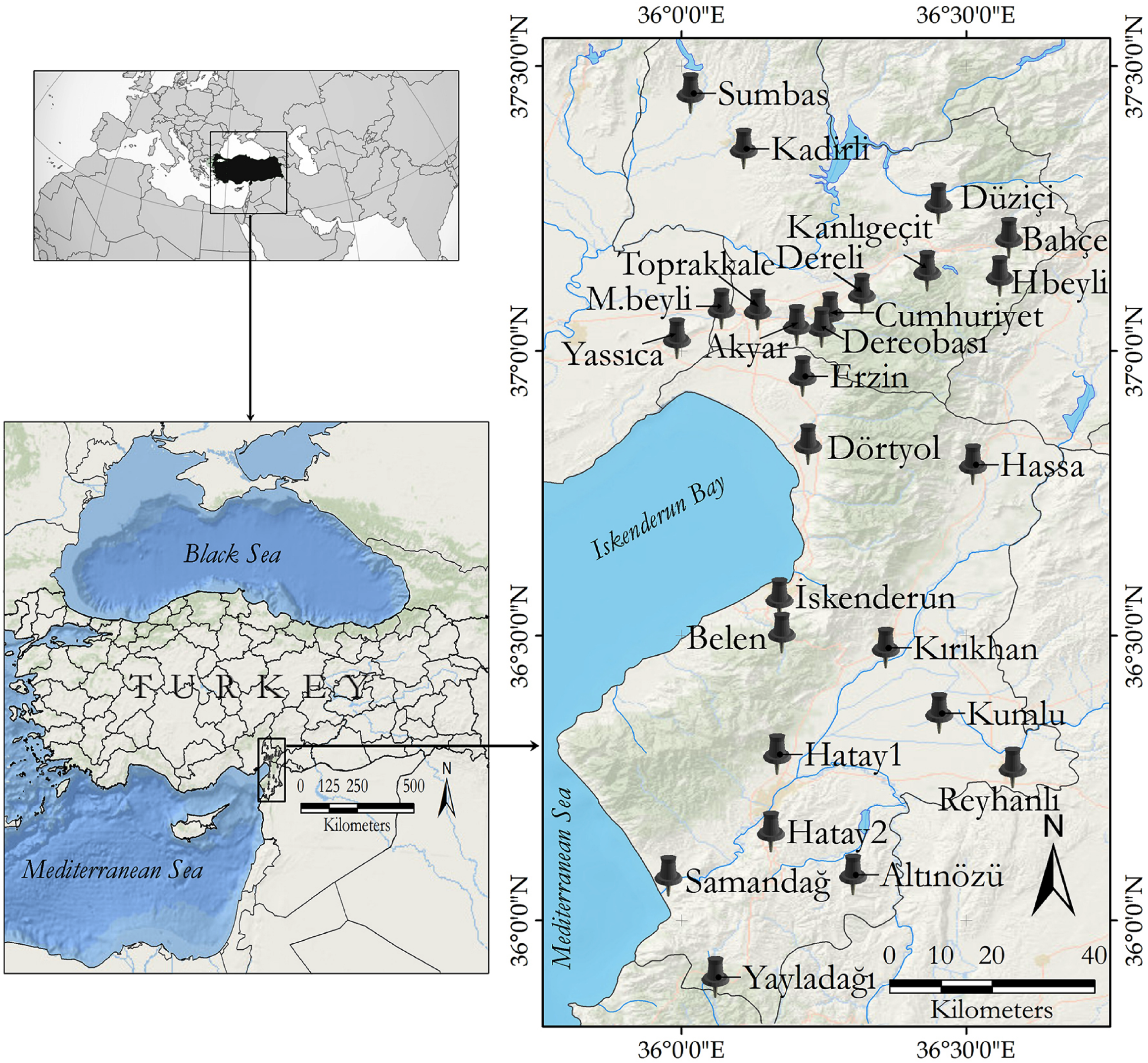


**Figure 1. Map of sample location**

has an original Mediterranean climate. The climate of the study area is very favorable for olive trees. Common soil types in the study area are as follows: brown calcarousless soils, brown forest soils, terrarosa soils, reddish-brown Mediterranean soils, colluvial soils, and mixed land types [15].

## Sample preparation for radionuclide analysis

The olive samples were dusted and the edible parts were separated from the kernels. Then, 5 kg of the edible parts of each sample was dried by heating at 110 °C for about three days before grinding. The separated 2 kg of the olive kernels were ground by grinding and pulverized. The homogenized edible parts and kernel samples were separately placed in Marinelli beakers, weighed and hermetically sealed. Before starting the gamma spectrometric measurements, the sealed samples were stored for two months to reach radioactive equilibrium of the $^{226}$Ra, $^{232}$Th, and their decay products.

