DOSE ESTIMATIONS FOR INDIVIDUAL HUMAN ORGANS

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INTRODUCTION

Investigations carried out so far at the Wrocław Technical University were aimed at determining the pathways of radionuclides through particular environmental media, and providing a classification of radioactive substances with special emphasis placed on Sr-90 and Cs-137. The results obtained were presented at the Amsterdam Congress of IRPA. However, it has not been accurately explained to what extent man is exposed to radiation. There is still a doubt about the estimates of radiation impact on the exposed tissue, the dose distribution, the size of the exposed tissue, and the relationship between dose rate and dose efficiency.

EXPERIMENTAL AND RESULTS

The amounts of radionuclide intakes have been determined. These intakes result from the presence of radionuclides in the environment (whole-body dose), in the ambient air (lung doses from inhalation) and in the diets (doses due to ingestion). Radioisotopes deposited in the human organism also contribute to the total intake. To determine doses due to inhalation, measurements were made for air concentrations of Rn-222, Rn-220 and long-lived isotopes. The results are listed in Table 1. Doses introduced into the body through ingestion were estimated on the basis of radionuclide contents in the diets. The contamination of diets is in the most part due to doses from Sr-90 and Cs-137. Measurement results are shown in Table 2. To determine the whole-body dose, concentration data were established for standard man from bone, muscle and gonad sample testing. Total beta- and gamma-activities of the ash, as well as Ra-226, Cs-137, Po-210, Sr-90, Ca and K contents, were determined. Based on potassium concentration, the concentration of radioactive K-10 which forms 0.011.9% of the overall potassium, was estimated. Measurement results for gonads are listed in Tables 3 and 4 for man and woman, respectively.
The standard man is an individual characterized by a size of 1.70 m, a weight of 70 kg and a life-time of 70 years. The weight of the skeleton (excluding marrow), muscles, heart, testicles, and ovaries was 7 kg, 30 kg, 9.3 kg, 40 g and 8 g, respectively. After having burnt the soft tissues, 400 g of ash was obtained; burnt bone gave 1425 g of ash. Dose rates from the radionuclides tested to the critical tissues of standard man were calculated. Results are presented in Table 5. During our experiments emphasis was focused on the calculation of yearly radiation impact resulting from both man-made and natural radioisotopes (Table 6).
Gamma radioisotopes in samples were determined by using a gamma spectrometer. Beta radioisotopes were separated by radiochemical analyses and determined by a low-level anticoincidence beta counter, while alpha radioisotopes were measured by means of alpha scintillators.

CONCLUSIONS

1) The radioactivity of aerosols over the City of Wrocław results mainly from the presence of Rn-222 (93.3%). Radioactivity due to

Rn-220 equals some 6.6%. Lung doses from inhaled Rn-222 fall in the range of 630 mrad/yr.
2) Sr-90 and Cs-137 are introduced through ingestion. After having estimatd the radionuclide contents of diets, it was found that Sr-90 doses resulted from cereals (41.4%) and milk (41.4%) intakes, whereas doses from Cs-137 were in the most part (69.0%) due to the intakes of milk and milk products. Sr-90 is characterized by a long-term retention in bone. This is largely true for osteogenetic tissue, hematopoietic marrow, and periosteum. Bone doses from Sr-90 intakes are 6.68 mrad/yr, while whole-body doses due to ingestion of Sr-90 equal 0.70 mrad/yr. Cs-137 is being removed from the organism. To determine the exposure rate, a whole-body dose from Cs-137 equal to 0.038 mrad/yr was selected.
3) Po-210 and Ra-226 are deposited in bone, too, whereas the deposition of Po-210 was found to be four times that of Ra-226. Yearly bone dose from Po-210 falls in the range of 0.035 mrad. Bone dose due to Ra-226 equals 1.38 and 0.59 mrad for bone cells and Haversian canals, respectively.
4) The highest dose rate to soft tissue resulted from K-40. The estimated gonad dose was 20.34 mrad/yr.

TABLE 1. AVERAGE MONTHLY AIR CONCENTRATIONS (1974-1976)

MONTH	Average radioactivity (pCi/m^3)		
	^{222}Rn	^{220}Rn	Long-lived isotopes
January	236	18.2	absent
February	163	11.0	absent
March	254	20.7	0.3
April	108	9.2	0.6
May	93	6.3	0.1
June	106	13.5	absent
July	112	14.8	absent
August	63	8.4	absent
September	75	10.0	absent
October	419	31.8	0.9
November	456	32.3	0.6
Average	189	16.0	0.2

