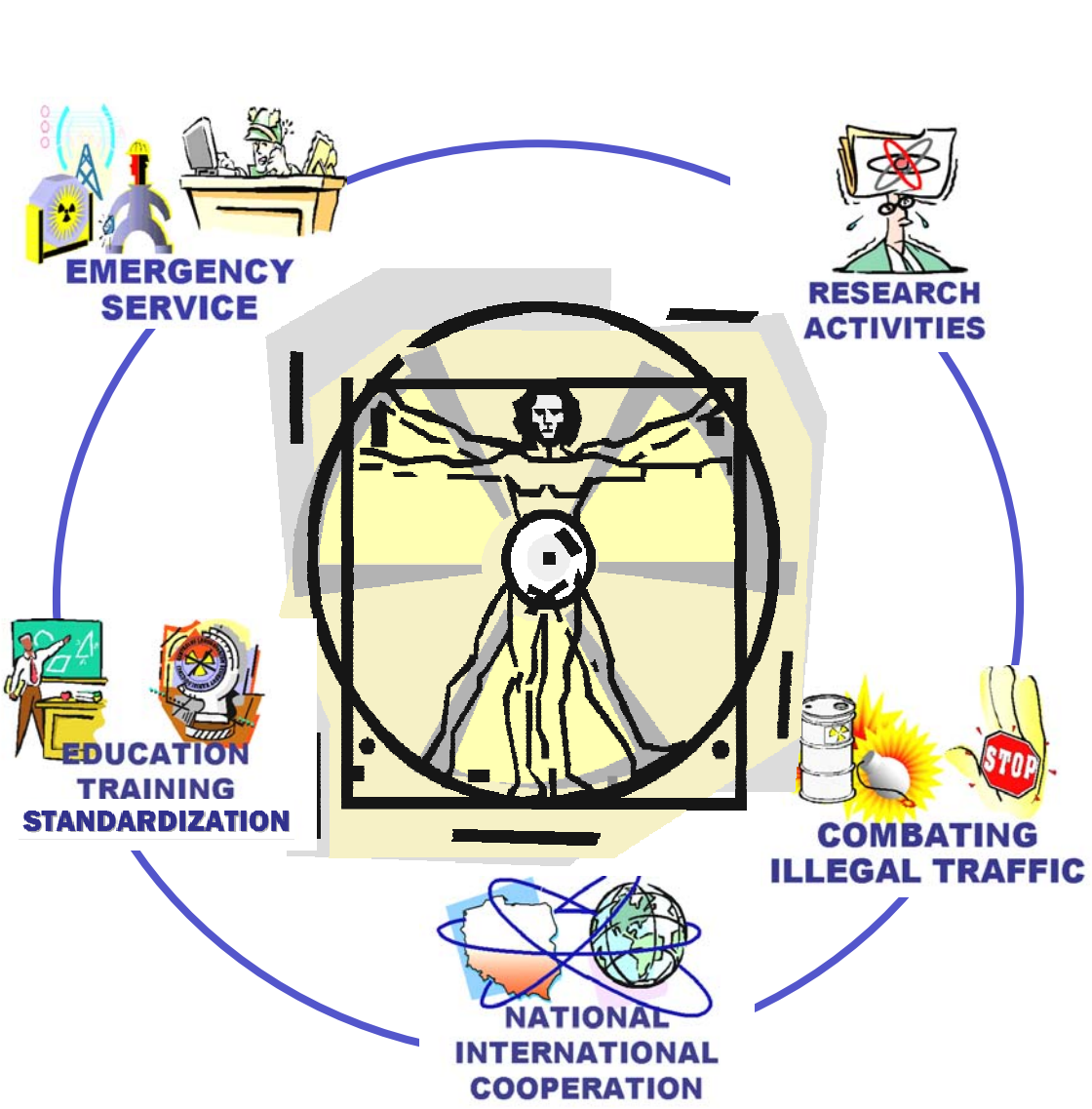
CENTRALNE LABORATORIUM OCHRONY RADIOLOGICZNEJ

CENTRAL LABORATORY FOR RADIOLOGICAL PROTECTION

REPORT OF CLOR

2002-2003

RESEARCH AND OPERATIONAL ACTIVITIES



PERSONAL MONITORING SERVICE

CYTOGENETIC DOSE RECONSTRUCTION

ENVIRONMENTAL CONTAMINATION

RAW AND BUILDING MATERIALS MONITORING

FOODSTUFFS CERTIFICATION

RADIOACTIVITY IN WATERS lakes, rivers, wells, mineral waters

MONITORING OF RADIOACTIVE IODINE IN THYROID

INSTRUMENTS TESTING & CERTIFICATS SERVICE

RADON Rn-222, radon daughters, measurements, calibration

RESEARCH DEVICES CONSTRUCTIONS

RADIATION PROTECTION ADVISER

WARSAW 2004

TRAINING AND INFORMATION DEPARTMENT OF CENTRAL LABORATORY FOR RADIOLOGICAL PROTECTION

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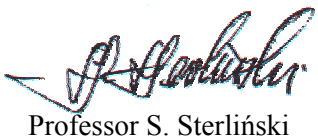
PREFACE

Central Laboratory for Radiological Protection (CLOR), established in 1957, until 2001 was under the authority of the National Atomic Energy Agency, and from August 2001 is under the authority of the Ministry of Economy and Work. The statutory responsibility of CLOR is protection of general population, occupationally exposed persons, and the environment against the hazards of ionizing radiation. CLOR fulfils this task by routine practical activities, preventive and operational tasks, by scientific studies, and by providing sound advice to private and governmental organizations. As in the former years, in 2002 and 2003 the efforts of CLOR were concentrated on operational and preventive actions, aimed to ensure the radiation safety of the country. These activities, covering several public services, engaged about 70 percent of human and financial resources of CLOR. The operational programs were organized as long-term tasks, to guarantee the continuity of radiation protection services.

In 2002 and 2003 CLOR participated in several national and international research projects. Prime among them were those sponsored by the Six Frame Program of the European Union, by bilateral agreements between CLOR and Institute of Transuranium Elements in Karlsruhe, Germany, and also the EMRAS program coordinated by IAEA. In the latter project, a representative of CLOR leads the Iodine Working Group.

During these two years CLOR Center and Scientific Information, usually with scientific stuff of CLOR, released about 3000 consultations and informations on the matter of radiological protection of population and environment.

Multidisciplinary character of radiological protection, spanning several scientific disciplines, need a close cooperation between operational and research staff of our institution. Practically all research activity in CLOR is carried out to support operational services in radiation protection. Such arrangement seems rational as it ensures a more efficient use of equipment, limits of costs, and enables taking advantage knowledge and experience of scientists both in normal operations and in nuclear emergency. This marriage of practice and science, joined with experience of many decades, is invaluable for solving the unpredictable intricacies posed by emergency situations. No regulations, and even the best standards, may here suffice. I wish to recall in this respect the statement of Lauriston Taylor, the doyen of radiological protection, who in 1957 stated: "*Radiation protection is not only a matter of science. It is problem of philosophy, morality and the utmost wisdom"*.



Professor S. Sterliński

Director

ORGANIZATION*

Central Laboratory for Radiological Protection has a staff of 89 of which 52 have university level background. CLOR employs 2 professors and 26 senior researchers of whom 7 have Ph.D. degree.

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1 RESEARCH ACTIVITIES

1.1 IODINE-129 AND IODINE-127 IN BOTTOM SEDIMENTS OF THE BALTIC SEA – PRELIMINARY RESULTS

M. Suplińska, Z. Pietrzak-Flis
Radiation Hygiene Department

Iodine-129, with half-live of 1.57 x 10^7 years, is present in the environment from natural and anthropogenic sources. The estimated natural atom ratio of $^{129}I/^{127}I$ in the hydrosphere, the atmosphere and the biosphere is 10^{-12}-10^{-13}. This ratio has increased as a result of human activity. Sources of anthropogenic ^{129}I included nuclear weapon tests, normal operation of nuclear reactors, discharges from reprocessing facilities and from damaged nuclear reactor at the Chernobyl. In the hydrosphere the most important are liquid discharges to the sea by the nuclear fuel reprocessing plants at Sellafield and La Hague [1]. Presently, a wide range of values for $^{129}I/^{127}I$ ratio can be found, depending on geographic location, and type of material sampled.

Currently, the ratio of ^{129}I to ^{127}I observed in the Danish Straits (water and brown algae) is 10^{-7} and in the Bornholm Basin is one order of magnitude lower. For such high ratio are probably responsible the discharges from nuclear reprocessing plants at La Hague (France) and Sellafield (UK) to the English Channel and Irish Sea. These discharges are transported to the North Sea, and further to the Kattegat and Baltic Sea [2].

The objective of the present study was to determine the activity concentrations of ^{129}I, concentration of stable iodine (^{127}I) and concentrations of ^{137}Cs in the bottom sediments from Southern Baltic Sea and then to calculate the ratio of ^{129}I to ^{127}I and the ratio of ^{129}I to ^{137}Cs in particular layers along the sediment profile.

Sediment core samples were collected at three locations of Southern Baltic Sea: Gulf of Gdansk (P110), Gdansk Deep (P1) and Bornholm Basin (P39). Each core was divided into 6 depth layers: 0-2; 2-5; 5-7; 7-9; 9-13 and 13-19 cm.

The ^{129}I and ^{127}I were determined by radiochemical neutron activation analysis *(RNAA)* method described by Muramatsu and Yoshida [3], with some modifications by Z. Pietrzak-Flis et al. [4]. The ^{137}Cs concentrations were determined by gamma spectrometry.

The concentrations of ^{129}I in sediments differ depending on sampling site and layer (Table 1). The highest concentrations were found at P39 sampling station and in the 0-2 cm layer of sediment; it was equal to 15.6 mBq kg^{-1}_{dw} and it was two times higher than in the same layer at P 110 station (7.56 mBq kg^{-1}_{dw}). The lowest activity concentrations (0.90 mBq kg^{-1}_{dw}) was found in upper layer at P 1 station.

Activity concentrations of ^{129}I in core samples decreased exponentially with depth (Fig.1), and below 9 cm they were lower then detection limit (0.1 mBq kg^{-1}).

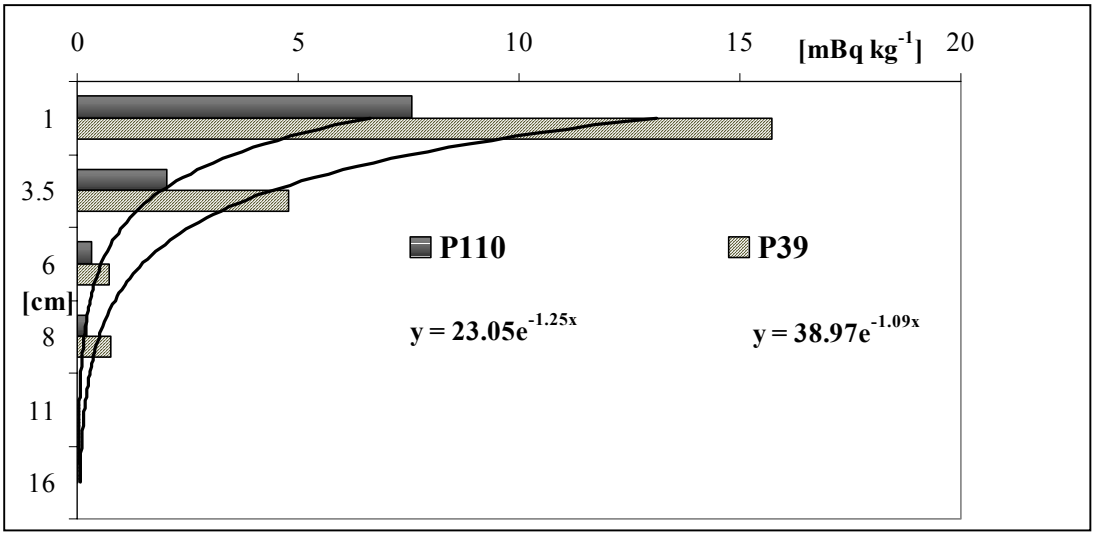

Fig. 1. Distribution of ^{129}I in sediments from Gulf of Gdansk (P-110) and Bornholm Basin (P-39)

Table 1. Distribution of ^{127}I, ^{129}I and ^{137}Cs in Baltic Sea bottom sediment

Sampling station	Layer [cm]	^{127}I [mg kg^{-1}]	^{129}I [mBq kg^{-1}]	^{137}Cs [Bq kg^{-1}]	^{129}I/^{127}I x10^{-8}	^{129}I/^{137}Cs
	0-2	64.5	7.56	332	1.802	12.5
P-110	2-5	66.8	2.04	165	0.464	6.60
1999	5-7	46.1	0.33	81.1	0.109	2.15
	7-9	42.9	0.22	60.4	0.080	1.94
	9-13	20.4	LLD	10.9	-	-
	13-19	39.5	LLD	1.61	-	-
Mean		46.7±17.2				
	0-2	87.2	0.90	279	0.159	1.73
P-1	2-5	88.0	0.48	110	0.084	2.34
2000	5-7	86.4	0.17	35.1	0.029	2.53
	7-9	82.1	LLD	10.2	-	-
	9-13	84.1	LLD	2.3	-	-
Mean		85.3±2.30				
	0-2	379	15.6	123	0.638	68.3
P-39	2-5	372	4.70	97.7	0.198	26.1
2000	5-7	403	0.62	44.9	0.028	8.63
	7-9	417	0.77	27.3	0.029	1.52
	9-13	452	LLD	11.2	-	-
	13-19	309	LLD	3.90	-	-
Mean		389±48.4				

The distribution of ^{127}I concentration were similar along the profiles, however, differences between sub-regions were considerable. At sampling station P 39 (Bornholm Basin) concentration of stable iodine (390±48 mg kg^{-1}_{dw}) was 5-8 times higher then at stations from Gdansk Basin: P1 (85±2.3 mg kg^{-1}_{dw}) and P110 (47±17 mg kg^{-1}_{dw}).

The atomic ratio of ^{129}I to ^{127}I in the upper 0-2 cm layers ranged from $1.8x10^{-8}$ to $1.6x10^{-9}$ and decreased along the profiles to the value of 10^{-10}; such ratio was found for global fallout after nuclear weapons tests.

The atomic ratios of ^{129}I to ^{137}Cs in the layers from 0 to 9 cm depth were in the range of 1.5 to 67.5. These values are at least one order higher then the ratio calculated for releases during Chernobyl Accident (0.18-0.28) [5].

Conclusion

- The highest activity concentrations of ^{129}I were observed in sediments from sampling station located in Bornholm Basin and they were evidently lower in the Gdansk Basin. Concentrations of ^{129}I decrease exponentially along the profiles.
- The distribution of ^{127} I concentrations were similar along the profiles, however, differences between sub-regions were considerable.
- The atomic ratio of ^{129}I to ^{127}I in the upper 0-2 cm layer is in range 10^{-9}- 10^{-8} and decreased along the profile to the range observed for nuclear weapons tests fallout equal to 10^{-10}.
- The atomic ratio of ^{129}I to ^{137}Cs in the layers from 0 to 9 cm depth were in the range of 1.5 to 67.5 and it is at least one order higher then the ratio calculated for realizes during Chernobyl accident (0.18-0.28).

ACKNOWLEDGEMENTS

This work was granted by State Committee for Scientific Research

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1.2 RADON PROGENY CONCENTRATION, PARTICLE SIZE DISTRIBUTION AND EFFECTIVE DOSE AT WORKPLACES AND HOMES

Kalina Mamont-Cieśla, Olga Stawarz

1.2.1 Introduction

Deposition of inhaled short-lived radon progeny in the respiratory tract is a main source of the radiation dose from exposure to radon. The dose is calculated as a product of potential alpha energy concentration (PAEC) and a dose conversion factor (DCF).

There are two approaches to estimation of the DCF (dose per unit intake). One of them, based on the Publication 65 ICRP (International Commission on Radiological Protection) [1], using a single dose conversion factor called conversion convention, is derived from the results of the epidemiological studies of uranium miners. However, the extrapolation from the lung cancer risk for uranium miners applied to the general population meets many objections related to two reasons: a difference of about 2-3 orders of magnitude in the radon exposure, and differences in the exposure environments (e.g. concentration, size distribution and chemical composition of aerosols), breathing rates, smoking pattern etc.. The second approach is based on the ICRP Publication 66 [2] which strongly recommends the usage of dosimetric models for inhalation of airborne radionuclides. These models reveal that the dose per unit intake of radon progeny depends on the site of particle deposition in the respiratory track, which, in turn, strongly depends on the particle size distribution. It is particularly important in the estimation of the dose to take into account the contribution of the ultra fine particles below 10 nm in diameter. To recapitulate, according to the dosimetric models for the reliable estimation of the radon dose it is necessary to know not only the potential alpha energy concentration (PAEC), but also the size distribution of radon progeny particles in the range from 1 to 1000 nm, which penetrate to lungs with the air. The dosimetric model approach uses a size-weighted dose conversion factor, which combines radon progeny size distribution with the particle-size dependent dose conversion factors in a particular exposure location.

The aim of this work was to compare radon effective doses estimated by means of these two methods and to investigate dependence of the difference on the free fraction.

1.2.2 Radon Progeny Particle Size Spectrometer

The Radon Progeny Particle Size Spectrometer (RPPSS - Fig.1), manufactured by Stephen Solomon (ARPANSA, Melbourne, Australia), is a unique research tool, which allows to estimate radon dose with a dosimetric model for inhalation of airborne radon progeny.

RPPSS comprises 8 stages operated in parallel: one open face stage, 4-stage diffusion battery system and 3-stage inertial impactor system. In the diffusion battery system filters are preceded by wire screens with increasing numbers: 1, 2, 13 and 32 and mesh 100,100,100,200 respectively in the consecutive stages. In the 3 impactor stages aluminized mylar foil is used as collector. The activity collected on filters and mylars are counted simultaneously by silicon detectors mounted adjacent to them. The counts are processed by deconvolution analysis for 43 size ranges between 0.60 nm and 2493.9 nm. It is done by means of two different algorithms: the Twomey non-linear iteration [3] and the expectation maximization method described by Maher and Laird [4].

Fig. 1. Radon Progeny Particle Size Spectrometer (RPPSS)

In the continuous mode the deconvolution yields particle size distributions for overall Rn-222 daughters. RPPSS produces among others the following data: total PAEC, distribution of PAEC for 8 stages, unattached fraction defined as the smallest particles collected by the stage No2, distribution of alfa-active aerosol sizes with information on each peak (activity median diameter, percentage contribution and geometrical standard deviation), size-weighted dose conversion factors (for an adult male with a breathing rates of 1.2 m^3/h and 0.78 m^3/h) derived from the ICRP66 Respiratory Tract Model implemented in the computer program RADEP (RAdon Dose Evaluation Program)[5]. Dependence of the dose conversion factors (DCF) on the particle diameters applied in the software of RPPSS is shown in Fig. 2. It reveals that for particle diameter of 2,9nm (the free fraction) the values of DCFs are ca. 22 times higher than for particles of ca. 500nm (the attached fraction). The RADEP-derived values of DCFs are adjusted by a factor of 0.3 to provide consistency with the results derived from the epidemiological risk estimate with the use of the ICRP65 conversion convention.

Collection efficiency curves for all eight stages, in the range of diameters from 0.6nm to 2494nm, applied in the RPPSS software are shown in the Fig. 3.

Fig. 2. RADEP DCF = f(Dp) for monodispersed particles

Assumption: ratio of activity concentration: ^{218}Po : ^{214}Pb : ^{214}Bi
for Dp<20nm - 0,8 : 0,08 : 0,0 and for Dp>=20nm - 0,8 : 0,6 : 0,4

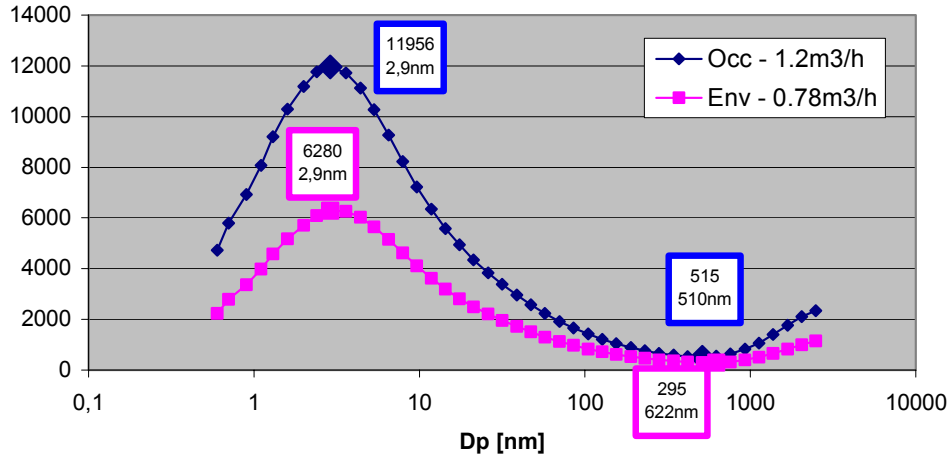
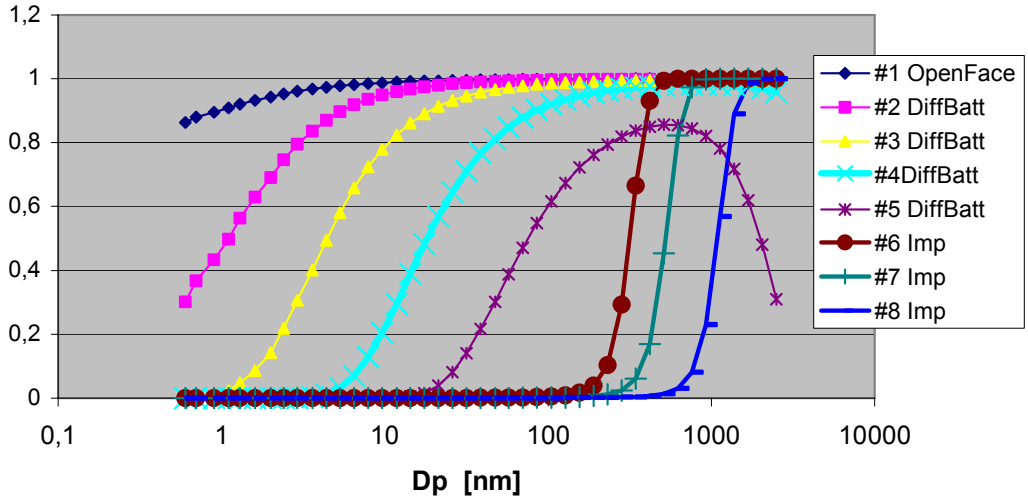


Fig. 3. The collection efficiency curves for all 8 stages



1.2.3 Measurements and results

Measurements of potential alpha energy concentration (PAEC) and radon progeny size distribution were performed with the Radon Progeny Particle Size Spectrometer at four workplaces: an attorney office with elevated radon level, Faculty of Physics at the Warsaw University, the Central Laboratory for Radiological Protection and an experimental coal mine “Barbara”. The measurements were conducted in two conditions of aerosols: natural and enhanced level aerosols from smoking

cigarettes. Simultaneously, radon concentration was measured with AlphaGUARD monitor to estimate the equivalent factor F.

In the Table 1 data on average radon and potential alpha energy concentration, equivalent factor F and free fraction fp in both: natural conditions and atmosphere of smoking cigarettes at investigated workplaces are summarized. In the "Barbara" coal mine the measurements were performed twice (on two days), both in natural conditions, which are characterized by high aerosol level. The free fraction ranges from 0.3% in high aerosol conditions at CLOR bunker to 30% in the attorney office (computer server room) in low aerosol level due to air conditioning. In the "Barbara" mine the free fraction is at the level of ca.5% with the high value of the equivalent factor F of 74%-89%. In the Table 2 data on the peaks in the particle size distributions: particle diameter, geometric standard deviation and percent contribution to the total PAEC are given. Examples of measured full distributions of particle size are shown in the Figs. 4a(single log scale) and 4b (double log scale). In the "Barbara" mine an additional ultra fine particle peak of 7.9 nm occurs.

To estimate the annual effective doses both approaches were applied: the epidemiological with use of the ICRP65 convention conversion (1.425 Sv/(J*h*m^{-3}) for occupational exposure and 1.1 Sv/(J*h*m^{-3}) for environmental exposure) and the dosimetric which is based on the size-weighted dose conversion factors for each particle size distribution. The doses were calculated for an adult male with a breathing rates of 1.2 m^3/h and 0.78 m^3/h, respectively to occupational and environmental exposure, and are compared in the Table 3. Fig. 5 shows the relationship between ratios of doses estimated by the dosimetric model to ones estimated with the use of the conversion convention and free fraction. Values of the ratios range from 0.6 (for HE Env), when the free fraction is below 1%, to 2.6 (for HE Occ), when the free fraction is ca.49%. Similar results were obtained by S.Solomon in the Fairy Cave, Buchan, Victoria, Australia in the studies performed with the use of his Effective Dosimeter. In this case the underestimation of the effective dose calculated according to ICRP 65 conversion convection reached a factor of 2 for the free fraction of 26% [6].

Fig. 4a. Particle size distributions (single log scale)

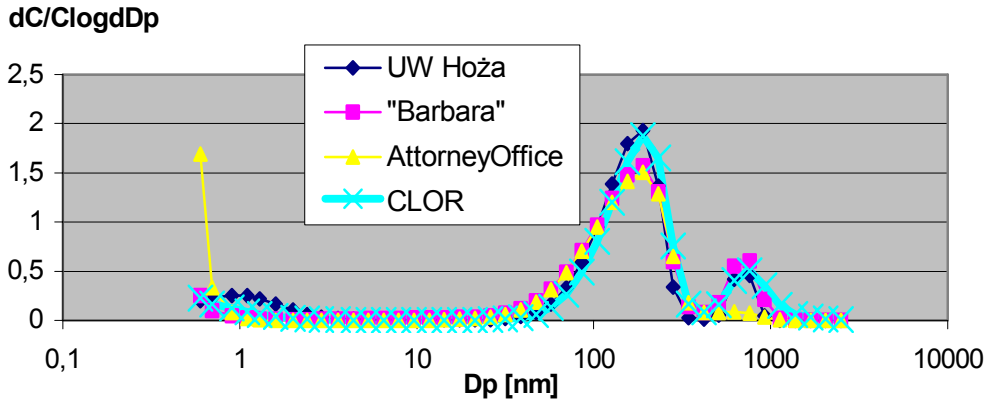


Fig. 4b. Particle size distributions (double log scale)

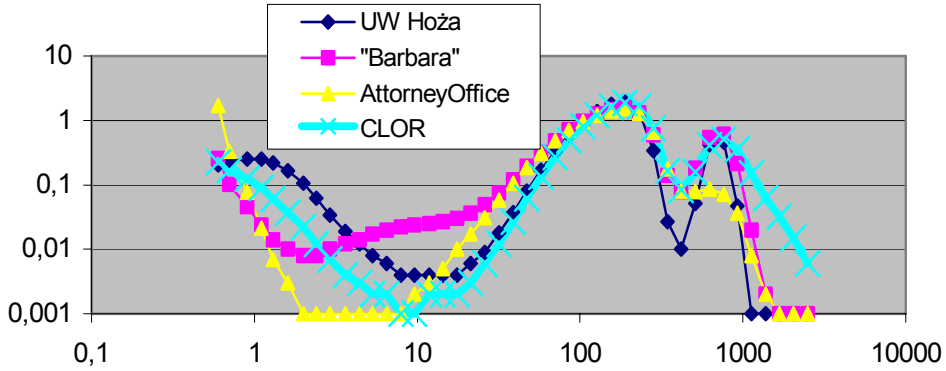


Fig 5. Ratio HE / D vs. fp

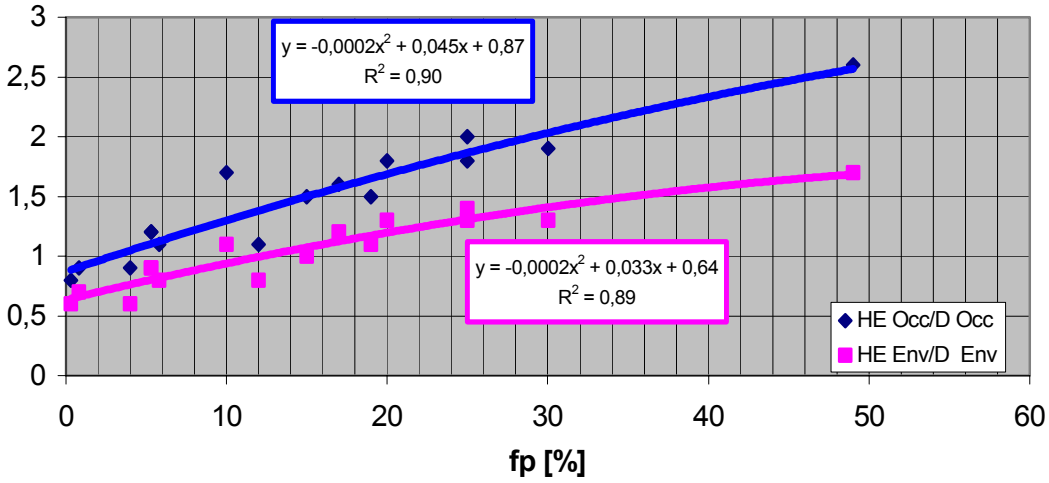


Table 1. Data on Rn-222 concentration, PAEC, equivalent factor F and free fraction fp at several investigated workplaces and homes.

Place	Aerosol conditions	^{222}Rn [Bq/m^3]	PAEC [nJ/m^3]	F [%]	fp [%]
Attorney	natural	1407	614	8	30
office	cigarette	1400	1410	18	19
UW Hoża	natural	224	39	3	10
pavilion	cigarette	426	216	9	0.8
CLOR	natural	118	430	65	5.8
bunker	cigarette	102	460	81	0.3
“Barbara”	natural	971	4040	74	5.3
coal mine	natural	915	4550	89	5.3
House	natural	65	76	21	25
KF	cigarette	67	160	43	17
House	natural	60	91	45	20
WK	cigarette	40	144	68	12
House	natural	130	81	11	49
IR	cigarette	137	356	50	15
House	natural	61	69	20	25
KM	cigarette	69	138	36	4

Table 2. Data on the peaks in the particle size distributions: particle diameter (AMTD), geometric standard deviation and percentage contribution of the peak to the total PAEC.

Place	Aerosol conditions	Peak#1			Peak#2			Peak#3		
		[nm]	GSD	[%]	[nm]	GSD	[%]	[nm]	GSD	[%]
Attorney	natural	0.6	1.2	30	153	2.1	70	599	1.4	1.3
office	cigarette	0.6	1.2	19	141	1.8	80	655	1.3	2.5
UW Hoża	natural	1.0	1.7	10	151	1.5	80	721	1.2	9.7
pavilion	cigarette	1.4	1.8	0.8	152	1.5	88	713	1.2	11
CLOR	natural	0.9	1.6	6	160	1.5	80	755	1.4	14
bunker	cigarette	1.0	1.7	0.3	170	1.4	90	711	1.2	9.4
“Barbara”	natural	0.7	1.3	5	131	2.0	83	622	1.2	12
	natural	0.7	1.3	5	135	1.9	81	681	1.3	14
House	natural	1.1	1.8	25	157	1.6	68	798	1.4	7.2
KF	cigarette	1.9	2.5	17	145	1.8	72	660	1.3	3.0
House	natural	1.1	2.0	20	134	1.7	74	794	1.3	6.0
WK	cigarette	1.0	1.7	12	145	1.5	82	1110	1.4	6.4
House	natural	0.7	1.4	49	97	2.8	45	864	1.7	6.2
IR	cigarette	0.9	1.6	15	150	1.6	77	752	1.2	8.1
House	natural	2.0	2.1	25	155	1.7	68	789	1.5	7.2
KM	cigarette	1.1	1.7	4	172	1.4	85	753	1.3	11

Table 3. Comparison of annual (8700h) effective doses estimated for an adult male with breathing rates of 1.2 m^3/h (Occ) and 0.78 m^3/h (Env) according to two models: dosimetric and epidemiological. HE Occ, HE Env correspond to dosimetric model and D Occ, D Env - to epidemiological one with the conversion conventions 1.425 for D Occ and 1.1 for D Env.

Place	Aerosol conditions	HE Occ [mSv/y]	HE Env [mSv/y]	D Occ [mSv/y]	D Env [mSv/y]	HE Occ/ D Occ	HE Env/ D Env
Attorney	natural	14.6	7.6	7.6	5.9	1.9	1.3
office	cigarette	27.0	14.5	17.5	13.5	1.5	1.1
UW Hoża	natural	0.8	0.4	0.5	0.4	1.7	1.1
pavilion	cigarette	2.5	1.5	2.7	2.1	0.9	0.7
CLOR	natural	6.0	3.4	5.3	4.1	1.1	0.8
bunker	cigarette	4.8	2.8	5.7	4.4	0.8	0.6
“Barbara”	natural	62	35	50	39	1.2	0.9
	natural	67	38	56	44	1.2	0.9
House	natural	1.9	1.0	0.95	0.7	2.0	1.4
KF	cigarette	3.3	1.8	2.1	1.5	1.6	1.2
House	natural	2.0	1.1	1.1	0.9	1.8	1.3
WK	cigarette	2.0	1.1	1.8	1.4	1.1	0.8
House	natural	2.6	1.3	1.0	0.8	2.6	1.7
IR	cigarette	6.5	3.5	4.4	3.4	1.5	1.0
House	natural	1.5	0.8	0.9	0.7	1.8	1.3
KM	cigarette	1.5	0.9	1.7	1.3	0.9	0.6

1.2.4 Conclusions

The radon effective doses based on ICRP65 conversion convention are underestimated in comparison with the ICRP66 dosimetric model derived doses for the free fraction greater than 3% for the occupational exposure, and greater than 12% for the environmental exposure. The underestimation reached the factor 2.6 for the occupational and 1.7 for the environmental exposure in the conditions of the free fraction of 49%.

ACKNOWLEDGEMENTS

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1.3 URANIUM ISOTOPES IN PUBLIC DRINKING WATER IN POLAND

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1.3.1 Introduction

Uranium enters the human body mainly through ingestion, and to a considerably smaller degree by inhalation [1,2]. Contribution of drinking water in the total intake of uranium isotopes varies in wide ranges [3]. In the United States, the intake of water-derived uranium is at average 5 – 10 times greater than the food-derived uranium [4], though in New York City the contribution of water-derived uranium is only about 8% [2].

In Poland, the intake of uranium isotopes through ingestion was determined for the regions of central Poland [5], Wałbrzych [6] and the Świętokrzyskie Mountains [7]. It was found that in these regions the contribution of water-derived ^{238}U and ^{234}U was from about 66% to 91%, and from 76% to 93%, respectively.

The aim of the present work was to determine activity concentration of uranium isotopes in tap water in various sites in Poland. Total ingestion of ^{238}U and ^{234}U was calculated using the data for drinking water obtained in this work, and data for the intake with foodstuffs from the publications [5,6,7].

1.3.2 Materials and methods

Samples of tap water were collected in years 2002 and 2003 from water supply systems located in various parts of Poland. The systems were supplied with surface water from rivers or lakes (16 water pipes) and from deep underground wells (16 water pipes). The sites of tap water collection are presented in Fig.1.

Determinations of uranium isotopes were performed in 5 liter samples of water. ^{232}U was used as an internal tracer for counting alpha activity and chemical recovery. After evaporation of water, uranium was chemically separated by anion exchange and extraction. Finally, uranium was electrodeposited on a stainless steel disc. Activity of deposited uranium was measured with alpha spectrometry system. PIPS detectors for alpha spectrometry were placed in vacuum chamber and connected with multichannel analyzer Multiport II MCA (Canberra MP2-GE) with GENIE 2000 spectroscopy software. Details of the analytical procedure were described elsewhere [6].

Average uranium tracer recovery was approx. 77%, lower limit of detection (LLD) with the counting time of 82.000 s was 0.22 mBq/sample for ^{234}U and 0.29 mBq/sample for ^{238}U and ^{235}U.

The reliability of the applied method was checked by the participation in the intercomparison run organized by the IAEA. Our values agreed well with reference values given by IAEA.

1.3.3 Results

Activity concentrations of ^{238}U, ^{234}U and ^{235}U in drinking water supplied from surface water are presented in Table 1. Activity concentration of ^{238}U ranged from 1.79±0.21 mBq L^{-1} in Kraków up to 23.9±1.66 mBq L^{-1} in Legnica, whereas concentrations of ^{234}U ranged from 2.47±0.27 mBq L^{-1} in Bydgoszcz to 34.1±2.33 mBq L^{-1} in Legnica. Concentration of ^{235}U were the lowest in Kraków (0.10±0.04 mBq L^{-1}) and the highest in tap water collected in Wrocław from water pipe supplied from Oława river 19.9±1.36 mBq L^{-1}. Mean activity concentrations of ^{238}U, ^{234}U and ^{235}U were 9.13 ±7.15 mBq L^{-1}, 12.1±9.75 mBq L^{-1} and 0.41±0.31 mBq L^{-1}, respectively. In all samples the activity concentration of ^{234}U was higher than that of ^{238}U. The activity concentration ratio was in the range from 1.07 to 2.60, with mean value 1.36±0.34.

Activity concentrations of ^{238}U, ^{234}U and ^{235}U in drinking water supplied from ground water are given in Table 2. In the majority of tap waters the activity concentrations of uranium isotopes were much lower than those supplied from surface water. The lowest concentration of ^{238}U was found in Ostrołęka and Gubin (0.36 mBq L^{-1}) and the highest in Suwałki (23.2±1.34 mBq L^{-1}). Similarly as in the case of tap water supplied from surface water, the activity concentration of ^{234}U were higher than those of ^{238}U, they ranged from 0.46 ±0.09 mBq L^{-1} in Ostrołęka up to 25.7 ±1.48 mBq L^{-1} in Suwałki. In six out of 16 water pipes the concentrations of ^{235}U were below the lower limit of detection (0.06 mBq L^{-1}); the highest value was noted in Suwałki (1.04 ±0.04 mBq L^{-1}). Mean activity concentrations of ^{238}U, ^{234}U and ^{235}U were 4.53 ±6.00 mBq L^{-1}, 5.68±6.89 mBq L^{-1} and 0.18±0.27 mBq L^{-1}, respectively. For the calculation of the mean value of ^{235}U it was assumed that in the samples with the concentration of this radionuclide below LLD, its concentration was 0.5 LLD, i.e. 0.03 mBq L^{-1}.

The average activity concentration ratio of ^{235}U to ^{238}U for water samples 0.044±0.007 which is very close to the value 0.046 for natural uranium.

