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RETENTION OF ^{90}Sr AND ^{137}CS IN ECOLOGICAL CHAIN

An attempt has been made to define metabolic pathways of ^{90}Sr and ^{137}Cs which are likely to appear in the environment. The discrimination values were estimated. The concentrations of ^{90}Sr and ^{137}Cs in air, water, soil and vegetables are reported. No significant radiation hazard to the environment of Poland has been found.

1. PREFACE

Atmospheric pollution is a problem of growing importance in the contemporary civilization, a problem that needs a quick and effective solution.

Considerable attention should be paid to such radioactive substances as ^{90}Sr and ^{137}Cs. Since the danger potential of these radionuclides both to man and the whole natural environment is rather commonly known, therefore the admissive concentrations of those radionuclides in particular environmental elements have been examined. Transfer steps that govern the behaviour of the above mentioned radioelements in "ecological chain" have also been studied. The consecutive steps assumed after Bovard [1] are the following:

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1. Dispersion of radioactive gases and aerosols in the atmosphere;
2. Dispersion of radioelements in water;
3. Water — sediment transfer;
4. Water — living organism transfer;
5. Penetration of radioelements into soil;
6. Soil — plant transfer;
7. Transit among animals;
8. Uptake by plants and transfer to man via agricultural products.

2. AIR POLLUTION

The presence of over 300 radionuclides in free air is mainly due to nuclear explosions. During the explosion, the radionuclides are getting into the stratosphere, whence they fall down at different rates. Entering the sphere nearest to the earth region — the troposphere — they are washed-out by rain falls. In this way most radioelements are eliminated from the atmosphere. Of the total radioactivity precipitated on the earth surface 65 % — on the average — comes from fallout. At the Symposium

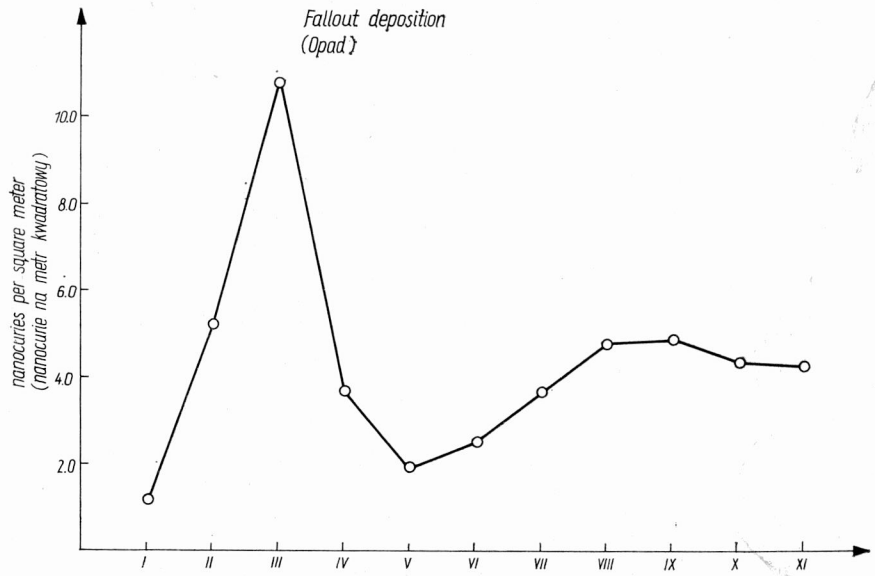

Fig. 1

on Radioecology (1972) Martin [5] presented a mathematical model of radionuclide washout from the air to fallout. Studies and measurements of such fallout were carried out in the Environment Protection Engineering Institute of the Wrocław Technical University during the last five years. The measurements were carried out continuously, taking place in the centre of Wrocław [2, 6].

The results of air radioactivity and deposition measurements taken in 1972, are presented in Fig. 1 and 2, respectively. The curves repre-