## Sample preparation for heavy metal analysis

The samples were prepared for heavy metal analysis according to method EPA 3052 using a closed microwave digestion instrument (CEM MARS 5) as follows: firstly, a 0.5 g sample was placed in a 100 ml polypropylene/TFM vessel [16]. The sample was digested using the closed microwave digestion instrument by adding 9 mL of concentrated nitric acid ($HNO_3$), 4 mL of concentrated hydrofluoric acid (HF), 2 mL of concentrated hydrochloric acid (HCl), and 1 mL of concentrated hydrogen peroxide (1200 watts, 20 min ramp access, 0.300 PSI, 10 minutes at 200 °C). The sample was then removed from the digestion instrument and cooled, and the boric acid procedure was applied by replacing it in the digestion instrument to retain chloride ions from the HF (1200 watts, 15 min ramp access, 0.300 PSI, 5 minutes at 210 °C). Double-distilled water was added to the sample extracted from the digestion instrument after it was filtered through a Whatman-542 filter paper. The sample was then ready for inductively coupled plasma optical emission spectrometer (ICP-OES) analysis. Before starting the analysis, the ICP-OES spectrometer was calibrated by preparing three different standard solutions (PerkinElmer Pure, Quality Control Standard 21).

## Radionuclide analysis

Radionuclide analyses were performed using a gamma ray spectrometer with a high-resolution coaxial p-type horizontal HPGe detector (Canberra GX3018) in the laboratory of the Cekmece Nuclear Research and Training Center. The resolution of the detector is 1.8 keV for the $^{60}$Co gamma ray energy line at 1332.5 keV, and it has a relative efficiency of 30 %. The detector was shielded to minimize natural background radiation from the environment. The certificated standard calibration source of a 1 L Marinelli beaker, which contains multiple nuclides distributed in 1.0 gcm$^{-3}$ epoxy (Eckert & Ziegler Isotope Products), was used for absolute efficiency calibration of the system in the energy range from 122 keV to 1836 keV [17]. The counting time for each table olive sample was adjusted to obtain a gamma ray spectrum with good statistics. The activity concentration of $^{226}$Ra was measured using the 351.9 keV gamma ray line from $^{214}$Pb and the 609.3 keV gamma ray line from $^{214}$Bi. The activity concentration of $^{232}$Th was measured using the 911.2 keV gamma ray line from $^{228}$Ac and the 583.2 keV gamma ray line from $^{208}$Tl. The activity concentrations of $^{40}$K and $^{137}$Cs were measured directly from their own photopeaks at 1460.8 keV and 661.8 keV, respectively [17].

The minimum detectable activity (MDA, in confidence level 95 %) of the gamma ray spectrometric system was calculated as [18, 19]

$$MDA\,[\mathrm{Bqkg}^{-1}] = \frac{2.75 + 4.66\,\delta_B}{\varepsilon P t M} \tag{1}$$

where $B$ is the standard deviation of the background in the region of interest, $\varepsilon$ – the absolute efficiency of the detector, $P$ – the absolute emission probability of the gamma decay, $t$ [s] – the measurement time, and $M$ [kg] – the mass of the sample. The detection limits for $^{226}$Ra, $^{232}$Th, $^{40}$K, and $^{137}$Cs in the table olive samples were 1.3, 1.4, 8.6, and 1.5 Bqkg$^{-1}$, respectively.

The uncertainty of the activity concentration, $A$, is calculated by the following formula [20]

$$\left(\frac{\Delta A}{A}\right)^2 = \left(\frac{\Delta CR}{CR}\right)^2 + \left(\frac{\Delta P}{P}\right)^2 + \left(\frac{\Delta \varepsilon}{\varepsilon}\right)^2 + \left(\frac{\Delta M}{M}\right)^2 \tag{2}$$

where $A$ is the activity concentration of the radionuclide, $\Delta CR$ – the count rate uncertainty, $\Delta P$ – the emission probability uncertainty found in the nuclear data tables, $\Delta\varepsilon$ – the efficiency uncertainty and $\Delta M$ – the weighing uncertainty.

## Heavy metal analysis

Analyses of heavy metals in the table olive samples were carried out using the ICP-OES in the laboratory of the Cekmece Nuclear Research and Training Center. The spectrometer is the ideal solution for research and quality assurance laboratories that have a wide variety of samples and a lower frequency of analysis. The CCD array detector provides flexibility and speed. It has exceptional reliability with a solid-state

RF generator. A dual-view optical system ensures the widest working range and excellent detection limits. Auto-integration by element dramatically improves the sample throughput. Dynamic wavelength stabilization eliminates peak profiling and searching, ensuring exceptional long-term stability. It has enhanced sample throughput and performance with simultaneous background correction [21].

### Estimation of the annual effective radiation dose

Internal exposure occurs by inhalation of contaminated air, or ingestion of contaminated water and food. Estimating the effective dose in foodstuffs is useful for assessing the health risks associated with intake of radionuclides into the body, which are proportional to the total dose delivered by the radionuclides. The effective dose rate (*AED* in μSv per year) due to ingestion of a radionuclide with table olive samples is calculated using the following expression [22]

$$AED \quad Cr \quad A_i DCF_i \tag{3}$$

where $C$ is the average annual consumption of table olives (4 kg), $r$ – the average ratio of the dry to the fresh mass of table olive samples (0.2 kg dw per kg fw); $A_i$ – the activity concentration of radionuclide i in the samples, and $DCF_i$ – the dose conversion factor for radionuclide $i$. The values of this conversion factor for adults are: 0.28, 0.23, 0.0062, and 0.013 $\mu SvBq^{-1}$ for $^{226}Ra$, $^{232}Th$, $^{40}K$, and $^{137}Cs$, respectively [22].