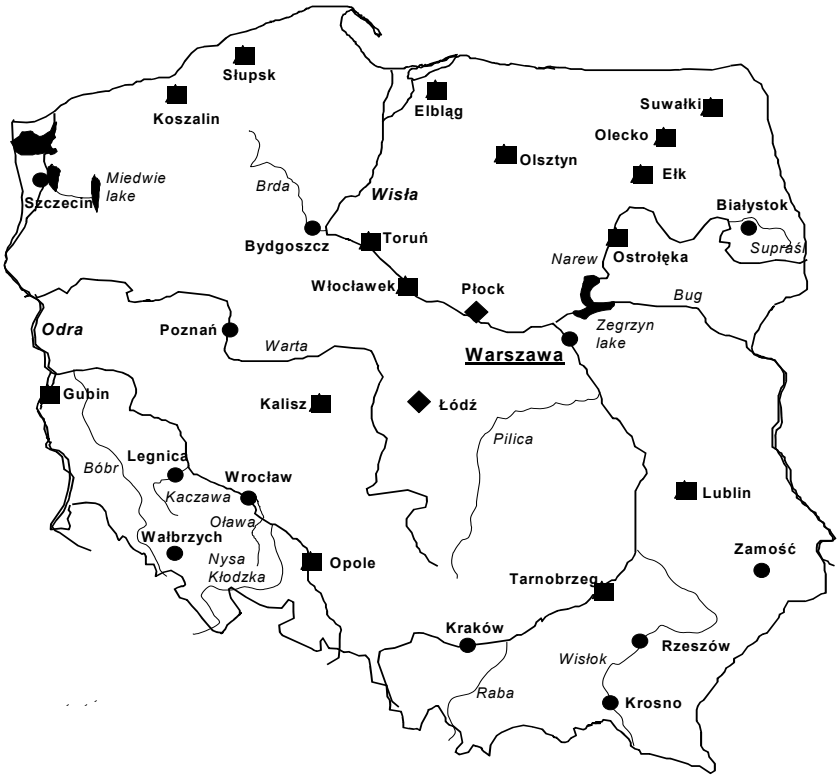

Fig.1. Sites of collection of tap water supplied from: ● surface water, ▲ ground water, ♦ surface and ground water

The assessment of uranium intakes with food and water performed in three regions of Poland showed that the variability of food-derived activity of ^{238}U and ^{234}U was smaller than that of water-derived activity [5-7]. The average activity of ^{238}U and ^{234}U which enters humans with ingested food was 2.27±0.46 Bq, and 2.66±0.74 Bq, respectively. These values were obtained for the regions with a wide variety of natural radionuclides [8], hence it can be supposed that they may also represent other regions of Poland. Annual intakes of ^{238}U and ^{234}U with water were evaluated from the concentrations of these radionuclides in tap water (Tables 1 and 2); annual consumption of water for adults was taken as 730 l after [9]. The estimated average total intakes with water and food are given in Table 3. The average total intake for all locations for ^{238}U was 7.41±5.10 Bq and 9.36±6.61 Bq for ^{234}U. Average total intake in locations supplied with surface water for ^{238}U were 9.24±5.24 Bq and 11.9±7.14 Bq for ^{234}U, whereas in location supplied from ground water they were much lower, being 5.58±4.38, and 6.80±5.03, respectively. The contribution of water was from 43.2% to 67.0% for ^{238}U, and from 45% to 69.6% for ^{234}U.

Annual committed effective doses resulting from 1-year ingestion calculated from the annual intake of ^{238}U and ^{234}U (Table 3) and from the dose coefficients given by the International Commission on Radiological Protection [10] were for ^{238}U 0.33±0.23 μSv, and 0.46±0.32 μSv for ^{234}U, being in total 0.79±0.39 μSv. In locations where tap water was taken from surface water this dose was about 1 μSv,

whereas in locations in which tap water was taken from ground water the dose was 0.56 μSv. Dose from uranium isotopes constitutes only a small fraction of the dose from natural radionuclides of uranium and thorium series ingested with food and water which was estimated to be about 90 μSv [11].

Table 1. Activity concentrations of ^{238}U, ^{234}U and ^{235}U, and $^{234}U/^{238}U$ ratio in drinking water supplied from surface water .

Location	River or lake	^{238}U mBq L^{-1}	^{234}U mBq L^{-1}	^{235}U mBq L^{-1}	$^{234}U/^{238}U$ ratio
Szczecin	Miedwie lake	14.5±0.93[a)]	15.5±1.02	0.56±0.07	1.07
Białystok	Supraśl river	6.91±0.58	8.35±0.69	0.29±0.07	1.21
Bydgoszcz	Brda river	2.00±0.23	2.47±0.27	0.11±0.04	1.24
Płock	Vistula river & ground water[b)]	4.56±0.40	5.87±0.50	0.19±0.05	1.29
Poznań	Warta river	13.6±0.93	16.11±1.09	0.48±0.08	1.19
Warszawa	Vistula river	4.25±0.40	5.47±0.49	0.17±0.04	1.29
Warszawa	Zegrzyn lake	6.43±0.81	7.86±0.99	0.28±0.08	1.22
Łódź	Pilica river Tomaszów[c)]	2.59±0.23	3.32±0.23	0.15±0.04	1.28
Legnica	Kaczawa river (infiltration)	23.9±1.66	34.1±2.33	0.96±0.09	1.43
Wrocław	Oława river (infiltration)	19.9±1.36	26.4±1.78	0.98±0.12	1.32
Wrocław	Nyska Kłodzka river	10.9±0.59	13.5±0.73	0.48±0.05	1.24
Wałbrzych	Bóbr river (infiltration)	5.07±0.42	13.2±0.98	0.24±0.08	2.60
Zamość	Łabuńka river (infiltration)	20.7±1.34	29.4±1.88	0.90±0.11	1.42
Kraków	Raba river	1.79±0.21	2.97±0.30	0.10±0.04	1.66
Rzeszów	Wisłok river Zwięczyca[c)]	11.4±0.81	13.5±0.95	0.52±0.07	1.18
Krosno	Wisłok river Iskrzynia[c)]	4.85±0.39	5.94±0.46	0.14±0.04	1.22
Mean ±SD		9.13±7.15	12.1±9.75	0.41±0.31	1.36±0.34

[a)] Value ± counting error at the 95% confidence level.

[b)] 1:1 mixture

[c)] Site of the water intake

Table 2. Activity concentrations of 238U, 234U and 235U, and 234U/238U ratio in drinking water supplied from ground water

Location	^{238}U mBq L^{-1}	^{234}U mBq L^{-1}	^{235}U mBq L^{-1}	$^{234}U/^{238}U$ ratio
Słupsk	10.5±0.73[a)]	12.3±0.84	0.58±0.08	1.17
Koszalin	0.80±0.07	1.36±0.11	<0.06	1.70
Elbląg	2.07±0.15	2.44±0.17	0.09±0.02	1.18
Suwałki	23.2±1.34	25.7±1.48	1.04±0.04	1.11
Olecko	1.90±0.22	2.92±0.30	0.10±0.04	1.54
Ełk	10.3±0.86	12.2±1.00	0.40±0.08	1.18
Olsztyn	4.71±0.41	5.76±0.48	0.12±0.04	1.22
Ostrołęka	0.36±0.08	0.46±0.09	<0.06	1.28
Toruń	6.90±0.55	8.63±0.67	0.28±0.06	1.25
Włocławek	0.89±0.12	0.99±0.13	<0.06	1.11
Łódź	1.34±0.11	1.56±0.13	0.06±0.02	1.16
Gubin	0.36±0.06	0.52±0.07	<0.06	1.44
Kalisz	0.61±0.06	0.67±0.07	<0.06	1.10
Lublin	2.07±0.18	2.28±0.19	0.08±0.03	1.10
Opole	5.19±0.41	11.4±0.82	0.16±0.04	2.19
Tarnobrzeg	1.35±0.11	1.63±0.12	<0.06	1.21
Mean ± SD	4.53±6.00	5.68±6.89	0.18±0.27[b)]	1.31±0.29

[a)] Value ± counting error at the 95% confidence level.

[b)] In the calculation it was assumed that in the samples with concentration of ^{235}U below LLD, the concentration was 0.5 LLD.

Table 3. Average annual intakes of ^{238}U and ^{234}U from drinking water and food (Bq) by adult population supplied with surface water (SW) and ground water (GW) and contribution of water-derived uranium (%)

	^{238}U*)		^{234}U*)	
	Intake, Bq	(%)	Intake, Bq	(%)
Average, for all locations	7.41±5.10[a)]	55.1±24.8	9.36±6.61	57.3±24.9
Locations supplied with SW	9.24±5.24	67.0±17.7	11.9±7.14	69.6±16.7
Locations supplied with GW	5.58±4.38	43.2±25.6	6.80±5.03	45.1±26.0

[a)] Mean ± SD

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1.4 DISTRIBUTION OF CAESIUM-137, PLUTONIUM-239,240, PLUTONIUM-238, STRONTIUM-90 AND RADIUM-226 IN BOTTOM SEDIMENTS FROM SOUTHERN BALTIC SEA

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Radioactive contaminations originate in the Baltic Sea from several sources. The main sources are direct atmospheric fallout: (1) from nuclear weapons tests, (2) from the Chernobyl accident and (3) run-off from the land into sea via rivers. Finally, hydrodynamic transport from (4) western European nuclear reprocessing plants direct discharges into the sea and (5) from nuclear installation in the Baltic Sea region [1].

Studies on the distribution of ^{137}Cs, $^{239,240}Pu$, ^{238}Pu and ^{226}Ra in bottom sediments from the Southern Baltic Sea were performed by CLOR for the long term Monitoring Program of Radioactive

Substances in the Baltic Sea, coordinated by Helsinki Commission. Its Polish part, HELCOM MORS, enables observation of the current contamination of marine environment and its changes in time.

Bottom sediment core samples were collected from various regions of southern part of the Baltic Sea, during the sampling cruises into the Baltic Sea with r/v "Baltica" organised once a year by In

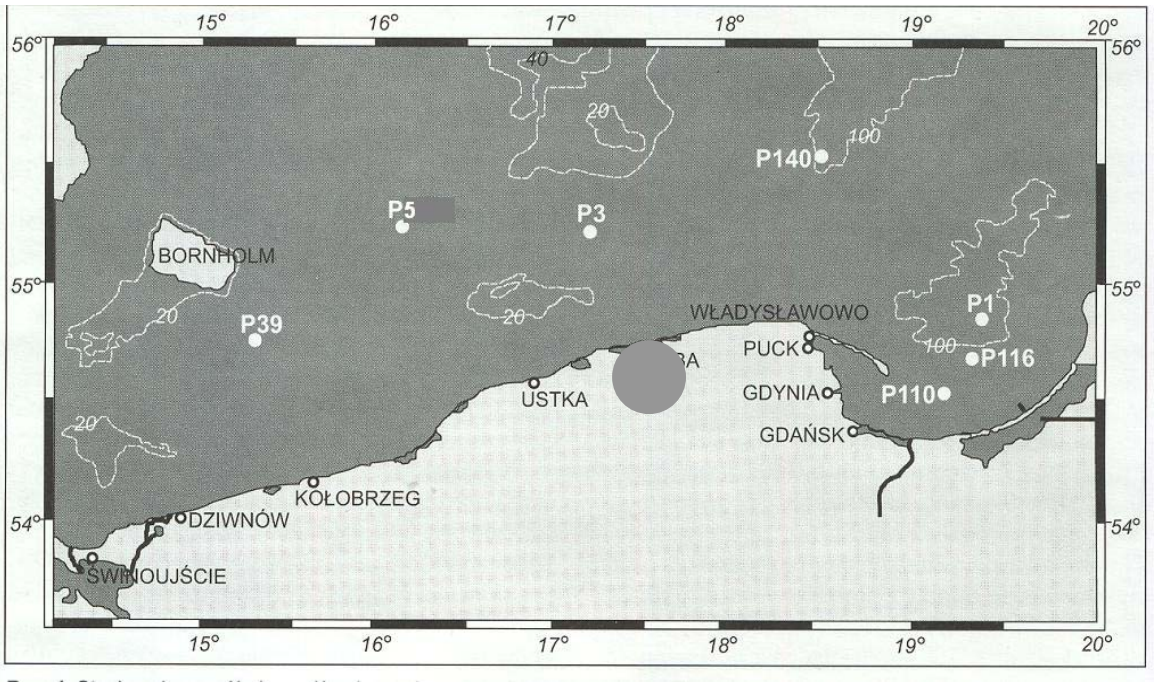

Fig.1 Sediment sampling stations in HELCOM MORS program.

For the determination of radionuclides the same methods as in previous years were applied [2]. The ^{137}Cs activity concentration was determined by gamma spectrometry. Plutonium was separated by ion exchange, followed by electrodeposition onto stainless steel disks. ^{242}Pu was used as an internal tracer. Activity of plutonium was measured by alpha spectrometry. Concentration of ^{226}Ra was determined radiochemically using emanation method (measurement of ^{222}Rn in Lucas-type scintillation chambers) preceded by separation of radium. Concentration of ^{90}Sr was determined by means of its short-lived daughter nuclide ^{90}Y precede radiochemical analyses and with low-level beta counting technique. The reliability of applied methods was checked by participation in inter-comparison exercises organised by IAEA and Risø National Laboratory.

The concentrations of ^{137}Cs in sediments differ depending on sampling site and sampling depth. The highest concentrations were found in the Gulf of Gdansk. In the upper 0-3 cm layer of sediments, ^{137}Cs concentrations in year 2003 ranged from 180 Bq kg$^{-1}_{dw}$ to 440 Bq kg$^{-1}_{dw}$ (Fig 2). In the sediments from Bornholm Basin, the ^{137}Cs concentrations were evidently lower (86-100 Bq kg$^{-1}_{dw}$). The average deposition of ^{137}Cs, ranged from 1170 Bq m^{-2} in Bornholm Basin to 4900Bq m^{-2} in Gulf of Gdansk.

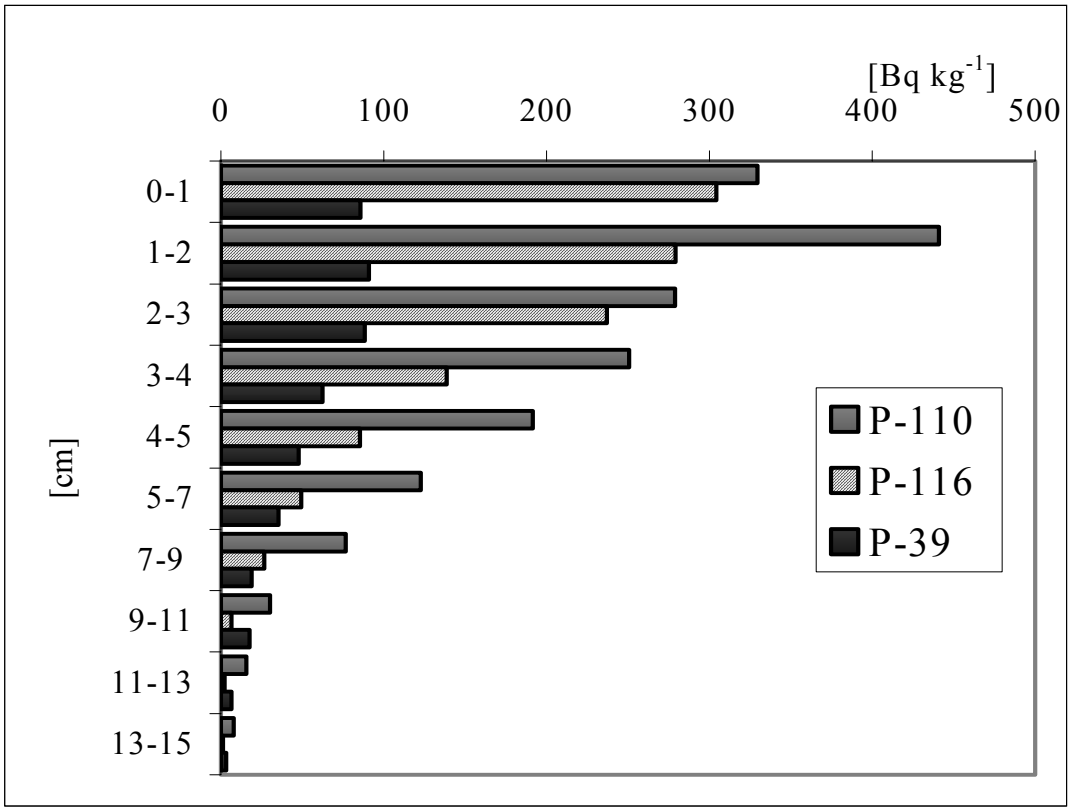

Fig 2. Vertical distribution of ^{137}Cs in bottom sediments from Gulf of Gdansk (P-110, P-116) and Bornholm Basin (P-39), 2003.

Similarly as for ^{137}Cs the highest concentrations of plutonium in bottom sediments (Fig.3) were found in Gulf of Gdansk, however the maxima of ^{238}Pu and ^{239,240}Pu were observed always in deeper layers. In core samples from station P-110, taken in 2002 maximum of ^{239,240}Pu and ^{238}Pu concentrations: 7.26±0.22 Bq kg^{-1} $_{dw}$ and 0.22± 0,03 Bq kg^{-1} $_{dw}$ respectively were observed in 9-11cm layer. The concentrations of plutonium in P-39 (Bornholm Basin) taken in 2003 were almost uniform along the profile to the depth of 7 cm and the average concentrations of ^{239,240}Pu and ^{238}Pu were 1.15±0.13 Bq kg^{-1}dw and 0.04± 0.01, respectively.

The deposition of ^{239,240}Pu ranged from 32.9 Bq m^{-2} in Bornholm Basin (P-39) to 213 Bq m^{-2} in Gulf of Gdansk (P110). Similar values were found in previous years [3].

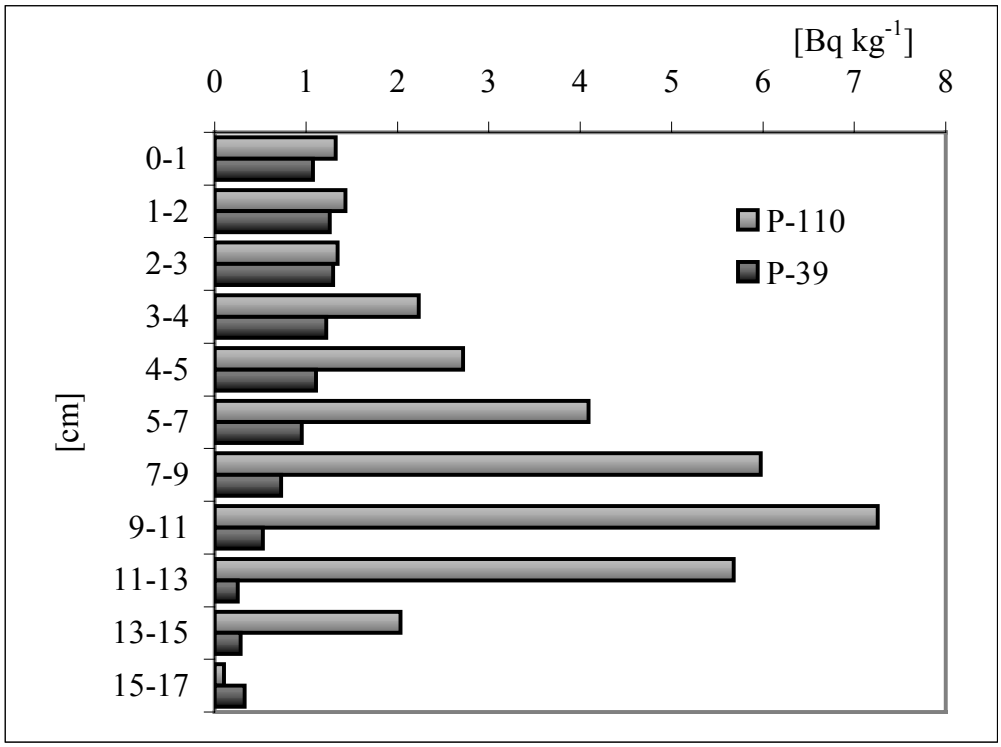

Fig. 3. Vertical distribution of ^{239,240}Pu in bottom sediment from Gulf of Gdansk (P-110) and Bornholm Basin (P-39), 2002-2003.

Concentrations of ^{90}Sr observed in upper 0-3 cm layer equal to 2.99 Bq kg^{-1} decreased to 0.85 Bq kg^{-1} in the layer of 7-9 cm, and after that ^{90}Sr concentrations increase to 4.57 Bq kg^{-1} was observed. This vertical distribution of ^{90}Sr (Fig. 4) indicates two marked sources of contamination: fallout from the Chernobyl accident and long-term fallout from nuclear weapons tests.

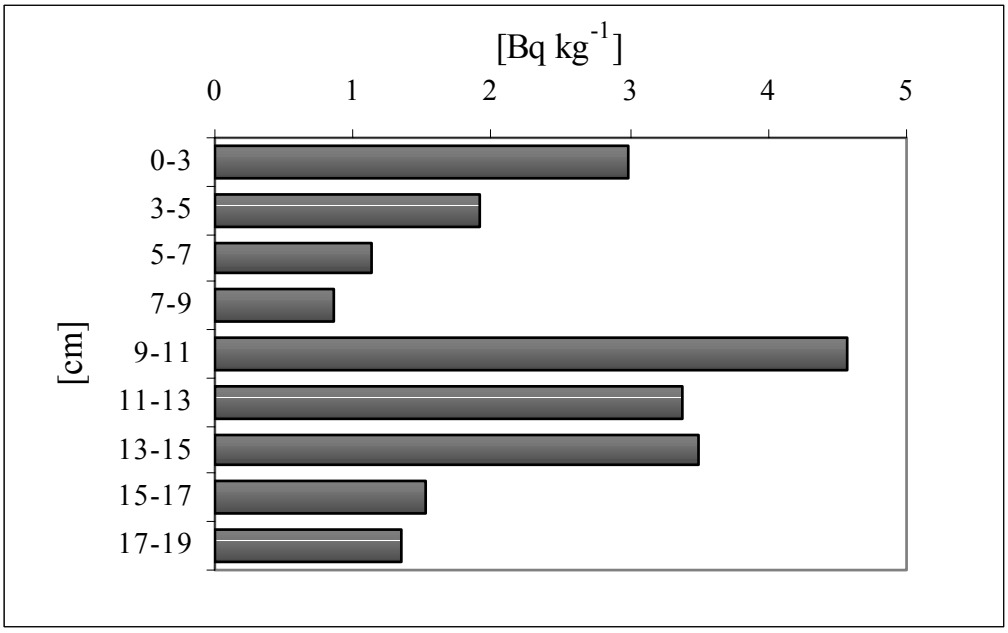

Fig.4. Vertical distribution of ^{90}Sr in bottom sediments from Gulf of Gdansk (P-116), 2003.

However, taking into account radioactive decay of this radioisotope, the input of radio-strontium caused by Chernobyl accident in Gulf of Gdansk area was less than 14% from that caused by nuclear weapons tests.

The distributions of ^{226}Ra concentration were uniform along the profiles, however, differences between particular sub-regions were observed. The lowest concentration of ^{226}Ra, 26.6±0.60 Bq kg$^{-1}_{dw}$, was found in Gulf of Gdansk and the highest, 52.3±3.04 Bq kg$^{-1}_{dw}$ in the Bornholm Basin.

Decrease of ^{137}Cs concentration in Baltic Sea bottom sediment proceeds very slowly. However, ^{137}Cs vertical distribution from Gulf of Finland indicate that the maximum of its concentration observed earlier in the layer 0-1cm, was moved to the deeper ones [4]. In the region of Gulf of Gdansk several patterns of ^{137}Cs vertical distribution indicate for similar process and the maxima of ^{137}Cs concentration were indicated: in 1-2 cm (P-110 core samples in 2002 and 2003 years) or to 2-3 cm layer (P-116 core sample in 2001 year).

The main source of plutonium in Southern Baltic Sea was global fallout. The highest concentrations of plutonium were observed always in deeper layers of the sediment cores. The ratios of ^{238}Pu to ^{239,240}Pu in majority of samples examined since 1991 ranged 0.03-0.05, being similar to the ratios found for the cumulative deposit from global fallout after the nuclear weapons tests [5].

1.4.1 Conclusions

- The highest concentrations of ^{137}Cs, originated from the fallout after Chernobyl accident, were observed in upper 0-3 cm layer of sediment. The patterns of ^{137}Cs vertical distributions suggested that ^{137}Cs containing sedimentation matter are still in new-formed layers of the bottom sediments.
- The maxima of ^{239,240}Pu concentrations observed in deeper layers of sediments and the ratios of ^{238}Pu to ^{239,240}Pu indicate that nuclear weapon tests were the main source of plutonium contamination.
- Vertical distribution of ^{90}Sr indicates two marked sources of contamination: fallout from the Chernobyl accident and from nuclear weapons tests.

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1.5 ASSESSMENT OF RADIATION DOSES FROM CS-137, RA-226 AND PU-239,240 FOR AQUATIC AND TERRESTRIAL REFERENCE ORGANISMS IN POLAND

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1.5.1 Abstract

The assessment of radiation doses for aquatic and terrestrial reference organisms was performed, based on the methodology elaborated by U.S. Department of Energy. Four organism types and their corresponding dose limits were used, and the principal exposure pathways were considered for aquatic animal, riparian animal, terrestrial plant, and terrestrial animal organism types respectively. Terrestrial rodent (apodemus flavicollis), Baltic Sea fish (cod, sprat, herring, plaice) and crustaceans (Sanduria entomon and Mytilus edulis) were taken in to special consideration. In the first "screening" approach the annual doses from ^{137}Cs and ^{239}Pu (bomb-tests-fallout & Chernobyl origin) and ^{226}Ra (natural radionuclide) to biota were calculated at average, minimum and maximum concentrations of these radionuclides observed in soil, water, and sediment using the default bioaccumulation factors as well as lumped parameters values recommended by DOE Standard. The concentrations of ^{137}Cs measured in the most contaminated region in Poland (Stare Olesno 380 Bq·kg^{-1} d.w.) and the concentrations of ^{226}Ra for Southern regions of Poland with elevated levels of ^{226}Ra in soil (100 Bq·kg^{-1} d.w.) were taken in the dose assessment for terrestrial animals. The concentrations of ^{137}Cs and ^{239}Pu and ^{226}Ra determined in see water and bottom sediments from two sub-areas (Gdańsk Basin and Bornholm Basin) were used in the dose assessment for aquatic biota. In the second "site specific" approach the average empirically measured concentrations of radionuclides in animal tissues were used. At the first approach the total maximal annual radiation doses for terrestrial plants were less then one percent of the recommended dose limits (3600 mGy·y^{-1}) and items for seawater organisms did not exceed a 40% of this limit whereas the total maximal annual doses for terrestrial animal were close to the recommended dose limit (360 mGy·y^{-1}). It prompted to start supplementary site-specific biota dose assessment through site-specific screening and apply site-representative parameters and conditions, with the empirically derived concentration ratios: animal tissue to water, animal tissue to sediment and animal tissue to soil. In this case the calculated annual doses for seawater organisms and terrestrial animals did not exceed one percent and ten percent of the relevant limit respectively. The default animal-water bioaccumulation ratios and animal-soil lump parameter values that are provided by screening methodology can be used with caution when they are applied to dose evaluation for biota.

1.5.2 Introduction

There is growing national and international interest in establishing a regulatory framework (e.g., to include standards or criteria) and supporting evaluation methodologies for demonstrating protection of the environment from the effects of ionizing radiation [1]. Environmental protection is specifically addressed in a number of international conventions and agreements, including "Convention on Environmental Impact Assessment in a Transboundary Context" (ESPOO CONVENTION 1991), "The Joint Convention on the Safety of Spent Nuclear Fuel Management and Radioactive Waste Management" (1997), "Ospar Convention for the Protection of the Marine Environment of the North East Atlantic" (1998) and others [2, 3].

Regarding radiological protection, the ICRP statement that "...if man is adequately protected then other living things are also likely to be sufficiently protected" [4], uses human protection to infer environmental protection from the effects of ionizing radiation. This assumption is most appropriate in cases where humans and other biota inhabit the same environment and have common routes of exposure, and less appropriate in cases where human access is restricted or pathways exist that are much more important for biota than for humans. The Commission is currently reviewing its existing recommendations for the protection of humans with the aim of developing its recommendations for the environment at whole [5]. Nationally and internationally, no standardized methods have been adopted for evaluating doses and demonstrating protection of plants and animals from the effects of ionizing radiation. The IAEA Technical Document, "Protection of the Environment from the Effects of Ionizing Radiation" (1999) references multi-tiered screening as a potentially cost effective and easy way of demonstrating compliance with radiation criteria for protection of biota [6]. Nevertheless U.S. Department of Energy elaborated the screening methodology that enables to estimate upper limit doses for reference organisms of fauna and flora for selected radionuclides [7, 8, 9, 10]. Although, methodologies where the limits derived and biological end points - or risk relating to them are subject of number of questions but the assumption that the population will be adequately protected if the dose rate to the maximally exposed individual does not exceed that level of exposure, with reproduction being the critical end point of concern, could be adopted as practical tool in a case of lack internationally adopted framework. Moreover US DOE Technical Standard provides the relevant methodology and relevant sets of dose assessment parameters. This methodology was adopted as a starting point to create a framework for assessing the impact of radioactive contamination on the environment in Poland.

1.5.3 Materials

Determination of radionuclides in Baltic Sea environment in the frame of MORS [11] gave opportunity to evaluate doses for aquatic organisms from the Southern Baltic Sea. Concentrations of

radionuclides in sea water taken to dose calculation belong to own determinations (^{226}Ra), published data by IMGW (^{137}Cs) [12] and FMHG (^{239,240}Pu) [13]. Monitoring data on concentrations of ^{137}Cs, ^{226}Ra and ^{239,240}Pu in Baltic Sea fish (cod, sprat, herring, plaice) and crustaceans (Sanduria entomon and Mytilus edulis) also measurements' methods description one can find in [14]. The summary of environmental data from the last few years concerning ^{137}Cs (bomb-tests-fallout & Chernobyl origin), ^{226}Ra (natural radionuclide) and ^{239,240}Pu (bomb-tests-fallout) concentrations in biota, bottom sediment and water is presented in Table 1. The concentrations of ^{137}Cs measured in the most contaminated region in Poland (Stare Olesno 380 Bq·kg^{-1} d.w.) and the concentrations of ^{226}Ra for Southern regions of Poland with elevated levels of this radionuclide in soil (100 Bq·kg^{-1} d.w.) [15] and concentrations of ^{137}Cs and ^{226}Ra in surface inland waters [16] were taken in the dose assessment for terrestrial animals. Concentration of ^{137}Cs and ^{226}Ra in terrestrial rodents (Apodemus flavicollis) were also measured [17]. Summary of measurements data for terrestrial environment is shown in Table 2. The doses assessment of ^{137}Cs, ^{226}Ra and ^{239,240}Pu for aquatic and terrestrial animals was performed, based on the screening methodology elaborated by U.S. Department of Energy [8-10]. The following pathways of exposure for organisms were considered i.e. external doses from the concentrations of radionuclides determined in water, sediments and soil respectively, and internal doses from radionuclides concentrations observed in animal tissues. Calculations were performed using conservative assumptions about external dose conversion factors for simplified geometry and uniform distribution of radionuclide in animal tissues. The dose conversion factors used are presented in Table 3 and Table 4. The calculated doses were compared to the relevant recommended biota dose limits. These limits were proposed by US DOE as criteria to avoiding impairment of reproductive capability, e.g. the absorbed dose to aquatic animals and plants should not exceed 10 mGy·d^{-1} (3600 mGy·y^{-1}) and for terrestrial animals 1 mGy·d^{-1} (360 mGy·y^{-1}) from exposure to radiation or radioactive material releases into the environment [9].

Table 1. The environmental data from the last years concerning ^{137}Cs, ^{226}Ra and $^{239,240}Pu$ concentrations in biota, bottom sediment and water, (minimum and maximum observed values are shown in parenthesis).

Radionuclide	Bottom sediments layer: 0-10 cm period 1997-2001 $Bq \cdot kg^{-1}$ dry mass	Baltic Sea surface water periods 2000, 2001 $Bq \cdot L^{-1}$	Baltic Sea fish: cod, sprat, herring, plaice period 1998-2001. $Bq \cdot kg^{-1}$ fresh mass	Baltic Sea bottom animals, period 1998-2001 ($Bq \cdot kg^{-1}$ fresh mass)	
				Sanduria entomon	Mytilus edulis
^{137}Cs	1.2×10^{2} ($5.8\times10^{1}\div2.2\times10^{2}$)	5.8×10^{-2} ($1.7\times10^{-2}\div7.4\times10^{-2}$)	9.0 ($6.6\div1.2\times10^{1}$)	4.0 (2.2 ÷ 6.3)	1.2 ($5.8\times10^{-1}\div2.1$)
^{226}Ra	3.6×10^{1} ($2.6\times101\div4.9\times10^{1}$)	3.0×10^{-3} ($2.0\times10^{-3}\div3.7\times10$-3)	5.0×10^{-2} ($2.9\times10^{-2}\div7.1\times10$-2)	1.6 (1.1÷2.5)	1.7×10^{-1} ($1.4\times10^{-1}\div2.1\times10^{-1}$)
$^{239,240}Pu$	2.8 ($8.7\times10^{-1}\div5.5$)	3.6×10^{-6} ($1.6\times10^{-6}\div5.6\times10^{-6}$)		9.5×10^{-3} ($5.7\times10^{-3}\div1.9\times10^{-2}$)	4.0×10^{-3} ($2.5\times10^{-3}\div5.9\times10^{-3}$)

Table 2. The environmental data from the last years concerning ^{137}Cs, ^{226}Ra concentrations in biota, soil and surface water, (minimum and maximum observed values are shown in parenthesis).

Radionuclide	Soil layer: 0-10 cm period 1989-2001 $Bq \cdot kg^{-1}$ dry mass	Surface water period 1990- 2001. $Bq \cdot L^{-1}$	Inland waters sediment period 1998-2001. $Bq \cdot kg^{-1}$ dry mass	Terrestrial animals (apodemus flavicollis) period 1998-2001 ($Bq \cdot kg^{-1}$ fresh mass)
^{137}Cs	2.5×10^{1} ($1.0\times10^{1}\div3.8\times10^{2}$)	4.0×10^{-3} ($1.5\times10^{-3}\div1.4\times10^{-2}$)	8.8×10^{2} ($4.0\times10^{2}\div2.4\times10^{2}$)	7.2×10^{2} ($4.0\times10^{2}\div2.2\times10^{3}$)
^{226}Ra	2.5×10^{1} ($1.0\times10^{1}\div1.4\times10^{2}$)	4.0×10^{-3} ($2.0\times10^{-3}\div1.6\times10^{-2}$)	5.0×10^{-2} ($2.9\times10^{-2}\div7.1\times10^{-2}$)	1.2 ($6.0\times10^{-1}\div2.2$)

Table 3. Dose conversion factors applied in dose calculation according to DOE-STD-1153-2002

Radionucklide	Dose conversion factors			
	External exposure			Internal exposure
	soil $\frac{mGyy^{-1}}{Bqkg^{-1}dry}$	water $\frac{mGyy^{-1}}{BqL^{-1}}$	sediment $\frac{mGyy^{-1}}{Bqkg^{-1}dry}$	tissues $\frac{mGyy^{-1}}{Bqkg^{-1}fresh\ mass}$
$^{137}Cs+^{137m}Ba$	4.0×10^{-3}	2.0×10^{-3}	2.0×10^{-3}	4.3×10^{-3}
^{226}Ra +D* (RBEα=20)	1.4×10^{-2}	6.8×10^{-3}	6.8×10^{-3}	3.0
^{239}Pu (RBEα=20)	2.8×10^{-5}	1.4×10^{-4}	1.4×10^{-5}	5.3×10^{-1}

Table 4. Bioaccumulation factors for aquatic animals and lumped parameters for terrestrial animals according to DOE-STD-1153-2002.

Radionucklide	Aquatic	Terrestrial		Riparian	
	Animal-water ratio $\frac{L}{kg_{\text{fresh mass}}}$	Animal-water ratio $\frac{L}{kg_{\text{fresh mass}}}$	Animal-soil ratio $\frac{kg_{soil}}{kg_{\text{fresh mass}}}$	Animal-water ratio $\frac{L}{kg_{\text{fresh mass}}}$	Animal-sediment ratio $\frac{kg_{sediment}}{kg_{\text{fresh mass}}}$
$^{137}Cs+^{137m}Ba$	2.2×10^{4}	3.0	1.0×10^{2}	5.0×10^{4}	3.0×10^{-1}
^{226}Ra +D* (RBEα=20)	3.2×10^{3}	4.0×10^{-1} (1.1×10^{1})*	6.0×10^{-2} (1.3)*	8.0×10^{2}	3.0×10^{-2}
^{239}Pu (RBEα=20)	1.0×10^{3}	9.0×10^{-2}	3.0×10^{-3}	3.0×10^{1}	3.0×10^{-3}

*values used previously by DOE-STD-draft and RESRAD-BIOTA 1.0 12/20/2001

1.5.4 Results

In the first "screening" approach the annual doses from ^{137}Cs and ^{239}Pu (bomb-tests-fallout&Czarnobyl origin) and ^{226}Ra (natural radionuclide) to biota were calculated at average, minimum and maximum concentrations of these radionuclides observed in soil, water, and sediment. The default bioaccumulation factors for aquatic animals as well as lumped parameters values for plants, terrestrial and riparian animals recommended by DOE Standard were applied.

The doses from ^{137}Cs to the terrestrial plants and aquatic animals do not exceed a few percent of recommended dose limits. Maximal doses for terrestrial animals in the most contaminated region in Poland (Stare Olesno 380 Bq·kg^{-1} d.w.) were about 10% of the dose limit (360 mGy·y^{-1}).

The doses from ^{226}Ra to riparian animals living in inland aquatic environment were about 70% of the dose limit. The maximum doses of 390 mGy·y^{-1} were obtained for terrestrial animal living in Southern regions of Poland with elevated levels of ^{226}Ra concentration in soil (100 Bq·kg^{-1} d.w.) These doses are close to the dose limit (360 mGy·y^{-1}). It suggested considering the need of conducting an analysis through site-specific analysis and employing the site-representative parameters and conditions or an actual site-specific biota dose assessment.