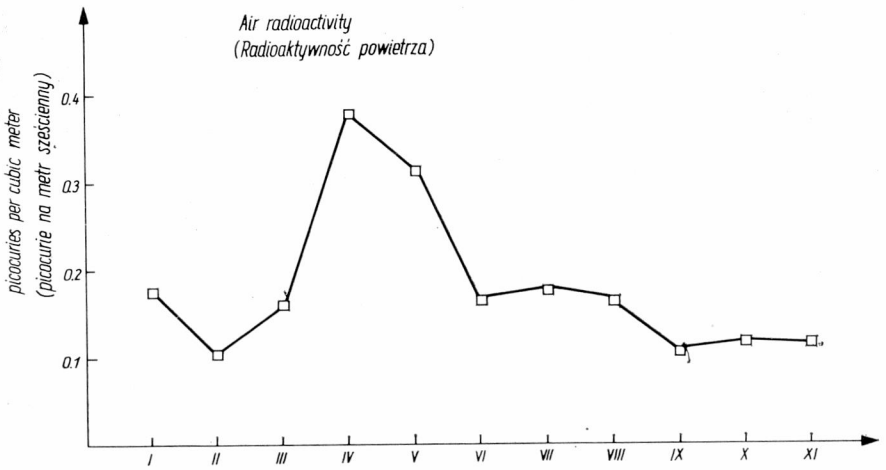

Fig. 2

senting ^{90}Sr and ^{137}Cs radioactivities show distinct peaks corresponding to spring months. The observed maxima are associated with so-called combustible period, i.e. with an increased coal combustion. The obtained data allowed for calculation of the average amount of ^{90}Sr in the gross β-air activity and in gross β-fallout deposition activity as being equal to 2.4 % and 1.2 %, respectively. Average amount of ^{137}Cs in air was 3.5 % and in deposition —1.7 % [2]. Thus the ^{137}Cs concentrations are slightly higher than those of ^{90}Sr. The former contents ranges from 1.25 to 1.71 for the air, yielding 1.47 average, and from 1.14 to 1.77 for fallout, giving an average value of 1.57 per year.

The relationship between aerosol radioactivity in air and fallout deposition is described by hyperbolic equation [3]

$$y = \frac{a}{x} + b, \tag{1}$$

where

y — air radioactivity, pCi/m^3,

x — fallout radioactivity, mCi/km^2,

a, b — constants depending on atmosphere contamination by man-made isotopes.

The measurements of the radioactivity of Odra river water within the urban area of Wrocław and its surroundings were carried out in the years 1968–1973. The results obtained are presented in Fig. 3. The analysis of

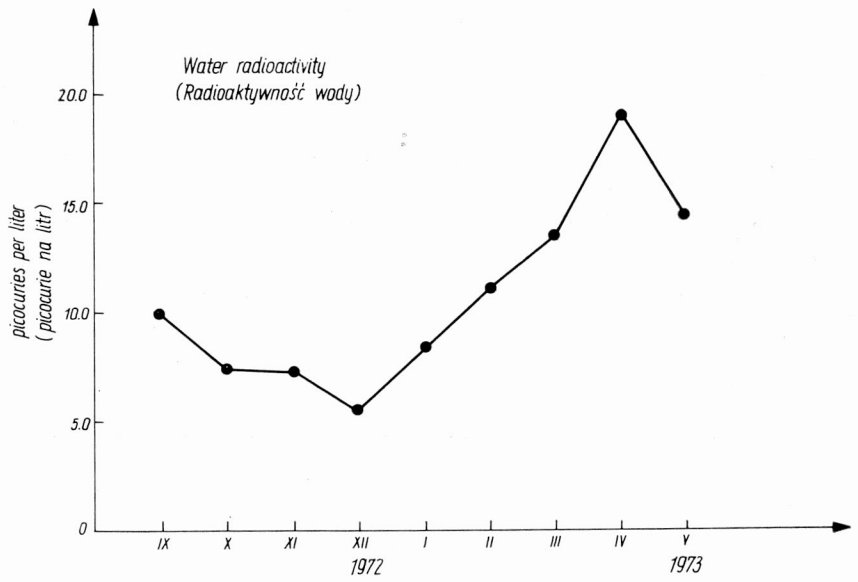

Fig. 3

the obtained results shows the presence of a spring maximum similar to that stated during the investigations of the atmosphere and fallout activities. Hence, the air contamination has a decisive influence on overall water pollution.

The above results allowed to find a correlation between the radioactivity of fallout, Odra river waters and dry land in the vicinity of the river banks:

$$C_W = K_0 \times C_0 + K_g C_g, \tag{2}$$

where

C_W — total β activity of the Odra river waters, pCi/l,

C_0 — total β activity of fallout, mCi/km^2,

C_g — total β activity of dry land near the river banks, mCi/km^2,

K_0, K_g — proportionality coefficients, defined by the following equations:

$$K_0 = \frac{F \times f_0}{V_w}, \tag{3}$$

$$K_g = \frac{F \times \lambda_g}{V_w}, \tag{4}$$

where

F — dry land surface,

V_w — average flow intensity per month,

f_0 — percentage of radioactivity of fallout transferred to the Odra river waters,

λ_g — percentage of the radioactivity of dry land transferred to Odra river waters.