### Estimation of the daily intake of heavy metals

The daily intake of heavy metals (*DIM*) was estimated using the following [23]

$$DIM \quad \frac{C_{\mathrm{metal}}\, r\ DIF}{M} \tag{4}$$

where $C_{\mathrm{metal}}$ – the concentration of heavy metals in the table olive samples, $r$ – the average ratio of the dry to the fresh mass of table olive samples, $DIF$ – the daily average consumption of table olives (11 $gd^{-1}$), and $M$ is the average adult weight (70 kg).

## RESULTS AND DISCUSSION

### Radionuclide content

The activity concentrations of $^{226}Ra$, $^{232}Th$, $^{40}K$, and $^{137}Cs$ measured in the edible parts and kernels of the table olive samples are presented in tabs. 1 and 2, respectively. As can be seen from tabs. 1 and 2 the average activity of $^{226}Ra$ measured in the edible parts is twice that of the average activity in the kernels, while the average activity of $^{232}Th$, $^{40}K$, and $^{137}Cs$ measured in the edible parts is 1.5 times higher than the average activity in the kernels.

The radioisotope $^{226}Ra$, which is produced by phosphate, mining and coal combustion industries, is important from the viewpoints of health physics and environmental protection because it may enter the food chain by dissolving in ground water and passing through plant roots. It is easily incorporated into mammalian bones due to its chemical and biological behavior, which is similar to that of other alkaline earth metals such as Ca, Sr, and Ba [24]. The activity concentration of $^{226}Ra$ in the edible parts varied from 7.6  0.4 to 87.8  3.2 $Bqkg^{-1}$ with an average of 37.9  4.1 $Bqkg^{-1}$. The highest activity of $^{226}Ra$ was measured in a table olive sample from Hatay (Samandag), while the lowest activity was measured in a sample from Osmaniye (Sumbas).

Deposition of large quantities of $^{232}Th$ in lung, liver and skeletal tissues affects the health of humans by weakening the immune system and inducing various types of diseases [25]. The activity concentration of $^{232}Th$ in the edible parts varied from 2.7  0.5 to 12.0  0.5 $Bqkg^{-1}$ with an average of 7.1  0.5 $Bqkg^{-1}$. The highest activity of $^{232}Th$ was measured in a table olive sample from Hatay (Yayladag), while the lowest activity was measured in a sample from Osmaniye (Dereobasi).

The radioisotope $^{40}K$, which occurs in plants as soluble inorganic salts, is the most important from the viewpoint of health physics because it is one of the most important nutrients and an essential element in life processes [26]. The activity concentration of $^{40}K$ in the edible parts varied from 158.2  11.1 to 488.3  34.1 $Bqkg^{-1}$ with an average of 274.6  14.7 $Bqkg^{-1}$. The highest activity of $^{40}K$ was measured in a table olive sample from Hatay (Erzin), while the lowest activity was measured in a sample from Osmaniye (Dereobasi). The activity concentrations of $^{40}K$ measured in the table olive samples are higher than those obtainedbyBallesteros*et al*. [27] (50.0-379.6 $Bqkg^{-1}$).

The radioisotope $^{137}Cs$ occurs mostly as a result of fallout after nuclear accidents such as Chernobyl and Fukushima or from atmospheric nuclear weapons tests. It is absorbed, distributed and excreted in the same manner as stable cesium ($^{133}Cs$). It is strongly adsorbed by soils. The activity concentration of $^{137}Cs$ in the edible parts varied from 2.0  0.1 to 12.6  0.4 $Bqkg^{-1}$ with an average of 7.2  0.7 $Bqkg^{-1}$. The highest activity of $^{137}Cs$ was measured in a table olive sample from Osmaniye (Dereli), while the lowest activity was measured in a sample from Osmaniye (Dereobasi). The average activity of $^{137}Cs$ was significantly lower than the permitted value of 1000 $Bqkg^{-1}$ [28].

### Heavy metal content

The concentrations of heavy metals found in the edible parts and kernels of the table olive samples are presented in tab. 3. As can be seen from tab. 3 the aver-