Therefore, in the next "site – specific" approach the Baltic Sea fish (cod, sprat, herring, plaice) and crustaceans (Sanduria entomon and Mytilus edulis) as well as terrestrial rodents (Apodemus flavicollis) were taken in to consideration. The annual doses from ^{137}Cs , ^{226}Ra and ^{239}Pu to organisms were calculated at average concentrations of these radionuclides observed in animal tissues. Doses for ^{239}Pu are overestimated of about 20 % because the concentrations of 239,240Pu were used in the calculations. (The ratio of ^{240}Pu to ^{239}Pu in global fallout is about 0.18).

The results of doses evaluation are summarized in Table 5, Table 6, Table 7, Table 8 for Baltic Sea fish, Saduria entomon, Mytilus edulis and Apodemus flavicollis, respectively.

The total maximal annual doses to seawater organisms did not exceed a one percent of recommended dose limits however, the dominate contribution to the total dose depends on analyzed radionuclide. For ^{137}Cs a maximum contribution to the total dose gave external dose from bottom sediment (about 0.5 $mGy \cdot y^{-1}$). Only about 1% of the total ^{137}Cs dose was derived from internal dose however, animal-water ratio obtained from measurements was much lower (in a range 30-300 $L \cdot kg^{-1}$) comparing with recommended by DOE Standard value (22000 $L \cdot kg^{-1}$). For ^{226}Ra internal doses for fish and mytilus were similar (0.2 $mGy \cdot y^{-1}$, 0.6 mGy y^{-1} respectively) and they were comparable with external doses from sediment (0.3 $mGy \cdot y^{-1}$) whereas internal dose for sanduria was about 10 times higher (7 $mGy \cdot y^{-1}$). A measured animal- water ratios (20 - 500 $L \cdot kg^{-1}$) differed remarkably from default DOE Standard value (3200 $L \cdot kg^{-1}$). Internal dose from plutonium ^{239}Pu was the main contributor to the total dose of crustaceans but total dose lay pretty far below the dose limit. The contribution of external dose from water is negligible for all analyzed radionuclides. A measured animal-water ratios for Mytilus edulis (2600 $L \cdot kg^{-1}$) was much higher then default DOE Standard value (1000 $L \cdot kg^{-1}$) and it suggested careful verification of this parameter.

The total maximal annual doses to terrestrial rodent from ^{137}Cs and ^{226}Ra did not reach 15% of recommended limit where ^{137}Cs ingestion dose was the main contributor. External doses from ^{137}Cs and ^{226}Ra were comparable (maximal dose 1.5 $mGy \cdot y^{-1}$ and 2 $mGy \cdot y^{-1}$ respectively). Although for ^{226}Ra the ingestion pathway still dominate (maximal dose 8.5 $mGy \cdot y^{-1}$), but empirically obtained lumped parameters - animal/soil of about 0.01 was folder six lower then currently recommended DOE Standard value (0.06). Nevertheless, value 0.06 could be acceptable for screening purposes. However, when one applies previously reported values 1.29 (DOE-STD-draft and RESRAD-BIOTA 1.0 12/20/2001) then one would get dose values exciding recommended dose limit of 360 $mGy \cdot y^{-1}$.

The default animal-water bioaccumulation ratios and animal-soil lump parameter values that are provided by screening methodology can be used with caution when they are applied to dose evaluation for biota.

Table 5. Annual doses for Baltic Sea fish (cod, sprat, herring, plaice), (minimum and maximum values in parenthesis).

Radionuclide	Sediment external dose mGy·y^{-1}	Water external dose mGy·y^{-1}	Internal dose mGy·y^{-1}	empirically measured bioaccumulation factors and values suggested by screening methodology L·kg^{-1} fresh mass	Total dose mGy·year^{-1}
^{137}Cs	2.4×10^{-1} ($1.2\times10^{-1}\div4.5\times10^{-1}$)	1.2×10^{-4} ($3.4\times10^{-5}\div1.5\times10^{-4}$)	3.9×10^{-2} ($2.8\times10^{-2}\div5.2\times10^{-2}$)	155 (160÷390) 22000*	2.8×10^{-1} ($1.4\times10^{-1}\div5.0\times10^{-1}$)
^{226}Ra	2.4×10^{-1} ($1.7\times10^{-1}\div3.3\times10^{-1}$)	2.0×10^{-5} ($1.4\times10^{-5}\div2.5\times10^{-5}$)	1.5×10^{-1} ($8.7\times10^{-2}\div2.1\times10^{-1}$)	17 (14÷19) 3200**	3.9×10^{-1} ($2.6\times10^{-1}\div5.4\times10^{-1}$)
Sum	4.8×10^{-1} ($2.9\times10^{-1}\div7.8\times10^{-1}$)	1.4×10^{-4} ($4.8\times10^{-5}\div1.7\times10^{-4}$)	1.9×10^{-1} ($1.2\times10^{-1}\div2.7\times10^{-1}$)		6.7×10^{-1} ($4.0\times10^{-1}\div1.0$)

*value adapted by DOE Standard derived from crustaceans

** value adapted by DOE Standard derived from freshwater gammarus

Table 6. Annual doses for in Baltic Sea bottom animals (Saduria entomon), (minimum and maximum observed values are shown in parenthesis).

Radionuclide	Sediment external dose mGy·y^{-1}	Water external dose mGy·y^{-1}	Internal dose mGy·y^{-1}	Empirically measured bioaccumulation factors and values suggested by screening methodology L·kg^{-1} fresh mass	Total dose mGy·y^{-1}
^{137}Cs	2.4×10^{-1} ($1.2\times10^{-1}\div4.5\times10^{-1}$)	1.2×10^{-4} ($3.4\times10^{-5}\div1.5\times10^{-4}$)	1.7×10^{-2} ($9.6\times10^{-3}\div2.7\times10^{-2}$)	69 (85÷132) 22000*	2.6×10^{-1} ($1.3\times10^{-1}\div4.8\times10^{-1}$)
^{226}Ra	2.4×10^{-1} ($1.7\times10^{-1}\div3.3\times10^{-1}$)	2.0×10^{-5} ($1.4\times10^{-5}\div2.5\times10^{-5}$)	4.9 (3.2 ÷ 7.4)	540 (520÷660) 3200**	5.1 (3.4 ÷7.7)
^{239}Pu	3.9×10^{-5} ($1.2\times10^{-5}\div7.7\times10^{-5}$)	5.0×10^{-11} ($2.2\times10^{-11}\div7.8\times10^{-11}$)	4.9×10^{-3} ($3.2\times10^{-3}\div7.4\times10^{-3}$)	2600 (1600÷5200) 1000***	5.0×10^{-3} ($3.0\times10^{-3}\div1.0\times10^{-2}$)
Sum	4.8×10^{-1} ($2.9\times10^{-1}\div7.8\times10^{-1}$)	1.4×10^{-4} ($4.8\times10^{-5}\div1.7\times10^{-4}$)	4.9 (3.2 ÷7.4)		5.4 (3.5 ÷ 8.2)

*value adapted by DOE Standard derived from crustaceans

** value adapted by DOE Standard derived from freshwater gammarus

*** value adapted by DOE Standard derived from crustaceans

Table 7. Annual doses for in Baltic Sea bottom animals (Mytilus edulis), (minimum and maximum values in parenthesis).

Radionuclide	Sediment external dose $mGy \cdot y^{-1}$	Water external dose $mGy \cdot y^{-1}$]	Internal dose $mGy \cdot y^{-1}$	Empirically measured bioaccumulation factors and values suggested by screening methodology $L \cdot kg^{-1}$ fresh mass	Total dose $mGy \cdot y^{-1}$
^{137}Cs	2.4×10^{-1} ($1.2\times10^{-1}\div4.5\times10^{-1}$)	1.2×10^{-4} ($3.4\times10^{-5}\div1.5\times10^{-4}$)	5.1×10^{-3} ($2.5\times10^{-3}\div9.2\times10^{-3}$)	30 (20÷35) 22000*	2.4×10^{-1} ($1.2\times10^{-1}\div4.6\times10^{-1}$)
^{226}Ra	2.4×10^{-1} ($1.7\times10^{-1}\div3.3\times10^{-1}$)	2.0×10^{-5} ($1.4\times10^{-5}\div2.5\times10^{-5}$)	5.2×10^{-1} ($4.2\times10^{-1}\div6.3\times10^{-1}$)	60 (56÷70) 3200**	7.7×10^{-1} ($5.9\times10^{-1}\div9.6\times10^{-1}$)
^{239}Pu	3.9×10^{-5} ($1.2\times10^{-5}\div7.7\times10^{-5}$)	5.0×10^{-11} ($2.2\times10^{-11}\div7.8\times10^{-11}$)	2.1×10^{-3} ($1.3\times10^{-3}\div3.1\times10^{-3}$)	1110 (690÷1640) 1000**	2.1×10^{-3} ($1.3\times10^{-3}\div3.2\times10^{-3}$)
Sum	4.8×10^{-1} ($2.9\times10^{-1}\div7.8\times10^{-1}$)	1.4×10^{-4} ($4.8\times10^{-5}\div1.7\times10^{-4}$)	5.3×10^{-1} ($4.2\times10^{-1}\div6.4\times10^{-1}$)		1.0 ($7.1\times10^{-1}\div1.4$)

*value adapted by DOE Standard derived from crustaceans

** value adapted by DOE Standard derived from freshwater gammarus

*** value adapted by DOE Standard derived from crustaceans

Table 8. Annual doses for terrestrial rodent (Apodemus flavicollis), (minimum and maximum calculated values are shown in parenthesis.

Radionuclide	Soil external dose $mGy \cdot y^{-1}$	Water external dose $mGy \cdot y^{-1}$	Soil internal dose $mGy \cdot y^{-1}$	Water internal dose $mGy \cdot y^{-1}$	Empirically measured lumped parameters and values suggested by screening methodology	Total dose $mGy \cdot y^{-1}$
^{137}Cs	8.0×10^{-1} ($4.0\times10^{-2}\div1.5$)	8.0×10^{-6} ($2.0\times10^{-6}\div2.8\times10^{-5}$)	6.0 ($1.3\times10^{-1}\div2.8\times10^{1}$)	5.8×10^{-5} ($1.5\times10^{-5}\div2.0\times10^{-4}$)	7.1 (2.4÷17) 100*	6.8 ($1.7\times10^{-1}\div2.9\times10^{1}$)
^{226}Ra	3.5×10^{-1} ($1.4\times10^{-1}\div2.0$)	2.7×10^{-5} ($1.4\times10^{-5}\div1.1\times10^{-4}$)	9.1×10^{-1} ($1.8\times10^{-1}\div8.5$)	4.8×10^{-3} ($2.4\times10^{-3}\div1.9\times10^{-2}$)	1.2×10^{-2} ($6\times10^{-3}\div2.0\times10^{-2}$) 6×10^{-2}*	1.3 ($3.2\times10^{-1}\div1.0\times10^{1}$)
Sum	1.95 ($1.8\times10^{-1}\div4.5$)	3.5×10^{-5} ($1.4\times10^{-5}\div1.4\times10^{-4}$)	6.9 ($1.9\div3.6\times10^{1}$)	4.9×10^{-3} ($2.5\times10^{-3}\div1.9\times10^{-2}$)		8.1 ($4.9\div3.9\times10^{1}$)

*values adapted by DOE Standard

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1.6 CREATING OF A DATA BASE WITH IN VITRO DOSE-RESPONSE CURVES FOR CYTOGENETIC DOSE ASSESSMENT IN EMERGENCY RADIATION EXPOSURES

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The wide use of radioactive sources and X-rays in medicine, industry and research, as well as illicit use of radioactive materials, increase the risk of overexposure of occupationally exposed persons and members of the general population. In the case of overexposure, an approximate and rapid assessment of doses received is important for two reasons. The knowledge of radiation doses will help to plan for the therapy of persons exposed above the threshold for early somatic effects of radiation, and these data will assist in counselling for the risk of late cancer diseases.

Biological dosimetry, based on the study of chromosome damage in lymphocyte preparations from a peripheral blood of an overexposed person, has been a routine component of accidental dose assessment (*IAEA, Vienna 2001: Cytogenetic Analysis for Radiation Dose Assessment: A manual. Technical Reports Series No.405*). Experience of its application in hundreds of cases of suspected or verified overexposures has proved the value of the method. It is sensitive and reliable, does not require a large blood sample, can be performed at any moment and can not be intentionally modified by the subject under study. Three different cytogenetic methods are currently available for biodosimetry. These are dicentric, micronucleus and fluorescence in situ hybridisation (FISH) based translocation assays. The dicentric assay is routinely used for dose assessment in the case of an accident involving a few subjects. In a mass accident involving a large number of subjects overexposed with various levels of ionising radiation, the micronucleus assay is the method of choice for rapid dose assessment. The FISH based translocation assay is the only method for assessing a chronic dose or a dose received many years ago. The cytogenetic endpoints scored in the lymphocytes of exposed or suspected persons are interpreted in terms of absorbed dose by reference to a dose response calibration curve. This curve is produced by exposure of blood *in vitro* to calibration doses of the appropriate quality radiation. The doses given to the blood samples have to be monitored with a physical instrument calibrated by the secondary standard dosimetry laboratory.

In the years 2002-2003, the Central Laboratory for Radiological Protection started to organize a service point for accidental dose assessment by cytogenetic biodosimetry. Organizing of this point was supported by the State Committee for Scientific Research under the grant No. 6T11 0051 2002C/05826. From funds of the grant the CLOR was equipped with the fluorescence microscope, water bath, oven, hot plate, centrifuge, shaker, and pH meter for conventional and FISH analysis of chromosome damage. All three cytogenetic assays were adapted to use in the CLOR and standard

procedures of blood collection, blood culturing and fixation the blood cultures were prepared according to the IAEA recommendations.

Moreover, the study of the relationship between exposure to a range of doses of X-rays or Co^{60} γ-rays and the frequency of micronuclei in peripheral blood lymphocytes (PBL) of 3 female and 3 male donors of different age was started. All blood donors were volunteers informed about the aim of the study and experimental details. These dose response data will be used for producing *in vitro* dose-response calibration curves.

*The Maria Skłodowska-Curie Institute of Oncology and Cancer Centre in Warsaw.

ACKNOWLEDGEMENTS

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2 PUBLIC SERVICE – RADIATION SAFETY AND RADIOLOGICAL MONITORING

2.1 PREVENTION AND EMERGENCY SERVICE

Roman Tańczyk
Prevention and Emergency Service Department

Following tasks are performed by the Dispatch Center of Emergency Service (ODSA) CLOR

a. Accepting notices on radiological accidents and incidents,

b. „First-aid" advising and recommendations,

c. Supervising the remedial actions after radiological accidents and incidents,

d. Notification of police on the radiological emergency.

In order to perform these tasks, the officer of ODSA and a team of health physics engineers are on round - the - clock duty at CLOR. Their means of communication include the emergency telephone (number 0-22 811-15-15). A car and dosimetric equipment (portable radiation monitors, spectrometer, containers and manipulators) are at their disposal. The officer on duty decides on dispatching the emergency team.

In spite of a strict control of use and disposal of radioactive materials, a number of incidents have taken place in the past two years. The most serious incidents were caused by blocking the sources in gamma radiography units. In some cases, the sources were lost, stolen or misplaced. These incidents are presented in Table 1.

Table 1. Radiological incidents in Poland.

Type of incident	Number of radiological incidents in year:	
	2002	2003
Robbed, damaged or lost sources	8	8
Uncontrolled source in a public area, smuggling or illegal possessing of sources	10	9
Fire at the place of radiation source	1	2
Disturbance in work of devices with a source	1	5
other	13	9
Total	33	2036

In 2002 - 2003 ODSA collaborated with the:

National Fire Guard in preventing accidents involving radiation hazard,

Border Guard in preventing uncontrolled exportation and importation of radiation sources,

Police and State Security services in preventing illegal nuclear and radioactive traffic.

At the end of 2002 2285 users of radioactive sources were registered in the ODSA-CLOR data base. The sources are utilized in medicine, research, industry and agriculture. Dealers and producers of radioactive sources are also registered. Documents on licensing and activities of the users are stored in CLOR. Type and number of plants and sealed sources are presented in Table 2 and 3.

Table 2. Number of registered plants using radioactive sources.

Kind of plants	Number of plants		
	Started in 2002 - 2003 years	Stopped in 2002 - 2003 years	Total at the end of the 2003 year
Industrial plants - sealed sources	25	66	890
Laboratories - unsealed sources	9	46	329
Laboratories - unsealed and unsealed sources	1	4	47
Laboratories - sealed sources	11	19	365
Laboratories - accelerators and sealed sources	0	0	20
Laboratories - accelerators	3	2	26
Magazines of radioactive materials	44	50	417
Total	92	186	2094

Table 3. Number of registered sealed sources used at the end of the 2003-year

Isotope	Number of sealed sources	Total activity [TBq]
Am-241	1774	14,20
Pu-239	4191	32,15
Cf-252	14	0,004
Co-60	6176	5331,80
Cs-137	2142	1258,70
Kr-85	192	0,82
Ra-226	523	1,10
other	2485	
Total	17497	

ACKNOWLEDGEMENTS

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2.2 POLISH WARNING POINT OF THE INTERNATIONAL NOTIFICATION SYSTEM FOR NUCLEAR ACCIDENTS AND RADIOLOGICAL EMERGENCIES

Roman Tańczyk

Prevention and Emergency Service Department

The Polish Warning Point (PWP) is operated by officers working in 24 hours cycle, and by experts on the „call duty". For economy reasons, the officer on duty in the point of contact is at the same time the officer on duty in the Dispatch Centre of Emergency Service.

In 2002 – 2003 PWP has received 55 information concerning emergencies and exercises in which PWP participated.

Here are several of them:

an INES 3 event during transportation of radioactive material from Studsvik′s nuclear facility 100 km south of Stockholm to USA (January 2002),

finding Co-60 contaminated steel slabs (originated from a foundry in Skopje in the Former Yugoslavian Republic of Macedonia) in three different shipyards in Italy (January – March 2002),

finding two unshielded Sr-90 sources by three persons from the Republic of Georgia who received estimated doses of 4-5 Gray each (January – February 2002),

missing two AM-Be radioactive sources belonging to an oil service company operating in the Niger Delta in Nigeria (February – March 2003),

emergency exercise "Zona 2002" in the NPP Temelin (March 2002),

exercise "Procedure Trial" organised by ERC-IAEA,

exercise "CONVEX 1a" organised by ERC-IAEA (July 2003),

exercise "CONVEX 2a" organised by ERC-IAEA (November 2003).

ACKNOWLEDGEMENTS

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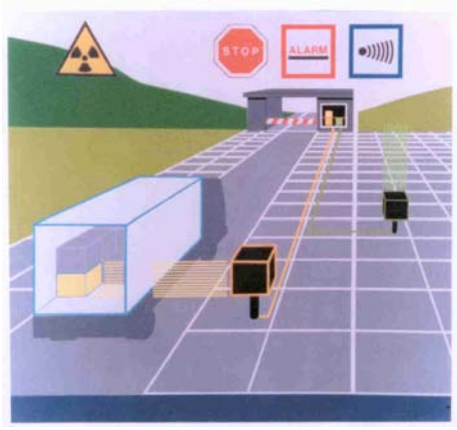
2.3 SUPPORT TO COMBAT ILLICIT TRAFFICKING IN NUCLEAR AND RADIOACTIVE MATERIALS

S. Sterliński, G. Smagała, D. Grabowski, K. Isajenko, I. Kamińska, P. Lipiński, M. Suplińska, R. Tańczyk



Since 2002 activities to support the countermeasures against illicit nuclear traffic have been intensified and tightened within the Central Laboratory for Radiological Protection - CLOR. Its hitherto operational activity of providing assistance to the law enforcement services in detection of nuclear and radioactive materials of unknown origin and response to illicit trafficking cases involving such materials, had to be upgraded and adjusted not only to the new legal provisions, but also to the current security concerns.

Moreover, countries like Poland had been offered an international help in establishing a system for improved response to combat nuclear trafficking. CLOR providing the whole territory radiological emergency service, and performing categorization and measurements of the all seized nuclear and radioactive materials in Poland, was pointed out by the President of the National Atomic Energy Agency (NAEA) to be the executor of the project proposed by the European Commission (EC). With the assistance of the European Institute for Transuranium Elements (ITU) in Karlsruhe, under the PECO (Pays Europe Centrale Orientale) project of the EC Joint Research Centre (JRC), CLOR has elaborated the handbook for the response to illicit trafficking, or inadvertent movement of nuclear and radioactive materials in Poland. The book is compatible with the model action plan (MAP) recommended for the Response to Illicit Trafficking of NUclear Material (RITNUM) by the International Technical Working Group (ITWG) created under the auspices of the G-8 Non-Proliferation Experts Group. Besides its primary aim of implementing the MAP into the response system to illicit nuclear cases, the project included upgrading capabilities of the radioanalytical laboratory, i.e. CLOR, to accurately categorize and characterize on-site the seized radioactive and nuclear materials.

The final product of the project i.e. the RITNUM handbook should be validated in a demo exercise in the field, which is the on-going action to be finalized in 2004.

Only consolidated action and co-operation between all institutions involved in response system to illicit trafficking in nuclear and radioactive materials enable an effective prevention and elimination of hazards involved in inadvertent or intentional use of such materials. The process following a seizure of radioactive material of unknown origin requires involvement and expertise in several fields, such as radiation protection, health physics, pyrotechnics, criminal investigation, laboratory analysis, nuclear material safeguards and its physical protection, transport, etc.. In addition, an international cooperation is available when needs arise to perform further special analysis of material, or of data acquisition on the producer of material. This necessitates a well-defined cooperation between Competent Authorities and other organizations, both domestically and internationally. Each identified authority and service should have its internal procedures to execute the specified duties after the seizure of radioactive and nuclear materials of unknown origin.

The current version of the handbook number 05 is the result of a two year work carried out with participation and contribution of the all identified entities involved in this issue in Poland. This product of the interdepartmental involvement of CLOR was subject to verification process.
The most important role in that respect played the following events:

- the first meeting with competent authorities and services of the central administration held on 4 June 2002 in Warsaw;
- the review meeting of the PECO project held, with participation of state and local (from the Podlasie Province) competent authorities and services and with the representatives of the ITU and of the International Atomic Energy Agency (IAEA), on 1-2 April 2003 in Warsaw;
- the tabletop exercise on the response to incidents involving the seizure of illegally possessed nuclear and radioactive materials carried out in Warsaw on 7 October 2003.

In the October 2003 exercise participated more than 50 persons from 26 institutions. The main players of the game were the representatives of the competent authorities and services of the Podlasie Voivodship, where the predetermined place of the emergency event was located. The main players were supported by the representatives of central administration authorities and services, specialized institutions and independent experts.
The main objectives of the tabletop exercise were to:

- test cooperation of the competent authorities and services involved in the response action;
- verify a draft of the RITNUM Handbook.

The in-field demonstration exercise will enable the verification of the handbook and will help to elucidate what are Poland's competencies in categorization and identification of radioactive and nuclear materials, besides the operational and logistic ones.

Categorization, as was explained in the handbook, is to answer questions such as, for example, what it is, isn't it a washing powder, but a plutonium oxide, is it a contaminated scrap, or a radioactive source embedded in the scrap, etc.

In the case of the gamma emitters, it is known that, the matter is solved usually with the use of the hand, mobile or the stationary devices. The problem is with the categorization of the fissile materials, especially on the site of the incident, which cannot be performed with a simple instrument. Determination in the field, e.g. what is the enrichment of a seized uranium sample needs techniques and instruments more advanced than those installed at the Mobile Spectrometric Laboratory being at the disposal of the CLOR experts. At present this task can be performed in the measurement laboratories at the premises of CLOR by non-destructive analyses, or destructive methods.

Identification of nuclear material should answer where the fissile material comes from, who was its producer and what was the route of smuggling. Laboratories already operating highly sophisticated nuclear forensic applications and having databases with chemical and physical characteristics of the produced in the world fissile materials are able to provide a fully professional expert opinion for the legal prosecution procedures.

Some information on the nature of the threat (radiotoxicity, weapon applicability) of the seized nuclear material, or on its physical and chemical properties can be provided by the scientists from CLOR. Other important classical forensics information needed to support prosecution, can be provided by the law enforcement services, such as criminal police laboratories. Close cooperation of these two expert groups and sharing their results and experience, is most desirable. If the need arises to apply

highly advanced nuclear forensic expertise, the sample of plutonium or uranium should be send to the ITU or the IAEA laboratory for analysis. Poland can request the help of the ITU on the grounds of the signed agreement, between the President of the NAEA and Director of CLOR from Poland's side, and the Director of the ITU from the EC side, on performing at the premises of ITU, a joint analysis by ITU and CLOR experts, of the seized nuclear material.

CLOR systematically tests and upgrades its technical and professional capabilities, but much more is still in waiting for financing to be upgraded and expanded.

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2.4 MOBILE SPECTROMETRIC LABORATORY

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Dosimetry Department

2.4.1 Introduction

In 1999, following the Agreement between Polish and Danish governments, the Kingdom of Danmark donated to Poland a Toyota LandCruiser GX-90 car, with the Mobile Spectrometric Laboratory installed.

In 2000 the car was transferred to the Central Laboratory for Radiological Protection (CLOR) and, according to the agreement between CLOR and the Polish National Atomic Energy Agency (PAA), it will be used for:

- measuring of the radioactive contamination of environment, both along the measurement routes and in-situ;
- creating of the radiological maps of various regions of Poland;
- identification and search for the lost radioactive sources;
- assisting in activities of the border guard and security authorities in preventing illicit trafficking and inadvertent movement of radioactive sources;
- other emergency purposes.

Fig. 1. Mobile Spectrometric Laboratory.

2.4.2 Equipment

The scintillation detector type Exploranium GPX-256 with the NaI(Tl) crystal having the volume of 4 litres (dim. 16" x 4" x 4") is mounted on the roof of the car. The detector is placed in the aluminium container and covered with the polyurethane foam. Its task is to permanently measure the environmental gamma spectra, both along the measuring route and while standing.

Fig. 2. GPX-256 detector with the NaI(Tl) crystal.

The Mobile Spectrometric Laboratory is also equipped with the GR-660 system mounted on the back seat of the car in the special shockproof container. The GR-660 system consists of the on-board computer with touch screen connected to the computer with a long cable. The computer stores the collected measurement data and performs the on-line visualization. The second element of the GR-660 system is 256-channel spectrum analyzer Exploranium GR-320 connected to the detector placed on the roof of the car (Fig. 3). The computer works under the control of Windows 2000.

Fig. 3. System GR-660 with the computer and GR-320 analyzer.

Additionally the Laboratory is equipped with the portable NaI(Tl) detector type GPX-21A. When there is a need to perform measurements outside the car the spectrometer can be dismounted and used as a portable device with this detector.

Fig. 4. GPX-21A – portable NaI(Tl) detector

Fig. 5.Geographic Positioning System.

Besides, the car is equipped with the differential Geographic Positioning System (DGPS) allowing very precise determination of the position of the car (within 0.5 meters). The results from the DGPS are transferred to the on-board computer. The measuring route is presented on the screen and the collected data allow preparing the radiological maps.

Fig. 6. Exploranium miniSpec GR-130.

Additionally the Mobile Spectrometric Laboratory is equipped with the hand-held nuclide identifier Exploranium miniSpec GR-130. It has NaI(Tl) detector for the determination of dose rate, search for the sources and collection of the gamma spectra. For the measurements in the high-dose fields it has GM detector. At the high level of the dose rate, the device automatically switches to use GM for dose rate measurement.

2.4.3 Results

The Mobile Laboratory is used by CLOR for many different tasks including search for the orphan, or lost sources, preparation of the radiological maps of the measured areas, etc. Outfitted with additional equipment it is often used in cooperation with state security services (Border Guard, Police etc.). The Mobile Laboratory is used for monitoring of the area near Różan Radioactive Waste Repository and Nuclear Reactor in Świerk.

Below is the example of the maps of the Cs-137 levels around Różan (fig. 7) and Świerk (fig. 8):

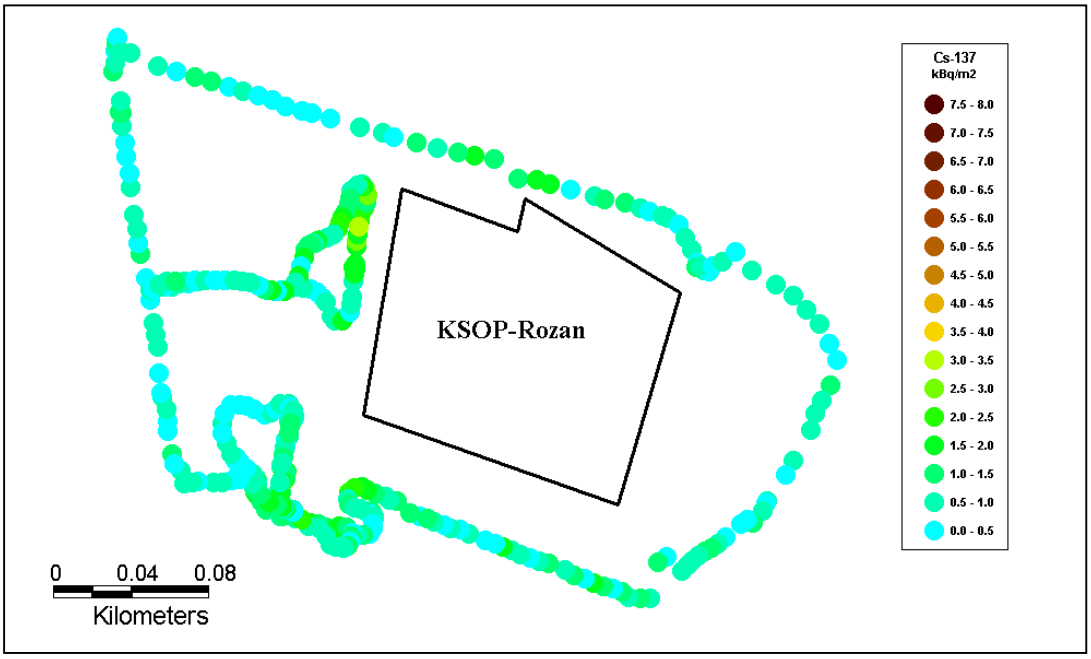

Fig. 7. Cs-137 concentration near Różan Radioactive Waste Repository.

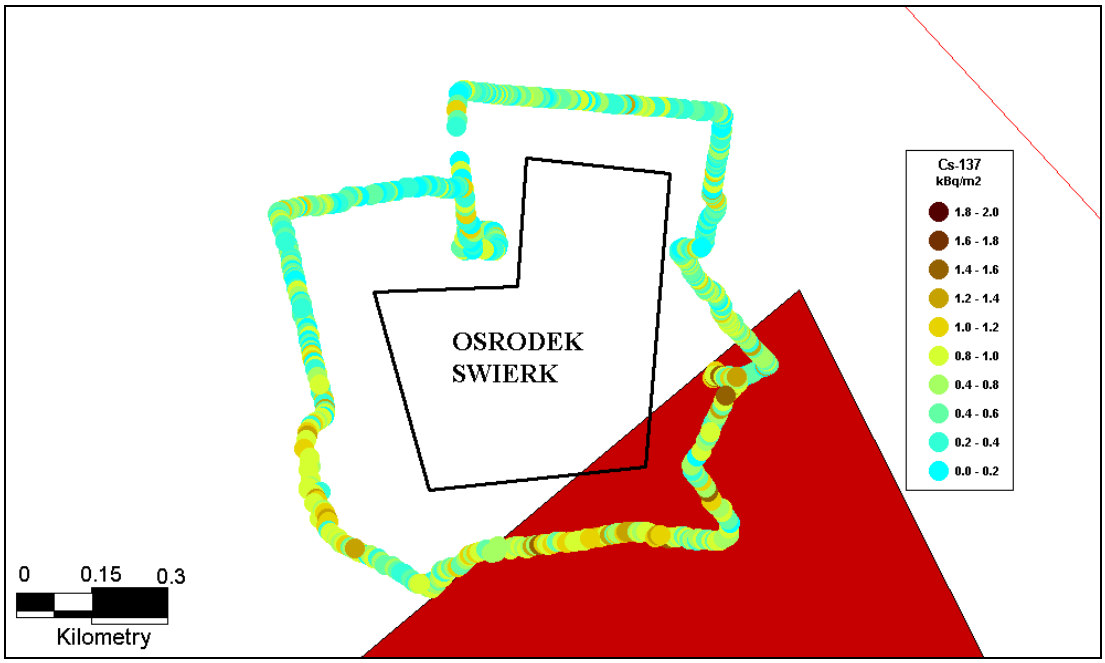

Fig. 8. Cs-137 concentration near Świerk Nuclear Centre

In September 2003 Mobile Laboratory was used to map the area of the former uranium mining waste dump in Radoniów (south-west Poland) [2].

The example of the mapping capabilities for uranium content in the soil are presented on figure 8.

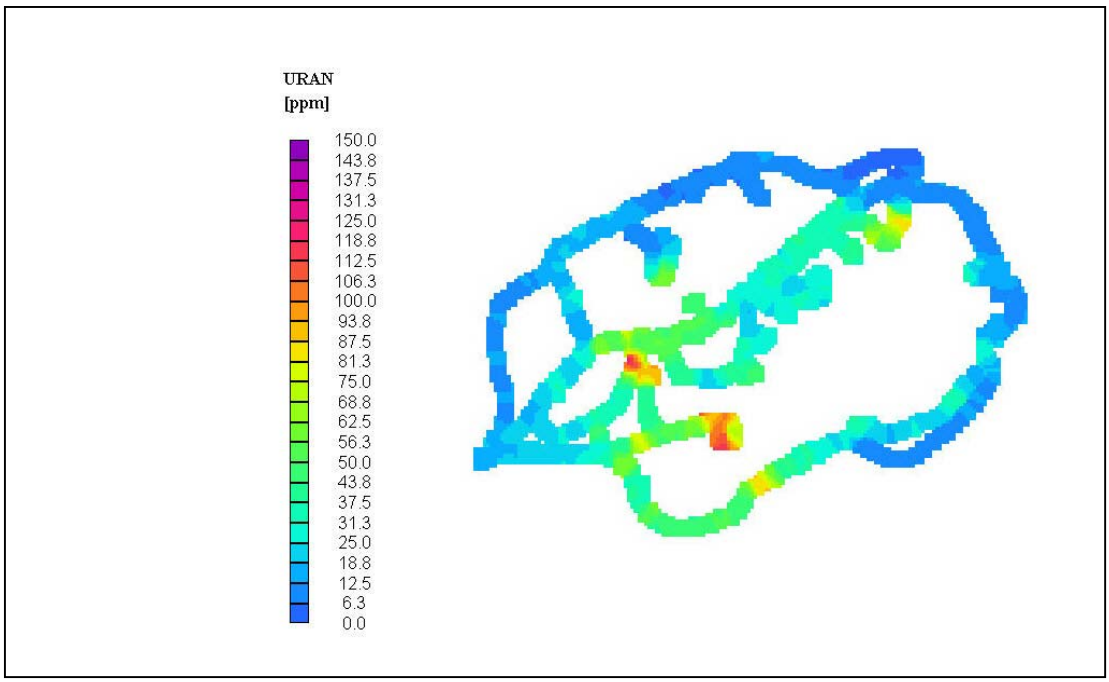

Fig. 8. Uranium concentration in soil near Radoniów

In September 2003 the mobile Laboratory participated in the International Mobile Spectrometric Laboratories Exercise TURAWA 2003, organized by CLOR near Opole [1]. The region is an area of Poland most contaminated during Chernobyl accident. The exercise was divided into three parts:

- estimation of the distance to the hidden source;
- comparison the results for Cs-137 concentration in soil on the common road;
- mapping of the terrain near Opole.

The results of the TURAWA 2003 exercise are presented in other part of this report.

ACKNOWLEDGEMENTS

This work was sponsored by National Atomic Energy Agency

References:

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2.5 RADIOACTIVITY OF GROUND-LEVEL AIR IN POLAND IN 2002 AND 2003: RESULTS FROM AEROSOL SAMPLING STATIONS TYPE ASS-500

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In 2002 the ASS-500 aerosol sampling stations were located in Warsaw, Świder, Białystok, Katowice, Kraków, Lublin, Gdynia, Wrocław, Szczecin and Sanok. In 2003 the network was enlarged by stations located in Toruń and Łódź . Nine of the 10 stations in 2002 and of the 12 stations in 2003 were equipped with NaI(Tl) detectors placed above the filter. The gamma spectra and other parameters, eg. the air flow rate through the filter, are transmitted to the PMS station computer and – together with PMS data - sent to CLOR [1]. The networks of ASS-500 stations and PMS stations (with 8 common locations in 2002 and 10 in 2003) belong the Polish Early Warning System.

The station in Sanok was out of order in the first 10 weeks of 2003. The stations in Toruń and Łódź have got into the network, respectively, in the week 11 and 27 of 2003. The other stations were working without longer breaks. This resulted in collecting of 518 weekly aerosol samples in 2002 and 577 in 2003. Filters with the deposited aerosol, i.e. the total dust, were kept at least for 2 days in room temperature, then pressed into tablets 50 mm in diameter, and measured with HPGe detectors and multichannel analyzers. The affectivities of the detectors were in the range from several to 40 %. The thickness of the tablets were in the range of 2,9-8,2 mm. Two radioactivity standards of 4,1 and 6,1 mm thick were used for calibration of the gamma spectrometers. In emergency situations the filters can be measured immediately after collecting the aerosols.

In 2002 the average mass of the weekly sampled total dust was 3.4 g with a range of 0,8-7,4 g. The average volume of filtered air was 75070 m^3, ranging 11659-109459 m^3. In 2003 the average mass of the total dust samples was 3,3 g, ranging 0,9-6,8 g. The average volume of the filtered air was 70111 m^3, ranging 24393-107894 m^3. The wide ranges of the weekly samples of total dust and filtered air resulted from using ASS-500 stations of different electric power, as well as from different dustiness at the particular sites.

In computing and analysing the results of concentrations of radionuclides in the ground-level air it was assumed, that concentrations lower than the lower detection limit, LLD (confidence level 70 %), were at the LLD values, instead of the zero ones.

Log-normal probability plots of contents of ^{137}Cs, ^{7}Be, ^{40}K, ^{210}Pb, ^{226}Ra and ^{228}Ra in 1 g of total dust, and in 1 m^3 of air, for data from all stations in 2002 and 2003, revealed linear relationships. However some irregularities appeared at the lower concentration range, caused mainly by measurements with poorer detectability (^{40}K ^{131}I, ^{226}Ra).

Arithmetic means, and general weekly trends, for air and total dust in 2002 and 2003 are presented in Table 1 and Table 2 and in Fig 1-4.