By transformation of the equation (2) the following relation may be obtained:

$$\frac{C_w}{C_0} = \frac{C_g}{C_0} \times K_g + K_0, \tag{5}$$

while the transformation of equations (3) and (4) yields:

$$\frac{K_0}{K_g} = \frac{f_0}{\lambda_g}. \tag{6}$$

The values of K_g and K_0 determined from (5) are equal to 0.26600 and 0.00381, respectively. From the data obtained from formula (5) it follows however, that the percentage of the Odra river radioactivity resulting from the fallout is 27.1 times higher than that coming from dry land situated in vicinity of the river. Thus, it may be inferred that the radioactivity of water depends considerably on the radioactivity of the atmosphere.

The calculated $^{137}Cs/^{90}Sr$ ratio has allowed to state that the concentration of ^{90}Sr in Odra river waters is ten times higher than that of ^{137}Cs. It has been stated, however, that in the atmosphere the concentration of ^{137}Cs is higher than that of ^{90}Sr. Thus, the transfer of ^{90}Sr from the atmosphere to water is easier.

Table 1

Characteristics of investigated soils

Charakterystyka badanych gleb

Sample number	Type of soil	Soil fractions (percentage by weight)				pH	Contents (mg/100 g soil)	
		1.0 mm	1.0–0.1 mm	0.1–0.02 mm	0.02 mm		Ca^{++}	K^{+}
1	Heavier sand					4.5	134	5.2
2						4.6	138	5.6
3		2.0	56.0%	24	18.0	4.6	128	5.4
4						4.4	132	5.8
5						4.4	136	5.6
6						4.4	130	5.4
7	Light loam					5.6	159	9.0
8						5.3	162	10.2
9		3.0	34.0	33.0	30	5.4	162	8.2
10						5.2	160	8.4
11						5.0	151	8.2
12						5.2	156	8.0
13	Light sand	–	82.2	10.8	7.0	6.3	200	10.4
14						6.5	192	9.6
15	Light loam	1.7	52.6	22.4	23.3	6.6	234	11.0
16						6.5	250	10.8
17	Medium – seep					7.0	1033	4.2
18	decay	–	–	–	–	7.0	1040	4.5
19						6.8	1008	4.4
20						6.9	1010	4.6

Besides, on the basis of ^{90}Sr and ^{137}Cs concentrations, the transfer steps: fallout deposition – soil, and soil – plant, have been throughly examined. Results of the soil radioactivity measurements are presented in Tables 1 and 2. Table 1 gives the characteristics of the examined soils. The ^{90}Sr and ^{137}Cs concentrations stated in those soils have been presented in Table 2. From the above data it follows that the average values for ^{90}Sr and ^{137}Cs are 27.6 mCi/km^2 and 52.1 mCi/km^2, respectively. These values are similar to the results given for Polish soils in the years 1960–

–1965. Both results, however, are not fully comparable, since the data found previously concern the contamination of uncultivated soils.

The analysis of the results obtained leads to conclusion that in heavy soils ^{90}Sr and ^{137}Cs contents are greater than in light ones, and that ^{137}Cs

Table 2

^{90}Sr and ^{137}Cs contents in soils

Zawartości ^{90}Sr i ^{137}Cs w glebach

Sample number	Types of Soil	^{90}Sr activity		^{137}Cs activity	
		pCi/kg	pCi/g Ca^{++}	pCi/kg	pCi/g K^{+}
1	Heavier sand	81	60.4	89	1710
2		87	63.0	61	1088
3		96	75.0	49	908
4		78	59.0	76	1315
5		87	64.0	45	805
6		82	63.0	67	1240
7	Light loam	114	72.0	280	3110
8		99	61.0	220	2160
9		108	67.0	262	3140
10		117	73.5	212	2520
11		111	72.0	239	2915
12		106	68.0	188	2350
13	Light sand	66	33.0	184	1770
14		78	40.5	159	1660
15	Light loam	90	38.4	262	2380
16		99	39.5	222	2066
17	Medium-seep decay	87	8.4	228	5640
18		81	7.8	198	4400
19		90	8.9	196	4455
20		85	8.4	217	4720

fallout precipitates easier than ^{90}Sr. The transfer of ^{90}Sr and ^{137}Cs fallouts to soil may be determined by discrimination coefficients of those nuclides in relation: air–fallout–soil. These coefficients are presented in Table 3.