**Table 1. Radionuclide concentration in the edible part of the table olive samples**

| Sample location | Activity concentration [$Bqkg^{-1}$] | | | |
|---|---|---|---|---|
| | $^{226}Ra$ | $^{232}Th$ | $^{40}K$ | $^{137}Cs$ |
| **Osmaniye province** | | | | |
| Bahce | 42.7 1.3 | 6.4 0.4 | 243.1 17.0 | 7.6 0.2 |
| Hasanbeyli | 32.7 1.4 | 10.0 0.5 | 338.2 23.7 | 11.9 0.4 |
| Duzici | 48.0 1.9 | 6.6 0.4 | 250.4 17.2 | 8.0 0.3 |
| Kanligecit | 43.2 1.7 | 8.7 0.4 | 304.5 21.4 | 10.2 0.2 |
| Dereli | 43.6 1.6 | 10.4 0.5 | 363.6 25.4 | 12.6 0.4 |
| Cumhuriyet mahallesi | 48.0 2.0 | 7.2 0.6 | 262.1 18.3 | 5.2 0.4 |
| Dereobasi | 12.2 0.4 | 2.7 0.5 | 158.2 11.1 | 2.0 0.1 |
| Akyar | 48.0 2.1 | 10.0 0.6 | 339.4 23.6 | 12.3 0.6 |
| Toprakkale | 64.0 2.3 | 7.2 0.6 | 269.5 17.7 | 8.3 0.4 |
| Kadirli | 16.3 0.7 | 9.4 0.6 | 319.7 22.4 | 10.8 0.4 |
| Sumbas | 7.6 0.4 | 3.8 0.4 | 199.9 13.8 | 4.3 0.3 |
| **Adana province** | | | | |
| Mustafabeyli (Adana) | 43.9 1.8 | 9.1 0.6 | 314.10 22.1 | 10.7 0.5 |
| Yassica (Adana) | 11.7 0.5 | 6.5 0.4 | 243.6 13.9 | 4.7 0.2 |
| **Hatay province** | | | | |
| Erzin | 44.5 1.5 | 4.4 0.4 | 488.2 34.1 | 3.7 0.4 |
| Dortyol | 51.0 1.6 | 3.2 0.3 | 169.5 11.8 | 2.4 0.5 |
| Hassa | 8.5 0.4 | 4.2 0.5 | 223.4 15.6 | 3.2 0.4 |
| Iskenderun | 38.0 1.1 | 6.5 0.5 | 236.3 16.5 | 4.8 0.5 |
| Belen | 71.9 3.1 | 9.8 0.6 | 335.1 23.5 | 11.7 0.6 |
| Kirikhan | 18.7 0.9 | 3.4 0.3 | 179.6 12.5 | 2.6 0.5 |
| Kumlu | 14.4 0.7 | 8.6 0.4 | 319.7 15.4 | 9.6 0.3 |
| Reyhanli | 34.2 1.1 | 4.1 0.5 | 216.9 15.7 | 3.1 0.2 |
| Merkez I | 49.9 1.9 | 10.9 0.8 | 375.1 26.5 | 12.5 0.8 |
| Merkez II | 9.4 0.4 | 4.8 0.4 | 224.2 15.4 | 3.7 0.4 |
| Samandag | 87.8 3.2 | 8.0 0.5 | 309.5 21.8 | 5.6 0.3 |
| Altinozu | 36.5 1.4 | 5.9 0.3 | 228.6 16.1 | 6.8 0.4 |
| Yayladagi | 58.6 1.8 | 12.0 0.5 | 226.7 15.8 | 9.1 0.5 |
| Average | 37.9 | 7.1 | 274.6 | 7.2 |
| Standard deviation | 20.9 | 2.7 | 74.8 | 3.6 |
| Min | 7.6 | 2.7 | 158.2 | 2.0 |
| Max | 87.8 | 12.0 | 488.3 | 12.6 |

age concentrations of Cr, Ni, Cu, Zn, and Co measured in the edible parts are higher than those in the kernels, while the average concentrations of Mn, Fe, Sr, and Pb in the edible parts are lower than those in the kernels. In the edible parts, the amount decreased with the order of Fe, Zn, Cu, Mn, Ni, Pb, Sr, Cr, and Co, respectively.

Fe accumulates in the liver and plays an essential role in living organisms such as in the formation of hemoglobin and transferrin, and in metabolic processes [3]. The concentration of Fe found in the edible parts of the table olive samples varied from 138.80 4.00 to 194.40 0.80 $\mu gg^{-1}$ with an average of 166.60 4.08 $\mu gg^{-1}$. Fe was found to have the highest concentration among the other elements in the table olive samples. Several studies related to the concentration of Fe in Turkish olive samples were performed using various analytical techniques. The results obtained in the study are higher than those obtained by Sahan *et al.* [7] (6.11-48.58 $\mu gg^{-1}$), Nergiz *et al.* [9] (9.71-82.5 $\mu gg^{-1}$) and Tuna [11] (14.51-64.82 $\mu gg^{-1}$).

Zn is one of the major essential elements required by the human system and has several functions in the human body, such as wound healing, blood clotting, proper thyroid function, maintenance of good vision, taste acuity, protein synthesis, DNA synthesis, RNA transcription, cell division and cell activation [3]. The concentration of Zn found in the edible parts of the table olive samples varied from 12.82 0.02 to 15.86 0.26 $\mu gg^{-1}$ with an average of 14.34 0.26 $\mu gg^{-1}$. Zn concentrations analyzed in the table olive samples are higher than those obtained by Sahan *et al.* [7] (4.25-13.33 $\mu gg^{-1}$), Nergiz *et al.* [9] (0.77-1.98 $\mu gg^{-1}$) and Tuna [11] (2.36-7.66 $\mu gg^{-1}$).

Cu is found in the environment and its biological functions include cell metabolism, normal iron metabolism, red blood cell synthesis, connective tissue metabolism and bone development [3]. The concentration of Cu found in the edible parts of the table olive samples varied

