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Determination of radionuclides in samples of middle-aged and older human femurs

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ABSTRACT

The paper presents the studies of the presence of gamma isotopes and ^{90}Sr in 19 middle-to old-aged human femur samples. The samples were taken up during routine orthopedic operations in 2012. The aim of the paper was determination of some radionuclides in human bones and estimation of radiation dose created by ^{90}Sr and ^{90}Y (in bones). The ^{137}Cs, ^{40}K, ^{226}Ra, ^{228}Th, ^{234}Th and ^{210}Pb isotopes were determined by gamma spectrometry. The above mentioned radionuclide contents were in the ranges: ^{137}Cs (0.04–1.45); ^{40}K (13–86); ^{226}Ra (1–21.5); ^{228}Th (1.4–40.2); ^{234}Th (0.4–5.7); ^{210}Pb (0.7–8.4) Bq/kg d.w. ^{90}Sr was assayed based on radiometric measurement of ingrown ^{90}Y. The ^{90}Sr content was in the range 0.27–1.85 Bq/kg d.w. Measurements of concentration of ^{90}Sr and ^{90}Y in bones were used to estimation of health risk by calculation of radiation dose. Adsorbed doses ranged from $2.7 \cdot 10^{-7}$ to $1.9 \cdot 10^{-6}$ Gy/y for ^{90}Sr and from $1.2 \cdot 10^{-6}$ to $8.3 \cdot 10^{-7}$ Gy/y for ^{90}Y.

1. Introduction

The use of a nuclear bomb in 1945 (Hiroshima, Nagasaki) and then intensification of nuclear weapon tests (there were registered 50 nuclear explosions from 10.07.1945 to 31.12.1953) made the public aware of the danger resulting from uncontrolled radioisotope releases. Another sources are from deficiencies in structure and functioning of some reactors and the inconsiderate behavior of their users. These sources resulted in the appearance in the natural environment of, among others, long lived anthropogenic isotopes such as ^{137}Cs ^{90}Sr, ^{241}Am, ^{238}Pu, ^{239}Pu, ^{240}Pu and ^{241}Pu. Considering the half-life ($T_{1/2}$), it is assumed that the long-lived radionuclides ^{137}Cs, ^{90}Sr and Pu contribute to the natural environment contamination to the largest extent. Therefore these isotopes should be systematically analysed. Such activities are carried out by some state institutions which publish their results in the form of reports e.g (Grabowski et al., 1999; Kwapuliński, 1975; *Nadzór radiologiczny środowiska – PTJ, s. Ochrona przed promieniowaniem*, 1970; *Roczniki Statystyczne Ochrona Środowiska*, n.d.; *Skażenia promieniotwórcze środowiska i żywności w Polsce w 1999 roku*, 2000; PIOŚ CLOR, 1998; Żarnowiecki, 1988).

Based on the reports by Monetti (1996), and UKAEA (DATE NEEDED) the highest contamination with radiostrontium was found in 1958–1963 which is consistent with the literature data about the Polish region (Siemiński, 1994).

Moreover, as a result of Chernobyl Nuclear Power Station failure there appeared on the European territory the isotopes of the total activity 1.25 10^{19} Bq including 6.5 10^{18} Bq of noble gases, $8.14 \cdot 10^{15}$ Bq of ^{90}Sr and from $8.14 \cdot 10^{16}$ to $9.25 \cdot 10^{16}$ Bq of ^{89}Sr; from $1.85 \cdot 10^{16}$ to $4.44 \cdot 10^{16}$ Bq of ^{134}Cs and from $3.70 \cdot 10^{16}$ to $8.51 \cdot 10^{16}$ Bq of ^{137}Cs (IAEA, 2001). Such large amounts of radionuclides introduced into the natural environment require permanent monitoring. ^{90}Sr was recognized as the second after ^{14}C as dangerous from the dosimetric point of view (Lieser, 2008). Harmfulness of ^{90}Sr for living organisms is much higher than that of ^{137}Cs due to emission of two beta particles of total energy higher than gamma quantum, good availability especially in bones (^{90}Sr ≈ Ca replacement of calcium and also long time of incomplete removal – biological half-period).