The values of discrimination coefficients are rather low, varying from 0.01 to 0.09 for ^{90}Sr – and from 0.015 to 0.08 for ^{137}Cs. It may

be due to the fact that in the studied period most ^{90}Sr and ^{137}Cs impurities have entered the soil through irrigation. The analysis of particular kind of soil allow, to state that discrimination coefficient is the highest for a medium-seep decay i.e. for a basic type of the examined soils. Light

Table 3

Discrimination coefficients of ^{90}Sr and ^{137}Cs for air—fallout—soil relation

Współczynniki dyskryminacji ^{90}Sr i ^{137}Cs w układzie: powietrze—opad—gleba

Sample number	Type of soil	S U*	M U**
1	Heavier sand	0.0111	0.0189
2		0.0116	0.0196
3		0.0330	0.0164
4		0.0261	0.0218
5		0.0185	0.0240
6		0.0182	0.0370
7	Light loam	0.0133	0.0344
8		0.0112	0.0240
9		0.0297	0.0511
10		0.0322	0.0420
11		0.0210	0.0486
12		0.0200	0.0392
13	Light sand	0.0146	0.0295
14		0.0179	0.0276
15	Light loam	0.0169	0.0265
16		0.0175	0.0230
17	Medium-seep dacay	0.0037	0.0625
18		0.0034	0.0614
19		0.0036	0.0740
20		0.0035	0.0790

* — Sunshine Unit, $SU = \frac{\text{pCi } ^{90}Sr/g\ Ca^{2+} \text{ in soil}}{\text{pCi } ^{90}Sr/g\ Ca^{2+} \text{ in fallout.}}$

** — Moonshine Unit, $MU = \frac{\text{pCi}^{137}\ Cs/g\ Ca^{2+} \text{ in soil}}{\text{pCi } ^{137}Cs/g\ Ca^{2+} \text{ in fallout.}}$

soils have also high discrimination coefficients. Hence, it follows that ^{90}Sr and ^{137}Cs follout is accummulated easier by light soils than by heavy ones. The discrimination coefficient of ^{137}Cs to K^+ is, moreover, higher than ^{90}Sr to Ca^{++}, since cesium is retained by soil easier than ^{90}Sr.

3. ^{90}Sr AND ^{137}Cs CONTENTS IN PLANTS

Plant contamination may be either direct — through deposition of air radionuclides onto the plant surfaces, or indirect — through uptake of soil radionuclides through plant roots. Results of the measurements are given in Table 4. The measurements were carried out in 4 groups of plants. The highest ^{137}Cs concentration has been found in grass, where the average ^{137}Cs activity in summer amounted to 42.0 pCi per one gram of dry weight, i.e. 393 pCi/gram of ash. The corresponding values for autumn being 37.2 pCi per gram of dry weight and 385 pCi per gram of ash respectively, are due to the large surface of grass leaves.

Table 4

^{137}Cs concentrations in plants

Zawartości ^{137}Cs w roślinach

Sample number	Kind of plant	Global radioactivity		^{137}Cs	
		pCi/g ash	pCi/g dry matter	pCi/g ash	pCi/g dry matter
1	2	3	4	5	6
1	Winter	2920	164.0	200.0	11.2
2	wheat	2980	167.0	192.0	9.6
3	grain and	2310	218.0	251.0	23.6
4	chaff	2425	256.0	221.0	21.2
5		3010	114.0	307.0	11.6
6		2800	118.0	310.0	12.5
7		2300	187.0	326.0	26.6
8		2520	203.0	251.5	20.2
9		2850	158.0	275.5	15.4
10		2730	142.0	218.0	12.4
11		2180	180.0	219.0	18.0
12		2270	183.0	242.5	19.5
13		3100	207.0	310.0	20.7
14		2450	166.0	271.5	18.4
15		2010	127.0	216.0	13.8
16		2100	135.0	228.5	14.6
17		3410	108.0	321.5	10.5
18		3520	112.0	340.0	12.1
19		2780	188.0	270.0	18.3
20		2610	172.0	301.0	19.0