**Table 2. Radionuclide concentration in the kernel of the table olive samples**

| Sample location | Activity concentration [Bqkg$^{-1}$] | | | |
|---|---|---|---|---|
| | $^{226}$Ra | $^{232}$Th | $^{40}$K | $^{137}$Cs |
| **Osmaniye province** | | | | |
| Bahce | 9.9 0.4 | 5.5 0.4 | 204.2 7.2 | 6.3 0.4 |
| Hasanbeyli | 35.6 1.4 | 5.2 0.3 | 196.3 6.4 | 3.9 0.5 |
| Duzici | 6.5 0.4 | 3.2 0.4 | 147.4 6.1 | 2.4 0.5 |
| Kanligecit | 4.3 0.5 | 2.1 0.5 | 127.2 5.3 | 1.6 0.5 |
| Dereli | 29.7 1.2 | 3.3 0.5 | 151.4 5.6 | 1.9 0.4 |
| Cumhuriyet mahallesi | 9.4 0.4 | 5.3 0.4 | 194.7 7.4 | 6.0 0.4 |
| Dereobasi | 31.5 1.1 | 5.2 0.4 | 195.4 6.9 | 6.1 0.3 |
| Akyar | 39.3 0.9 | 5.2 0.4 | 196.2 6.8 | 6.1 0.3 |
| Toprakkale | 28.2 0.7 | 5.4 0.4 | 201.5 7.9 | 6.2 0.4 |
| Kadirli | 27.1 0.6 | 7.2 0.5 | 252.5 8.7 | 8.6 0.6 |
| Sumbas | 5.9 0.5 | 2.2 0.5 | 132.1 5.0 | 1.7 0.4 |
| **Adana province** | | | | |
| Mustafabeyli (Adana) | 7.5 0.4 | 5.3 0.4 | 196.6 6.8 | 6.0 0.3 |
| Yassica (Adana) | 7.6 0.4 | 4.0 0.5 | 170.3 6.2 | 4.8 0.4 |
| **Hatay province** | | | | |
| Erzin | 8.7 0.4 | 2.4 0.5 | 129.4 4.7 | 1.8 0.4 |
| Dortyol | 13.7 0.6 | 5.3 0.4 | 200.2 7.2 | 6.1 0.5 |
| Hassa | 11.1 0.4 | 2.4 0.5 | 135.1 4.4 | 2.8 0.4 |
| Iskenderun | 5.7 0.5 | 2.6 0.5 | 137.4 4.2 | 1.9 0.4 |
| Belen | 40.8 1.5 | 5.5 0.5 | 210.2 7.3 | 6.3 0.4 |
| Kirikhan | 28.3 0.9 | 7.5 0.4 | 265.2 9.0 | 8.7 0.5 |
| Kumlu | 19.4 0.7 | 5.3 0.4 | 200.9 8.4 | 6.1 0.5 |
| Reyhanli | 8.6 0.4 | 3.2 0.5 | 150.4 6.4 | 2.5 0.6 |
| Merkez I | 30.5 1.4 | 5.1 0.5 | 195.6 7.3 | 5.0 0.6 |
| Merkez II | 26.0 0.7 | 5.1 0.5 | 193.7 7.1 | 5.9 0.4 |
| Samandag | 9.2 0.4 | 5.3 0.4 | 199.8 8.1 | 6.0 0.3 |
| Altinozu | 9.1 0.5 | 5.0 0.4 | 190.4 7.8 | 5.7 0.3 |
| Yayladagi | 28.4 0.8 | 5.2 0.4 | 200.2 8.6 | 6.2 0.4 |
| Average | 18.5 | 4.6 | 183.2 | 4.9 |
| Standard deviation | 12.2 | 5.1 | 35.7 | 5.1 |
| Min | 4.3 | 2.1 | 127.0 | 1.6 |
| Max | 40.8 | 7.5 | 265.0 | 8.7 |

**Table 3. Heavy metal concentration in the kernel and edible part of the table olive dw samples**

| Metal | Concentration [μgg$^{-1}$] | | | |
|---|---|---|---|---|
| | Edible part | | Kernel | |
| | Range (min-max) | Average | Range (min-max) | Average |
| Cr | 1.64 0.01-2.43 0.05 | 2.04 0.05 | 1.13 0.03-2.68 0.05 | 1.91 0.06 |
| Mn | 9.97 0.20-12.19 0.30 | 11.08 0.36 | 12.05 0.27-15.22 0.18 | 13.64 0.32 |
| Fe | 138.80 4.00-194.40 0.80 | 166.60 4.08 | 210.90 4.30-215.70 7.70 | 213.30 6.37 |
| Co | 0.13 0.01-0.26 0.01 | 0.20 0.01 | < DL-0.22 0.01 | 0.17 0.01 |
| Ni | 2.92 0.01-17.67 0.26 | 10.29 0.26 | 2.13 0.04-2.35 0.01 | 2.24 0.04 |
| Cu | 9.84 0.22-17.78 0.67 | 13.81 0.71 | 4.36 0.26-4.80 0.20 | 4.58 0.33 |
| Zn | 12.82 0.02-15.86 0.26 | 14.34 0.26 | 9.02 0.14-9.15 0.31 | 9.09 0.34 |
| Sr | 3.14 0.28-5.86 0.11 | 4.50 0.30 | 7.28 0.23-13.75 0.38 | 10.52 0.44 |
| Pb | 3.88 0.04-5.22 0.01 | 4.55 0.04 | 3.93 0.08-5.87 0.03 | 4.90 0.09 |

from 9.84 0.22 to 17.78 0.67 μgg$^{-1}$ with an average of 13.81 0.71 μgg$^{-1}$. Cu concentrations analyzed in the table olive samples are higher than those obtained by Sahan *et al*. [7] (0.73-2.55 μgg$^{-1}$), Nergiz *et al.* [9] (1.61-4.51 μgg$^{-1}$) and Tuna [11] (0.60-3.85 μgg$^{-1}$).

Mn is needed by biological systems and plays an essential role in living things including humans [3]. The concentration of Mn found in the edible parts of the table olive samples varied from 9.97 0.20 to 12.19 0.30 μgg$^{-1}$ with an average of 11.08 0.36 μgg$^{-1}$. Mn concentrations analyzed in the table olive samples are higher than those obtained by Tuna [11] (3.20-8.29 μgg$^{-1}$).