TABLE 2. ^{90}Sr AND ^{137}Cs CONTENTS IN DIETS

No.	Food	kg/year	^{90}Sr			^{137}Cs		
			pCi/kg	pCi/year	Total contamin. %	pCi/kg	pCi/year	Total contamin. %
1.	Milk and milk products	412.0	1.20	494.4	41.1	4.9	2018.6	69.0
2.	Meat	70.9	0.58	41.4	3.4	2.3	163.1	5.6
3.	Cereals	125.0	3.97	497.3	41.4	27.5	343.7	11.8
4.	Vegetables	276.0	0.52	143.5	11.9	0.97	267.7	9.2
5.	Drinking water	642.0	0.04	25.7	2.2	0.2	128.4	4.4
	Total			1202.3	100.0		2921.7	100.0

TABLE 3. TOTAL BETA- AND GAMMA-ACTIVITIES (INCLUDING ^{210}Po, ^{226}Ra, ^{90}Sr, ^{137}Cs, ^{40}K, Ca and K contents) IN STANDARD MAN

Age	Gross-β		Gross-γ		^{226}Rs		^{210}Po		^{137}Cs		^{90}Sr		^{40}K		$^{90}Sr/Ca$	$^{137}Cs/K$
	S	B	S	B	S	B	S	B	S	B	S	B	S	B		
	nCi/capita		nCi/capita		pCi/capita		pCi/capita		nCi/capita		nCi/capita		nCi/capita			
> 30	84.0	21.4	16.8	5.7	11.4	31.4	9.4	255.1	0.64	0.07	0.15	2.3	85.2	11.4	2.35	5.35
30-44	92.4	24.2	17.2	5.7	17.7	32.8	9.8	179.6	0.72	0.09	0.27	2.9	86.0	17.1	2.86	5.84
45-60	97.7	31.4	21.2	6.6	12.2	41.3	10.9	156.7	0.72	0.13	0.26	3.3	83.6	21.4	3.40	6.51
< 60	87.2	27.1	15.2	5.6	11.0	29./	10.4	183.8	0.60	0.07	0.17	2.4	76.8	14.3	2.52	4.97
Average	90.3	26.0	17.6	5.9	13.1	33.9	10.1	193.8	0.67	0.09	0.21	2.7	82.9	16.1	2.87	5.67

S = soft tissue, B = bone.

TABLE 4. TOTAL BETA- AND GAMMA-ACTIVITIES (INCLUDING ^{210}Po, ^{226}Ra, ^{90}Sr, ^{137}Cs, ^{40}K, Ca AND K CONTENTS) IN STANDARD WOMAN

Age	Gross-β		Gross-γ		^{226}Ra		^{210}Po		^{137}Cs		^{90}Sr		^{40}K		$^{90}Sr/Ca$	$^{137}Cs/K$
	S	B	S	B	S	B	S	B	S	B	S	B	S	B		
	nCi/capita		nCi/capita		pCi/capita		pCi/capita		nCi/capita		nCi/capita		nCi/capita			
>30	90.8	20.0	18.0	6.3	11.9	29.9	9.2	222.3	0.64	0.06	0.18	2.1	90.0	14.2	2.16	5.09
30–44	90.4	22.8	17.2	4.7	11.2	34.2	9.5	183.8	0.68	0.11	0.24	2.8	90.0	19.9	2.79	5.43
45–60	88.8	19.9	17.6	4.0	10.1	30.6	10.1	158.2	0.60	0.10	0.18	2.4	88.4	18.5	2.38	4.87
<60	82.0	12.8	16.4	2.6	11.9	32.8	9.4	200.9	0.44	0.10	0.17	2.3	81.6	12.8	2.18	3.78
Average	88.0	18.9	17.3	4.4	11.3	31.9	9.6	191.3	0.59	0.09	0.19	2.4	87.5	16.4	2.38	4.82

S = soft tissue, B = bone.

TABLE 5. DOSE RATES TO CRITICAL TISSUE (K) FROM ^{226}Ra, ^{210}Po, ^{40}K, ^{137}Cs, AND ^{90}Sr FOR STANDARD MAN

Tissue	^{137}Cs		^{90}Sr		^{40}K		^{226}Ra		^{210}Po	
	nCi	%	nCi	%	nCi	%	nCi	%	nCi	%
Soft tissue	0.63(K)	0.730	0.20	0.232	85.42(K)	99.012	12.12	0.014	9.83(K)	0.011
Bone	0.09	0.471	2.54(K)	13.298	16.26	85.063	32.81(K)	0.172	192.43	1.007
Whole body	0.72	0.683	2.74	2.600	101.68	96.482	44.93	0.043	202.26	0.192

TABLE 6. YEARLY EXPOSURE

Isotope	Dose mrad/year	Percent of total intake %	Reference organ
^{40}K	20.34	3.08	gonads
	00.01	0.001	whole body
^{222}Rn	630.00	95.45	lungs
^{226}Ra	0.04	0.006	whole body
	1.38	0.210	bone cells
	0.59	0.089	Haversian canals
^{210}Po	0.004	0.005	whole body
	0.035	-	bone tissue
^{90}Sr	6.86	1.040	bone tissue
	0.70	0.106	whole body
^{137}Cs	0.038	0.006	whole body
Total	659.997	99.993	