It can be seen from the tables, that the maxima of ^{131}I concentrations in dust and of air have occurred in 2002 at Świder during the week 2 (7.01-14.01), in 2003 at Sanok in the week 15 (7.04-14.04). The source of the maximum concentration in 2002 has not been identified. In 2003 the maximum concentration was measured in the week of the fuel cleaning incident releases from the Nuclear Power Plant at Paks, Hungary, on 10.04.2003 [2].

In 2002 the maxima for ^{137}Cs concentrations in air and dust were observed at Białystok, but in different weeks: for air in the week 36 (2.09-9.09), for dust in the week 31 (29.07-5.08). However, the next greatest concentration in dust, 0,586 Bq/g, was measured also in Białystok in the week 36. Further greatest concentrations in the week 36 (49,4 $\mu Bq/m^3$ and 0,541 Bq/g) were measured in Lublin. In the same week the concentrations at the other 8 stations were in the range of 7,7-26,4 $\mu Bq/m^3$ and of 0,143-0,255 Bq/g. The masses of total dust sampled in this week , as well as the ^{40}K concentrations, were rather high and ranged, respectively, from 4,25g to 6,70 g and from 14,9 to 49,5 $\mu Bq/m^3$. The ratio of $^{137}Cs/^{40}K$ concentrations ranged from 0,29 to 1,37 with the two highest values 1,37 and 1,01, for Białystok and Lublin, respectively. The annual mean, median, s.d. and range of this ratio were higher in 2002 (0,16 ; 0,10; 0,18 and 0,009-2,33) than in 2003 (0,12 , 0,089, 0,099 and 0,003-0,969).

During August and the first 2 weeks in September2002 higher ^{137}Cs concentrations in aerosols coincided with winds from the east. In the beginning of August 2002 the Polish radio reported about forest fires on areas heavily contaminated with the Chernobyl accident releases lying behind the eastern border of Poland. This resulted in higher concentrations of aerosol ^{137}C concentrations in Poland with the maximum for Białystok in the week 31 (36,3 $\mu Bq/m^3$ and 0,639 Bq/g).

Reports on Polish radio in the beginning of September, and summarized on television in the beginning of October 2002, identified fires of peat fields situated on areas of the Biebrza National Park of Poland. These fires could not be stopped easily because of permanent dry and hot weather and still new fires were initiated. Such situation, together with the winds from east, resulted in maximum ^{137}Cs concentrations in aerosols demonstrated for the week 36 (2.09-9.09) and slightly lower concentrations in the week 37 (see Fig. 1 and Fig. 2).

The maximum ^{137}Cs concentration in air in 2003 was about 4 times lower than in 2002 and was measured in Lublin in the week 16 (14.04-21.04). The concentrations in this week at 11 stations in Poland ranged from 3,1 $\mu Bq/m^3$ and 0,036 Bq/g to 12,1 $\mu Bq/m^3$ and 0,166 Bq/g with the highest values in Lublin. Similar concentrations were measured, with maximum in Lublin, in the week 17 (see Fig 3 and Fig. 4). Winds from the east, much dust collected (3,03-6,80 g), and a ^{137}Cs concentration in air of 27.3 $\mu Bq/m^3$ measured at Rivne, Ukraina, in the period from 10.04-21.04.2003 [3] suggest, that the source of ^{137}Cs responsible for the concentrations observed in Poland during the

weeks 16-17 was situated in Ukraine. A ^{137}Cs concentration of 4.5 μBq/m^3 was measured in Braunschweig, Germany, in the week 17 [4]. However, it cannot be excluded, that these concentrations were also connected with the releases of radioactive aerosols during the fuel cleaning incident at the NPP in Paks, Hungary, in April 2003.

The above mentioned foreign data on ^{131}I and ^{137}Cs in air were available thanks to exchanges of measurement results between the Central Laboratory for Radiological Protection and the State Nuclear Regulatory Committee of Ukraine in Kiev and the PTB in Braunschweig, Germany.

The new station in Łódź measured 1,7-130,8 μBq/m^3 of ^{60}Co in the air during the weeks 29-42. The source of ^{60}Co in air was a leaking irradiation device belonging to the Technical University of Łódź.

Searching for proportionality between the measured concentration in total dust and in the respective filtered air volume, the following Pearson correlation coefficients (r) were found:

- 2002: 0,91 for ^{137}Cs; 0,56 for ^{7}Be; 0,49 for ^{40}K; 0,48 for ^{210}Pb; 0,74 for ^{226}Ra; 0,82 for ^{228}Ra.
- 2003: 0,84 for ^{137}Cs; 0,53 for ^{7}Be; 0,51 for ^{40}K; 0,64 for ^{210}Pb; 0,79 for ^{226}Ra; 0,81 for ^{228}Ra.

The calculated r^2 values indicate, that the average strength of the relationships is about 0,5 (0,2-0,8). This means, that the activity of 1 m^3 of air is caused by the activity of the sampled dust and by some other factors, like the amount of total dust in 1 m^3 of air or unknown parameters of the analytical procedures responsible for the left r^2=0,5.

The influence of the amount of total dust was checked by searching for proportionalities between the concentrations in air and the total dust amount in 1 m^3 of filtered air. The following "r" values have been obtained:

- 2002: 0,47 for ^{137}Cs; 0,43 for ^{7}Be; 0,75 for ^{40}K; 0,60 for ^{210}Pb; 0,23 for ^{226}Ra; 0,21 for ^{228}Ra.
- 2003: 0,64 for ^{137}Cs; 0,37 for ^{7}Be; 0,67 for ^{40}K; 0,43 for ^{210}Pb; 0,14 for ^{226}Ra; 0,21 for ^{228}Ra.

The r^2 values indicate, that the average strength of these relationships amounted to 0,2 (0.002-0.6) and does not totally explain the above mentioned left average strength of 0,5. This can suggest that an average strength of 0.3 can be anticipated for reasons of analytical origin.

Examination of linear correlations based on yearly data between the concentrations of ^{137}Cs and ^{7}Be in total dust (dust) and air (air) revealed in 2002 "r" values of 0,03 (dust) and 0,39 (air) ; in 2003 values of -0,06 (dust) and 0,37 (air).

Linear correlation based on yearly data between ^{137}Cs and ^{40}K revealed in 2002 "r" values of 0,22 (dust) and 0,58 (air); in 2003: 0,13 (dust) and 0,49 (air).

Linear correlation based on yearly data between the concentrations of ^{210}Pb and ^{7}Be in total dust and air identified in 2002 "r" values of 0,32 (dust) and 0,46 (air); in 2003 of 0,24 (dust) and 0,25 (air).

Pearson's r examined on quarterly data of 2002 revealed that the lowest values, 0,04 (dust) and 0,18 (air), were in the first quarter, the highest, 0,61 (dust) and 0,72 (air), in the third quarter. In 2003 the

lowest values, 0,31 (dust) and 0,39 (air), were got in the first quarter , the highest, 0.72 (dust) and 0.74 (air), in second quarter.

In the period of 1993-2003 the quarterly "r" values of the ^{210}Pb-^{7}Be linear correlations were roughly from -0,5 to 0,4 (dust) and from 0,1 to 0,6 (air) in the first ,
from 0,4 to 0,7 (dust) and from 0,4 to 0,8 (air) in the second,
from 0,1 to 0,6 (dust) and from 0,3 to 0,8 (air) in the third and
from 0,1 to 0,6 (dust) and from 0,2 to 0,7 (air) in the fourth quarter.

The number of sampling sites, and of the analysed pairs of data, has increased in these 11 years from 2 to 11, and from 95 to 523, respectively.

The measurements carried out in 2002-2003 clearly demonstrated that the Polish Early Warning System is sensitive enough to detect even tiny changes in environmental radioactivity, caused by local radiation events, and by comparatively minor releases from distant sources in foreign countries (see also [5]).

Table 1. Radionuclide concentrations in ground-level air, Poland, 2002-2003. Annual summaries.

Radio-nuclide	Concentration, μBq/m^3		n	Maximum of concentration	
	Mean ± σ/√n	Range		Location	Period
		2002			
^{131}I	0,5±0,02	<0,02- 5,9	516	Świder	7.01-14.01
^{137}Cs	2,9±0,2	<0.1-49,9	518	Białystok	2.09- 9.09
^{7}Be	3020±50	960-8670	518	Katowice	19.08-26.08
^{40}K	17,4±0,4	<2,7-61,8	518	Białystok	9.12-16.12
^{210}Pb	474±11	79-1310	466	Białystok	9.12-16.12
^{226}Ra	5,4±0,2	<1,4-23,6	511	Lublin	26.08- 2.09
^{228}Ra	1,4±0,05	<0,3-<6,9	516	Sanok	9.12-16.12
		2003			
^{131}I	0,6±0,08	<0,04-43,6	577	Sanok	7.04-14.04
^{137}Cs	1,8±0,07	<0.1-12,1	577	Lublin	14.04-21.04
^{7}Be	3000±50	540-7430	577	Lublin	26.05- 2.06
^{40}K	16,4±0,4	<2,0-56,7	577	Katowice	14.07-21.07
^{210}Pb	472±12	97-2001	523	Białystok	6.01-13.01
^{226}Ra	5,4±0,1	<1,7-17,8	577	Łódź	10.11-17.11
^{228}Ra	1,3±0,05	<0,2- 7,6	577	Katowice	14.07-21.07

n=number of results obtained at all sampling sites.

Table 2. Radionuclide concentrations in total dust, Poland, 2002 - 2003. Annual summaries.

Radio-nuclide	Concentration, Bq/g		n	Maximum of concentration	
	Mean ± σ/√n	Range		Location	Period
		2002			
^{131}I	0,012±0,001	<0,001-0,165	516	Świder	7.01-14.01
^{137}Cs	0,052±0,003	<0.003-0,639	518	Białystok	29.07- 5.08
^{7}Be	67,5±1,2	13,8-157,1	518	Świder	3.06-10.06
^{40}K	0,356±0,007	<0,041-1,101	518	Białystok	10.06-17.06
^{210}Pb	10,07±0,19	3,03-30,9	466	Kraków	2.12- 9.12
^{226}Ra	0,126±0,005	<0,020-0,597	511	Sanok	12.11-18.11
^{228}Ra	0,031±0,001	<0,005-<0,192	516	Sanok	9.12-16.12
		2003			
^{131}I	0,014±0,003	<0,001-0,165	577	Sanok	7.04-14.04
^{137}Cs	0,034±0,001	<0.003-0,639	577	Lublin	14.04-21.04
^{7}Be	66,6±1,2	14,0-212,3	577	Lublin	28.07- 4.08
^{40}K	0,343±0,006	<0,053-1,186	577	Gdynia	1.09- 8.09
^{210}Pb	10,05±0,21	1,97-30,4	523	Białystok	30.12- 6.01
^{226}Ra	0,125±0,004	<0,024-0,670	577	Sanok	6.10-13.10
^{228}Ra	0,029±0,001	<0,004- 0,227	577	Sanok	6.10-13.10

n=number of results obtained at all sampling sites.

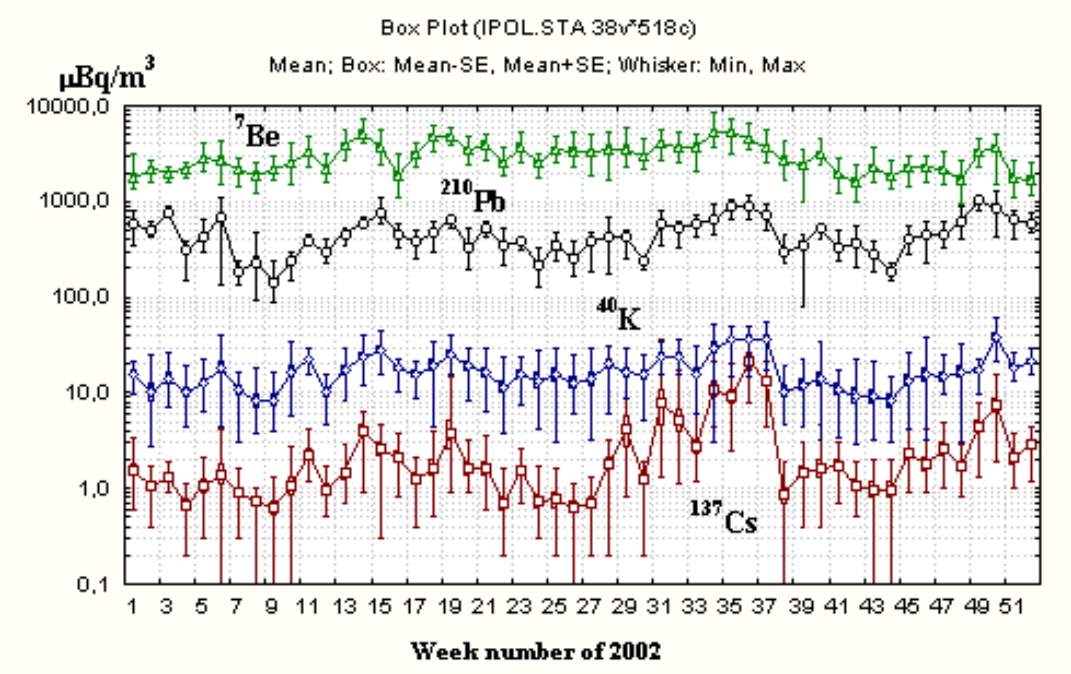

Fig.1.Weekly radionuclide concentrations in ground-level air, Poland, 2002, µBq/m^3 .

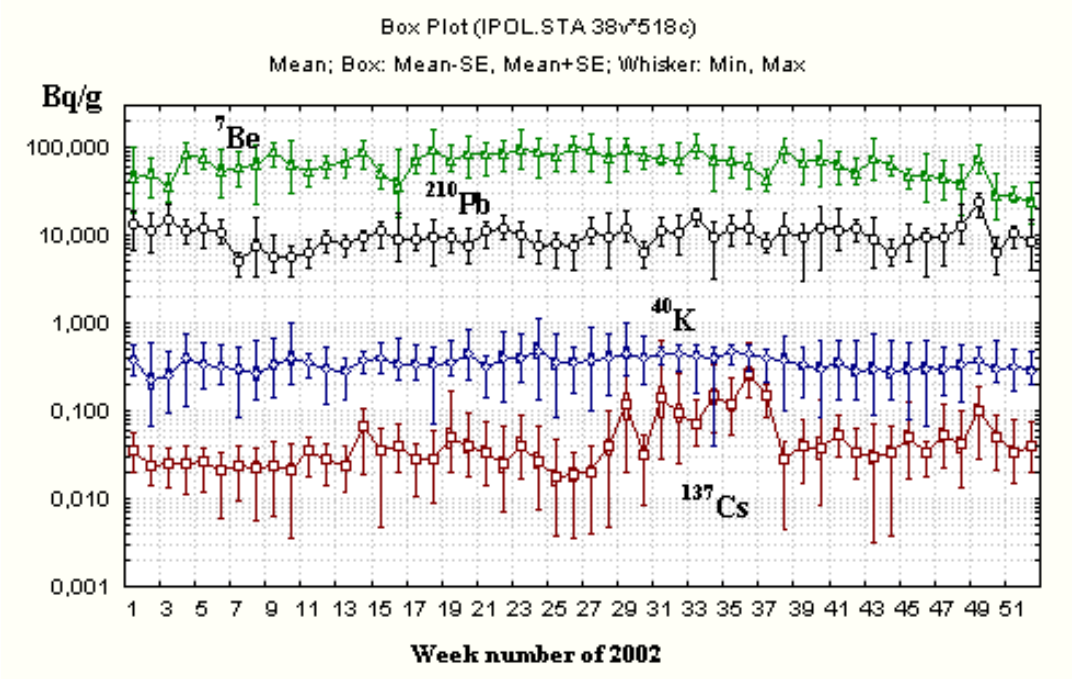

Fig. 2. Weekly radionuclide concentrations in ground-level total dust,
Poland, 2002, Bq/g,

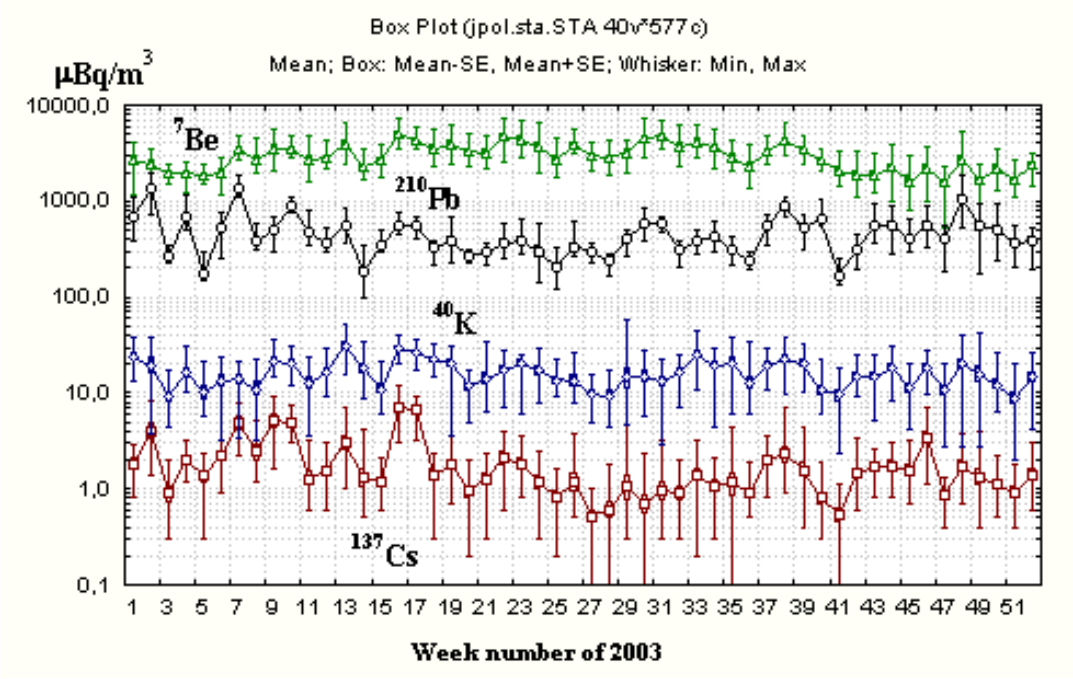

Fig. 3. Weekly changes of radionuclide concentrations in ground-level air,
Poland, 2003, µBq/m^3 .

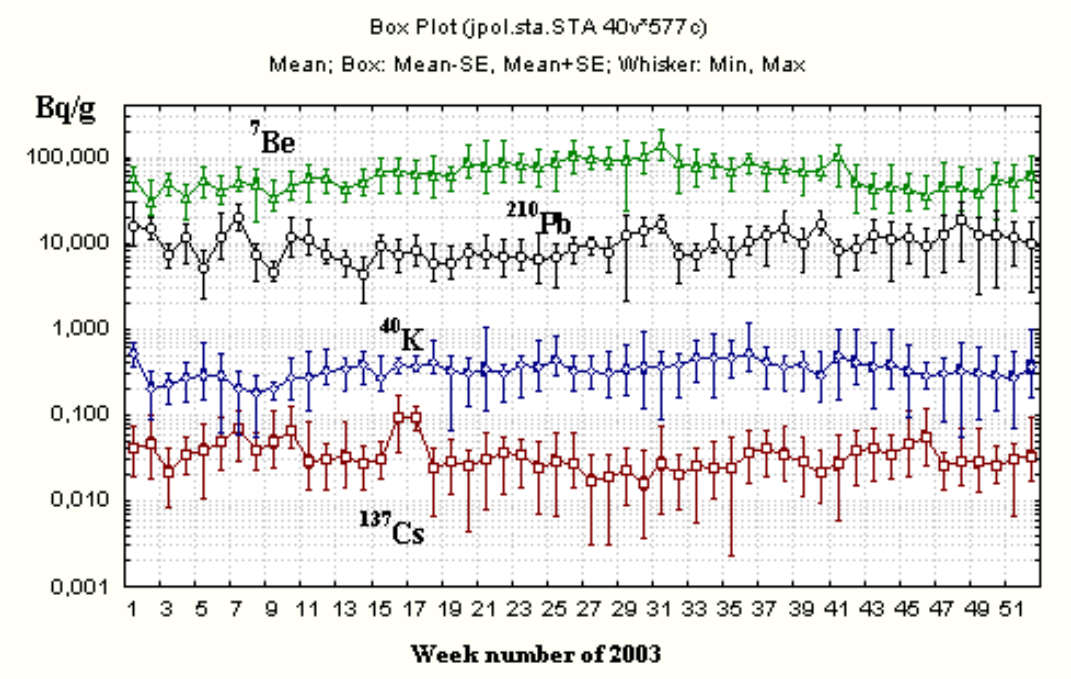

Fig.4. Weekly changes of radionuclide concentrations in ground-level total dust, Poland, 2003, Bq/g.

ACKNOWLEDGEMENTS

This work was sponsored by National Atomic Energy Agency

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2.6 PERMANENT RADIATION DOSE RATE MONITORING STATIONS (PMS) NETWORK IN POLAND

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Dosimetry Department

2.6.1 Polish-Danish cooperation – historical overview

The PMS network in Poland originated in consequence of an agreement on cooperation signed between Polish National Atomic Energy Agency and Danish Emergency Management Agency in May 1994 (the cooperation has ended in 2003). In the years 1995-2001 the automatic „on-line" network consisting of thirteen stations, produced by Greenwood Engineering, Denmark, was installed in Poland and put into operation. These stations were located in Białystok, Gdynia, Koszalin, Kraków, Lublin, Łódź, Olsztyn, Sanok, Szczecin, Toruń, Warszawa, Wrocław and Zielona Góra. At the same time a central system managing the measurement network was installed at CLOR in Warsaw. The location of the PMS and ASS-500 stations is presented in Figure 1. The PMS system is a part of the Early Warning System of the Polish Service of Radiation Monitoring which is a subsystem of the National Environmental Monitoring System of the Ministry of Environment, and it is integrated with the network of the ASS-500 stations into one coherent system, in which data collected from particular stations are transferred to a central station in CLOR.

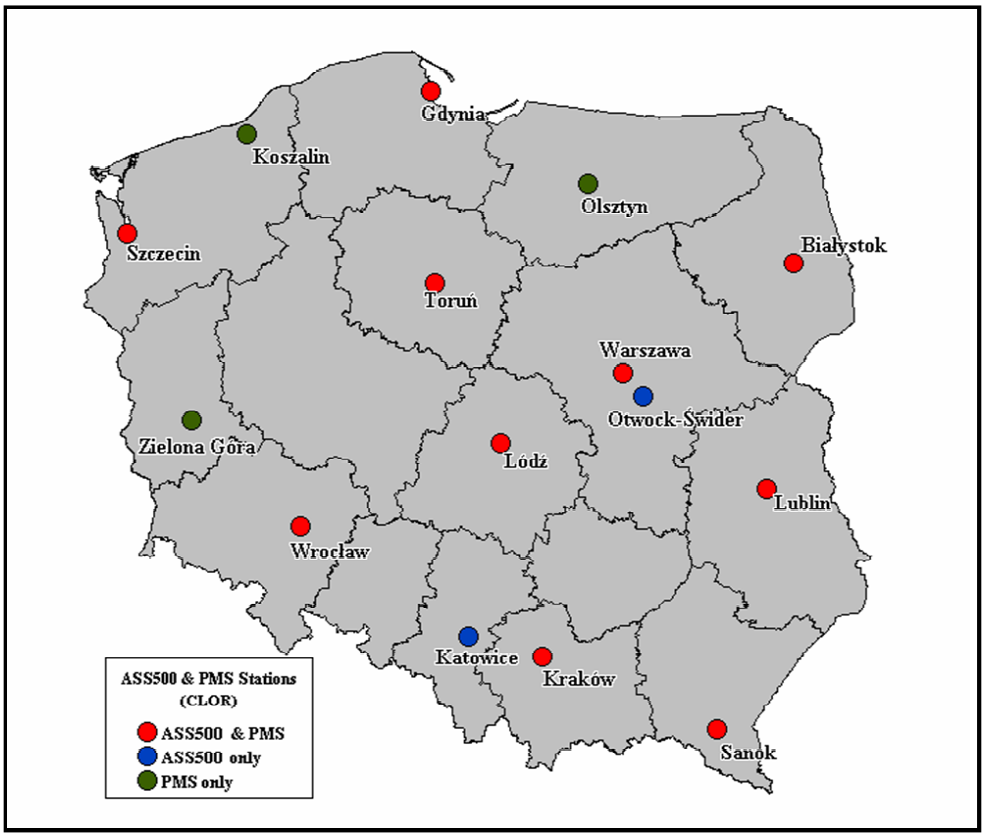

Fig. 1. The location of the PMS and ASS-500 stations in Poland.

Besides PMS system, the expert system for decision aiding in nuclear emergencies ARGOS_NT and internet/intranet based nuclear information system NUCINFO were also put into operation.
In each year the training course on the maintenance of the PMS system and the usage of the ARGOS_NT and NUCINFO systems took place in Denmark. In consequence, CLOR is able to perform full service of the PMS system in Poland, and to utilize the potential of ARGOS_NT and NUCINFO.

2.6.2 Description of the PMS system

The PMS stations continuously monitor radioactive contamination of the environment and store collected data on the disk in the station computer. The parameters monitored are: background gamma radiation spectra measured by 3"x3" NaI(Tl) scintillation detector and deconvoluted into four components: natural radium, natural thorium, natural ^{40}K and the remaining; background gamma dose rate measured by Geiger-Müller counter; precipitation in mm/h; outdoor temperature; temperature at NaI crystal and temperature inside the electronics cabinet. Since 1999 the network („on-line" part) of Aerosol Sampling Stations type ASS-500 is connected to PMS system. The block diagram of the PMS station is presented in Figure 2.

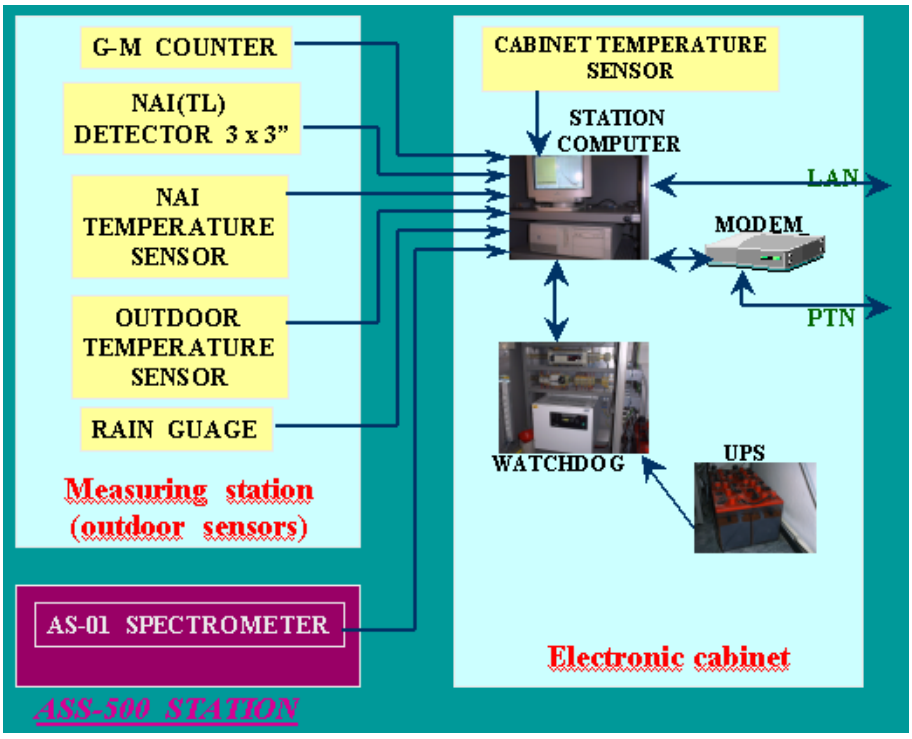

Fig. 2. PMS station block diagram.

The data collected by the station computer are transmitted to the central system which is located in Dosimetry Department of CLOR in Warsaw. The central system consists of two computers: one controlling the transmission and second having the MS SQL Server 7.0 (upgraded to version 2000 in

August 2003) database management software for the PMS and ASS-500 systems and, also, for ARGOS_NT and NUCINFO systems. The central transmission computer manages data transmission from the stations. Its functions allow to choose the transmission mode (using either modem on the PTN or LAN connection), transmission interval (in normal situation of 10-12 hours) and to set up the alarm thresholds. After detection of a radiation level exceeding a given threshold (set approximately 10% above the background level) the station calls the central computer and forces immediate data transmission. In the same time the information about alarm is sent (in SMS format) to mobile phone of system operator. The audible alarm is generated on the central computer. In normal situation the station data are averaged hourly, but in emergency there is a possibility to switch to 10-min averages. Figure 3 shows the user interface of the central system at CLOR. Figure 4 shows two parts of PMS station – sensors (measurements) and electronic parts.

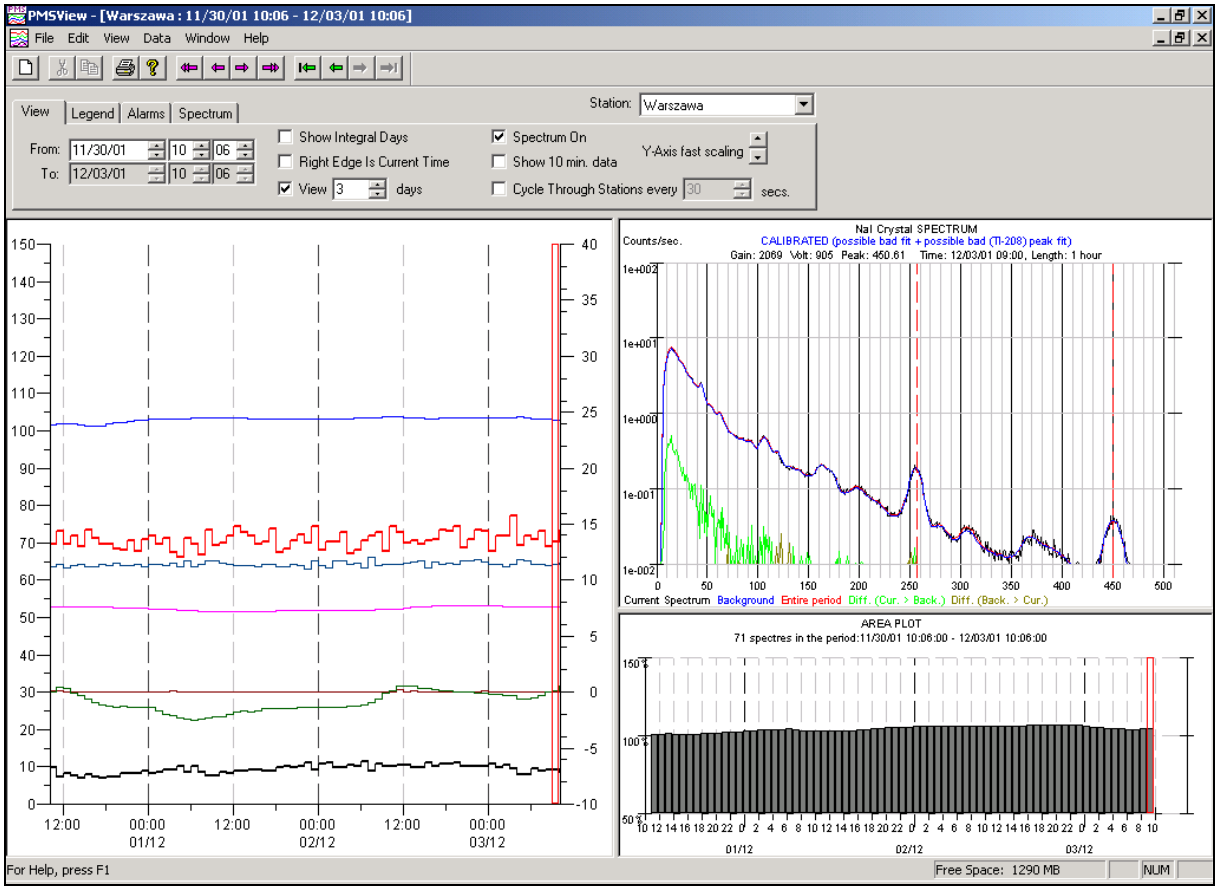

Fig. 3. PMS server graphical user interface.

Fig. 4. PMS station (sensors and electronic parts).

2.6.3 The monitoring results of the PMS station network

Every month the Dosimetry Department of CLOR prepares the report of the PMS station network status for the Polish National Atomic Energy Agency. It contains month averages, minimum and maximum values of the dose rate for all of the stations, and some comments on the monitoring results. The example of the monthly report is presented in Table 1.

Table 1. Monthly report (April 2003).

PMS STATION	Number in PMS network	Dose rate measured by G-M counter [μGy/h] AVER.	MIN	MAX	Dose rate from Th component (NaI(Tl) detector) [μGy/h] AVER.	MIN	MAX
Gdynia	5	- *)	- *)	- *)	- *)	- *)	- *)
Lublin	6	- *)	- *)	- *)	- *)	- *)	- *)
Białystok	7	0,083	0,080	0,087	- *)	- *)	- *)
Warszawa	8	0,072	0,069	0,077	0,066	0,063	0,067
Kraków	9	0,104	0,101	0,110	0,099	0,096	0,101
Szczecin	20	0,095	0,091	0,099	0,078	0,076	0,080
Wrocław	21	0,060	0,057	0,066	0,060	0,056	0,064
Sanok	22	0,086	0,078	0,091	0,079	0,067	0,083
Zielona Góra	40	0,079	0,076	0,081	0,075	0,075	0,076
Koszalin	41	0,081	0,079	0,086	0,078	0,076	0,079
Olsztyn	42	0,080	0,076	0,086	0,074	0,072	0,076
Łódź	50	0,073	0,069	0,078	0,062	0,059	0,068
Toruń	51	0,090	0,088	0,093	0,087	0,085	0,090

*) *– No data – NaI(Tl) detectors malfunction.*

More detailed reports are prepared quarterly. The excerpt from a report (dose rate curves for all stations) of the second quarter of 2003 is presented in Figure 4.

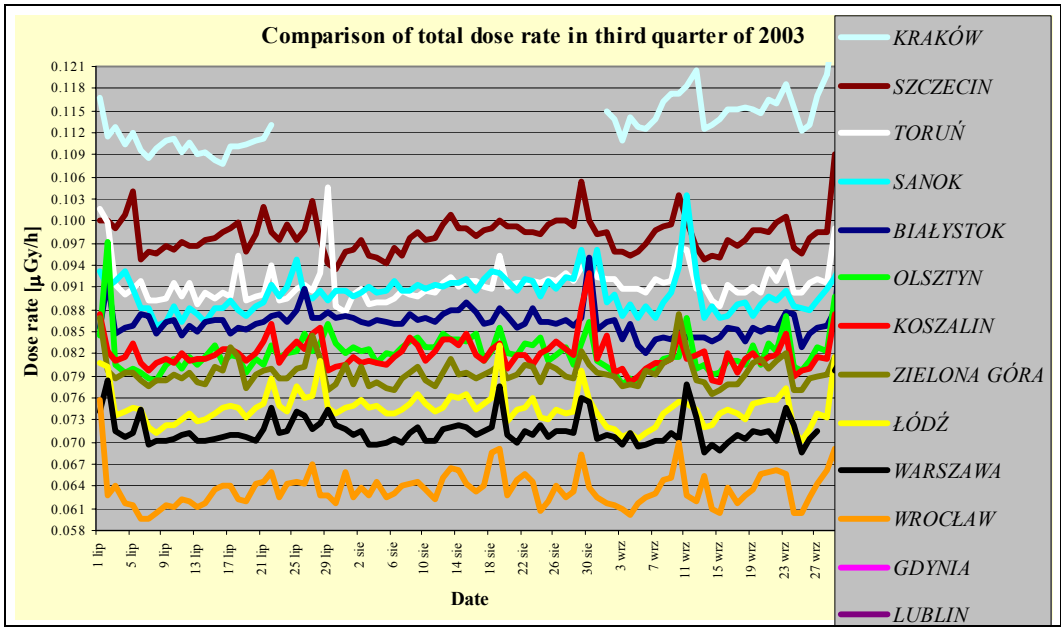

Fig. 5. Comparison of the total gamma dose rate on seven PMS stations in the third quarter of 2003.

The lowest dose rate was observed at Lublin in August 2002 (55 nGy/h), and the highest also at Lublin station in June 2002 (148 nGy/h) - the result of heavy rainfall and, thus, radon washout. The average dose rate value for Poland in 2002 was 87 nGy/h and in 2003 was 84 nGy/h. Table 2 shows the averages, minima and maxima of the dose rate measured by PMS stations in Poland in 2002-2003. In the table the average dose rate for Wroclaw and Gdynia stations is lower comparing to previous years. The reason is the exchange of the GM tubes for the new ones having self counting rejection circuits.

Table 2. Gamma dose rate in 2002-2003 – average, minimum and maximum for all PMS stations.

Station	Gamma dose rate [nGy/h]			
	Average 2002	Average 2003	2002 - 2003 MIN	MAX
BIAŁYSTOK	83	84	68	99
GDYNIA	110	93	87	136
KOSZALIN	81	81	65	93
KRAKÓW	104	107	86	128
LUBLIN	92	-	55	148
ŁÓDŹ	74	73	63	88
OLSZTYN	80	80	60	97
SANOK	86	87	71	110
SZCZECIN	95	96	87	109
TORUŃ	91	91	82	105
WARSZAWA	73	71	61	83
WROCŁAW	89	62	56	311*)
ZIELONA GÓRA	79	79	71	96

*) – *GM probe malfunction.*

Data collected by the PMS system are shared with European Union Radiological Data Exchange Platform (EURDEP), with the Council of Baltic See State (CBSS) on the FTP server, and with German Integrated Measurement and Information System (IMIS) - biweekly.

ACKNOWLEDGEMENTS

This work was sponsored by National Atomic Energy Agency

2.7 SYSTEMATIC MEASUREMENTS OF GAMMA RADIATION BACKGROUND AND OF RADIOACTIVE CONTAMINATION OF THE GROUND

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These investigations are performed in the frame of the Polish National Environmental Monitoring System. In 2002 the measurements were carried out at the premises of the network of meteorological stations of the Institute of Meteorology and Water Management.

The results of these measurements are used for the all-country computerized radiological data base and for preparation of radiological maps of Poland produced in MapInfo 6.0 PL system. This system visualizes results of the investigation at the measurement and sampling points as circle cart-diagrams or extrapolates results of the point measurements to the whole area of Poland.

Measurements of gamma radiation dose were performed at of 254 points. In the same sites soil samples were collected to determine concentration of the natural radionuclide and caesium isotopes by means of the spectrometric analysis.