There are a few reports about the presence of radionuclides in bones of animals, birds and people (Froidevaux et al., 2006, 2002; Komosa et al., 2009; Landstetter and Wallner, 2006; Mietelski et al., 2011, 2001; Stamoulis et al., 1999; Tandon et al., 1998;

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Table 1
Characteristics of studied femur samples.

No	Gender	Age (years)	Discase	Sample mass [g]	Sample mass after drying [g] d.w.	Ash mass after combustion [g]
5	F	56	os	43.0	39.4	18.2
1	F	62	os	36.5	34.1	16.1
9	M	68	os	39.8	36.5	18.8
2	F	69	fracture	17.7	16.7	4.9
16	M	71	os	45.9	43.1	20.8
4	F	77	os	33.7	31.3	14.1
8	F	77	os	45.2	41.1	19.1
11	F	77	fracture	23.7	21.5	9.2
15	F	79	fracture	25.6	24.2	8.8
12	M	80	fracture	38.2	35.4	15.3
19	M	82	os	50.8	18.2	7.2
10	F	82	fracture	19.3	47.5	22.3
14	F	83	os	31.1	29.0	13.2
3	F	84	fracture	19.2	17.4	6.7
6	F	88	fracture	19.3	17.8	6.4
18	F	88	fracture	21.5	20.4	7.3
13	F	90	fracture	18.3	16.5	5.4
17	F	95	fracture	23.0	21.7	8.1
7	F	97	fracture	19.8	18.6	7.1

F – female, M– men, os – osteoporosis and osteoarthrosis.

Table 2
Results of ^{90}Sr determination in the reference materials.

Name of sample	Reference activity, confidence range [Bq/kg]	Activity determined and calculated on the reference date [Bq/kg]	MDA value [Bq/kg]
IAEA–SOIL–6, average from 4 measurements	30.34 (24.20–31.67)	34.8 ± 4.3	0.02
IAEA–375, average from 3 measurements	108 (101–114)	104.2 ± 23.9	0.02
flour I (PAA)	0.15 ± 0.05	0.18 ± 0.03	0.01
flour II (PAA)	0.48 ± 0.01	0.47 ± 0.03	0.01
Word-wide open proficiency test IAEA – CO-2007-03	20.1 ± 2.1	20.89 ± 1.38	0.02
Spinach IAEA-30			

Wallova et al., 2012). Such research is particularly difficult because of necessity of obtaining samples, especially difficult for human bones, and the structure and composition of bone itself. One of the significant papers on bone analysis is the review by Tandon et al. (1998). It discussed the problems connected with the presence of some trace elements in bones and analytical difficulties caused by material specification, its complex character and variety as well as verification of results.

Taking into account the above quoted literature reports, the attempt was made to apply the information about uptake and preparation of samples as well as determination methods.

2. Experimental

Bone samples (femoral heads) were acquired during routine total hip arthroplasty. The project has been approved by Bioethical Council of Medical University of Lublin. Samples were taken from anonymous patients during surgical operations. After surgeries the bones were cleaned of any soft tissues, washed with saline and each frozen in a separate containers. Then all samples were collected, bones were defrosted and underwent physical examination (weight, volume etc). Each head was then divided into smaller pieces with a chisel and separately suspended the excessive amount of Benzinum Purum to flush the fat. Sample symbols and their characterization are shown in Table 1.