Ni is one of the trace heavy metals and plays a role in physiological processes as a cofactor in the absorption of iron from the intestine [29]. The concentration of Ni found in the edible parts of the table olive samples varied from 2.92 0.01 to 17.67 0.26 μg g$^{-1}$ with an average of 10.29 0.26 μgg$^{-1}$. Ni concentrations analyzed in the table olive samples are higher than those obtained by Sahan *et al*. [7] (0.18-0.53 μgg$^{-1}$), and Tuna [11] (0.10-0.42 μgg$^{-1}$).

Pb induces reduced cognitive development and intellectual performance in children and increased blood pressure and cardiovascular diseases in adults [30]. The concentrations of Pb found in the edible parts of the table olive samples varied from 3.88 0.04 to 5.22 0.01 μgg$^{-1}$ with an average of 4.55 0.04 μgg$^{-1}$. Pb concentrations analyzed in the table olive samples are higher than those obtained by Sahan *et al*. [7] (0.57-0.91 μgg$^{-1}$), Nergiz *et al*. [9] (0.09-0.278 μgg$^{-1}$), and Tuna [11] (0.25-0.88 μgg$^{-1}$).

Sr is a mineral found in seawater and soil and is similar to Ca. It appears to play a role in bones. The concentrations of Sr found in the edible parts of the table olive samples varied from 3.14 0.28 to 5.86 0.11 μgg$^{-1}$ with an average of 4.50 0.30 μgg$^{-1}$.

Cr is toxic and highly detrimental to humans when its concentrations exceeds tolerable limits [3]. It aids the biosynthesis of the glucose tolerance factor, utilization of sugar protein and fats, and the maintenance of blood glucose [3]. The concentration of Cr found in the edible parts of the table olive samples varied from 1.64 0.01 to 2.43 0.05 μgg$^{-1}$ with an average of 2.04 0.05 μgg$^{-1}$. Cr concentrations analyzed in the table olive samples (0.35-0.88 μgg$^{-1}$) are higher than those obtained by Sahan *et al*. [7].

Co is an essential (mineral) micronutrient for humans. The primary function of cobalt in humans is based on its role in cobalamin (vitamin B12), which acts as the cofactor for two enzymes present in humans [31]. The concentration of Co found in the edible parts of the table olive samples varied from 0.13 0.01 to 0.26 0.01μgg$^{-1}$ with an average of 0.20 0.01 μgg$^{-1}$. Co concentrations analyzed in the table olive samples are higher than those obtained by Sahan *et al*. [7] (0.05-0.08 μgg$^{-1}$).

## Annual effective radiation dose

Table 4 gives the *AED* estimated for the edible parts and kernels of the table olive samples. The *AED* for the edible parts and kernels of the samples varied from 3.4 to 22.7 μSv per year with an average of 11.2 μSv per year and 2.0 to 11.3 μSv per year with an average of 5.9 μSv per year, respectively. The average *AED* from $^{226}$Ra, $^{232}$Th, $^{40}$K, and $^{137}$Cs in the edible parts of the samples were estimated as 8.5, 1.3, 1.4, and 0.1 μSv per year, respectively. The results show that the annual effective dose due to eating table olive samples comes mainly from the naturally occurring $^{226}$Ra radionuclide. The average *AED* was significantly lower than the global average annual radiation dose of 2 400 μSv per year resulting from ingestion [1].

**Table 4. Annual effective radiation dose estimated for the samples**

| Sample location | Annual effective dose [μSv] | |
|---|---|---|
| | Edible | Kernel |
| **Osmaniye province** | | |
| Bahce | 12.0 | 4.3 |
| Hasanbeyli | 11.0 | 9.9 |
| Duzici | 13.3 | 2.8 |
| Kanligecit | 12.9 | 2.0 |
| Dereli | 13.6 | 8.0 |
| Cumhuriyet mahallesi | 13.4 | 4.1 |
| Dereobasi | 4.0 | 9.0 |
| Akyar | 14.4 | 10.8 |
| Toprakkale | 17.1 | 8.4 |
| Kadirli | 7.1 | 8.7 |
| Sumbas | 3.4 | 2.4 |
| **Adana province** | | |
| Mustafabeyli (Adana) | 13.2 | 3.7 |
| Yassica (Adana) | 5.1 | 3.3 |
| **Hatay province** | | |
| Erzin | 13.2 | 3.0 |
| Dortyol | 12.9 | 5.1 |
| Hassa | 3.8 | 3.6 |
| Iskenderun | 10.9 | 2.4 |
| Belen | 19.7 | 11.3 |
| Kirikhan | 5.7 | 9.1 |
| Kumlu | 6.5 | 6.4 |
| Reyhanli | 9.5 | 3.3 |
| Merkez I | 15.2 | 8.8 |
| Merkez II | 4.1 | 7.8 |
| Samandag | 22.7 | 4.1 |
| Altinozu | 10.5 | 3.9 |
| Yayladagi | 16.5 | 8.4 |
| Average | 11.2 | 5.9 |
| Standard deviation | 5.1 | 3.1 |
| Min | 3.4 | 2.0 |
| Max | 22.7 | 11.3 |

## Daily intake of heavy metals

Table 5 gives the average *DIM* estimated for the edible parts and kernels of the table olive samples. The average *DIM* for the edible parts were found to be 0.06, 0.35, 5.24, 0.01, 0.32, 0.43, 0.45, 0.14, and 0.14 μgkg$^{-1}$ for Cr, Mn, Fe, Co, Ni, Cu, Zn, Sr, and Pb, respectively. The results showed that the average *DIM* were below the maximum daily intakes recommended by the WHO [32].