Gamma dose was measured in one year periods using in each point three thermoluminescent detector sets mounted 1 m above the ground.

In each point the samples of soil were taken in October 2000 with a knife-edge pipe of 2 inches diameter from the 10 cm thick surface layer at six places, at the circumference of the circle of 2 m radius, and in the centre of the circle. The measurements of radionuclide concentrations in soil samples were made using spectrometers with HPGe detectors, located in low-background lead shielding houses. The time of each measurement was 80000 s.

The mean values of concentrations of natural radionuclides in soil in Poland are:

for ^{226}Ra - 24.0, for ^{228}Ac - 23.3 and for ^{40}K – 399 Bq·kg^{-1}, i.e. lower than the mean world concentrations of 33, 45 and 420 Bq·kg^{-1}, respectively [1].

The highest mean concentrations of ^{226}Ra and ^{228}Ac occur in the southern parts of Poland, depending on the geological structure of the country. For instance in a soil sample taken in Szklarska Poręba the concentrations are: 132,1 Bq·kg^{-1} of ^{226}Ra and 103,3 Bq·kg^{-1} of ^{228}Ac.

The mean value of ^{137}Cs deposition density in Poland is 3.20 kBq·m^{-2}, ranging from 0.20 to 34.28 kBq·m^{-2}. The activity of ^{134}Cs in soil is below the low limit of detection. The radiological map of ^{137}Cs deposition density is presented in Fig.1. Such distribution of ^{137}Cs was mainly due to the weather conditions - in particular rainfall - in Poland in May 1986, i.e. in the period immediately after the Chernobyl accident. All results refer to soil samples taken in October 2000.

The values of gamma dose rate of the outdoor radiation (terrestrial and cosmic) in 2002 are given in Table 1.

Table 1. The values of gamma dose rate of the outdoor radiation in Poland in 2002.

Gamma dose rate [nGy/h]			
Terrestrial		With cosmic radiation	
Mean	Range	Mean	Range
43.3	19.0 - 82.6	76.7	51.2 - 117.4

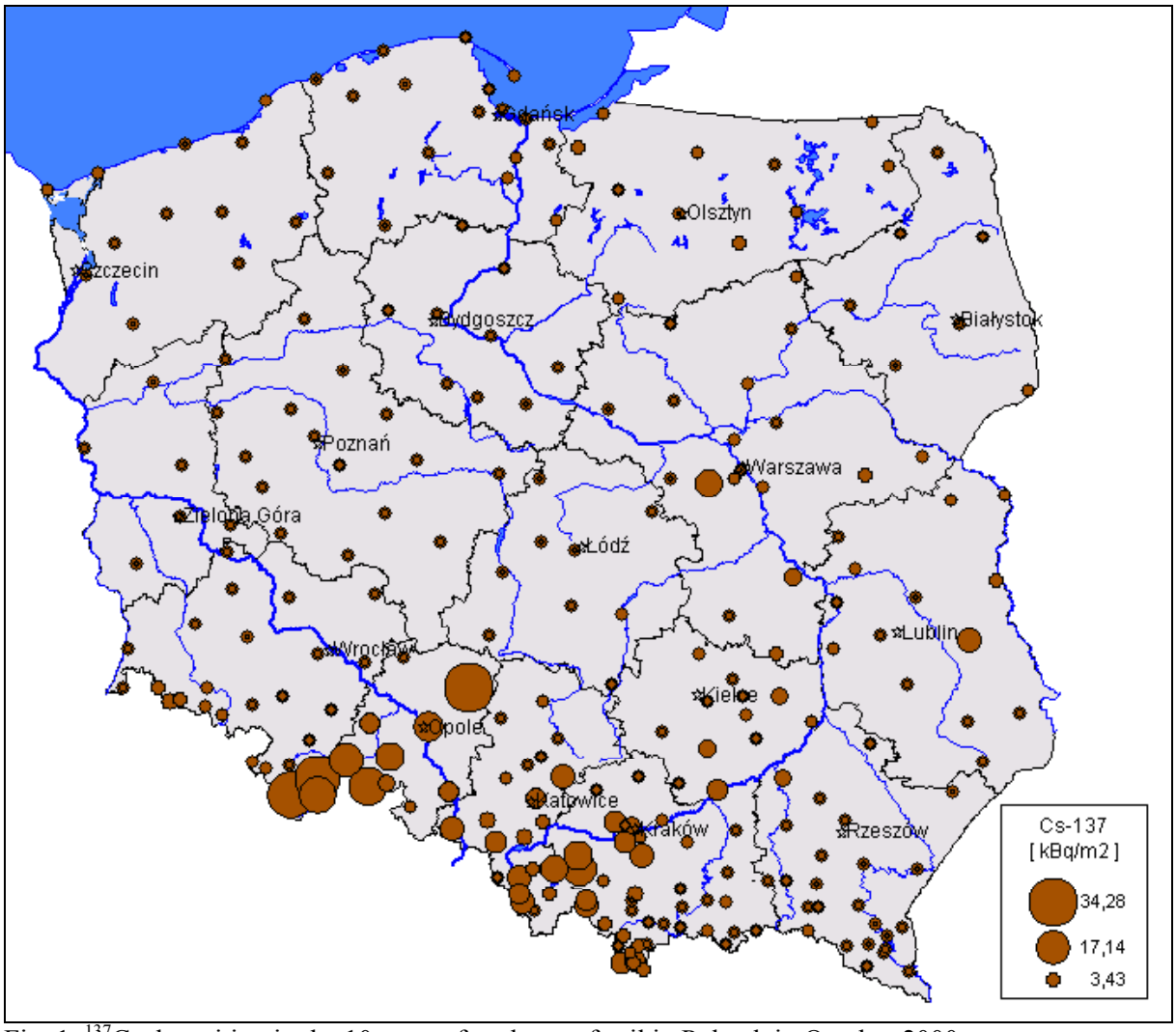

Fig. 1. ^{137}Cs deposition in the 10 cm surface layer of soil in Poland, in October 2000

References:

[1] United Nations Scientific Committee on the Effects of Atomic Radiation: Sources and Effects of Ionizing Radiation. United Nations , New York, 2000.

ACKNOWLEDGEMENTS

This project was supported by the National Environmental Protection and Water Management Fund.

2.8 RADIOLOGICAL SITUATION IN SURROUNDINGS OF RADIOCTIVE WASTES REPOSITORY IN RÓŻAN

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[*]Dosimetry Department

[+]Department of Radiation Hygiene

The Central Laboratory for Radiological Protection performs the measurements of environmental radioactivity in the surroundings of KSOP-Różan (National Repository of Radioactive Wastes in Różan), beginning in 2001. The purpose of this surveillance programme is to collect data on the existing levels of radioactivity, and to detect their changes, thus providing a full control of the radiological situation.

In the vicinity of KSOP-Różan the following samples were collected:

river water (r. Narew) - four times a year from the tree control points,
well water - twice a year from the two control points,
spring water - twice a year from the tree control points,
ground water - four times a year from the eight control points,
soil – twice a year from the five control points,
grass - twice a year from the five control points,
corns - once a year from the four control points.

In the 20 litres samples of river, well and spring water, after evaporation to 220 ml, the preliminary gamma spectra analyses were performed and later, using the radiochemical method, the concentration of radiocesium were determined. In 1 litre water samples from the same places the concentrations of tritium were determined.

In the ground water samples the gross beta and the concentrations of tritium were determined. In the samples of soil, grass and corns the gamma spectra analyses were performed.

Around this repository the gamma dose rates were controlled (two or three times a year) and the radioactive contaminations of surrounding terrain were measured using the Mobile Spectrometric Laboratory (twice a year).

All methods of sampling and measurements were conducted according to procedures in "The measurement technique applied in control survey for estimation of radiological situation in surrounding of Centre Świerk and KSOP-Różan".

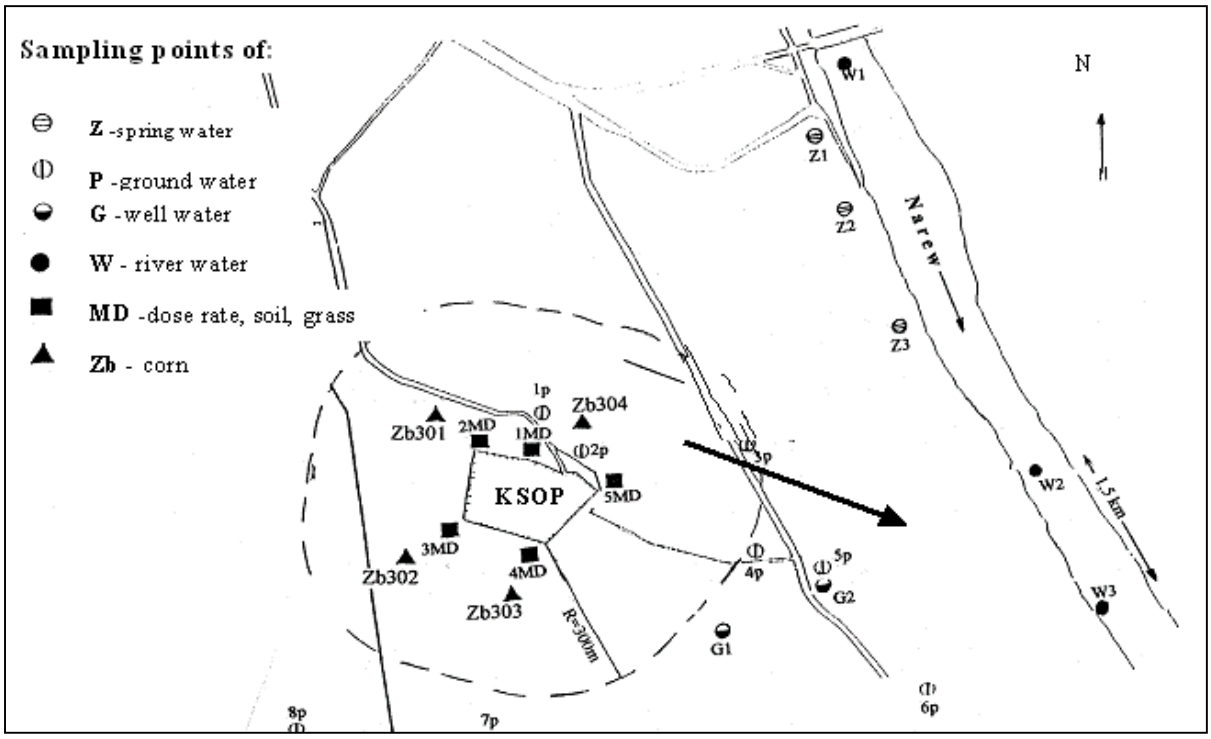

Fig.1. Map of KSOP-Różan with environmental sampling points. Thick arrow indicates the direction of ground water flow.

Table 1. Mean concentrations of radiocaesium, gross β activity* and tritium concentrations in the samples of water from KSOP-Różan area (activity range in parenthesis).

Type of sample	Radiocaesium concentrations mBq/dm^3		gross β activity Bq/dm^3		Tritium concentrations Bq/dm^3	
	2002	2003	2002	2003	2202	2003
River Narew	2.8 (1.3-6.7)	2.2 (1.4-2.8)	-	-	1.3 (0.9-1.7)	1,2 (0,6-1,7)
Wells water	1.6 (1.2-2.1)	1.3 (0.9-1.7)	-	-	1.6 (0.9-2.3)	1.6 (1.4-1.8)
Springs water	10.4 (1.0-19.9)	1.7 (13-2.0)	-	-	2.5 (2.5-2.5)	2.0 (2.0-2.0)
Ground water	-	-	0.135 (0.055-0.281)	0.113 (0.032-0.366)	3.6** (1.6-8.6) 66.8*** (63.7-70.0)	2.6** (1.8-3.6) 45.4*** (41.9-47.4)

* gross β activity measurements are a conventional means for the monitoring changes of radioactivity in the environment. They are not applicable for radiation dose estimation.
** without one sampling point (2p).
*** in one sampling point (2p).

The concentrations of radiocaesium and gross β activity in the various samples of water are at very low levels, except one sample of spring water in 2002. The tritium concentrations in river and well water, are at low level, similar to that in other surface waters measured in Poland which range from 0.7 to 1.9 Bq/dm^3 [1]. At all sampling points, tritium concentration in the samples of ground water were slightly higher than typical concentrations in Poland, except point 2p where the measured concentrations were constantly much higher than at other points.

Table 2. Mean concentrations of 137Cs and 40K in various environmental samples from KSOP-Różan area (activity range in parenthesis).

Sample	^{137}Cs Bq/kg		^{40}K Bq/kg	
	2002	2003	2002	2003
Soil	3.30 (1.60-4.98)	2.00 (1.92-4.28)	487 (433-586)	458 (422-554)
Corn	0.88 (0.28-1.49)	0.35 (0.30-0.40)	142 (142-143)	159 (157-160)
Grass (dry)	8.0 (1.9-16.2)	22.6 (<0.5-73.4)	416 (340-511)	459 (118-439)

The concentrations of ^{137}Cs and ^{40}K in the soil samples were comparable to the concentrations measured in many other places in Poland [2] and were at low level. The concentrations of both isotopes in all corn samples were also very low. In grass samples the concentrations of ^{40}K were at normal level encountered in Poland. The same situation was observed as regards ^{137}Cs concentrations, except for one grass sample taken in spring 2003.

The mean gamma radiation dose rate (including cosmic radiation) around KSOP-Różan in 2002 was 97 (84-109) nGy/h and in 2003 was also 97 (87-106) nGy/h. The mean gamma radiation dose rate in whole Poland is 75.5 (47-119.9) nGy/h [2].

Around this repository the radioactive contamination of terrain measured twice a year using the Mobile Spectrometric Laboratory was at the same levels as in the other regions in Poland.

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ACKNOWLEDGEMENTS

Project was supported by the National Atomic Energy Agency.

2.9 ASSESSMENT OF RADIOLOGICAL SITUATION IN SURROUNDING OF ŚWIERK CENTRE

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[*]Dosimetry Department

[+]Department of Radiation Hygiene

Since 2001 Central Laboratory for Radiological Protection surveid the radiological situation in the surrounding Świerk Center. Here, we present results for 2002 and 2003

The following samples were collected:

water from the river Świder - four times a year from the two control points ,

well water - twice a year from the two control points,

water after municipal sewage-treatment plant - twice a year from the one control points,

soil - once a year from the five control points,

grass - once a year from the five control points,

corns - once a year from the four control points,

atmospheric aerosols - once a week from the two control points.

In the 20 l samples of river water, well water, and water from municipal sewage-treatment plant, after evaporation to 220 ml, the preliminary gamma spectra analyses were performed. Later, using the radiochemical method, the concentration of radiocaesium was determined. In the soil, grass, corns and atmospheric aerosol the gamma spectra analyses were performed.

Around the Świerk centre the gamma dose rates were measured (once a year from the five control points) and the radioactive contamination of surrounding terrain was measured using the Mobile Spectrometric Laboratory (once a year).

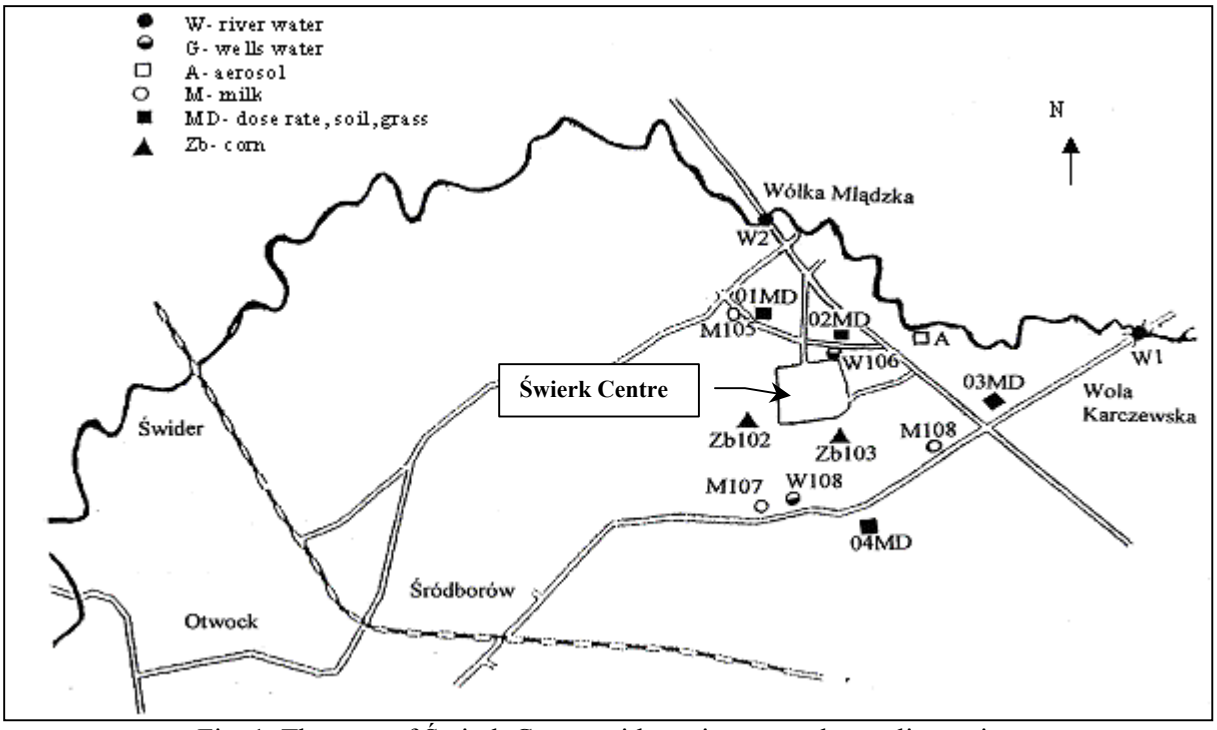

Fig. 1. The map of Świerk Centre with environmental sampling points

All methods of sampling and measurements were conducted according to methods described in "The measurement technique applied in control survey for estimation of radiological situation in surrounding of Centre Świerk and KSOP-Różan".

Table 1. Mean concentrations of radiocaesium in the samples of water from Świerk Centre area (activity range in parenthesis).

	Radiocaesium concentrations mBq/dm^3	
	2002	2003
River Świder	3.5 (1.6-7.1)	1.1 (0.7-2.0)
Wells	6.1 (4.7-8.1)	4.7 (4.3-5.3)
Municipal sewage-treatment plant	8.0 (7.8-8.3)	8.7 (7.6-9.8)

The concentrations of radiocaesium in the all samples of water are at low levels, similar as in other regions of Poland.

Table 2. Mean concentrations of ^{137}Cs and ^{40}K in environmental samples from Świerk Centre area (activity range in parenthesis).

Sample	^{137}Cs		^{40}K	
	2002	2003	2002	2003
Soil, Bq/kg	1.78 (0.07-3.56)	1.67 (1.18-3.20)	226 (130-376)	196 (117-280)
Corn, Bq/kg	0.14 (<0,07-0.22)	0.21 (<0.09-0.30)	135 (118-148)	125 (110-137)
Grass (dry), Bq/kg	18.6 (<0.73-67.2)	10.4 (1.20-39.8)	317 (207-480)	617 (380-1216)
Atmospheric aerosol	3.6 (0.6-20.7)	1.9 (0.2-8.5)	13.7 (<3.0-44.0)	11.9 (<2.0-32.0)

The concentrations of ^{137}Cs and ^{40}K in the soil samples were comparable to the concentrations measured in many other places in Poland [1] and the measured activities are at low level. The concentrations of both isotopes in all corn samples were very low. In grass samples the concentrations of ^{40}K were at normal level encountered in Poland. The same situation was observed as regards ^{137}Cs concentrations for grass sample, except the samples taken in point of 01MD where the concentrations were always higher. In the samples of atmospheric aerosol the concentrations of both radionuclides were in low level, similar as in other regions in Poland.

The mean gamma radiation dose rate (including cosmic radiation) around Świerk Centre measured in 2002 was 69 (64-81) nGy/h and in 2003 was 73 (60-83). The mean gamma radiation dose rate in whole Poland was 75.5 (47-119.9) nGy/h [1].

Around the Świerk Centre the radioactive contamination of terrain was at the same levels as in the other regions in Poland.

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ACKNOWLEDGEMENTS

Project supported by the National Atomic Energy Agency.

2.10 CAESIUM-137 RADIUM-226 AND POTASIUM-40 IN THE FLESH OF FISH FROM THE SOUTHERN BALTIC SEA

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Radionuclides occurring in sea environment, especially in seawater, are incorporated into the marine organisms and give rise to radiation exposure of humans from ingestion of seafood. The purpose of this study was to determine activity concentrations of ^{137}Cs, ^{226}Ra and ^{40}K in four fish species: herring, sprat, cod and plaice. Annual intake of ^{137}Cs and ^{226}Ra with fish for adult population was estimated from the concentrations determined and average annual consumption of fish. Fish samples were collected from Southern Baltic Sea in the years 2002 and 2003.

Activity concentrations of ^{137}Cs in fish flesh ranged from 5.5 Bq kg$^{-1}_{ww}$ to 13.1 Bq kg$^{-1}_{ww}$. Concentration of ^{137}Cs differs with fish species, however, they were similar in sub-regions of Southern Baltic Sea. The highest activity concentrations of ^{137}Cs were found in flesh of cod and the lowest in plaice. The average concentrations of ^{40}K, ^{137}Cs and ^{226}Ra in fish flesh, depending on species, in years 2002 and 2003 are presented in Table.1.

Table 1. The average concentrations of ^{137}Cs, ^{226}Ra and ^{40}K in Baltic Sea fish flesh

Species	Year	Fish length [cm]	^{137}Cs [Bq kg$^{-1}_{ww}$]	^{226}Ra [Bq kg$^{-1}_{ww}$]	^{40}K [Bq kg$^{-1}_{ww}$]
Herring	2002	12-26	8.00±0.68	0.037±0.001	125±5.89
	2003	15-25	7.35 ±0.55	0.025±0.002	129±12.0
Sprat**	2002	9-14	8.29±0.85	0.080±0.015	109±4.06
	2003	10-14	7.27±0.29	0.070±0.008	113±9.72
Plaice	2002	19-32	6,86±1.00	0.034±0.007	97.2±5.30
	2003	23-30	6.88±0.51	0.034±0.003	95.5±11.9
Cod	2002	20-37	9.65±0.85	0.064±0.010	120±13.5
	2003	28-55	9.50±1.68	0.065±0.010	121±7.91

** whole fish

The average concentrations of ^{137}Cs determined is particular species in years 2002 and 2003 were very similar. In cod samples above concentrations were 9.65±0.85 and 9.50±1.68 Bq kg$^{-1}_{ww}$, in plaice 6.86±1.00 and 6.88±0.51 Bq kg$^{-1}_{ww}$. The differences in ^{137}Cs concentrations between species approach 40%. The activity concentrations of ^{226}Ra in cod samples (0.064-0.065 Bq kg$^{-1}_{ww}$) were

about two times higher than in herring and plaice (0.025-0.037 Bq kg^{-1}_{ww}). Activity concentration of ^{40}K in four fish species ranged from 95.5 Bq kg^{-1}_{ww} to 129 Bq kg^{-1}_{ww}.

In the region of Southern Baltic Sea, maximum average concentration of ^{137}Cs in fish flesh (14.4±2.9 Bq kg^{-1}_{ww}) [1] was observed in 1989 and was about 7 times higher than before Chernobyl accident (about 2.0 Bq kg^{-1}_{ww}). During subsequent years, a decrease of ^{137}Cs concentrations in fish flesh was observed and in 2002-2003 the average value for all species (7.8±1.0 kg^{-1}_{ww}) was about 50% lower then in 1989. These changes are the result of ^{137}Cs activity concentration decrease in seawater from about 100 Bq m^{-3} in 1989 [2] to 55 Bq m^{-3} in 2002 [3].

Temporal changes of radiocaesium concentrations in fish observed in the period of 1985-2003 were presented in figur.1. From early 90-ties ^{137}Cs concentrations decreased exponentially with time. The calculated effective half times for a decrease of ^{137}Cs in fish (T_{eff}) is equal 16.3 years. This suggests that the pre-Chernobyl level may be achieved in 2035-2040 years.

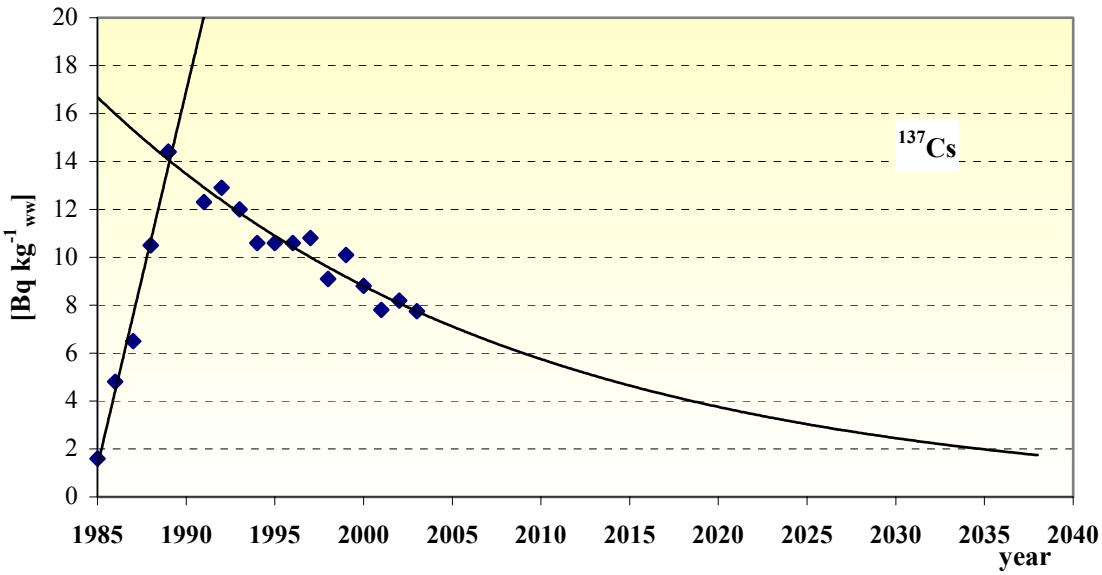

Fig. 1. Temporal changes of ^{137}Cs concentrations in Southern Baltic Sea fish flesh

Taking into account average ^{137}Cs activity concentrations obtained in 2002-2003, the average committed effective dose due to yearly intake from fish consumption (4.8 kg) was calculated as 0.5 µSv $year^{-1}$. In the same time, the average ^{40}K concentration in fish from the Baltic Sea (114 Bq kg^{-1}_{ww}) corresponds to a dose of 3.56 µSv $year^{-1}$. However, ^{137}Cs, from the Chernobyl fallout, contributed about 88% to the radiation dose from man-made radioactivity in Baltic Sea ecosystem. This dose is almost one order of magnitude smaller than the dose from for natural ^{40}K and about 50 times smaller than that from ^{210}Po [4].

Table.2 Average committed effective dose due to yearly intake from fish consumption in Poland, 2002-2003

	^{40}K	^{137}Cs	^{226}Ra
Activity concentration [Bq kg^{-1}_{ww}]	114	8.00	0.05
Dose coefficient [µSv Bq^{-1}]	0.006	0.013	0.28
Dose [µSv/year]	3.3	0.50	0.07

ACKNOWLEDGEMENTS

This work was performed in frame of Helsinki Commission , sponsored by National Atomic Energy Agency

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3 PROTECTION OF GENERAL POPULATION AND OCCUPATIONALLY EXPOSED PERSONS

3.1 ANNUAL EFFECTIVE DOSE (2003)

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The population of Poland is at present subject to ionizing radiation from natural and artificial sources at levels not much different from those in other European countries. Ionizing radiation of natural origin consists of cosmic radiation and radiation of natural radionuclides present in the environment and in various types of products and materials such as building materials, food, water and air. Man-made ionizing radiation presently consists of radiation used in medical diagnostics and, to a much lesser extent, of radiation emitted by radioactive fallout from nuclear tests explosions and from accidents in nuclear facilities.

The average annual total effective dose (for whole body) from natural and man-made sources, calculated according to the recommendation of UNSCEAR 2000[•)], amounted in 2003 to 3,35 mSv for the statistical inhabitant of Poland.

The most considerable contribution to this value, about 74% (2,48 mSv/year), is from radiation of natural radionuclides. Among them the highest individual dose arises from radon exposure (40,6% or 1,36 mSv/year). Cosmic radiation contributes only 8,5% (0,28 mSv/year). A very small contribution (0,2% or 0,006 mSv/year) arises from enhanced exposure to cosmic radiation during air travel at altitudes between 9-12 km.

The man-made sources contribute to the average annual total effective dose about 0,87 mSv/year, i.e. 26%, most of which comes from ionizing radiation used in medical diagnostics (25,4% or 0,85 mSv/year).

The average annual effective doses for inhabitants of Poland from various sources of radiation are shown in Figures 1 and 2.

• United Nations Scientific Committee on the Effects of Atomic Radiation: Sources and Effects of Ionizing Radiation. United Nations, New York, 2000.

According to the national regulations the dose limit for people living or staying in the vicinity of ionizing radiation sources, including nuclear installations, and for people exposed to the radiation resulting from the radioactive contamination of the environment, expressed as the effective dose, is 1 mSv within the period of 12 months. The dose limit does not include irradiation from cosmic rays and from natural radioactive elements presented in the environment or in human organism in physiological conditions.

Investigations carried out by the Central Laboratory for Radiological Protection allow to estimate the value of the annual effective dose due to man-made radiation (without medical diagnostics), for an average inhabitant of Poland in 2003, to be 0,019 mSv. This value contains the dose due to external gamma radiation and the dose from radiation of radionuclides incorporated to the body through alimentary and respiratory tracts.

Thus, in 2003 the average man-made radiation dose reached 1,9% of the dose limit for population (1mSv), and 0,6% of the average total annual effective dose to which the statistical inhabitant of Poland was exposed.

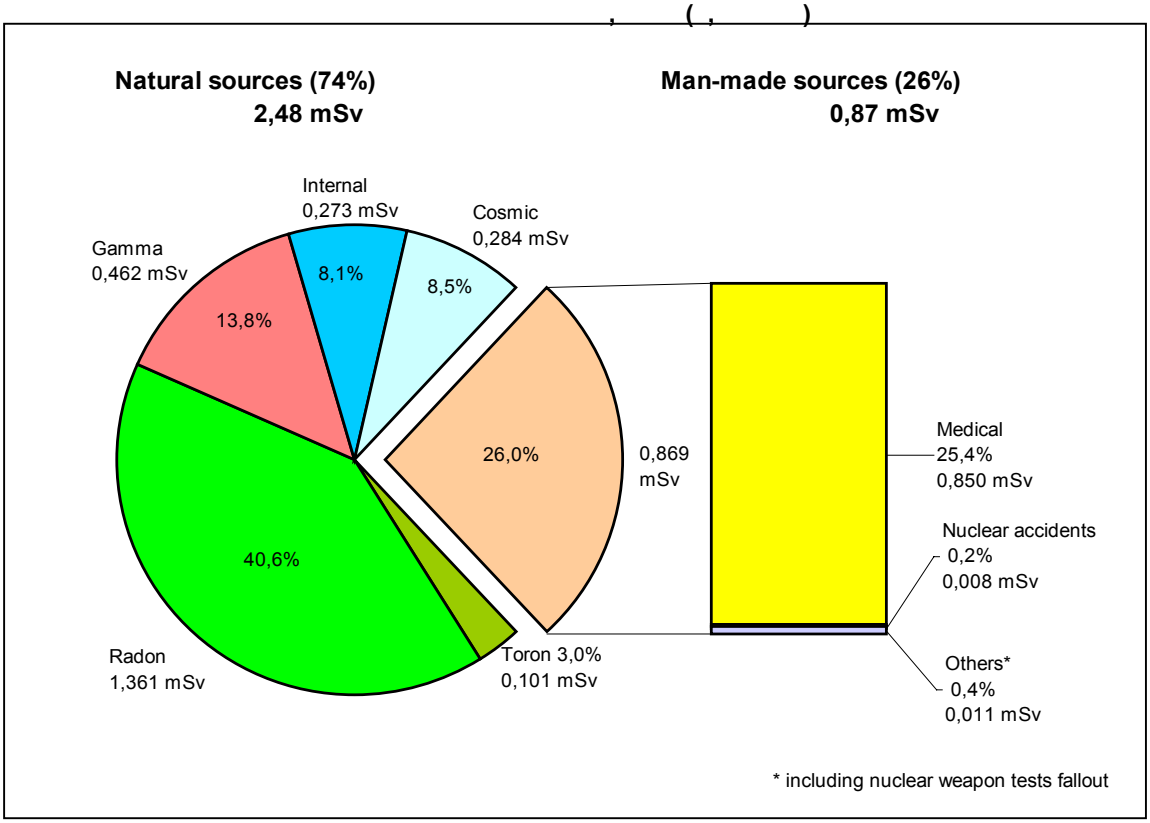
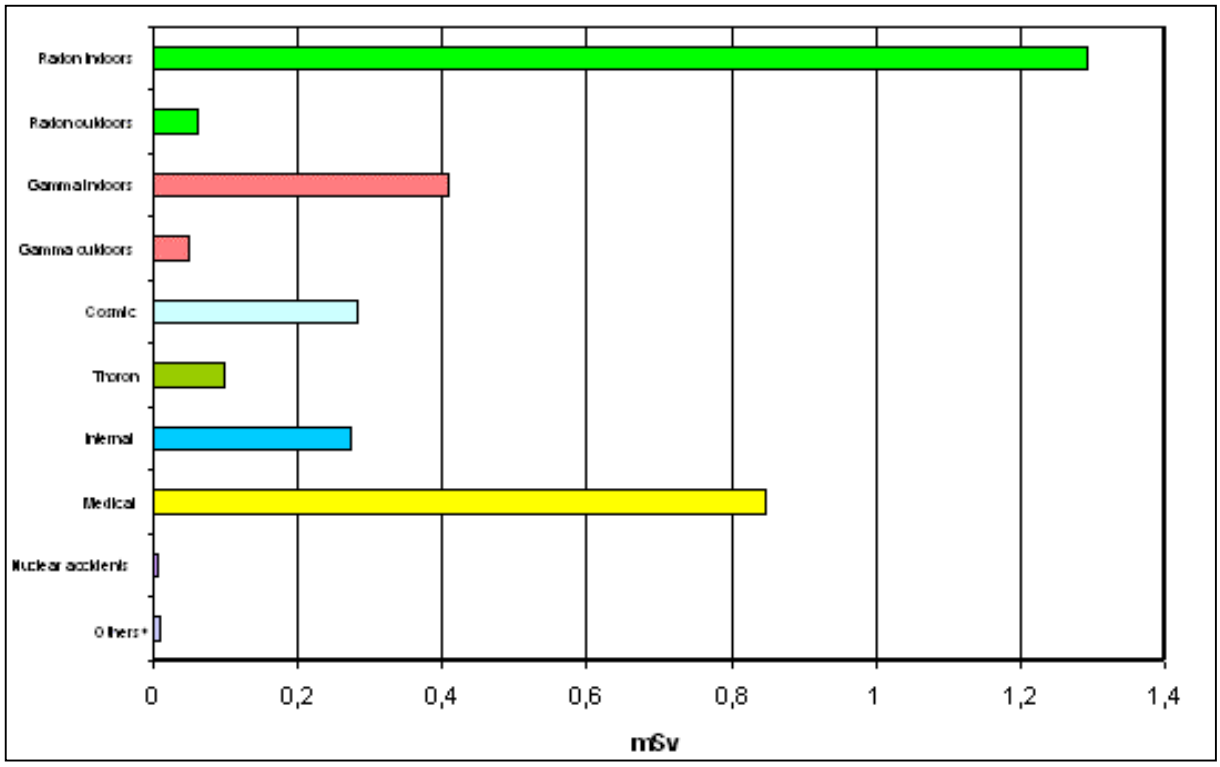


Fig. 1. Contribution of different radiation sources to the average annual individual effective dose in Poland, 2003 (3,35 mSv)



- including nuclear weapon tests fallout

Fig 2. Average annual individual effective dose from different radiation sources in Poland in 2003.

ACKNOWLEDGEMENTS

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3.2 RADIOACTIVITY OF FOOD IN POLAND IN 2002-2003

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The analysis of the radioactive contamination of food was carried out in Poland in 2002-2003. The results were compared with the data for the period 1985-1986. Since the Chernobyl accident gradual decrease of contamination level has been observed. Due to soil deposition of radioactive fallout from Chernobyl, after 1986 the level of radionuclides in food increased, especially in products of animal origin and in fruits. At present, the main source of additional radiation dose is ingestion of artificial isotopes with food. No significant regional differences in the distribution of the level of caesium over the territory of Poland have been registered. Milk is the main contributor of caesium to the total diet; its share is about 30% of annual intake of caesium. In Poland the average annual effective dose resulting from consumption of food contaminated with ^{137}Cs was 6 μSv per caput in both 2002 and 2003.

Table 1. Mean activity of ^{137}Cs in foodstuffs in Poland [Bq kg^{-1}]

	1985	1986	2002	2003
milk	0,3	5,2	0,7	0,8
meat	0,8	16,4	1,7	1,9
poultry	0,3	3,1	1,1	0,9
fish	0,3	6,3	1,7	1,8
eggs	-	2,4	1,0	0,7
potatoes	0,2	1,2	0,8	0,7
vegetables	0,7	5,0	0,5	0,7
fruit	0,4	8,2	0,5	0,6
cereals	0,6	7,4	0,2	0,3

Table 2. Annual mean intake of ^{134}Cs, ^{137}Cs, ^{90}Sr via ingestion in Poland [Bq/year]

	^{134}Cs	^{137}Cs	^{90}Sr
1985	-	325	110
1986	2054	4324	131
2002	-	467	<110
2003	-	503	-

Table 3. Per capita annual effective dose due to radionuclides intakes via ingestion in Poland [μSv]

	^{134}Cs	^{137}Cs	^{90}Sr
1985	-	4	6
1986	34	54	7
2002	-	6	<6
2003	-	6	-

In 2002 and 2003 Department of Radioactive Contamination took part in international intercomparisons of radioisotope determinations organised by PROCORAD (FRANCE) and IAEA in 2002. Gamma emitters were determined in samples (urine, mineral matrix) by gamma spectrometry. Statistical evaluation shows that the results of determination carried out in the Department are satisfactory.