Then the samples were taken from Benzinum Purum, placed on a Perti pan and dried at 60 °C for 24 h. Next they were weighed, disintegrated using a hydraulic press, again put on the pans and dried to constant mass at 105 °C for 24 h. The dried bones were moved quantitatively into porcelain beakers and after covering them with quartz glasses placed in the high temperature oven with automatic temperature regulation. The combustion process proceeded as follows:

- after reaching the temperature 200 °C for 10 hours, the oven was heated for another 10 hours,
- the temperature was increased up to 400 °C for 3 hours, and heated for 6 hours,
- the temperature was increased to 600 °C for 3 hours and heated for 10 hours.

After cooling the ash was examined with respect to colour. In all cases it was gray powder which indicates proper mineralization without carbon formation. The samples were weighed to determine the ash mass (Table 1).

The whole amount of ash was moved quantitatively to flat polyethylene boxes of thin walls. An aliquot of 0.2 g was taken and after the addition of 7.8 g of a flux, it was melted in a platinum

Table 3
Radioactive concentration of determined gamma radionuclides in human femur.

No	Age (years)	^{137}Cs [Bq/kg d.w.]	^{40}K [Bq/kg d.w.]	^{226}Ra [Bq/kg d.w.]	^{228}Th [Bq/kg d.w.]	^{234}Th [Bq/kg d.w.]	^{210}Pb [Bq/kg d.w.]
5	56	0.58 ± 0.39	<MDA	2.5 ± 2.8	<MDA	3.9 ± 4.9	0.7 ± 4.4
1	62	0.14 ± 0.09	43 ± 2.9	3.9 ± 3.5	27.7 ± 7.1	4.9 ± 13.1	2.7 ± 5.3
9	68	0.60 ± 0.49	18 ± 5.0	<MDA	27.2 ± 5.5	5.4 ± 9.9	4.1 ± 4.7
2	69	<MDA	<MDA	1.0 ± 0.7	8.8 ± 42.6	2.6 ± 3.6	1.5 ± 1.7
16	71	0.04 ± 0.34	17 ± 3.5	<MDA	15.1 ± 4.4	<MDA	2.8 ± 3.4
4	77	0.30 ± 0.57	48 ± 3.4	5.4 ± 3.3	<MDA	<MDA	1.0 ± 6.3
8	77	1.37 ± 0.45	38 ± 4.8	5.7 ± 2.2	20.8 ± 5.8	5.6 ± 9.2	5.2 ± 4.6
11	77	<MDA	86 ± 5.0	14.9 ± 5.2	14.9 ± 12.3	1.4 ± 2.9	<MDA
15	79	<MDA	55 ± 4.0	21.5 ± 4.4	1.8 ± 3.1	3.9 ± 3.5	4.2 ± 8.7
12	80	0.80 ± 0.54	<MDA	<MDA	22.6 ± 6.9	<MDA	6.2 ± 6
19	82	<MDA	<MDA	<MDA	25.4 ± 25.2	<MDA	7.8 ± 11.7
10	82	0.68 ± 0.32	40 ± 2.4	4.5 ± 2.3	<MDA	<MDA	2.2 ± 3.6
14	83	<MDA	13 ± 4.9	4.6 ± 3.1	17.7 ± 10.6	2.6 ± 11.4	6.3 ± 4.9
3	84	<MDA	23 ± 10.1	11.5 ± 6.5	<MDA	0.4 ± 3.7	4.2 ± 12.3
6	88	0.16 ± 1.01	59 ± 5.1	11.2 ± 6.5	<MDA	3.6 ± 6.1	1.4 ± 13.7
18	88	1.15 ± 0.75	<MDA	16.4 ± 5.4	1.4 ± 23.4	1.6 ± 2.4	<MDA
13	90	1.45 ± 0.95	58 ± 5.4	4.6 ± 6.8	40.3 ± 3.3	<MDA	8.4 ± 15.1
17	95	<MDA	<MDA	9.1 ± 5.5	11.6 ± 18.9	7.1 ± 9.1	5.9 ± 10.7
7	97	0.09 ± 0.83	61 ± 5.1	11.7 ± 0.6	<MDA	<MDA	<MDA