## CONCLUSIONS

The radioactivity levels of $^{226}$Ra, $^{232}$Th, $^{40}$K, and $^{137}$Cs in each table olive sample investigated in the

**Table 5. Daily intake of heavy metals estimated for the samples**

| Metals | Daily intake of heavy metals [$\mu gkg^{-1}$] | |
|---|---|---|
| | Edible | Kernel |
| Cr | 0.06 | 0.06 |
| Mn | 0.35 | 0.43 |
| Fe | 5.24 | 6.70 |
| Co | 0.01 | 0.01 |
| Ni | 0.32 | 0.07 |
| Cu | 0.43 | 0.14 |
| Zn | 0.45 | 0.29 |
| Sr | 0.14 | 0.33 |
| Pb | 0.14 | 0.15 |

study were determined using gamma ray spectrometry, and the radiological hazards from these table olive samples were assessed. It was observed that the average annual effective radiation doses due to intake of these radionuclides through ingestion of the olive samples produced in the Mediterranean region (Osmaniye, Hatay, and Adana) of Turkey are far below the recommended level of 1 000 μSv. The concentrations of heavy metals (Cr, Mn, Fe, Co, Ni, Cu, Zn, Sr, and Pb) were determined using ICP-OES spectrometry and the daily intake of heavy metals was estimated.

The results reveal that consumption of the table olives examined in this study does not pose any health hazards from a radiological and heavy metal toxicity point of view.

## ACKNOWLEDGEMENTS

The author wants to thank the Turkish Atomic Energy Authority (TAEA).

## REFERENCES

[1] ***, United Nations Scientific Committee on the Effects of Atomic Radiations (UNSCEAR, 2008), Sources and Effects of Ionising Radiation. Volume I: Sources, Report to the General Assembly Scientific Annexes A and B. United Nations Publication, New York, USA, 2010

[2] ***, United Nations Scientific Committee on the Effects of Atomic Radiations (UNSCEAR, 2000), Sources and effects of ionising radiation. United Nations Publication, New York, USA, 2000

[3] Izah, S.C., *et al*., A Review of Heavy Metal Concentration and Potential Health Implications of Beverages Consumed in Nigeria, *Toxics 5* (2017), 1, pp. 1-15

[4] de Castro, L. P., *et al*., Artificial and Natural Radioactivity in Edible Mushrooms from Sao Paulo, Brazil, *J. Environ. Radioact., 113* (2012), 11, pp. 150-154

[5] Unal, K., *et al*., The Effect of Table Olive Preparing Methods and Storage on the Composition and Nutritive Value of Olives, *Grasas y Aceites, 54* (2003), 1, pp. 71-76

[6] Madejan, P., *et al*., Biomonitoring of Trace Elements in the Leaves and Fruits of wild Olive and Holm Oak Trees, *Sci Total Environ., 355* (2006), 1-3, pp. 187-203

[7] Sahan, Y., *et al*., ICP-MS Analysis of a Series of Metals (Namely: Mg, Cr, Co, Ni, Fe, Cu, Zn, Sn, Cd and Pb) in Black and Green Olive Samples from Bursa, Turkey, *Food Chem., 105* (2007), 1, pp. 395-399

[8] Lopez, A. L., *et al*., Heavy Metals and Mineral Elements Not Included on the Nutritional Labels in Table Olives, *J. Agric. Food Chem., 56* (2008), 20, pp. 9475-9483

[9] Nergiz, C., *et al*., Research on the Amount of Trace Elements in Table Olives Commonly Produced in Turkey, *Riv. Ital. Sostanze Gr., 85* (2008), 1, pp. 39-44

[10] Hernandez, A. F., *et al*., Determination of Mineral Elements in Fresh Olive Fruits by Flame Atomic Spectrometry, *Span. J. Agric. Res., 8* (2010), 4, pp. 1183-1190

[11] Tuna, B., *et al*., Determination of Heavy Metals and Micronutrients in Olives Grown under Different Conditions, *Fresen. Environ. Bull., 20* (2011), 11, pp. 2883-2889

[12] Vossen, P., Olive Oil: History, Production, and Characteristics of the World's Classic Oils, *Hortscience, 42* (2007), 5, pp. 1093-1100

[13] ***, TUIK (Turkish Statistical Institute) Web page: http://www.turkstat.gov.tr/, 2017

[14] Bozdogan, H., Ecological Distribution and Seasonality of Chrysopids (Neuroptera: Chrysopidae) in the East Mediterranean Region of Turkey, *ACU J. For. Fac., 18* (2017), 2, pp. 130-136

[15] Turkmen, N., *et al*., The Flora of Dortyol and Erzin Districts of Hatay Province in Turkey, *Tr. J. Botany, 22* (1998), 2, pp. 121-141

[16] ***, USEPA 1995, EPA Method 3052: Microwave Assisted Acid Digestion of Siliceous and Organically Based Matrices. Test Methods for Evaluating Solid Waste (3rd)

[17] Turhan, S., *et al*., Radiometric Analysis of Volcanic Tuff Stones Used as Ornamental and Structural Building Materials in Turkey and Evaluation of Radiological Risk, *Radioprotection, 50* (2015), 4, pp. 273-280

[18] Currie, L. A., Limits for Qualitative Detection and Quantitative Determination, *Anal. Chem., 40* (1968), 3, pp. 586-93

[19] Turhan, S., *et al*., Radiometric Measurement of Lignite Coal and its By-Products and Assessment of the Usability of fly Ash as Raw Materials in Turkey, *Radiochimica Acta, 106* (2018), 7, pp. 611-621.