Table 4. Results of international intercomparision of radioisotope determinations

	Isotope	Sample	Certified sample [Bq/l]	Our results [Bq/l]
PROCORAD 2002	Cs-137	B	6,79	6,44±0,27
		C	8,48	7,99±0,30
	Ba-133	B	4,69	4,11±0,24
		C	5,87	5,19±0,27
	Eu-152	B	6,64	5,94±0,34
	K-40	B and C	62,5	59,3
IAEA 2002	Mn-54	120 A	36,5	40,87±2,57
		120 B	18,2	18,32±0,79
	Co-57	120 A	33,9	42,27±2,11
		120 B	5,84	5,24±0,35
	Co-60	120 A	145,0	168±7,56
		120 B	24,9	24,29±1,04
	Zn-65	120 B	3,95	4,30±0,26
	Y-88	120 A	34,9	39,72±2,86
		120 B	10,4	10,06±0,43
	Cs-134	120 A	76,0	77,48±4,02
		120 B	13,01	11,12±0,48
	Cs-137	120 A	160,0	190,32±8,56
		120 B	27,0	25,92±1,11
	Eu-152	120 B	14,6	13,22±0,62
	Am-241	120 B	17,0	14,39±0,69
PROCORAD 2003	Co-58	B	5,67	5,82±0,15
	Cs-134	B	5,21	4,57±0,08
	Ce-139	B	6,61	6,68±0,19
	Na-22	C	5,08	4,68±0,16
	K-40	B and C	57,3	56,7±2,65

ACKNOWLEDGEMENTS

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3.3 RADIOACTIVE CONTAMINATION OF FOREST ENVIRONMENT*

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Radioactive Contamination Department

Relatively high activity level of caesium 137 isotopes in the forest environment results from a complexity of the ecosystem and low human interference. Caesium slowly migrates in the soil and accumulates in the litter, lichens and mosses that many wild animals feed on.

The ^{137}Cs activity measured in game such as deer, boar and stag meat is shown in Fig 1. A significant scatter of results is attributed to the individual feeding habits of particular species.

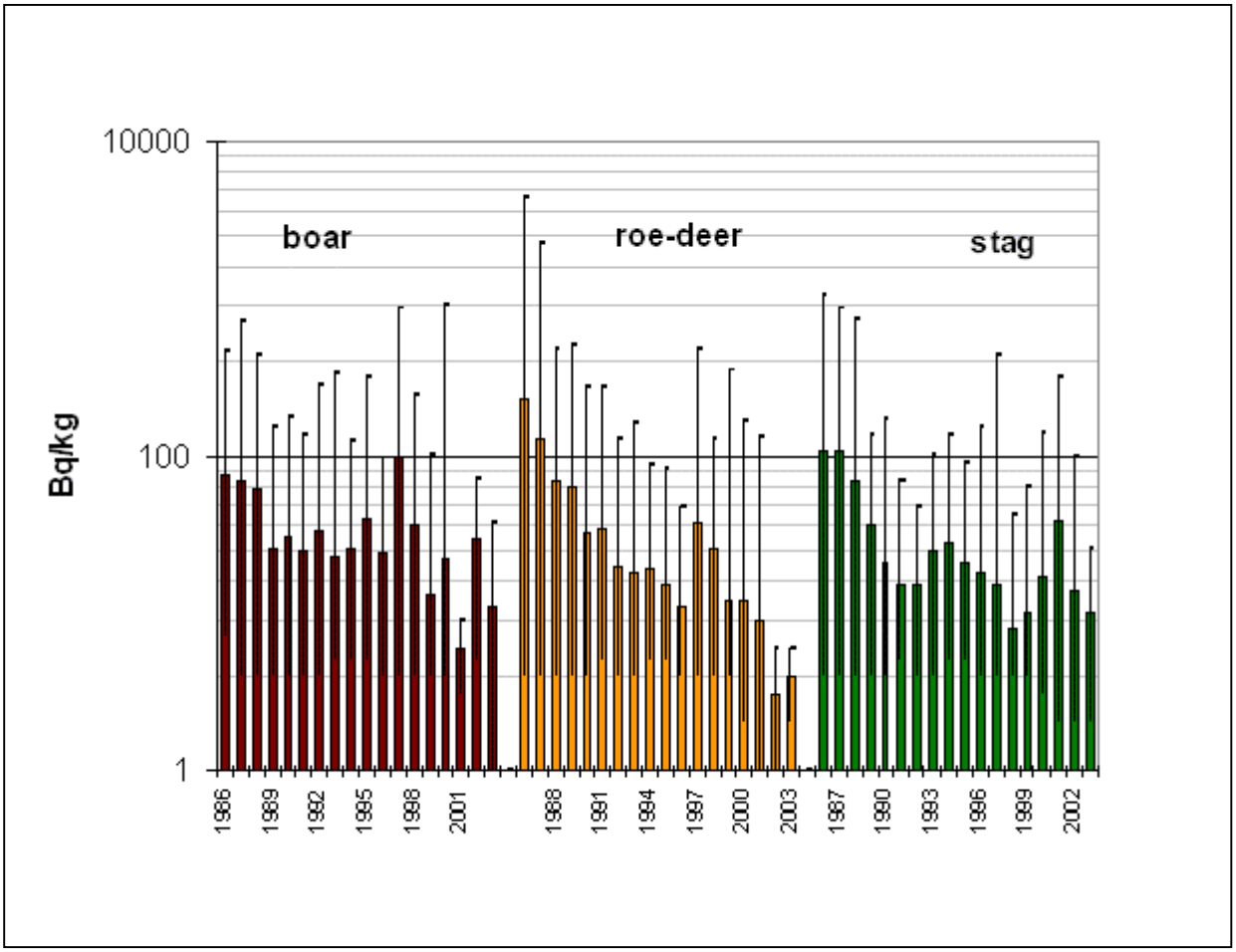

Fig.1. Concentration of ^{137} Cs in game meat in Poland, 1986 – 2003

Therefore, it is rather difficult to conclude on a systematic year-by-year changes in the Cs-137 activity because of the different number of samples analysed every year. Moreover, the samples did not originated from the same area.

Several kinds of mushrooms have been analysed. The results for Xerocomus Badius, Cantharella Cibarius, Boletus Edulis in the period 1985-2003 are shown on the Fig 2. Activity in mushrooms is generally much higher that non-forest foodstuffs such as: vegetables, fruits, cereals. The values range from few tens to about a hundred Bq/kg. The fact that high activity has been observed over such a long period of time proves the durability of the caesium accumulation. The presence of caesium-137 in samples from the pre-Chernobyl period points to its origin from the fallout following tests of nuclear weapons. In cultivated species from the period the activity was at a level of about 1 Bq/kg.

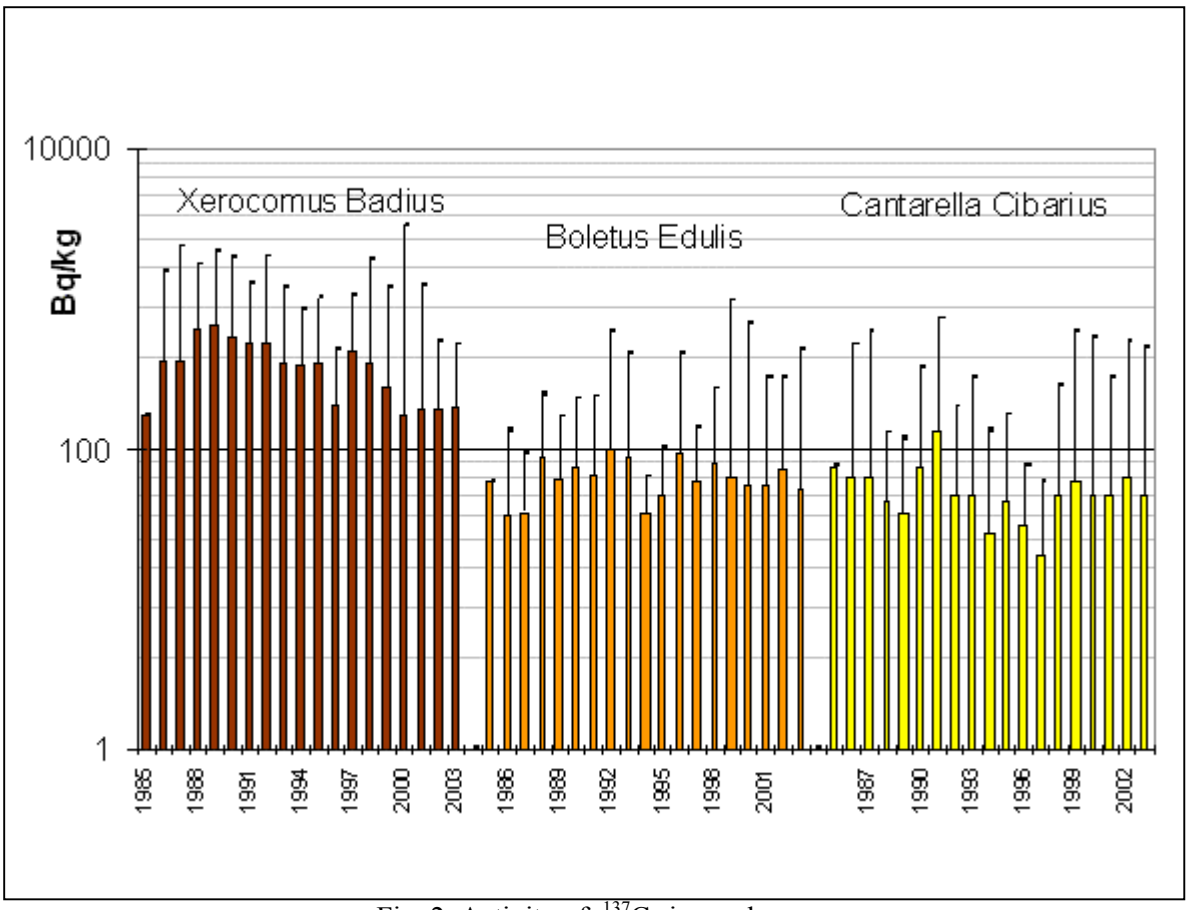

Fig. 2. Activity of ^{137}Cs in mushrooms.

*project was performed in a frame of own CLOR funding

3.4 RISK ASSESMENT FOR POPULATION OF POLAND in 2003

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The aim of this work was to assess radioactive doses received by the population of the Warsaw area resulting from the ingestion of food containing ^{137}Cs and ^{90}Sr. The amount of these isotopes was determined in foodstuffs being important in a regular diet. The food products were gathered from hypermarkets network located on the outskirts of Warsaw. Products sold in such stores originate from all districts of Poland. We assume that on average, at least once a year, each inhabitant of the Warsaw area would shop and consume food from these shops. In the selection of samples for examination we have taken into account the share of respective products in a average diet. This was based on the data from the Statistical Yearbook, 2003. The sampling scheme is shown in Table 1.

Table 1. Sampling of foodstuffs

Category	Sampling frequency
Milk	1 per month
Milk products: various brands of cheese and milk drinks	2 per year
Meat: various kinds	2 per year
Poultry, hen eggs	2 per year
Sea and fresh water fish	2 per year
Fruits and vegetables: various kinds	1 per year
Corn products	1 per year

Radiochemical and spectrometric methods were applied to determine activity of ^{137}Cs. For spectrometric measurements a gamma spectrometer with HPGe detector was used. Measurements performed both in the Marinelli geometry after homogenization of products, and in ash samples in a geometry of a flat cylinder placed on the detector. For radiochemical analysis a dissolved sample was filtered through a radiochemical funnel with ammonium molybdenum-phosphate (AMP) bed, selective for caesium. The activity of caesium in the bed was measured using Low-Level GM Multicounter System (production of Riso, Denmark). Strontium 90 was determined from the beta radiation of ^{90}Y, after equilibrium ^{90}Sr – ^{90}Y was reached. Activity of caesium and strontium in various foodstuffs is shown in Table 2.

Table 2. Activity of ^{137}Cs and ^{90}Sr in foodstuffs from supermarkets in Warsaw area.

Product	^{137}Cs activity* [Bq/kg]	^{90}Sr activity* [Bq/kg]
Milk and milk products	0,10- 2,59	0,01 – 0,13
Meat	0,21 – 8,50	0,04 – 0,08
Poultry	0,34 – 0,41	0,03
Fish	0,41 – 11,11	0,02 – 0,06
Eggs	0,16 - 0,23	0,02
Potatoes	0,20	0,06
Vegetables	0,04 – 1,48	0,01 – 0,22
Fruits	0,08 – 0,56	0,01 – 0,12
Corn products	0,04 – 0,48	0,01 – 0,33

*) standard deviation less than 15 %

In meat and fish products the greatest level of contamination was found in beef (8.50 Bq/kg) and cod (11.11 Bq/kg). In vegetables the most significant level was detected in beans (“Jaś” – 1.48 Bq/kg) and black current (0.56 Bq/kg).

On this basis we calculated the average annual effective dose due to consumption of contaminated foodstuffs for inhabitants of the Warsaw area. For comparison a value for Cs-137 dose is given, based on results of activity of Cs-137 in food stuffs obtained from Sanitary Epidemiological Station. The results are shown in Table 3.

Table 3. Average annual effective radiation dose for Warsaw area and Poland in 2003, from contaminated foodstuffs

	Effective dose [μSv]	
	Cs-137	Sr-90
Households	3,2	1,2
Total consumption	3,9	1,5
Mean value for Poland	5,9	-

Difference of doses based on household and total consumption data is caused by differences in methods of data collecting and of statistical elaboration.

ACKNOWLEDGEMENTS

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3.5 INVESTIGATION OF RADIOACTIVITY OF RAW AND BUILDING MATERIALS*

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Central Laboratory for Radiological Protection (CLOR) supervises the operation of Polish laboratories monitoring concentration of natural radionuclides in raw and building materials, organizes training of the personnel and collects results of the measurements. Since 1980 the results of the measurements are stored in our computer data base. 28276 samples were analysed up to 2003.
The number of samples investigated in 2002 and 2003 by particular laboratories and the minimum, average and maximum values of radioisotopes concentrations found in building materials, are given in Tables 1, 2 and 3.

The most numerous is a group of raw materials of industrial origin. These materials consist of industrial wastes in which the radionuclide concentrations most frequently exceed permissible limits. The group of final building materials is also numerous because their activity content is directly linked with the radiation exposure of people and therefore these materials are investigated more intensively.
The lowest concentrations of radionuclides were found in some natural raw materials (marble, chalk, gypsum, limestone) and therefore control of these samples is not obligatory. The slag remaining after copper production process and certain sorts of phosphogypsum distinguish themselves particularly unfavourably and they are generally eliminated from all applications associated with housing.

Since 1980 till 2002 the raw and building materials were investigated according to the Instruction No. 234/95 of Institute of Building Technology (Recommendations for investigating the natural radioactivity of raw and building materials). The following two criteria of usability of a building material in housing and public building construction have been established:

Coefficient f_1 (no units) is connected with the limitation of whole-body exposure to gamma radiation. It comes from the limitation of the natural isotope concentration in raw materials, building materials and wastes. It is calculated according to the formula below:

$$f_1 = 0.00027 \cdot S_K + 0.0027 \cdot S_{Ra} + 0.0043 \cdot S_{Th}$$

where S_K, S_{Ra}, S_{Th} are the values of concentration of ^{40}K, ^{226}Ra and ^{232}Th in Bq/kg.

Coefficient f_2 is connected with the additional limitation for the ^{226}Ra concentration in the product coming from radon emanation:
$f_2 = S_{Ra}$ where S_{Ra} is the ^{226}Ra concentration in Bq/kg.

* Laboratory possesses documented and implemented quality system within the scope of investigation of raw and building materials radioactivity that meets the requirements of PN-EN ISO/IEC 17025:2001

Corrected (total measurement error at the confidence level of 0.95 is added) values f_{1max} and f_{2max} of the coefficients are applied to check for the compliance with the regulations:

$f_{1max} = f_1 + \Delta f_1 \leq 1$; $f_{2max} = f_2 + \Delta f_2 \leq 185$ Bq/kg

The evaluation of raw and building materials gives positive result when both of the above criteria are satisfied. It means that the consignment of the tested material can be accepted for production of building materials applied for buildings intended for permanent stay of people.

If f_{1max} or f_{2max} coefficient exceeds admissible value by no more than 20%, the consignment of raw materials may be utilized in production of building materials in a part that guarantees satisfaction of the requirements for final product.

In case where f_{1max} or f_{2max} coefficient exceeds admissible value by more than 20% it may be recommended utilizing of the material consignment in other applications, such as road or underground construction.

The values of qualification coefficients f_1 and f_2 in 2002 are presented in Table 2.

Radionuclide concentration in natural origin raw and building materials does not usually exceed limits for coefficients f_1 and f_2. For samples of industrial origin raw materials f_1 and f_2 coefficients frequently have values higher than the permissible coefficients f_1 and f_2 (Table 2).

Since 2003 for the purpose of evaluation of raw and building materials for use in constructions of various types, the criteria given in the Regulation of Council of Ministers of 3 December 2002 "*on natural radioactive isotope content in raw and building materials used in buildings for population and livestock, as well as in industrial wastes used in construction, and monitoring of the concentration of these isotopes*", Dziennik Ustaw no 220/2002 pos. 1850 (later called Regulation) are applied.

According to the Regulation the concentration of the natural radioactive isotopes in raw and building materials, as well as wastes is calculated using:

- activity coefficient f_1 defined by equation

$$f_1 = \frac{S_K}{3000} + \frac{S_{Ra}}{300} + \frac{S_{Th}}{200}$$

- activity coefficient f_2

$$f_2 = S_{Ra}$$

where: S_K, S_{Ra}, S_{Th} are the concentrations of potassium ^{40}K, radium ^{226}Ra and thorium ^{228}Th, in Bq/kg.

§3 of the Regulation states that the values of f_1 and f_2, cannot exceed 20% of the following:

1. f_1 = 1 , f_2 = 200 Bq/kg related to raw and building materials applied in construction for public or livestock;
2. f_1 = 2, f_2 = 400 Bq/kg related to industrial wastes used in surface constructions situated on the ground and built on the inhabited (used) areas or devoted for construction in the local urbanization plans, and for levelling of such terrains;
3. f_1 = 3,5, f_2 = 1000 Bq/kg related to industrial wastes for constructions situated on the ground not mentioned above and for levelling of the terrains not mentioned above;
4. f_1 = 7, f_2 = 2000 Bq/kg related to industrial waste used in underground parts of constructions mentioned in point 3 and in underground constructions such as railway and road tunnels excluding industrial wastes used in underground mining galleries.

§4 of the Regulation determines, in addition, that while using industrial wastes for the levelling of the terrain quoted § 3 pt. 2 and 3, and for road, sports and recreation object construction it should be assured that achievement required values of f_1 and f_2 will cause the absorbed dose rate at 1 meter above terrain, road or object be less than 0.3 micro grey per hour (300 nGy/h), in particular by putting the additional layer of another material.

The recommended procedures on sampling and preparation of samples, measurement, and elaboration of the results can be found in the "*Guidelines on the Determination of Natural Radioactivity in Raw and Building Materials*", Instruction 234/2003 of Institute of Building Technology.

The values of activity coefficients f_1 and f_2 in 2003 are presented in Table 3.

The values of these coefficients f_1 are about 20% higher than values of qualification coefficients f_1.

Three samples of light weight and cellular concrete in the group of building materials exceed the limit value of activity coefficient f_1 ($f_1 = 1$), but the excess is lower than 20%.

Table 1. Number of samples investigated in 2002-2003 at laboratories supervised by CLOR.

Laboratory investigating raw and building materials	2002	2003
Design and Research Office of Building Ceramic Industry in Toruń	267	281
Central Laboratory for Radiological Protection in Warszawa	59	112
Central Laboratory of Concrete Industry "CEBET" in Warszawa	269	204
Power Plant in Łódź	66	64
Establishment of Technology and Management of Power Plant Waste "Energopomiar" in Katowice	232	239
POLLYTAG S.A. Laboratory in Gdańsk	290	225
Institute of Building Materials of Natural Origin in Opole	0	0
Institute of Nuclear Physics in Kraków	0	0
Power Plant II in Gdańsk	253	245
Power Plant in Bydgoszcz	65	77
LAFARGE Cement Polska, Laboratory in Bielawy	111	75
EKOBET – SIEKIERKI Laboratory in Warszawa	91	86
Power Plants in Warszawa	160	143
Power Plants in Poznań	12	20
Technical University in Wrocław	18	14
ELPOLAB Laboratory in Połaniec	62	90
ZUTTER in Radom Laboratory in Ostrołęka	52	74
Total	2014	1949

Table 2. Concentration of natural radionuclides and the values of qualification coefficients f_1 and f_2 measured in selected building and raw materials in 2002.

Name of building raw or materials	Number of samples	Concentration of natural radionuclides (S_K, S_{Ra}, S_{Th})*) [Bq·kg^{-1}]			Values of coefficients*)	
		potassium ^{40}K	radium ^{226}Ra	thorium ^{228}Th	f_1	f_2 [Bq·kg^{-1}]
RAW MATERIALS OF NATURAL ORIGIN						
Marble	0	-	-	-	-	-
Chalk	2	95 – 95 – 95	12 – 13 – 14	2 – 3 – 4	0,07 – 0,07 – 0,07	12-13-14
Gypsum	9	20 – 63 – 140	4 – 15 – 72	1 – 5 – 30	0,01 – 0,07 – 0,35	4 – 15 – 72
Limestone	1	98	11	4	0,07	11
Lime	0	-	-	-	-	-
Sand	5	115 – 245 – 337	4 – 7 – 11	6 – 8 – 9	0,07 – 0,12 – 0,16	4 – 7 – 11
Marl	1	304	24	14	0,20	24
Clinker	5	55 – 127 – 257	19 – 29 – 46	12 – 14 – 17	0,13 – 0,17 – 0,27	19 – 29 – 46
Still stock	3	478 – 738 – 904	25 – 29 – 37	40 – 43– 45	0,39 – 0,46 – 0,51	25 – 29 – 37
Clay	5	337 – 659 – 783	25 – 33 – 40	26 – 37– 43	0,27 – 0,43 – 0,49	25 – 33 – 40
Clump	2	708 – 777 – 846	64 – 67 – 70	59 – 65 – 70	0,61 – 0,66 – 0,71	64 – 67 – 70
RAW MATERIALS OF INDUSTRIAL ORIGIN						
Fly ashes	800	46 – 686 – 1027	11 – 117 – 276	2 – 96 – 152	0,11– 0,90 – 1,47	11 – 117 – 276
Boiler slag	420	36 – 595 – 2240	10 – 92 – 252	4 – 74 – 132	0,04 – 0,72 – 1,39	10 – 92 – 252
Metallurgical slag	6	26 – 118 – 207	17 – 105 – 164	4 – 30 – 41	0,06 – 0,44 – 0,63	17 – 105 – 164
Copper slag	0	-	-	-	-	-
Phospho-gypsum	1	52	7	1	0,03	7
Ash aggregate	228	290 – 676 – 1058	6 – 102 – 140	1 – 83 – 103	0,10 – 0,81 – 0,96	6 – 102 – 140
BUILDING MATERIALS						
Cement	41	82 – 328 – 819	19 – 54 – 97	11 – 30 – 59	0,15 – 0,35 – 0,60	19 – 54 – 97
Lightweight and cellular concrete	167	150 – 499 – 685	13 – 76 – 172	5 – 60 – 88	0,11 – 0,59 – 0,89	13 – 76 – 172
Other concrete	2	105 – 122 – 138	19 – 20 – 20	8 – 8 – 8	0,11 – 0,12 –12	19 – 20 – 20
Building ceramics**)	254	150 – 715 – 1240	4 – 50 – 95	3 – 48 – 93	0,04 – 0,53 – 0,80	4 – 50 – 95

*) Values: minimum - average – maximum; **) Bricks, hollow ceramic bricks, roof tiles, shapes etc.

Table 3. Concentration of natural radionuclides and the values of activity coefficients f1 and f2 measured in selected building and raw materials in 2003.

Name of building	Number of samples	Concentration of natural radionuclides (S_K, S_{Ra}, S_{Th})*) [Bq·kg^{-1}]			Values of coefficients*)	
raw or materials		potassium ^{40}K	radium ^{226}Ra	thorium ^{228}Th	f_1	f_2 [Bq·kg^{-1}]
RAW MATERIALS OF NATURAL ORIGIN						
Marble	2	39 – 49 – 58	1 – 1 – 1	1 – 2 – 2	0,02 – 0,02 – 0,02	1 – 1 – 1
Chalk	0	-	-	-	-	-
Gypsum	25	1 – 201 – 599	3 – 49 – 133	1 – 31– 95	0,02 – 0,37 – 1,01	3 – 49 – 133
Limestone	1	629	51	54	0,64	51
Lime	0	-	-	-	-	-
Sand	5	8 – 219 – 360	3 – 8 – 11	5 – 8 – 10	0,08 – 0,14 – 0,19	3 – 8 – 11
Marl	1	136	15	6	0,12	15
Clinker	5	63 – 111 – 158	25 – 31 – 49	13 – 15 – 18	0,17 – 0,21 – 0,29	25 – 31 – 49
Still stock	4	795 – 815 – 857	36 – 43 – 47	37 – 42– 44	0,57 – 0,62 – 0,65	36 – 43 – 47
Clay	0	-	-	-	-	-
Clump	0	-	-	-	-	-
RAW MATERIALS OF INDUSTRIAL ORIGIN						
Fly ashes	821	39 – 684 – 1183	11 – 118 – 377	11 – 91 – 173	0,10– 1,03 – 2,24	11 – 118 – 377
Boiler slag	336	5 – 581 – 1436	9 – 86 – 210	3 – 72 – 124	0,04 – 0,83 – 1,43	9 – 86 – 210
Metallurgical slag	5	101 – 115 – 126	110 – 129 – 142	25 – 30 – 33	0,54 – 0,61 – 0,66	110 – 129 – 142
Copper slag	6	842 – 919 – 988	267 – 321 – 386	45 – 65 – 142	1,41 – 1,69 – 2,27	267 – 321 – 386
Phospho-gypsum	0	-	-	-	-	-
Ash aggregate	143	542 – 718 – 872	82 – 124 – 165	71 – 81 – 93	0,91 – 1,04 – 1,20	82 – 124 – 165
BUILDING MATERIALS						
Cement	45	73 – 237 – 472	23 – 53 – 104	12 – 27 – 48	0,16 – 0,38 – 0,60	23 – 53 – 104
Lightweight and cellular concrete	169	173 – 542– 1015	10 – 65 – 131	6 – 58 – 100	0,12 – 0,68 – 1,04	10 – 65 – 131
Other concrete	2	56– 299 – 542	16 – 60 – 104	7 – 37 – 66	0,10 – 0,48 – 0,86	16 – 60 – 104
Building ceramics**)	217	217 – 733 – 1298	13 – 50 – 104	2 – 47 – 85	0,13 – 0,64 – 0,98	13 – 50 – 104

*) Values: minimum - average – maximum; **) Bricks, hollow ceramic bricks, roof tiles, shapes etc

ACKNOWLEDGEMENTS

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3.6 OCCUPATION EXPOSURE TO EXTERNAL RADIATION MONITORED BY CLOR IN 2002 – 2003*

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The individual monitoring of workers depend on radiation conditions in the area concerned and on the type of work. According to the Polish Atomic Law (Article 17) [1] two categories of workers shall be established, depending on magnitude of exposure:

category A, for workers who may be exposed to an effective dose exceeding 6 mSv in one year or to an equivalent dose exceeding one-third of the dose limits for eye lens, skin and extremities; and

category B, for workers who may be exposed to an effective dose exceeding 1 mSv in one year or to an equivalent dose exceeding on-twentieth of the dose limits for eye lens, skin and extremities

The limiting dose quantities are the effective dose equivalent for the whole body exposure, and the dose equivalent for exposure of certain tissues or organs, defined in ICRP 60 [2].

Individual dose measurements and assessment of doses resulting from internal contamination according to the Polish Atomic Law (Article 21 p. 2) [1] should be performed by bodies possessing appropriate accreditation. The Laboratory has been approved by Polish Centre For Accreditation and granted Accreditation Certificate (Nr AB 450) in December 2003. The laboratory can perform all necessary procedure connected with external radiation monitoring.

A personal monitoring service in 2002-2003 has been carried out for about 5000 radiation workers from about 350 institutions. The monitoring was based on photographic dosimeters, TLD and track detectors. For gamma, beta and thermal neutrons the Kodak Personal Monitoring Film Type 2, and TL-LiF:Mg,Ti sintered detectors were used. Monitoring of fast neutrons was performed by means of the Kodak NTA nuclear emulsion. The detection limit of monitoring system was 0,4 mSv.

The radiation workers controlled by CLOR are divided into four groups: SCIENTIFIC, INDUSTRIAL, MEDICAL and OTHERS. The SCIENTIFIC group consists of persons from institutes and universities. The INDUSTRIAL group contains persons engaged in industrial radiography, thickness and mass gauging, manufacturing of smoke detectors and miscellaneous. The MEDICAL group consists of persons working in nuclear medicine and radiotherapy. The OTHER includes servicing technicians, personnel at airport custom checkpoints, and the border guards.

The results of measurements are summed up for each calendar year (Table 1 and Table 2) . To accomplish the estimation of occupational radiation hazards in the country, the results are grouped to the dose values and type of establishment.

Table 1. Distribution of annual doses from occupational exposure in 2002.

GROUP OF WORKERS	Number of persons					
	Annual personal dose equivalent range [mSv]					
	Total	below 5	below 15	below 50	Above 50	% *)
SCIENTIFIC	1715	1690	1713	1715	0	98,5
INDUSTRIAL	1307	1267	1301	1306	1	96,9
MEDICAL	2180	2170	2178	2180	0	99,5
OTHER	319	314	316	319	0	98,4
ALL GROUPS	5521	5441	5508	5520	0	97,0

*) – Per cent of persons who received annual doses below 5 mSv.

Table 2. Distribution of annual doses from occupational exposure in 2003.

GROUP OF WORKERS	Number of persons					
	Annual personal dose equivalent range [mSv]					
	Total	below 2	below 6	below 20	above 20	% *)
SCIENTIFIC	1062	1039	1059	1062	0	97,8
INDUSTRIAL	1242	1170	1220	1240	2	94,2
MEDICAL	2310	2255	2299	2309	1	97,6
OTHER	280	268	275	279	1	95,7
ALL GROUPS	4894	4732	4853	4890	4	96,7

*) – Per cent of persons who received annual doses below 2 mSv.

Annual collective dose equivalents and annual mean dose equivalents calculated for persons employed in different establishments and for the whole population being monitored are shown in Table 3.

Table 3. Annual collective dose equivalents and annual mean dose equivalents in 2002 and 2003.

GROUP OF WORKERS	Number of persons		Annual mean dose equivalent [mSv]		Annual collective dose equivalent [man mSv]	
	2002	2003	2002	2003	2002	2003
SCIENTIFIC	1715	1062	0,91	0,13	1561	138
INDUSTRIAL	1307	1242	1,31	0,44	1712	546
MEDICAL	2180	2310	0,80	0,25	1744	901
OTHER	319	280	0,98	0,39	313	109
ALL GROUPS	5521	4894	0,97	0,28	5355	1370

Annual dose equivalent greater then limit 20 mSv per year received 1 person in 2002 (in industrial sector) and 4 persons in 2003 (in industrial and medical sector). Analysis of these cases are given in Table 4.

Table 4. Analysis of cases of personal doses above 20 mSv in 2002 and 2003.

Cause of irradiation	Number of cases (dose)	
	2002	2003
unclear (industrial gammagraphy)	1 (42,3 mSv)	3 (23,4; 22,3 and 27,0 mSv)
unclear (nuclear medicine ^{99m}Tc)	-	1 (20,4 mSv)

The annual personal doses monitored by CLOR in 2002 and 2003 in different workers groups present similar occupational exposures monitored during the last few years [3,4]. This suggests a lack of changes in the radiation conditions in the workplaces.

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2. International Commission on Radiological Protection. *1990 Recommendations of the International Commission on Radiological Protection,* ICRP Publication 60. Ann ICRP 21 (1-3) (Oxford: Pergamon Press) 1991
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*project was performed in a frame of own CLOR funding

3.7 THE ACTIVITY OF CALIBRATION LABORATORY - SECONDARY STANDARD DOSIMETRY LABORATORY FOR RADIATION PROTECTION IN POLAND

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In Poland, calibration of radiation protection instruments is required by the "Law of Measures" (Act of Parliament, 2001) and "Atomic Law" (Act of Parliament, 2000). Taking in consideration the importance of radiation dosimetry accuracy, and the requirements for coherent relationship between national and international measurement systems, Calibration Laboratory was upgraded (1999) to the level of Secondary Standard Dosimetry Laboratory (SSDL).

The "Atomic Law" (Art. 27 p.2) includes the requirement, the calibration certificate for dosimetric instruments have to be issued by accredited laboratories. According to this statement, the activity of SSDL in the year 2002 concerned the development of the quality system documents, including quality manual, general and measurement procedures and instructions in compliance with the International Standard EN ISO/IEC 17025: 2001 adopted as a Polish Standard titled: "Ogólne wymagania dotyczące kompetencji laboratoriów badawczych i wzorcujących".

In December 2002, the accreditation process of Laboratory started passing on the Application Form for calibration laboratories with the required quality system documentation to Polish Centre of Accreditation. During the accreditation process Laboratory was assessed in the following areas: technical competencies, organization and management system, which assures impartiality, independence and quality of rendered services in the scope of testing and calibration. Based on the opinion of the Accreditation Committee and decision on granting of accreditation, SSDL received Accreditation Certificate of Calibration Laboratory No AP 057 on 7 November 2003. Accredited activity is defined in the Scope of Accreditation No AP 057 containing the ranges of measurement and the list of accredited staff.

The ranges of measurement (in short) according to the type of Calibration System are given below:

3.7.1 X-ray Calibration System for the following types of spectra:

low kerma series	– energy from 48 keV to 87 keV	– 2,0 μGy/h ÷ 20 mGy/h;
narrow-spectrum series	– energy from 33 keV to 250 keV	– 3,9 μGy/h ÷ 215 mGy/h;
wide-spectrum series	– energy from 45 keV to 208 keV	– 70 μGy/h ÷ 1079 mGy/h;

3.7.2 Gamma Calibration System No.1:

59,5 keV (^{241}Am) – 3,0 μGy/h ÷ 20 μGy/h;
661,6 keV (^{137}Cs) – 15,0 μGy/h ÷ 100 mGy/h;
1250 keV (^{60}Co) – 18,0 μGy/h ÷ 16 mGy/h;
(values given for I quarter of 2003)

3.7.3 Gamma Calibration System No.2:

661,6 keV (^{137}Cs) – 0,2 μGy/h ÷ 2,5 mGy/h;
1250 keV (^{60}Co) – 0,2 μGy/h ÷ 0,5 mGy/h;
(values given for I quarter of 2003)

3.7.4 Alpha and beta surface contamination Calibration System

Table I: Reference sources for the calibration of surface contamination monitors

Wide area reference sources *)	Radionuclides					
	^{14}C	^{147}Pm	^{36}Cl	^{204}Tl	^{90}Sr	^{241}Am
Surface activity [Bq/cm^2]	1,16 5,65 20,9	23,9	1,29 6,93 23,6	18,6	1,15 5,39 21,2	1,17 5,01 16,9

*) Calibration certificates issued by the Deutscher Kalibrierdienst (DKD-K-06501) are traceable to national standards (PTB, Germany), 13 November 1996 reference date

The full ranges of measurement are presented in the Scope of Accreditation for following physical and operational quantities (dose, doserate): exposure, photon dose equivalent, air-kerma in air, absorbed dose, dose equivalent, ambient dose equivalent, personal dose equivalent and surface activity.

In the period 2002-2003, the average number of calibrations performed was about 1200 instruments per year. Figure 1 and Figure 2 show the diagrams of the number of different type of instruments calibrated in 2002-2003.

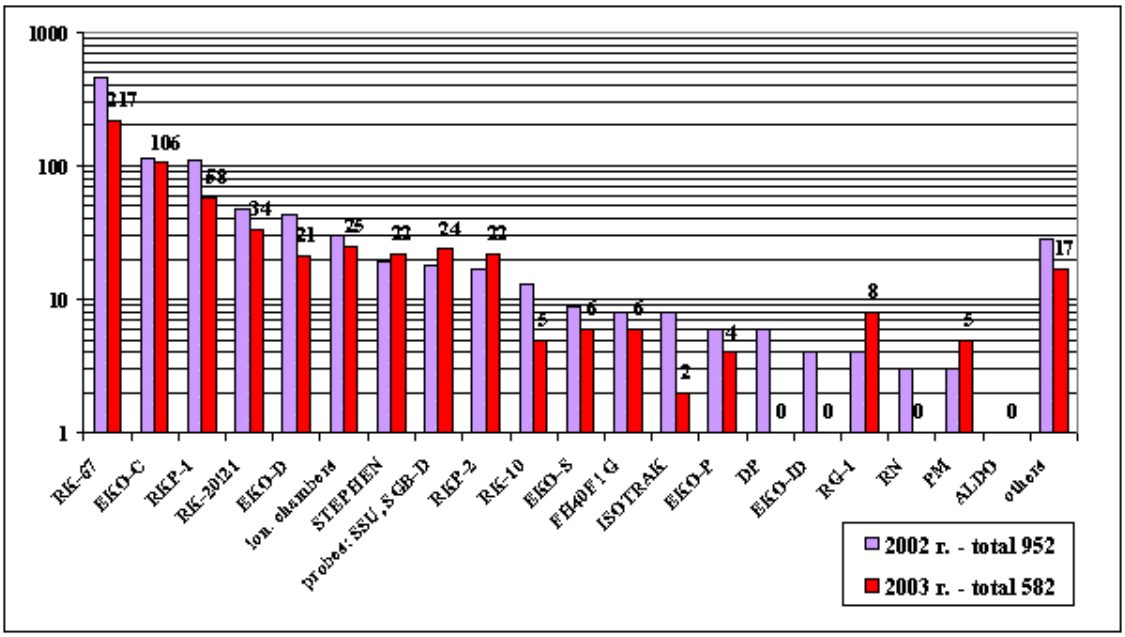

Fig.1. The contribution of different types of dose- and doserate meters in the total number of instruments

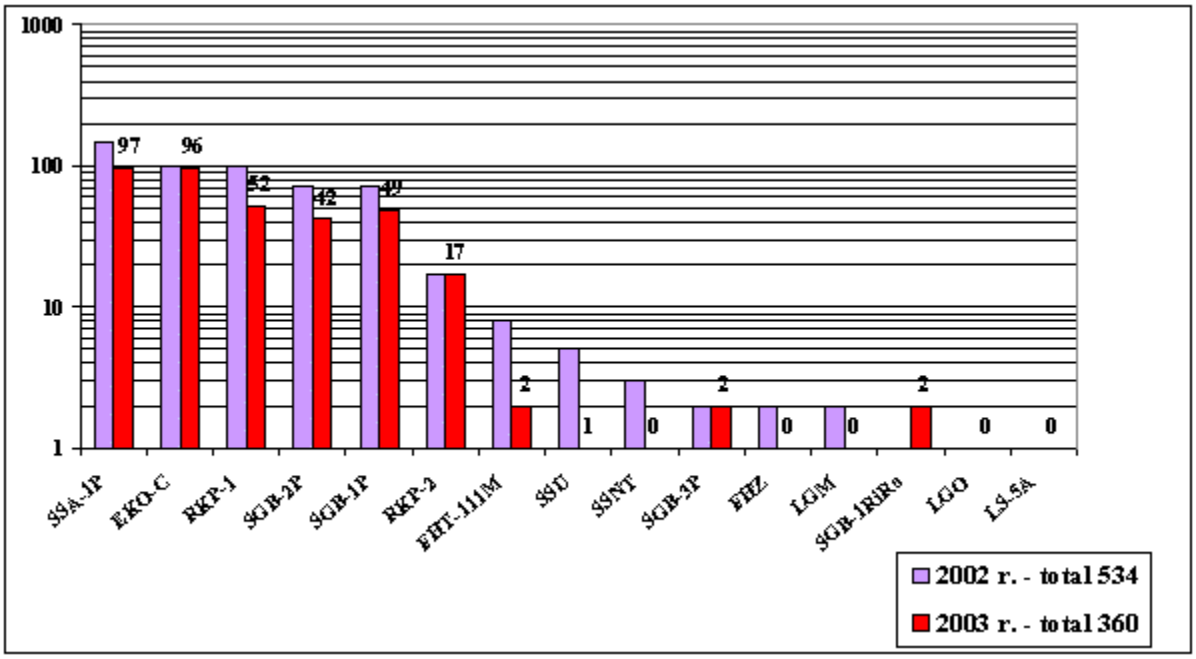

Fig.2 The contribution of different types of contamination meters in the total number of instruments

Parallel to above work, Laboratory staff was involved in training of radiation protection officers and preparation of ISO standards.