Table 4, continuated

1	2	3	4	5	6
21	Winter	5510	334.0	458.0	31.4
22	wheat	5400	346.0	471.0	30.2
23	grain and	4350	518.0	420.0	50.0
24	chaff	4200	485.0	410.0	47.4
25	Winter	1100	34.7	117.0	3.7
26	wheat	1120	32.5	115.0	3.4
27	grain	380	5.6	92.0	1.4
28		377	5.3	89.0	1.4
29	Grass	3600	400.0	382.0	42.5
30		3620	393.0	356.0	38.7
31		3640	198.0	390.0	40.0
32		3840	203.0	401.5	40.8
33		4100	491.0	410.0	45.8
34		4180	468.0	402.5	44.2
35	Lettuce	1300	365.0	160.0	45.0
36		1330	368.0	152.0	41.2
37		1430	924.0	129.0	38.2
38		1550	473.0	148.5	45.4
39		1450	304.0	171.0	36.0
40		1420	294.0	180.0	38.2
41	Potatoes	1450	79.2	116.0	7.0
42		1370	73.2	129.0	7.8
43		1930	104.2	102.0	6.3
44		2020	100.0	112.5	6.8
45	Cabbage	920	108.0	101.5	11.9
46		1020	119.0	105.0	12.2
47		1430	265.5	108.0	20.0
48		1180	217.0	107.0	19.7
49	Pease	784	31.3	90.5	3.6
50		798	32.0	85.5	3.5
51		330	20.7	71.5	4.5
52		316	19.6	70.5	4.4
53	Maize	1730	115.0	200.0	13.3
54		1860	121.0	210.0	13.6
55	Grass	2937	321.6	382.5	41.8
56		3309	359.8	365.5	39.7
57		4080	385.7	391.0	33.2
58		3200	262.0	402.0	34.1

Table 4, continuated

1	2	3	4	5	6
59	Maize	1405	157.5	152.0	17.9
60		1830	218.0	168.5	18.9
61	Beet leafs	1842	264.5	170.0	24.4
62		1635	235.7	161.0	23.2
63		2262	288.0	125.0	24.2
64		2220	281.3	198.0	25.0
65		1942	343.5	137.5	16.1
66		1928	237.7	141.0	16.6
67		1817	283.0	198.0	27.8
68		3102	484.0	182.5	25.3
69	Beet roots	1180	216.0	142.0	21.2
70		1492	271.0	151.0	24.3
71		1023	186.0	106.5	9.2
72		1025	185.0	117.5	10.1
73		923	159.0	198.0	30.2
74		1305	225.3	182.0	31.4
75		827	39.1	109.5	5.7
76		850	40.9	113.5	6.0
77	Potatoes	1640	211.0	121.0	7.6
78		1570	87.8	132.0	7.4
79		1333	73.5	118.0	6.5
80		1096	59.5	121.0	6.6

^{137}Cs enters the plants mainly by direct deposition. One of the factors increasing this type of contamination is a large surface of the leaves. In soil-plant system the absorption has a minor effect on the total ^{137}Cs contents in plants.

A group of leafed vegetables (including lettuce and cabbage of the early variety) shows a slightly lower ^{137}Cs concentration. Despite large leaves, characteristic of those plants, the effect of root uptake, when compared with direct contamination is much greater than in grass. It has been found that ^{137}Cs concentration in vegetables is three times lower than of ^{90}Sr, and equals to 30–40 pCi ^{137}Cs per gram of dry weight, i.e. 100–200 pCi ^{137}Cs per gram of ash.

The third category of vegetation analyzed was cereals, especially winter wheat and maize. Average concentration of ^{137}Cs in winter wheat (entire plant analyzed) was 16.5 pCi per gram of dry, weight (263.0 pCi per gram of ash). Winter wheat grains have been also examined and

only 2.5 pCi per gram of dry weight ascertained. Analogical measurements performed in maize have shown that this plant contains 13.5 pCi of ^{137}Cs per gram of dry weight. Maize was examined because of its agricultural importance, especially in preparing cattle forage. In transfer of cesium to forage the role of maise as a component of fodder will be always more important than that of grains.

The analyzed group consisted of root crops, including potatoes and beets. The average ^{137}Cs accumulation in potatoes was 7.0 pCi per gram of dry weight (115 pCi per gram of ash). It is interesting that since 1965, when ^{137}Cs contents was tested for the first time, no changes in this value have been found. It can be noticed that radiocesium content in beet leaves exceeds root content some four times.

4. RADIOACTIVITY IN MILK

The investigations were carried out in two farms (in the sequel quoted as farm I and farm II) situated 40 km apart. Both farms were similar with respect to fallout activity, but different in respect of soil conditions. Farm I was characterized by light soils, while close textured ones prevailed in farm II.

While determining ^{90}Sr and ^{137}Cs concentrations in cow milk, two kinds of feeding — cow shed and pastural alimentation — were taken into account. According to the first system the cows were fed with farm-made (silage, hay) as well as outdoor produced fodders (concentrates, and others). In milk produced by applying the second feeding plan (i.e. pastural alimentation) the contamination was mainly due to local, and in particular, to soil conditions.