[20] Canbazoglu, C., *et al*., Analysis of Gamma Emitting Radionuclides (Terrestrial and Anthropogenic) in Soil Samples from Kilis Province in South Anatolia, Turkey, *Ann. Nucl. Energy, 62* (2013), 12, pp. 153-157

[21] ***, Perkinelmer 2017. Web page: http://www.perkinelmer.com.cn/Content/ relatedmaterials/ productnotes/prd_optima-7000dv-icp-oes.pdf

[22] ***, ICRP 1996, Age-Depended Doses to Members of the Public from Intake of Radionuclides, Part 5: Compilations of Ingestion and Inhalation Dose Coefficient, Vol. 72

[23] Khan, S., *et al*., Health Risks of Heavy Metals in Contaminated Soils and Food Crops Irrigated with Wastewater in Beijing, China, *Environ. Pollut., 152* (2008), 3, pp. 686-692

[24] Jia, G., *et al.*, Determination of Radium Isotopes in Environmental Samples by Gamma Spectrometry, Liquid Scintillation Counting and Alpha Spectrometry: a Review of Analytical Methodology, *J. Environ. Radioact., 106* (2012), 4, pp. 98-110

[25] Addo, M. A., *et al*., A Preliminary Study of Natural Radioactivity Ingestion from Cassava Grown and Consumed by Inhabitants around a Cement Production Facility in the Volta Region, Ghana, *Int. J. Environ. Sci., 3* (2013), 6, pp. 2312-2323

[26] Gautam, Y. P., *et al*., Evaluation of Internal Dose, Due to the Ingestion of Primordial Radionuclide $^{40}$K around Narora Site, India, *Ambit J. Res. Environ. Studies, 1* (2015), 1, pp. 1-12
[27] Ballesteros, L., *et al*., An Overview of Measurements of Radionuclides in Foods of the Comunidad Valenciana (Spain), *Radiat. Phys. Chem., 116* (2015), 11, pp. 111-115
[28] Gorur, F. K., *et al.*, Radionuclide and Heavy Metals Concentrations in Turkish Market Tea, *Food Control, 22* (2011), 12, pp. 2065-2070
[29] Das, K. K., *et al*., Nickel, Its Adverse Health Effects & Oxidative Stress, *Indian J. Med. Res., 128* (2008), 4, pp. 412-425
[30] Cevik, U., *et al*., Radioactivity and Heavy Metal Levels in Hazelnut Growing in the Eastern Black Sea Region of Turkey, *Food Chem. Toxicol., 47* (2009), 9, pp. 2351-2355
[31] Yamada, K., Cobalt: Its Role in Health and Disease. Interrelations between Essential Metal Ions and Human Diseases, Volume 13 of the Series Metal Ions in Life Sciences 2013, pp 295-320
[32] ***, WHO (World Health Organization), An Evaluation of Certain Food Additives and Contaminants, 41$^{st}$ Report of the Joint FAO/WHO Expert Committee on Food Additives, Switzerland, Geneva, 1989

Received on July 2, 2018
Accepted on October 2, 2018

---

**Мухамет КАРАТАШЛИ**

## САДРЖАЈ РАДИОНУКЛИДА И ТЕШКИХ МЕТАЛА У МАСЛИНАМА (OLEA EUROPAEA L.) ИЗ МЕДИТЕРАНСКЕ ОБЛАСТИ У ТУРСКОЈ

У овом раду приказане су концентрације радионуклида и тешких метала у двадесет шест узорака маслина (*Olea Europaea L.*) као и процена здравственог ризика услед њихове потрошње. Узорци су прикупљани из различитих градова Медитеранске области Турске, која је један од највећих произвођача маслина у свету. На основну гамаспектрометријских мерења просечне концетрације активности радинуклида $^{226}$Ra, $^{232}$Th, $^{40}$K и $^{137}$Cs у јестивим деловима маслине износиле су: 37.9 4.1, 7.1 0.5, 274.6 14.7, и 7.2 0.7 Bqkg$^{-1}$, респективно. Ефективна годишња доза услед уноса ових радионуклида ингестијом била је у опсегу од 3.4 μSv до 22.7 μSv са средњом вредношћу од 11 1 μSv. Применом оптичке емисионе спектрометрије индуктивно везаном плазом просечне концентрације Cr, Mn, Fe, Co, Ni, Cu, Zn, Sr и Pb у јестивим деловима маслина су износиле 2.04, 11.08, 166.60, 0.20, 10.29, 13.81, 14.34, 4.50, и 4.55 μgg$^{-1}$, респективно. На основу измереног садржаја радионуклида и тешких метала, може се закључити да су ове маслине безбедне за људску потрошњу.

*Кључне речи: маслина, радионуклид, тешки метал, ефективна доза, гама спектрометрија, оптичка емисиона спектрометрија индуктивно везаном плазом*