*project was performed in a frame of own CLOR funding

3.8 MEASUREMENT OF IODINE CONTENT IN THYROID OF OCCUPATIONALLY EXPOSED PERSONNEL

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3.8.1 Introduction

In 1997, Central Laboratory for Radiological Protection set up a programme "The Laboratory for monitoring of radioiodine in thyroid for population in emergency situation". Its task was to establish monitoring assembly and develop risk assessment methods for people internally contaminated with I-131 in the event of a nuclear accident or radiological emergency. This programme takes advantage of unique opportunity for testing monitoring devices and dose estimation methods on the base of measurements of activity of I-131 and I-125 in thyroid of occupationally exposed workers.

The monitoring assembly of the Laboratory consists of two independent measuring units:

1. Stationary Unit for measuring I-131 and I-125 with low limit of detection
2. Mobile Unit for "in situ" measurements of I-131 and I-125. It has been mainly foreseen for fast screening population in radiological emergency situation, or for monitoring occupationally exposed people far away from Laboratory.

The measurements of iodine content of occupationally exposed personnel were performed with mobile detection unit (prod. Canberra-Packard) (Fig.1.) , which consists with:

1. Scintillation Detector NaI -hermetically sealed assembly which includes a high resolution NaI(Tl) crystal (size 76 x 76 mm, resolution 9%) , a photomultiplier tube, an internal magnetic/light shield, an aluminium housing, and a 14-pin connector and is integrated with preamplifier powered by computer,
2. The InSpector NaI – it is a full featured 8192-channel, battery-powered, portable Multichannel Analyzer, paired with the notebook computer,
3. Genie-2000 Basic Spectroscopy Software is a comprehensive environment for data acquisition, display and analysis in personal computers. It provides independent support for multiple detectors, extensive networking capabilities, windowing interactive human interface and comprehensive batch procedure capabilities,
4. The commercially available phantom for calibration of this units (the RSD - Radiology Support Devices, Incorporated, USA) phantom comprises a neck and shoulder region (without arms), fitted with a snap-I n thyroid shell and cover-plate. The hollow thyroid is made in one piece from a clear plastic and has posterior ports for rapid filling with a radioactive solution and through flushing after use.

Fig.1. Mobile detection unit for I-131 measurements

The more detailed information concerning methodology of measurements and dose assessments are described in [1].

3.8.2 Personnel Monitoring

In the period 2000-2002 the measurements of I-131 content in the thyroid of staff members working with radioiodine has been measured in Nuclear Medicine Units performing therapy and diagnosis of thyroid disease in Poland . The measurements were performed with mobile detection unit.

The counting configuration for monitoring personnel was identical to that used in the calibration procedure. Typically, detector set at a neck - to - detector distance of 10 or 15 cm, using a 600 seconds counting time. The background was measured with detector placed 15 cm away from the RSD neck phantom, prior to or just following the count performed on the person. The measurements were performed at low background places. The minimum detectable activity for mobile unit ranges from 10 – 50 Bq at the time measurement of 600 second and depends on background condition in particular units.

Following categories of persons were examined:

1. Technical staff performing routine diagnostic investigation,
2. Nuclear medicine staff (physician, nurse) working with *in vivo* administration of I-131 to patients,
3. Hospital services staff (orderlies, cleaners) performing auxiliary activities to the patients (cleaning of the rooms, changing of bedclothes).

3.8.3 Results

The measurements of radioiodine content in the thyroid were performed in twelve medical units that use I-131 for therapy and diagnosis of thyroid diseases. About of two hundred exposed persons were investigated. The results of measurements are presented in Table 1.

All individuals actively working with iodine show measurable amounts of the radioiodine in their thyroids (Fig.2.). The average measured activity in the thyroid of the nuclear medicine staff was 400 Bq, ranging from 30 Bq to 3500 Bq. The average and range of I-131 activity measured in thyroids for all medical units were: 590 Bq, (30 Bq - 3000 Bq), 300 Bq, (30 Bq - 3000 Bq), 140 Bq, (30 Bq - 700 Bq) for), for categories 1, 2, 3 respectively. Nevertheless, the categories 1 and 2 show higher I-131 thyroid level then category 3.

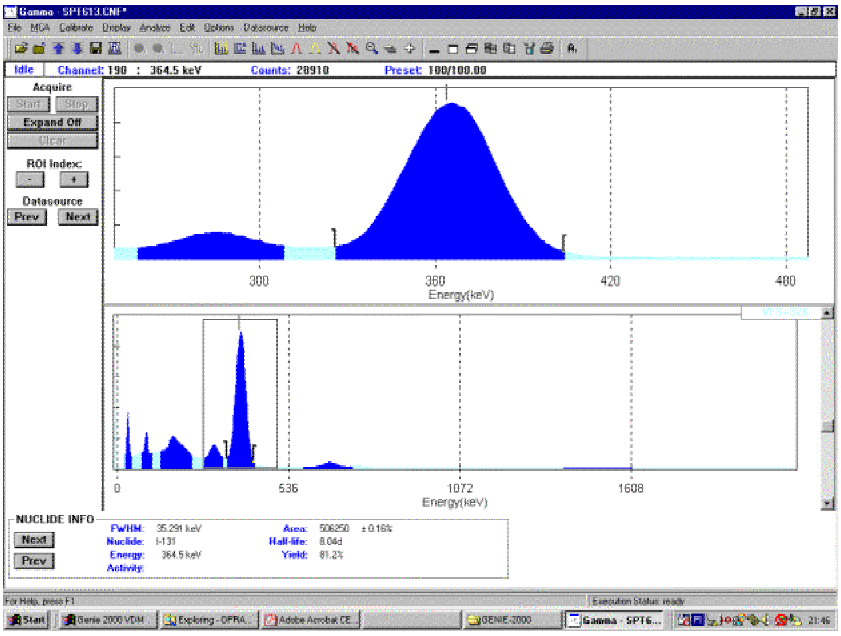

Fig.2. Typical spectrum of I-131with photopeak of 364keV collected at thyroid of exposed worker

3.8.4 Conclusions

The results of I-131 content in the thyroid of staff members working with radioiodine in twelve Departments of Nuclear Medicine do not show any correlation between the measured I-131 levels and risk categories. The averages of I-131 thyroid contents calculated for the particular medical unit item differ remarkably. These differences do not depend on I-131 usage in the particular medical unit but rather on its specific and complex work conditions, staff training, etc.

The Effective Dose Equivalent for particular persons due to inhalation of I-131 was calculated with a conservative assumption that I-131 thyroid content remains constant during the whole year. Calculated average Effective Dose Equivalent for particular medical staffs below 25 per cent of 20 mSv/year.

Table 1. The I-131 content and effective doses assessment for personnel of Nuclear Medicine Units

Medical Unit No.	I-131 monthly usage [MBq]	Category	Measured I-131 thyroid content [Bq]			Effective Dose Equivalent from inhalation of I-131 [mSv]		
			Mean	Min.	Max.	Mean	Min.	Max.
1.	4500	1	477	462	492	1.47	0.45	3.47
		2	145	29	1110			
		3	371	29	713			
		All	210	30	1110			
2.	2600	1	988	11	2940	3.27	0.00	9.19
		2	793	38	2410			
		3	214	11	418			
		All	736	30	2940			
3.	2200	1	431	21	1490	2.68	0.00	4.66
		2	880	589	1170			
		3	21	21	21			
		All	485	30	1490			
4.	2000	1	-	-	-	0.35	0.00	0.43
		2	52	20	136			
		3	31	20	76			
		All	43	30	136			
5.	3200	1	55	40	110	0.36	0.00	0.45
		2	60	20	150			
		3	45	30	82			
		All	45	20	150			
6.	1600	1	-	-	-	0.37	0.00	0.46
		2	50	25	120			
		3	56	40	95			
		All	50	25	120			
7.	2800	1	335	105	830	1.20	0.00	2.84
		2	246	50	540			
		3	98	25	120			
		All	198	25	830			
8.	4500	1	385	120	654	1.32	0.45	2.95
		2	402	98	870			
		3	102	30	210			
		All	228	30	870			
9.	2600	1	732	210	1125	2.62	0.85	5.13
		2	560	150	1655			
		3	160	52	430			
		All	495	52	1655			
10.	2200	1	150	106	220	1.48	0.48	2.70
		2	380	320	553			
		3	60	37	140			
		All	215	37	553			
11.	3100	1	200	140	390	1.45	0.50	2.86
		2	580	508	848			
		3	101	45	140			
		All	240	45	848			
12.	2000	1	350	130	568	1.20	0.52	2.58
		2	324	120	608			
		3	105	50	219			
		All	261	50	608			

ACKNOWLEDGEMENTS

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4 QUALITY ASSURANCE AND TECHNICAL COMPETENCE

4.1 THE QUALITY ASSURANCE PROGRAMME FOR CALIBRATION LABORATORY AT CLOR - SECONDARY STANDARD DOSIMETRY LABORATORY FOR RADIATION PROTECTION

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4.1.1 Introduction

Since 2003 year, the CLOR Calibration Laboratory – SSDL is operated under an established quality assurance programme (QA) that was implemented in practice during past few years. The QA programme is a well-documented continuous work, performed in accordance to organisational specificity, directives and policies pertinent to the laboratory. The purpose of the programme is to ensure quality of measurements and calibrations through documented system.

In years 2002-2003 the work concerned: - the new edition of Quality Manual and improvements of procedures in accordance to PN-EN ISO/IEC 17025 Standard; - validation of the multiple procedures among others by practising internal and external audits. In 2003 year, SSDL was accredited by Polish Centre for Accreditation (AP 057 Certificate).

Accurate calibrations are needed for reliable measurements in radiation protection in order to conform with safety requirements. Traceable calibrations are becoming more important for international trade. Recent changes in political situation in Poland and introduction of the free market economy prompted Polish manufacturers of radiation protection measuring instruments to comply with national and international standards of ISO and IEC.

The role of SSDL is to provide traceable and reliable calibrations with the goal of achieving an uncertainty of the calibration factors of the order adequate to radiation protection criteria. The implementation of the quality system requires high commitment of all SSDL staff members and can be achieved through well -organised and documented teamwork.

4.1.2 Measurements and adjustments of radiation characteristics

According to the quality assurance instructions, measurements and adjustments of X-ray and gamma assemblies has been continued. The frequency of the work to prove the current radiation characteristics was variable being defined in the instructions.

X-ray qualities and adjustment of X-ray assembly.

Taking into the account the HVL measurement results of different X-ray spectra, the high-tension values of the X-ray generator has been corrected, if necessary.

The measurement of 1-st and 2-nd HVL values concerned the following X-ray series:

low air-kerma spectra (1-st HVL only): L-55-70-100;

narrow spectra: N-40-60-80-100-120-150-200-250-300 ;

wide spectra: W-60-80-110-150-200-250-300.

In addition preliminary work has been done to prepare production of few high air-kerma spectra as a new tool for the laboratory.

In the Table 1 an example of narrow-spectrum characteristics series obtained for X-ray radiation reference beam is presented.

The values of determined layers agree within ± 5% with appropriate ISO values. It means that reference radiation qualities in SSDL comply with the PN-ISO 4037-1 Standard.

X-ray tube inherent filtration.

It was proved that the value of X-ray tube inherent filtration is low enough i.e. much less than 3,5 Al limit fixed in PN-ISO Standard and any action level.

Tab.1. Characteristics of narrow-spectrum series

Spectra	Mean energy KeV	Tube potential kV	1-st HVL ISO mm Cu	1-st HVL SSDL mm Cu	Δ % [2)]	2-nd HVL ISO mm Cu	2-nd HVL SSDL mm Cu	Δ % [2)]	(h) [1)] 1./2. HVL
N-40	33	37,3	0,084	0,081	3,6	0,091	0,095	4,4	0,85
N-60	48	60,0	0,24	0,232	3,3	0,26	0,263	1,2	0,88
N-80	65	79,2	0,58	0,582	0,3	0,62	0,604	2,6	0,96
N-100	83	98,2	1,11	1,094	1,4	1,17	1,200	2,6	0,91
N-120	100	118,0	1,71	1,728	1,1	1,77	1,822	2,9	0,95
N-150	118	145,0	2,36	2,366	0,3	2,47	2,510	1,6	0,94
N-200	164	192,0	3,99	4,014	0,6	4,05	4,056	0,1	0,99
N-250	208	240,0	5,19	5,254	1,2	5,23	5,348	2,1	0,98
N-300	250	285,0	6,12	6,262	2,3	6,15	6,402	4,1	0,98

[1)] homogeneity coefficient

[2)] relative error: $\Delta = \frac{HVL_{ISO} - HVL_{SSDL}}{HVL_{ISO}} * 100\%$

Long- and short-term stability of the beams

Periodically done measurements at a fixed position and by a check source indicate that the time-dependent changes of general performance characteristics of X-ray and gamma assemblies as well as of secondary and working standard dosemeter are all below acceptable limit ± 2%.

Figure 1 shows the long-term stability check source measurements for reference ionisation chamber LS-01 type.

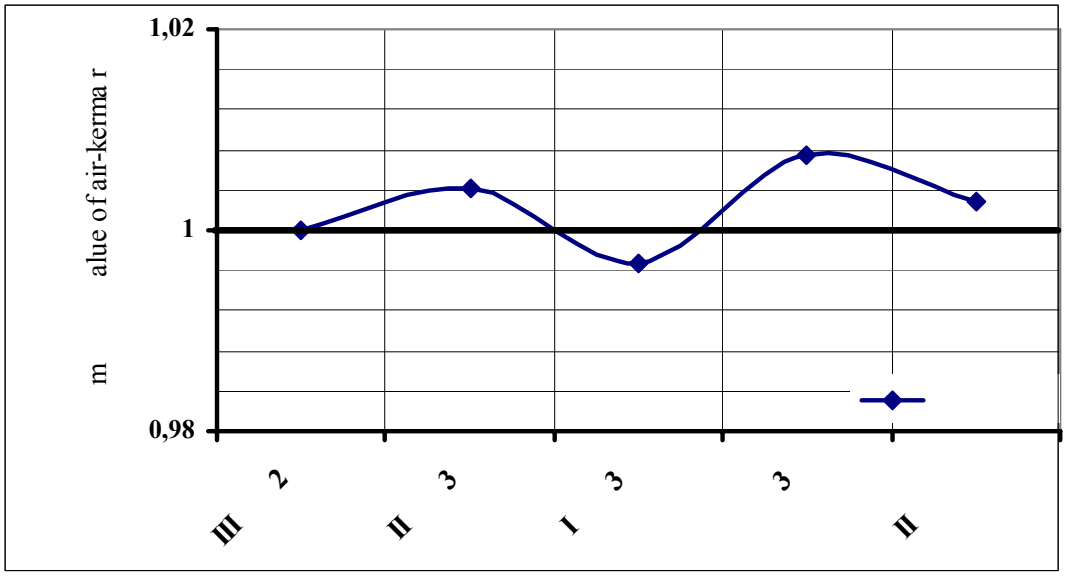


Fig.1
Radiation field uniformity and size of the beams

On the basis of measurements done in the plane perpendicular to the axis of the X-ray (different tube currents, voltages) and gamma beam (^{137}Cs, ^{60}Co) at the different source-detector distances cross-sectional area had been determined, where photon fluency is uniform to within 5%.

Calibration procedure repeatability.

The comparison of calibration factors obtained from two series of measurements by re-positioning of user's detector and repetition of whole calibration procedure by different staff members showed that the combined uncertainty of the calibration received is under the action level.

The results of the QA programme at the SSDL, despite it's simplistic form, show the respective recommended acceptance limits have not been exceeded in that past period.

ACKNOWLEDGEMENTS

This project was supported by the National Atomic Energy Agency.

4.2 INTERCOMPARISON OF INSTRUMENTS FOR MEASURING RADON AND RADON PROGENY CARRIED OUT IN THE CLOR CALIBRATION CHAMBER

Kalina Mamont-Cieśla, Olga Stawarz

Dosimetry Department

Staff from Participating Institutions: Central Laboratory for Radiological Protection – Kalina MAMONT-CIEŚLA, Olga STAWARZ; Wrocław University of Technology – Tadeusz PRZYLIBSKI, Anna ADAMCZYK; Central Mining Institute – Krystian SKUBACZ, Stanisław CHAŁUPNIK, The Henryk Niewodniczański Institute of Nuclear Physics of the Polish Academy of Sciences – Krzysztof KOZAK; AGH University of Science and Technology – Nguyen-Dinh CHAU; Institute of Nuclear Chemistry and Technology – Jakub BARTAK, National Atomic Energy Agency – Office for Financial Claims of Former Workers of Uranium Ore Facility in Jelenia Góra - Jerzy WRÓBLEWSKI

4.2.1 Introduction

Intercomparisons among radon laboratories are of particular importance, because calibrated standards for radon activity concentration and for radon progeny activity concentration in air are not available.

An intercomparison exercise for radon and radon progeny instruments was conducted at the Central Laboratory for Radiological Protection (CLOR) from June 9 to 13, 2003. to verify comparability of mainly continuously measuring instruments for radon and potential alpha energy concentration (PAEC). Seven Polish institutions participated to intercompare ten radon and six PAEC monitors. Radon devices included: six Genitron AlphaGUARD monitors, two Pylon AB-5 monitors and two Polish instruments: RMR1 and a radon probe SRDN2. Among PAEC devices there were five monitors measuring in continuous mode: three T/N Rn WL Meters co-working with AlphaGUARD monitors, Pylon WLx monitor, Radon Progeny Particle Size Spectrometer (RPPSS) designed and manufactured in ARPANSA, Melbourne and one grab sampling device: aspirator SKC equipped with ALFA unit.

4.2.2 Calibration facilities

CLOR operates a walk-in radon/aerosol chamber with ante-room shown in Fig 1. for use in the quality assurance program for radon and radon progeny measurements.

The chamber body is an air-tight climatized room made of sandwich elements covered inside with stainless steel. Its inner volume is of ca.12.37m^3 and the surface-to-volume ratio of ca. 2.6 m^{-1}. Climatic condition: temperature and relative humidity may be controlled manually or automatically. Temperature may be set up from –30°C to +60°C and relative humidity from 10% to 95% within ±5% (for the temperature range from +10 to +60°C). The chamber contains a radon atmosphere which can be varied from several Bq/m^3 to ca. 52000 Bq/m^3. Radon is delivered from two dry Pylon radium-226 sources, traceable to NIST standards and its concentration is continuously measured by means of one of two AlphaGUARD monitors.

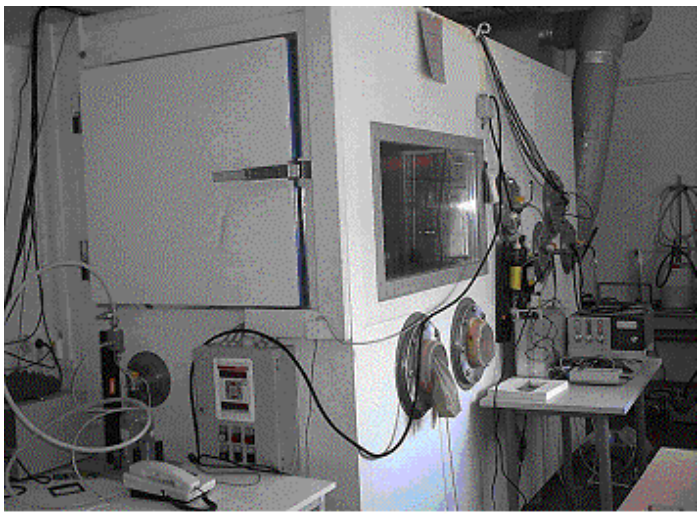


Fig.1. Radon chamber at CLOR

The aerosol conditions in the chamber can be altered as required for studies and calibrations using the TSI water aerosol generator to raise an aerosol level or running of air conditioning engine to lower an aerosol level. The concentration of neutral condensation nuclei is measured by an American condensation nuclei monitor RICH 100.

The concentration of potential α energy (PAEC) in the chamber and the distribution of size of particles-carriers of radon progeny are continuously monitored by means of a unique research tool: Radon Progeny Particle Size Spectrometer (RPPSS) from ACJ&Associates, Inc. designed and manufactured by Stephen B. Solomon in ARPANSA, Yallambie, Australia. This device is considered as a reference PAEC monitor.

RPPSS consists of eight stages operated in parallel: one open face stage, 4-stage diffusion battery system and 3-stage inertial impactor system and produces, among others, total PAEC corrected for the loss of the free fraction activity due to the plateout effect in the inlet of the first stage and the distribution of the alpha-active aerosol sizes. The first peak of the distribution corresponds to the free fraction (fp) of particle diameter of ca.1 nm.

The calibration factor converting counts per min. to PAEC expressed in nJ/m^3 is calculated for the average radon progeny alpha particle energy for decays on filter of 7.2 MeV and conversion factor of 1.6 x10^{-13} J/MeV.

The value of the free fraction in the chamber may be altered in the wide range from 0% to ca. 80% and the value of the equilibrium factor F – up to 99%.

CLOR owns also a small 320 dm^3 chamber, which was used as a thoron chamber provided with thoron from a dry flow – through Th-228 source working in the continuous mode.

4.2.3 Description of radon and thoron exposures

Instruments submitted for the intercomparison were placed inside the walk-in chamber at 0.5-1.5 m above the floor and started. Radon source was connected to two ports on the opposite sides of the chamber and radon was pumped out into the chamber in closed serial circuit. The total exposure lasted ca. 44 hours and consisted of four intervals, which differed with the relative humidity and concentration of condensation nuclei. In the first interval, continuing overnight, the relative humidity was ambient, of ca. 45%, with the concentration of condensation nuclei becoming lower and lower. In the second interval the relative humidity remained the same and the TSI generator worked injecting aerosols. In the third interval, lasting overnight, the relative humidity was increased up to 95% and the level of aerosols was low. In the fourth interval the relative humidity was high, of 95%, and the TSI generator again injected aerosols to increase their concentration in the chamber.

The radon concentration decreased from ca. 2500Bq/m^3 to ca. 700Bq/m^3 during the whole exposure. The potential alpha energy concentration altered in the range from ca. 1400 nJ/m^3 to ca. 6000 nJ/m^3, concentration of condensation nuclei – from below 200CN/cm^3 to 31000CN/cm^3, equilibrium factor F – from 15% to 99% and free fraction fp – from 0% to ca. 62%. The time courses of radon concentration according to six AlphaGUARD monitors and PAEC according to PAEC meters readings are shown in the Fig.2 and 3. In the Fig. 4 the time course of equilibrium factor F and free fraction fp is illustrated. In the figures the four intervals of interest are marked. Example of particle size distributions for various aerosol conditions during the exposure is given in the Fig. 5.

AlphaGUARD monitors were also compared in atmosphere of thoron in small 320 dm^3 chamber. Thoron was delivered from the Pylon dry flow-through Th-228 source working in the flow mode, what resulted in lowering of air pressure in the chamber. The activity of the source was 77 Bq. The monitors worked in turn: in the diffusion and flow mode over ca.17 hours each. The background radon concentration in the chamber was ca. 20 Bq/m^3 and the sum of radon and thoron of ca. 65 Bq/m^3.

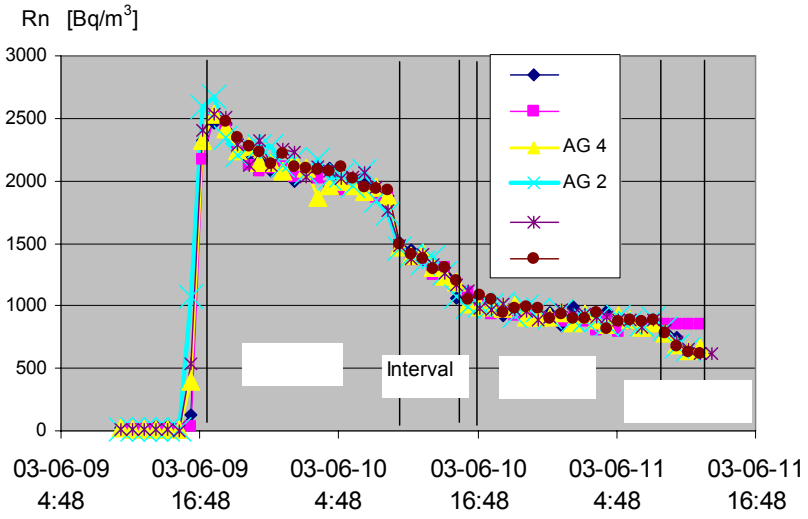


Fig. 2. The time course of radon concentration Comparison of 6 AlphaGUARD's

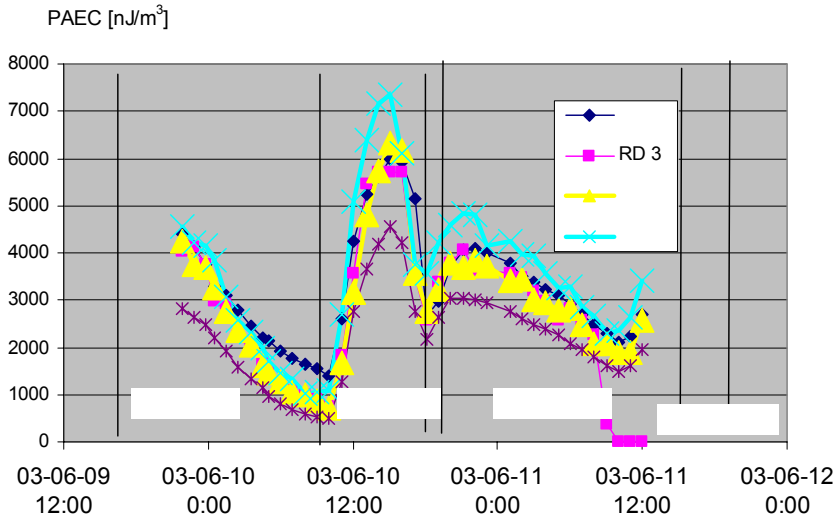


Fig.3. The time course of PAEC readings Comparison of 5 PAEC monitors

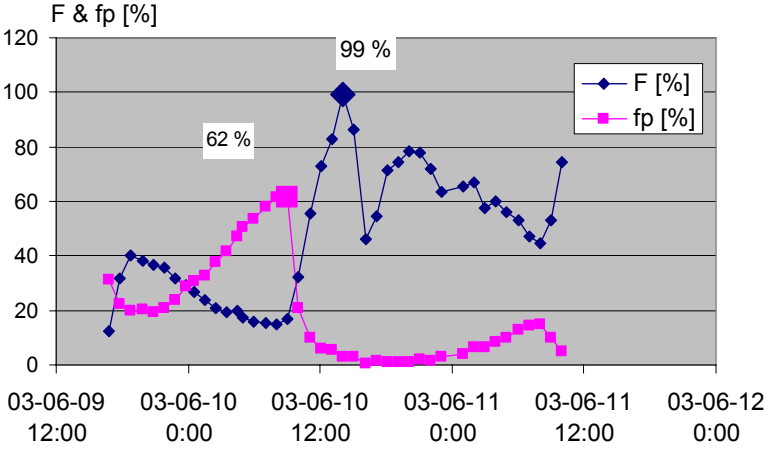


Fig.4. Time course of F & fp

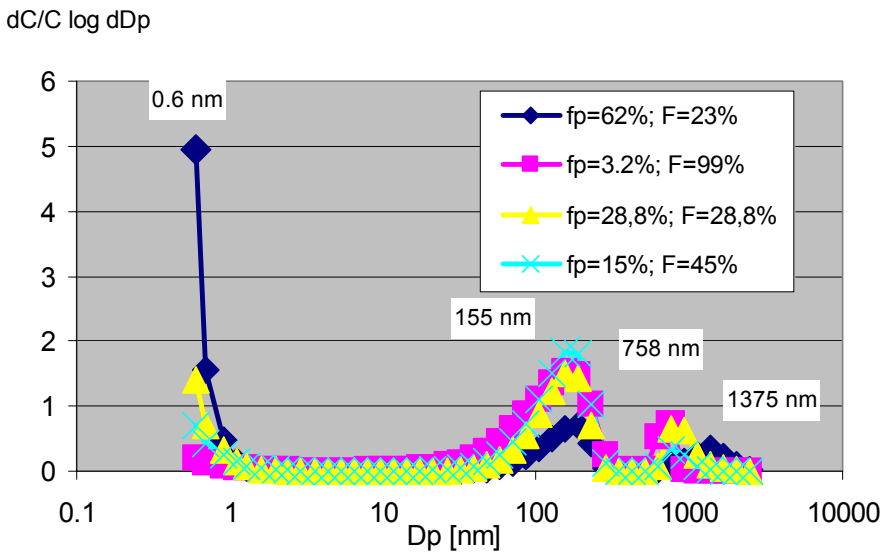


Fig. 5 Particle size distributions for various aerosol conditions

4.2.4 Results and discussion

After exposure has been completed the instruments were taken for analysis for the participating institutions. Upon analysis the results of the mean values of radon concentration and PAEC, and their uncertainties in the four intervals of exposure, were sent to CLOR for comparison and evaluation. For AlphaGUARDs values of temperature, relative humidity, pressure and gamma dose rates were also compared.

Results of radon concentration from all devices in four intervals are summarized in Figs. 6 - 9. Two mean values are marked in each of them: one for six AlphaGUARD monitors and the other for all devices together. The means for AlphaGUARDs are within a range from 0.4 % to 4 % showing very good agreement among the monitors in all intervals with the worse one of 4 % in the interval IV. Standard deviations of the means for all instruments range from 1.8 % to 6 % in four intervals. The highest value of 6 % is due to the value for the device Rn 7 strongly differing from others in the interval II i.e. in the high aerosol atmosphere. It can be explained with a filter imperfectly protecting the detector chamber against radon progeny. Unfortunately, the participant didn't report his result in the interval IV, when the aerosol concentration was also high.

To evaluate each device on the base of its results in four intervals a factor of merit was calculated. This factor is defined according to the following formula:

$$\delta_j = \frac{\sum_{i=1}^{n_j} |b_{ij} - 1|}{n_j}$$

where:

δ_j – the factor of merit of the method "j",

b_{ij} – a bias of the particular result "i" against reference value or an average value of several methods (ratios of results obtained with the method "j" to the reference or average value),

n_j – number of results obtained with the method "j".

The summing over "i" for the method "j" is from i=1 to i=n_j . It should be kept in mine that the better the method the lower the factor.

In the Table 1 the factors of merit of the methods calculated against the mean value for all AlphaGUARD monitors are presented. They range from 0.009 to 0.062 among AlphaGUARDs and to the high value of 0.265 for all devices.

Results of thoron concentration measurements from AlphaGUARD monitors working in the diffusion mode summarized in Table 2 reveal significant discrepancies possibly due to low values of measured concentrations.

Mean values of the climatic parameters (rates temperature, relative humidity and pressure) and gamma dose rates readings for AlphaGUARD monitors in six exposure intervals are compared in the Table 3. The biggest scatter of results equal to 9% (14% of the mean) is in the relative humidity. The readings of temperature and pressure do not scatter more than 0.7ºC (2% of the mean) and 2 mbar (0.2% of the mean), respectively.

The results of the intercomparison of PAEC instruments in four intervals are shown in Figs. 10 – 13. Standard deviations of the interval means range from 5.3% to 10.8%. The factors of merit of the methods calculated against the RPPSS readings are given in the Table 4. They range from 0.072 to 0.306.

In order to estimate the losses of PAEC attached with the free fraction due to plateout effect in inlet of the devices, the time courses of PAEC were normalized against the maximum value of the PAEC reading for RPPSS which corresponds to the maximum value of the equilibrium factor F equal to 99% and to a very small value of the free fraction fp equal to 3.2%. The normalized time courses for four radon progeny meters are shown in the Fig. 14. In the region of the highest value of the free fraction of 62% the loss of PAEC estimated in the comparison with the RPPSS reading ranges from 44% for the RD 4 meter to 60% for the RD3 meter.