It was considered desirable to make the measurements by sampling fodder and milk at the beginning and at the end of each feeding period. The obtained results were compared with the exponential model of contamination pathway from fodder to milk. This model — based on Pratt's calculation [6] — was constructed by means of the following equation:

$$\frac{dF(t)}{dt} = R - \lambda F(t), \tag{7}$$

where

$\frac{d}{dt}$ — differential operator,

R — constant speed of radionuclides inflow, i.e. ^{90}Sr or ^{137}Cs concentration in daily fodder dose,

λ — biological constant of contamination descrease in milk,

$F(t)$ — actually stated radionuclides concentration in the contamined medium (i.e. milk), expressed by a time function

$$F(t) = \left(F_0 - \frac{R}{\lambda}\right) \cdot e^{-\lambda t} - \frac{R}{\lambda}, \tag{8}$$

where

F_0 — milk contamination during the changes occuring in radionuclide concentration in fodder.

$F(t)$ values corresponding to respective R magnitudes are listed in Table 5. The value of λ being constant, the relationship between F/t

Table 5

Milk contamination by ^{90}Sr

Kontaminacja mleka przez ^{90}Sr

Feeding period	Farm I				Farm II			
	pCi/24 hrs R		pCi/l $F(t)$		pCi/24 hrs R		pCi/l $F(t)$	
	^{90}Sr	^{137}Cs	^{90}Sr	^{137}Cs	^{90}Sr	^{137}Cs	^{90}Sr	^{137}Cs
I	2188	3356	2.7	8.0	3300	1862	3.2	7.6
II	2805	3640	3.2	8.2	3793	4912	4.0	8.2
III	2208	4216	2.9	8.4	4142	4073	3.8	8.2
IV	2603	2423	3.0	7.4	3341	2352	3.4	7.5

and R should be similar to that between $F(t)$ and R/λ. From the data presented in tables quoted above, it follows that the changes in concentrations of ^{90}Sr and ^{137}Cs in a daily fodder dose yield the changes in concentrations of radionuclides in milk. It has been stated that an increase or decrease in the R value brings a respective growth or decrease in milk contamination. Those changes have been noticed very soon, i.e., a few weeks after the change in radionuclides concentration took place.

5. RADIOACTIVITY IN MAN

The contamination of individual organs of man results from
- partial transfer,
- direct transfer into tissues through open wounds or by injections,
- respiration in polluted atmosphere,
- consumption of contaminated food.

In order to assess the participation of the above agents in the contamination of separate human organs as well as to determine the course of the radionuclide accumulation process in those organs the content of ^{90}Sr and ^{137}Cs have been studied in brain, liver, ovaries, muscles and bones. During the examination of a patient various factors have been

Table 6

^{90}Sr concentrations in human body (pCi ^{90}Sr/g Ca)

Zawartości ^{90}Sr w ciele ludzkim

Brain	Liver	Ovaries	Muscles	Bones
12.5	8.75	10.6	1.89	26.4
14.6	6.5	5.45	3.21	23.0
14.2	14.1	3.6	1.38	11.8
25.3	10.5	17.0	1.08	16.7
27.2	6.4	8.4	0.76	22.0
12.8	9.65	7.25	1.64	14.2
8.75	6.3	16.6	0.8	17.4
20.8	11.4	21.0	0.98	42.6
30.8	15.4	18.5	4.03	31.7
30.8	23.3	11.4	0.54	30.2

taken into account, among others, his age and a complete case history. These factors helped to indicate the qualitative effects of the exposure time on the concentration of radionuclides, as well as to asses either the susceptibility of the given organ or its resistance to contamination. Table 6 shows the results obtained from the studies on ^{90}Sr concentrations in individual human organs. From the data given in the Table it follows that the highest ^{90}Sr concentrations are present in human bones. Because of similar physical and chemical properties of strontium-90 and calcium, the latter — being the main constituent of the bone mass — is

substituted by strontium-90. The data presented in Table 6 indicate also that ^{90}Sr concentrations in cerebrum, liver and ovaries are only slightly lower, the lowest values have been found in the muscles.

6. PREDICTED RADIOACTIVITY IN WHOLE-BODY FROM 1960 TO 2000

The study reported in this paper is a part of the overall review which is concerned with estimates and predictions of ionizing radiation doses from all sources. Estimates or predictions were made for each decade of period 1960 to 2000 [7]. The results are presented in Table 7.

Table 7

Summary of whole-body human irradiation and animal doses examined during 1960 to 1970 and predicted for 1980–2000

Całkowita dawka promieniowania pochłonięta przez organizmy zwierzęce i człowieka wyznaczona dla okresu 1960–70 oraz przewidywana dla okresu 1980–2000

Radiation Source	mrem per capita				
	1960	1970	1980	1990	2000
Environmental					
Natural	130.00	130.00	130.00	130.00	130.00
Global fallout	5.46	3.47	4.65	4.70	4.95
All others	0.04	0.03	0.35	0.30	0.05
Subtotal	135.50	133.50	135.00	135.00	135.00
Medical					
Diagnostic	72.10	72.20	72.10	72.00	72.00
Radiopharmaceutical	0.60	1.90	13.90	14.10	15.50
Subtotal	72.70	74.10	86.00	86.10	87.50
Occupational	0.80	0.70	0.85	1.25	1.10
Miscellaneous	2.00	2.70	2.15	1.65	1.40
TOTAL	211.00	211.00	224.00	224.00	225.00

6.1. ENVIRONMENTAL RADIATION

A major source of radiation doses in Poland originates from natural radiation. The total estimated annual whole-body dose is constant (130 mrem per capita). Global fallout from nuclear explosion test contributed to about 5.46 mrem per capita in 1960 and to 3.97 mrem per capita in 1970. Future doses from fallout are predicted to be 4.65 mrem per capita in 1980, and to increase to 4.95 mrem per capita in 2000; this repeated increase being due to population growth. The total dose contributed by all other environmental sources will increase from 0.04 mrem per capita in 1960 to 0.05 mrem per capita in 2000.

6.2. MEDICAL RADIATION

The greatest portion of the man-made radiation dose is due to medical diagnostic procedures. Medical diagnostic radiology accounts for at least 90 per cent of the total man-made radiation dose. This is at least 35 % of the total radiation dose from all sources (natural radioactivity included).

6.3. OCCUPATIONAL RADIATION

The contribution of occupational exposures to the total dose per capita is estimated to be less than 1 mrem/year. The major portion of this dose during 1960 and 1970 was due to the use of ionizing radiation in medicine and dentistry.

Increased industrial use of ionizing radiation, the predicted increase in nuclear power production will increase the per capita dose by approximately 0.1 mrem/year by 1990. During the 1990's the population dose from industrial sources and from medicine and dentistry procedures will probably be almost the same. The total dose from occupational radiation is estimated to be 0.8 mrem per capita in 1960 and predicted to reach 1.1 mrem per capita in the year 2000.

6.4. MISCELLANEOUS RADIATION

Miscellaneous radiation sources (television, consumer products, and air transport) contribute to the radiation dose of the population. Esti-

mated annual average whole-body doses to the population are 2.0 and 2.7 for 1960 and 1970, respectively. Predicted annual doses are 2.15 mrem for 1980 and 1.40 mrem for 2000.

6.5. TOTAL DOSE

The total dose (mrem) per capita will increase in the future. Annual doses are 211.0 mrem for 1960, and predicted ones are 224 mrem and 225 mrem for 1980 and 2000, respectively.

CONCLUSIONS

1. On the basis of air fallout radioactivity investigations conducted at various sites in Poland it should be stated that the concentrations of ^{90}Sr and ^{137}Cs in different environments are similar.
2. The maximum radioactivity concentration in air fallout and Odra river water may be observed during spring.
3. The concentration of ^{90}Sr and ^{137}Cs in humus soil is greater than in light soil.
4. The highest ^{137}Cs concentration is noted in grass and leafy vegetables (the category of large leaf surface); and the lowest values are found in root crops.
5. It seems worthwhile to conduct studies on radioecological capacity of the environment i.e. on the ability of ecosystems to accept a defined amount of radiocontaminants without detrimental biological, health and economic consequences.

RETENCJA ^{90}Sr i ^{137}Cs W ŁAŃCUCHU EKOLOGICZNYM

W pracy przedstawiono wyniki badań dotyczących przemieszczania się ^{90}Sr i ^{137}Cs w poszczególnych elementach środowiska. Jako ogniwo wyjściowe przyjęto atmosferę, a jako pośrednie — opad atmosferyczny, glebę, wodę, rośliny i zwierzęta. Ogniwem końcowym jest człowiek.

Po określeniu wielkości stężenia najgroźniejszych radionuklidów w atmosferze znaleziono zależności między zawartością radionuklidów w atmosferze a ich występowaniem w pozostałych elementach środowiska.

Badania pozwoliły na sformułowanie następujących wniosków:

1. Zależność między stężeniem radionuklidów można wyrazić funkcją hiperboliczną:

$$y = \frac{a}{x} + b \qquad (a, b - \text{wielkości stałe}).$$

2. Stężenie radionuklidów w opadzie atmosferycznym jest wprost proporcjonalne do ich stężenia w wodzie odrzańskiej.

3. Niskie wartości współczynników dyskryminacji radionuklidów (od 0,015 do 0,080) w układzie opad atmosferyczny – gleba, świadczą, że skażenie gleby powodowane jest głównie przez nawadnianie skażoną wodą, a nie bezpośrednio przez opad.

Otrzymane wyniki porównano z wynikami poprzednich badań, a także z uzyskanymi w innych ośrodkach. Stwierdzony niewielki wzrost ilości zanieczyszczeń radioaktywnych w atmosferze w ciągu ostatnich lat wiąże się z rozwojem techniki jądrowej, inżynierii reaktorowej i poszukiwaniem nowych źródeł energii.

W pracy podano także przewidywany stan radioaktywnego zagrożenia środowiska do roku 2000.

RETENTION VON ^{90}Sr UND $^{137}Cs7$ IN DER ÖKOLOGISCHEN KETTE

In der Arbeit wurden die Untersuchungsergebnisse dargestellt betraffs der Verlagerung von ^{90}Sr und ^{137}Cs in den einzelnen Elementen der Umwelt. Als Ausgangsglied wurde die Atmosphäre erachtet, Zwischenglieder sind: atmosphärischer Niederschlag, Boden, Wasser, Pflanzen und Tiere. Das Endglied ist der Mensch.

Durch Bestimmung der Konzentrationsgrösse der gefährlichsten Radionukliden in der Atmosphäre wird die Abhängigkeit zwischen dem Gehalt der Radionukliden in der Atmosphäre und ihrem Auftreten in den übrigen Elementen der Umwelt festgestellt.

Die Untersuchungen gestatten folgende Schlüsse zu ziehen:

1. Die Abhängigkeit zwischen der Konzentration der Radionukliden kann man mit der hyperbolischen Funktion ausdrücken:

$$y = \frac{a}{x} + b \qquad (a, b = \text{konstante Grössen}).$$

2. Die Konzentration der Radionukliden im atmosphärischer Niederschlag ist direkt proportional zu ihrer Konzentration im Oderwasser.

3. Die niedrigen Werte der Unterscheidungskoeffizienten der Radionukliden (von 0,015 bis 0,080) im System atmosphärischer Niederschlag – Boden zeugen dafür, dass die Verunreinigung des Bodens hauptsächlich durch die Bewässerung mit verunreinigtem Wasser bedingt ist und nicht direkt durch den Niederschlag.

Die erzielten Ergebnisse wurden sowohl mit den Ergebnissen früherer Untersuchungen wie auch mit denen anderer Zentren verglichen. Der festgestellte geringe Anstieg der radioaktiven Verunreinigungen in der Atmosphäre im Laufe der letzten Jahre steht im Zusammenhang mit der Entwicklung der Kerntechnik, der Reaktortechnik, und der Suche nach neuen Energiequellen.

In der Arbeit wurde der voraussichtliche Stand der radioaktiven Gefährdung der Umwelt bis zum Jahre 2000 angegeben.

УДЕРЖИВАНИЕ ^{90}Sr И ^{137}Cs В ЭКОЛОГИЧЕСКОЙ ЦЕПИ

Представлены результаты исследований по перемещению ^{90}Sr и ^{137}Cs в отдельных элементах среды. В качестве исходного звена принята атмосфера, а в качестве промежуточных звеньев — атмосферные осадки, почва, вода, растения и животные.

После определения концентрации наиболее опасных радиоизотопов в атмосфере обнаружены зависимости между содержанием радиоизотопов в атмосфере и их наличием в остальных элементах среды. В результате исследований стало возможным сформулирование следующих выводов:

1. Зависимость между концентрацией радиоизотопов можно выразить гиперболической функцией:

$$y = \frac{a}{x} + b, \qquad (a, b \text{ — постоянные величины}).$$

2. Концентрация радиоизотопов в атмосферных осадках прямо пропорциональна концентрации их в воде реки Одры.

3. Низкие значения коэффициентов различения радиоизотопов в системе атмосферные осадки—почва (от 0,015 до 0,080) показывают, что загрязнение почвы вызвано, главным образом, орошением загрязненной водой, а не непосредственно осадками.

Полученные результаты сопоставлены с результатами более ранних исследований, в том числе с результатами, полученными в других центрах. Обнаруженное незначительное повышение количества радиоактивных загрязнений в атмосфере за несколько последних лет связано с развитием ядерной техники и поиском новых источников энергии.

В работе описано также предвидимое состояние радиоактивной опасности в среде до 2000 г.

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