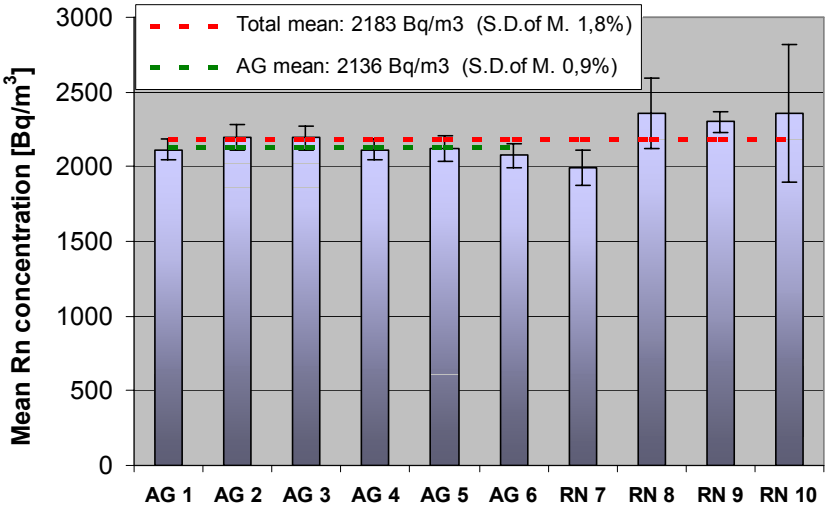


Fig. 6. Radon monitors - I interval (rH=45%, low aerosols)

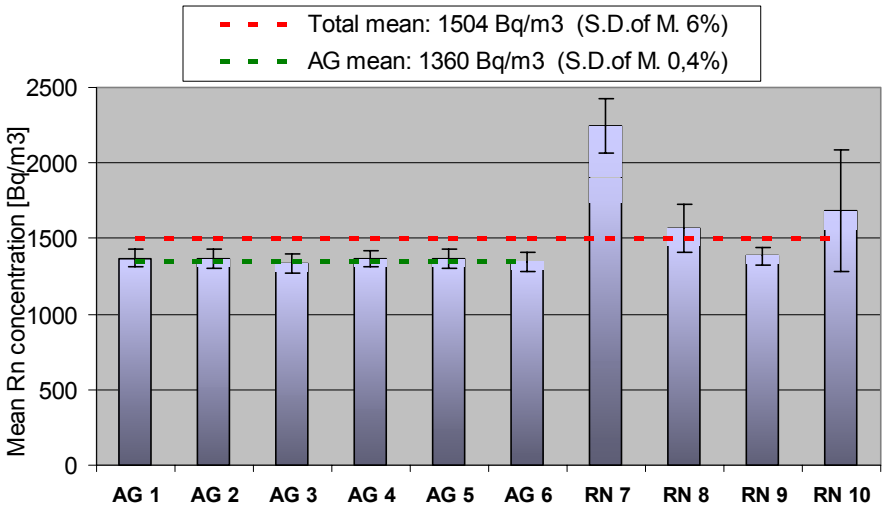


Fig.7. Radon monitors - II interval (rH=45%, high aerosols)

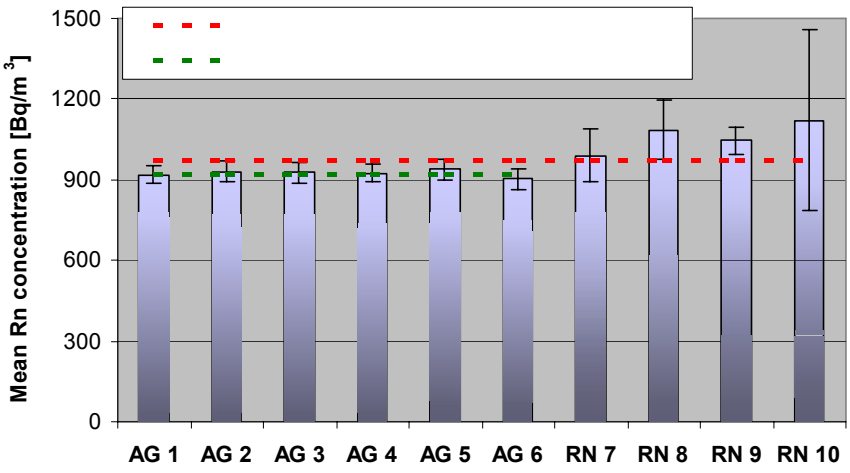


Fig. 8. Radon monitors - III interval (rH=95%, low aerosols)

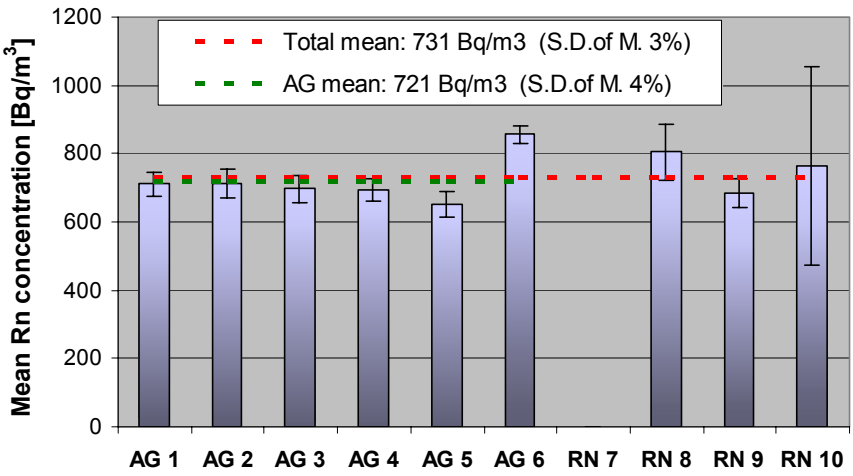


Fig.9. Radon monitors - IV interval (rH=95%, high aerosols)

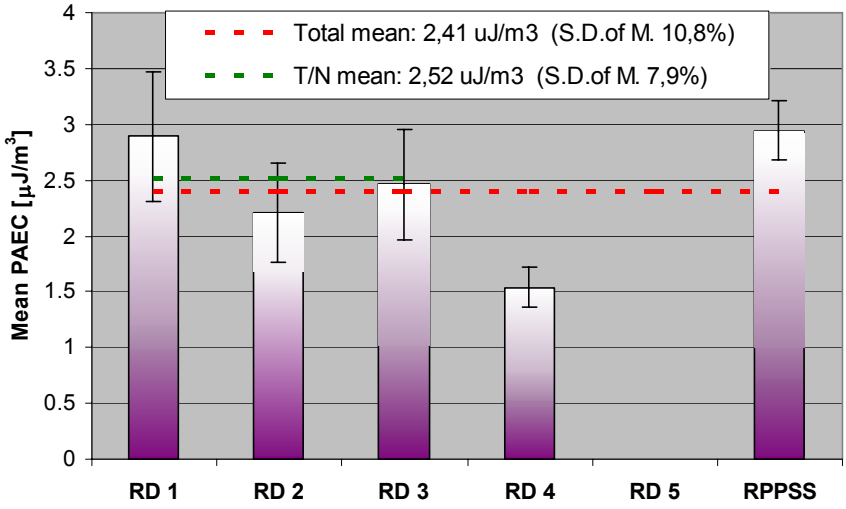


Fig. 10. PAEC monitors - I interval (rH=45%, low aerosols)

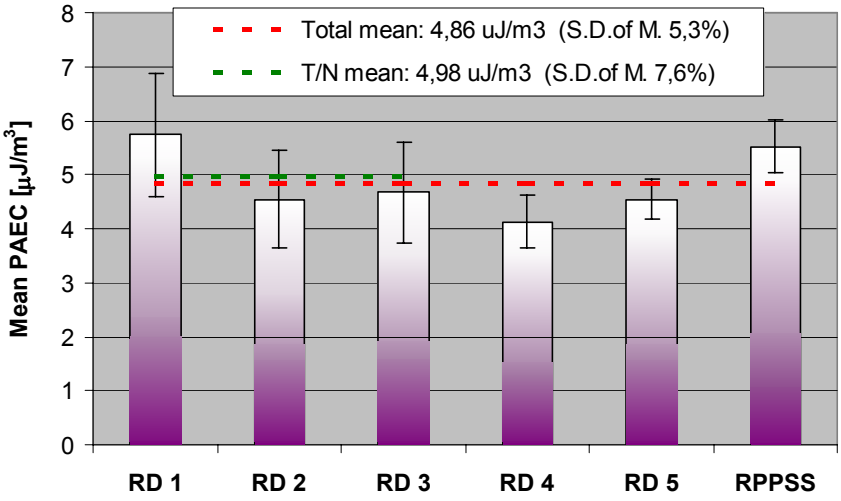


Fig. 11. PAEC monitors - II interval (rH=45%, high aerosols)

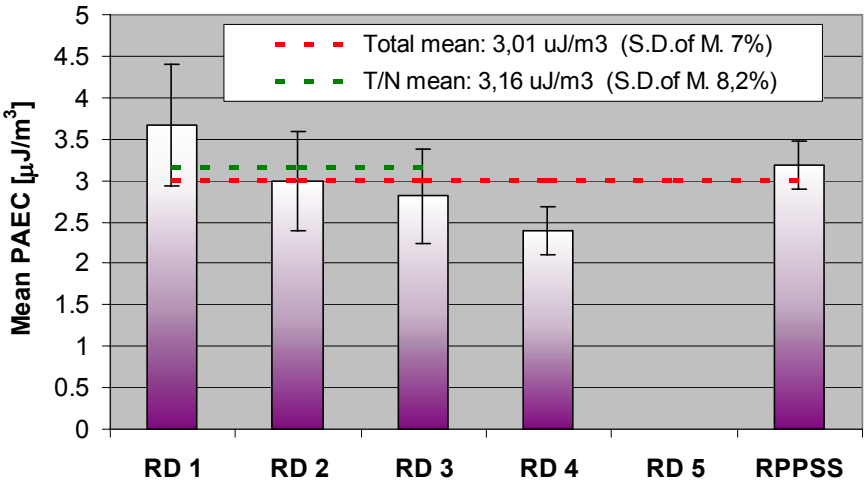


Fig. 12. PAEC monitors - III interval (rH=95%, low aerosols)

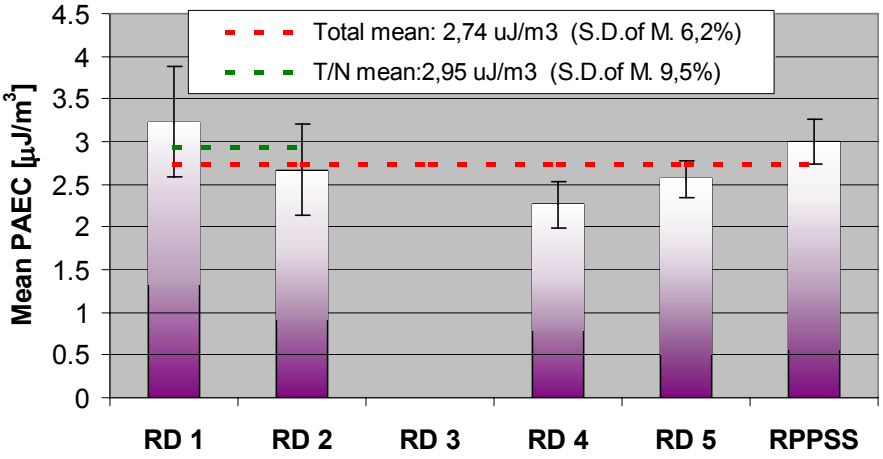


Fig. 13. PAEC monitors - IV interval (rH=95%, high aerosols)

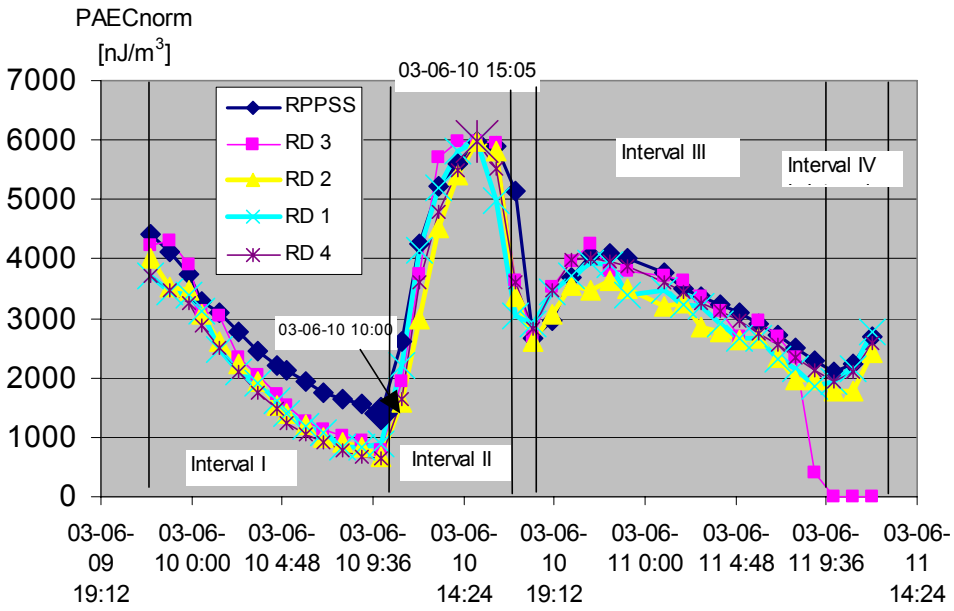


Fig. 14. The time course of PAEC results normalized against RPPSS at 03-06-10 15:05

4.2.5 Conclusions

The results of the intercomparison for radon monitors in the radon atmosphere above 700 Bq/m^3 show quite good coherence except for one which differed considerably from others in the conditions of high aerosols in the interval II. It indicates a need for intercomparison in high aerosol conditions for both PAEC and for radon monitors.

It should be emphasized that the coherence of radon concentration results in various aerosol and climatic conditions for AlphaGUARDs is very good in the applied range of radon concentration, and the factors of merit for them are low: from 0,01 to 0,06. The unsatisfactory results of the intercomparison of AlphaGUARDs in thoron atmosphere of low concentration and low air pressure suggest a need to compare the instruments in the low radon concentration, below 100 Bq/m^3, and to check them in the low air pressure conditions.

The results from the PAEC instruments show greater discrepancies than ones from radon monitors. It is due to many contributing factors such as: the stability of the flow rate in various climatic and aerosol conditions, the efficiency of the detector system, the integrity of the filter and filter holder and the radon progeny plateout effect upstream dependent on aerosol conditions .

Table 1. Factors of merit for the radon meters.

Radon monitors	Factor of merit
AG 1	0.009
AG 2	0.013
AG 3	0.019
AG 4	0.013
AG 5	0.031
AG 6	0.062
Rn 7	0.265
Rn 8	0.137
Rn 9	0.069
Rn 10	0.154

Table 2. Results for AlphaGUARD's from thoron exposures

AlphaGUARD	Th concentration Diffusion mode [Bq/m^3]	Th concentration Flow mode (1 dm^3/min.) [Bq/m^3]
AG 1	57 ± 4	39 ± 4
AG 2	42 ± 3	55 ± 4
AG 3	41 ± 3	-
AG 4	129 ± 7	-
AG 5	92 ± 6	76 ± 5
AG 6	38 ± 2	88 ± 6
Mean ±S.D.	67 ± 15 (22%)	65 ± 11 (17%)

Table 3. Comparison of readings of climatic parameters and gamma dose rate for AlphaGUARD monitors.

Interval	Parameter	AG 1	AG 2	AG 3	AG 4	AG 5	AG 6	Max. difference
I	Temperature	31.5	31.6	31.4	31.2	31.7	31.4	0.5
	Relative humidity [%]	46	48	52	46	51	50	6
	Pressure [mbar]	1008	1009	1008	1008	1008	1008	1
	Gamma dose rate [nSv/h]	-	153	142	-	153	-	11
II	Temperature	33.1	33.6	33.1	32.9	33.1	33.3	0.7
	Relative humidity [%]	45	47	51	45	49	49	6
	Pressure [mbar]	1010	1011	1010	1010	1010	1010	1
	Gamma dose rate [nSv/h]	-	153	147	-	153	-	6
III	Temperature	33.7	33.8	33.6	33.6	34	33.8	0.4
	Relative humidity [%]	99	99	99	97	99	99	2
	Pressure [mbar]	1008	1008	1007	1008	1008	1008	1
	Gamma dose rate [nSv/h]	-	150	145	-	152	-	7
IV	Temperature	33.3	33.3	33.3	33.3	33.4	33.7	0.3
	Relative humidity [%]	96	99	99	90	98	93	6
	Pressure [mbar]	1006	1006	1005	1006	1005	1005	1
	Gamma dose rate [nSv/h]	-	154	152	-	151	-	3
Th diff	Temperature	25.7	25.7	25.2	25.2	25.6	25.6	0.5
	Relative humidity [%]	60	64	68	59	64	63	9
	Pressure [mbar]	994	995	995	993	994	994	2
	Gamma dose rate [nSv/h]	-	111	117	-	118	-	7
Th flow	Temperature	26.5	26.7	-	-	26.2	27.3	1.1
	Relative humidity [%]	59	59	-	-	61	57	4
	Pressure [mbar]	975	976	-	-	975	972	2
	Gamma dose rate [nSv/h]		107	-	-	119	-	12

Table 4. Factors of merit for the PAEC monitors.

PAEC monitors	Factor of merit
RD 1	0.072
RD 2	0.148
RD 3	0.145
RD 4	0.306
RD 5	0.162

ACKNOWLEDGEMENTS

This work was partially supported by Radon Center – Non-govermental International Scientific Network

4.3 EXERCISE „TURAWA 2003" (8-12 September 2003): INTERNATIONAL INTERCOMPARISON OF MOBILE SPECTROMETRIC LABORATORIES INTERCOMPARISON EXERCISE

K. A. Isajenko, P. Lipiński

Dosimetry Department

4.3.1 Preface

The International Intercomparison Exercise of Mobile Spectrometric Laboratories "TURAWA 2003" was held in Turawa near Opole on 8-12 September 2003. The following teams participated in the exercise:

Denmark (2 persons): F. Andersen, K. Bargholz;
Estonia (3 persons): E. Jakobson, K. Peedo, A. Tera;
Latvia (3 persons): K. Bogucarskis, I. Kisite, A. Zalkalne;
Lithuania (2 persons): L. Juknevicius, J. Molis;
Poland (3 persons): K. Isajenko, P. Lipiński, A.Ząbek;
Russia (3 persons): E. Bouchouev, S. Stepanov, O. Sukhorukov.

Fig.1. All measuring teams during the exercise

The participants from Baltic States were sponsored by Danish Emergency Management Agency (DEMA), and Polish Team was financed by Polish National Atomic Energy Agency. The exercise was observed by: a representative from Danish Emergency Management Agency (DEMA), supervisor of the Danish-Polish cooperation, representatives of Polish National Atomic Energy Agency and the Director of the Central Laboratory for Radiological Protection (CLOR).

The exercise was divided in three parts:

- the estimation of the distance to a hidden non-shielded radioactive source of unknown isotopic identity and activity - every team performed the measurements of the same sources from the same distance;
- the measurement of the environmental radioactivity (particularly Cs-137) – all teams drove the same pre-defined route;

- mapping of the determined areas – every team performed the measurements within the rectangle 5 km x 10 km. Basing on the measurements the maps of particular areas, as well as the common maps were prepared.

Unfortunately, the equipment of Russian team was stopped by the Byelorussian customs. In this situation the Russian colleagues used the equipment of other teams. During the first day of exercise the Russian team used Polish car with Polish equipment. During the last day of exercise they used Russian car with Danish equipment (Danish team did not participate this part the exercise repairing the Estonian equipment). Every team used the cars with equipment, which were bought by the Danish Emergency Management Agency:

Denmark – Land Rover Discovery V8;
Estonia, Latvia and Lithuania – Nissan Patrol;
Poland and Russia – Toyota Land Cruiser GX 90.

4.3.2 EXERCISE 1 - The Estimation of the Distance to the Hidden Nonshielded Radioactive Gamma Source.

Four radioactive monoisotopic sources were used during the exercise. The "Defektoserwis" radiography company from Katowice delivered the sources.

Table.1. Data on the source isotopes.

Nuclide	$T_{1/2}$ [days]	Γ (at 1m) [μSv/MBqs]	Energy [keV]	Yield	Activity [GBq]
Se-75	119.7	0.278	121.12 136.00 264.66 279.54	0.172 0.582 0.589 0.2499	ca. 150
Cs-137	1.1e+04	0.111	400.66 661.66	0.1147 0.85	ca. 6.5
Ir-192	73.8	0.135	295.96 308.46 316.51	0.2872 0.2968 0.8275	ca. 37
Co-60	1925.3	0.337	468.07 1173.23 1332.49	0.4781 0.9985 0.999826	ca. 2.5

The exercise was performed on the grassy areas beside the water purifying station in Kotorz Wielki near Turawa. The terrain was selected by the local authorities. The police, who prevented unauthorized persons to approach the sources, controlled the access to the area. All teams took part in the exercise – Russian team used Polish car (so it was used by two teams). The teams performed their measurements one after another passing nearby the hidden source.

The results of distance estimation are presented in Table 2. All distances were calculated from the same line (called line 50). The real distance to all sources was 28 meters.

Table.2. Distance to the hidden source.

	Se-75	Cs-137	Ir-192	Co-60
Denmark	28 m	25 m	35 m	27.5 m
Estonia	26 m	34 m	18 m	41 m
Latvia	30 m	43 m	43 m	46 m
Lithuania	22.4 m	22.6 m	25.7 m	29.1 m
Poland	28 m	30 m	35 m	31 m
Russia	24 m	26 m	27 m	28 m
average	26.4 m	29.9 m	30.6 m	33.8 m
standard deviation	2.82 m	7.61 m	8.81 m	7.80 m
median	27 m	27.5 m	31 m	30.1 m

Besides the estimation of the distance to the source the next tasks were to estimate the activity of the source and its identification. No one had problems with identifying Cs-137 and Co-60. Some teams have little problem with identifying Ir-192. But most of the teams had problem with identifying Se-75. The source was identified correctly during the measurement only by Danish and Polish teams. Iridium and selenium are used in industrial radiography.

Table.3. Activity of the hidden source (results in GBq).

	Se-75	Cs-137	Ir-192	Co-60
Denmark				
Estonia	20.6	2.2	0.6	2.6
Latvia	6	3	4	2
Lithuania	9.6	1.6	2.7	1.9
Poland	17.5	1.6	3.9	1.3
Russia	8.9	0.7	2.3	0.6
average	12.5	1.8	2.7	1.7
standard deviation	6.21	0.86	1.39	0.77
median	9.6	1.6	2.7	1.9

The differences between the results of activity estimation were probably caused by different approach of activity calculation. Some teams (Latvia, Lithuania, Russia) used the dose rate value given by the carborne system and the equation (1) to calculate the activity:

$$H^*(10) = \frac{\Gamma_{amb} \cdot Q \cdot B}{r^2 \cdot \exp(-\mu r)} \quad (1)$$

where:

Γ_{amb} – gamma constant for given isotope;
Q – activity;
B – buildup factor (1.1);
r – distance to the source.

The rest of the teams (Estonia, Poland) used the formula (2), given in the report on "Search of Lost Radioactive Sources" prepared in Danish Technical University by Uffe Korsbech and Helle Karina Aage:

$$Q = \frac{CR \cdot 4 \cdot \pi \cdot r^2}{y \cdot T \cdot \eta \cdot A_0 \cdot \exp(-\mu_{air} \cdot r)} \quad (2)$$

where:

Q – activity;
CR – count rate;
r – distance to the source;
A_0 – cross section of the area of the detector seen from the source (0.04 m^2);
Tη - transmission factor times intrinsic efficiency of the detector (0.61);
y – photon yield;
μ_{air} – linear attenuation coefficient for the air.

4.3.3 EXERCISE 2 - The Measurement of the Radioactivity in the Environment along the Pre-defined Route.

The second day of the intercomparison TURAWA 2003 was devoted to the measurement of the same pre-defined route by all of the teams (the length of the route was about 135 km). The Russian teams did not participate in the exercise due to lack of the equipment on the car.

Figure 2 shows the route, which had to be followed by every team, with the measuring speed of 40 – 50 km/h.

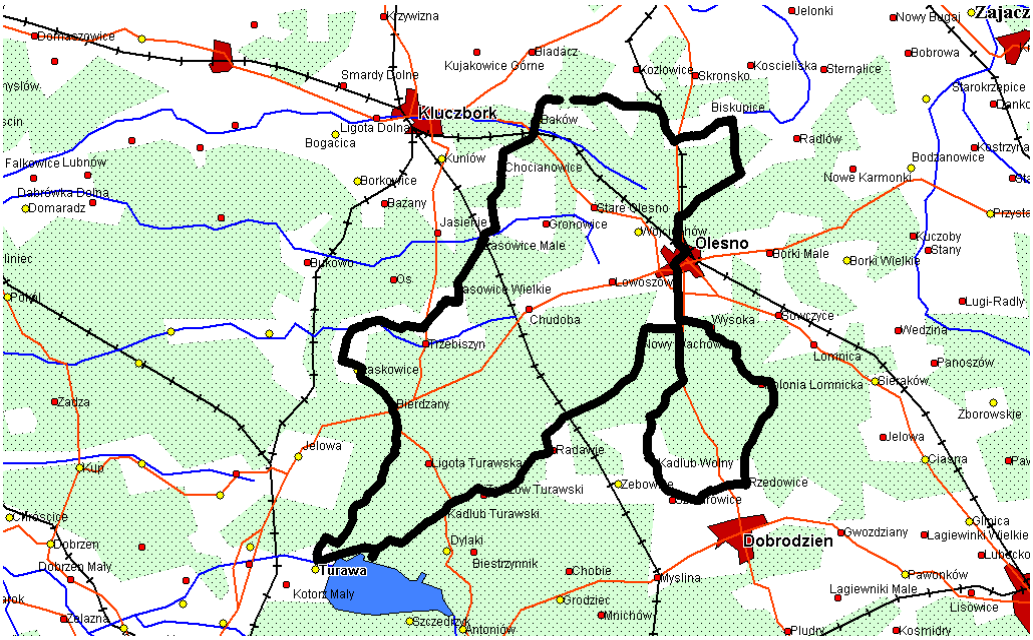


Fig.2. Pre-defined route for all teams (the length – about 135 km).

From the data collected in the exercise by all teams several maps were prepared. The examples of maps are presented in Figures 3 and 4 and show area concentration of Cs-137 (in kBq/m^2) and potassium content in soil (in %).

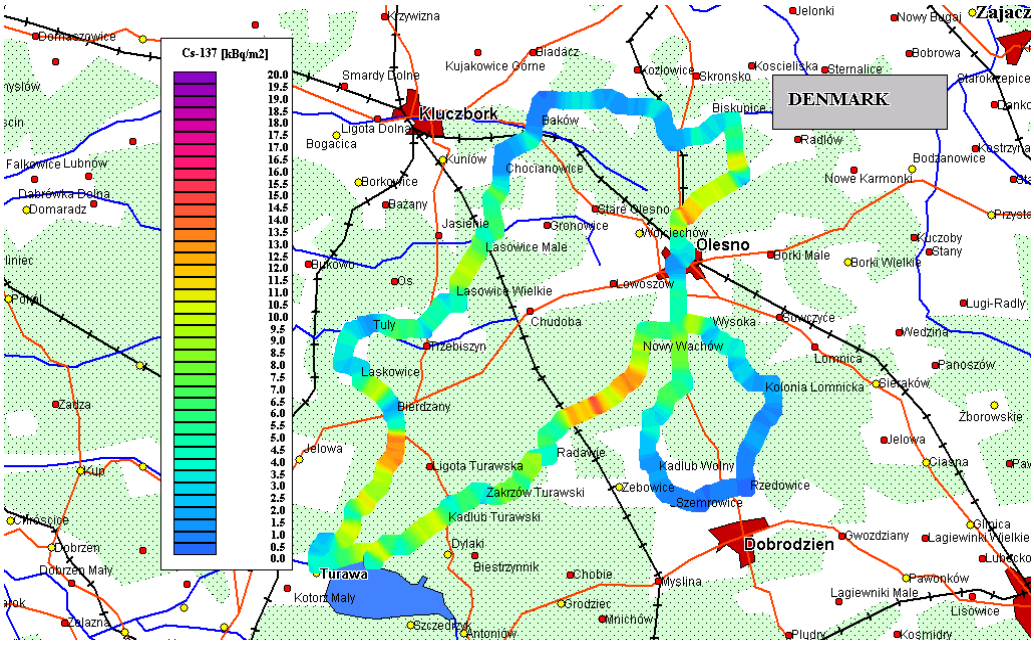


Fig.3. Concentration of ^{137}Cs along the pre-defined route (team from Denmark).

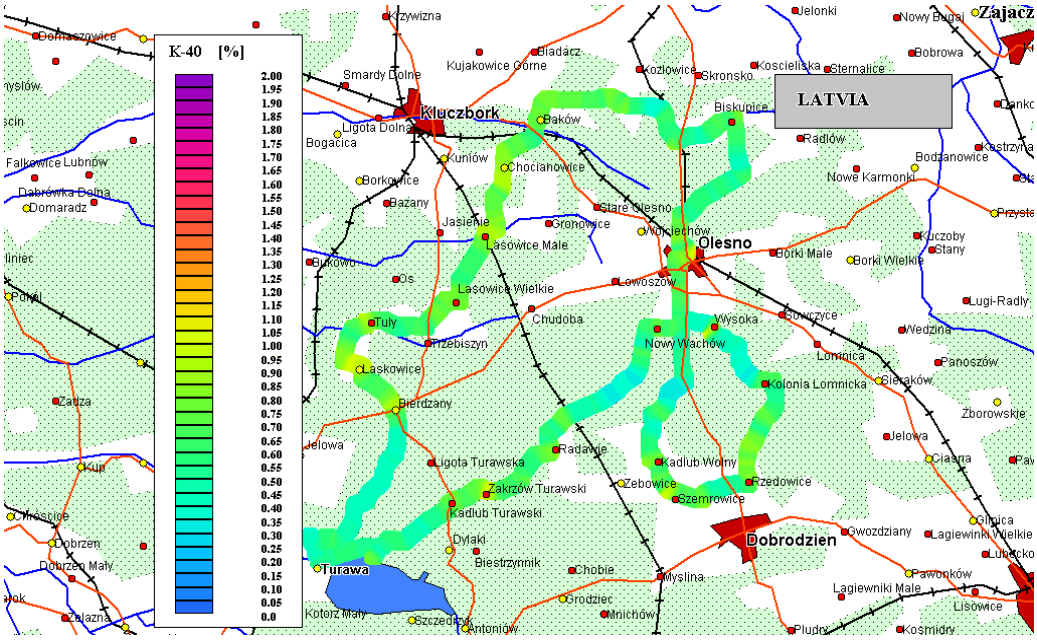


Fig.4. Concentration of potassium in soil along the pre-defined route (Latvian team).

The statistical analysis consisted in comparison of the carborne systems using the average, median and standard deviation of the results of measurements.

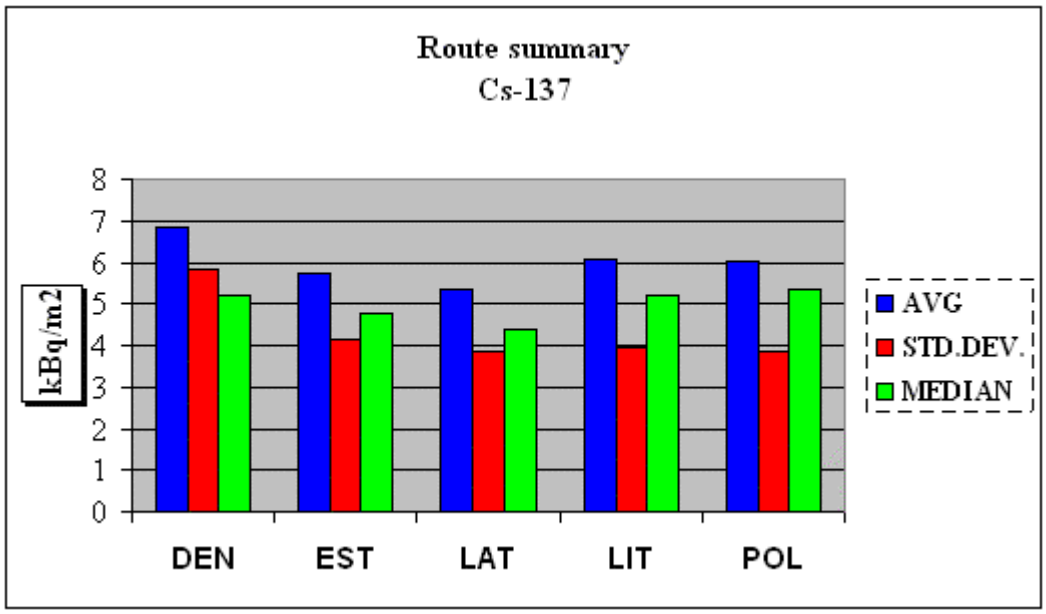


Fig.5. Average concentration, standard deviation and median of ^{137}Cs along the pre-defined route for all teams

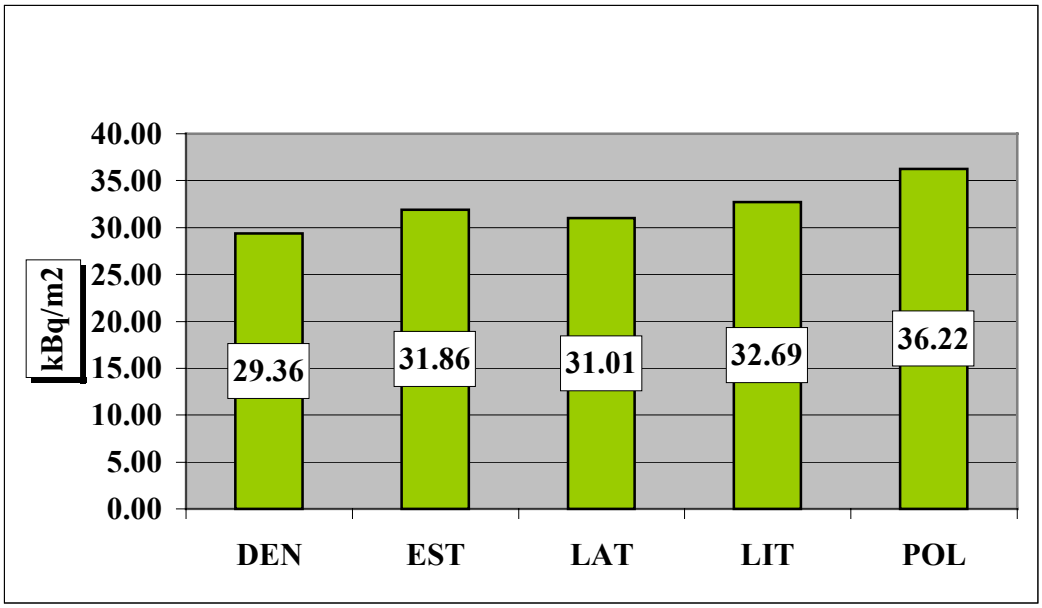


Fig.6. Maximum concentration of ^{137}Cs along the pre-defined route for all teams.

In Fig. 7 and 8 examples of Cs-137 concentration measured during the exercise are presented.

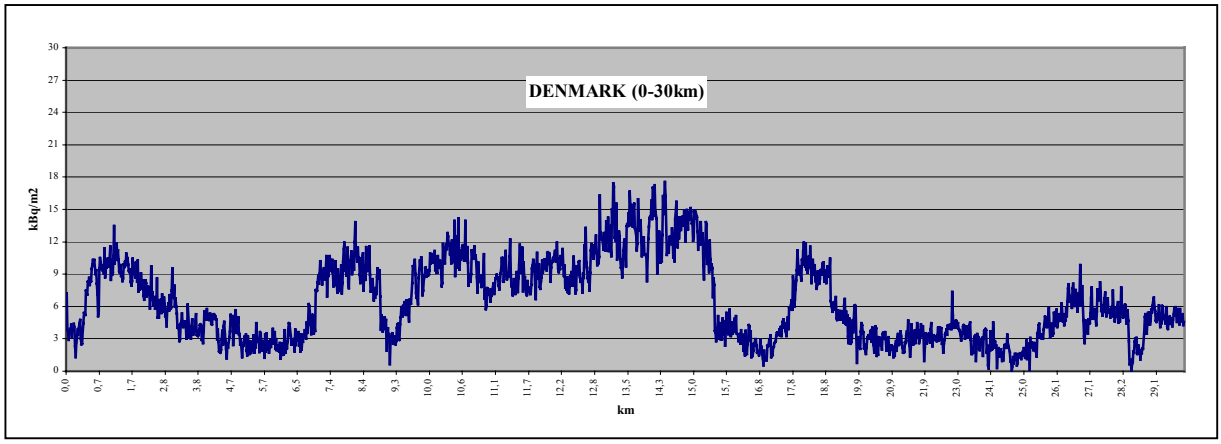


Fig.7. Concentration of ^{137}Cs along the pre-defined route found by the Danish team (dist.: 0-30 km).

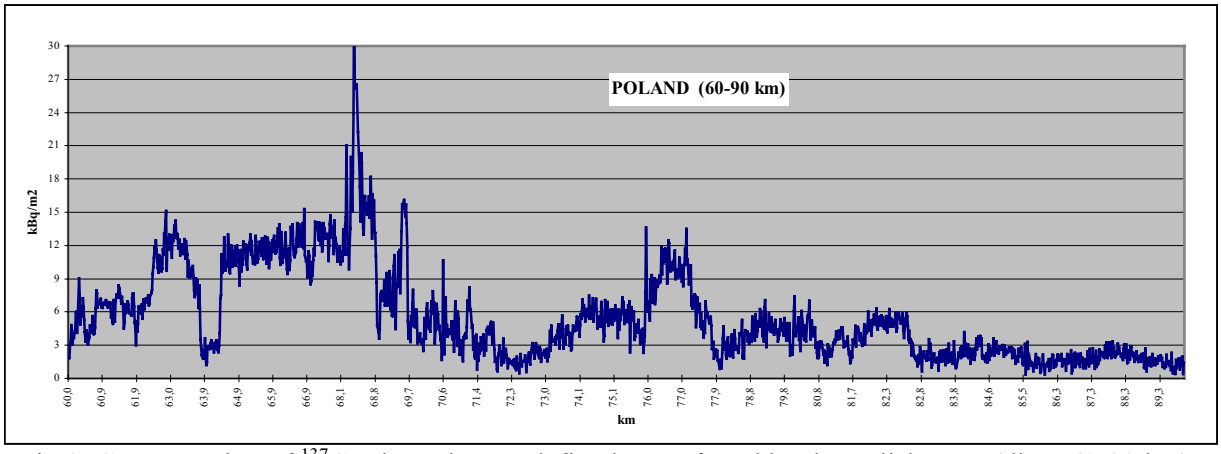


Fig.8. Concentration of ^{137}Cs along the pre-defined route found by the Polish team (dist.: 60-90 km).

4.3.4 EXERCISE 3 - Mapping of measurement areas.

In the last day of the exercise every team was assigned a rectangular area sized 5 x 10 km.

The task for each team was to cover each area with as much measurements as possible within 6-7 hours. Basing upon these measurements CLOR prepared the maps both for the team areas and common maps of the whole exercise area. The measurements were performed within forest districts: Olesno, Kluczbork, Opole i Ozimek, in

cooperation with forest authorities. The main aim was to prepare a common map of area concentration of Cs-137, in a region of Poland most highly contaminated with Cs-137 from the Chernobyl accident.

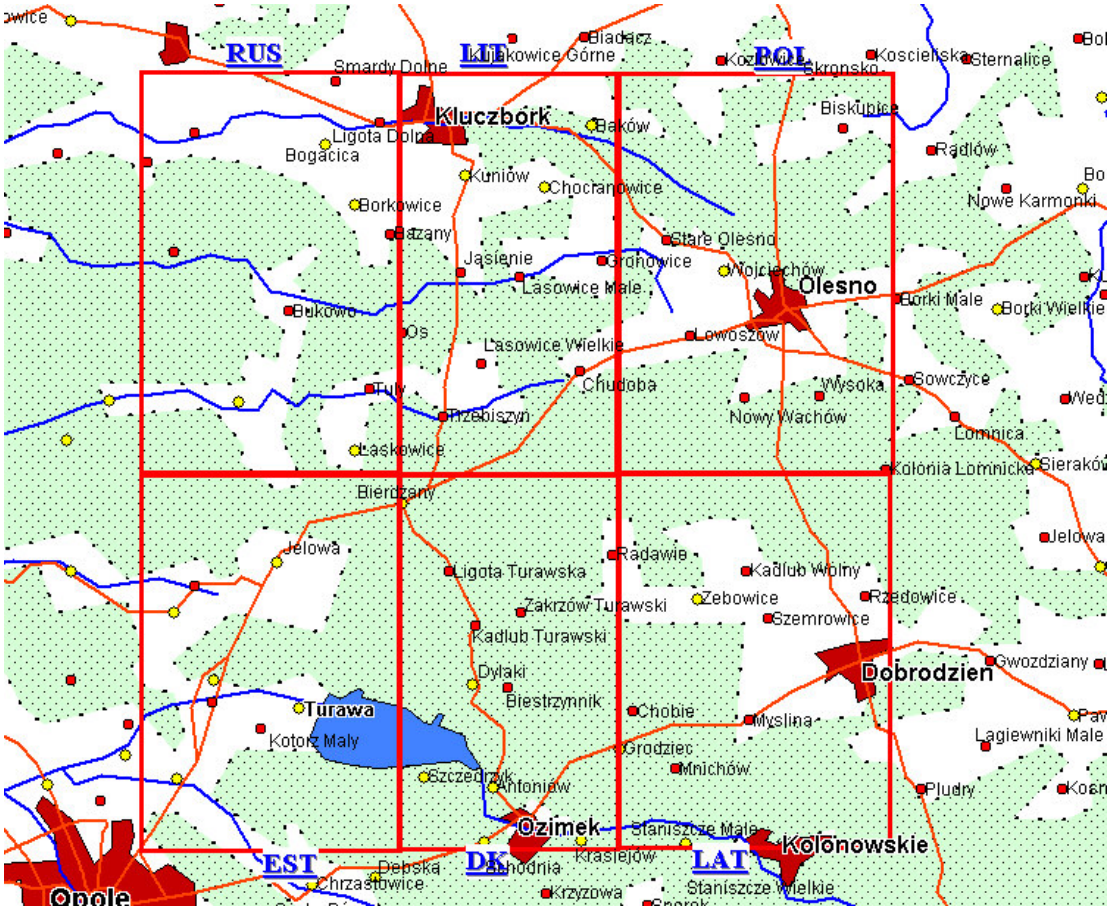


Fig.10. Rectangular areas (5 x 10 km) for mapping for all teams.

The common map of Cs-137 distribution (in kBq/m^2). created taking into account all data collected is presented in Fig.11. The map presents the concentration of Cs-137 It was prepared using MapInfo software. Because of technical problems, for the area which was to be measured by the Danish team (east of Turawa lake and north of Ozimek town) the data of the previous day (pre-defined route measurement) and the data of the teams passing the area on their way to/from their destination measurements (Latvia, Lithuania, Poland) were used to prepare the common map.

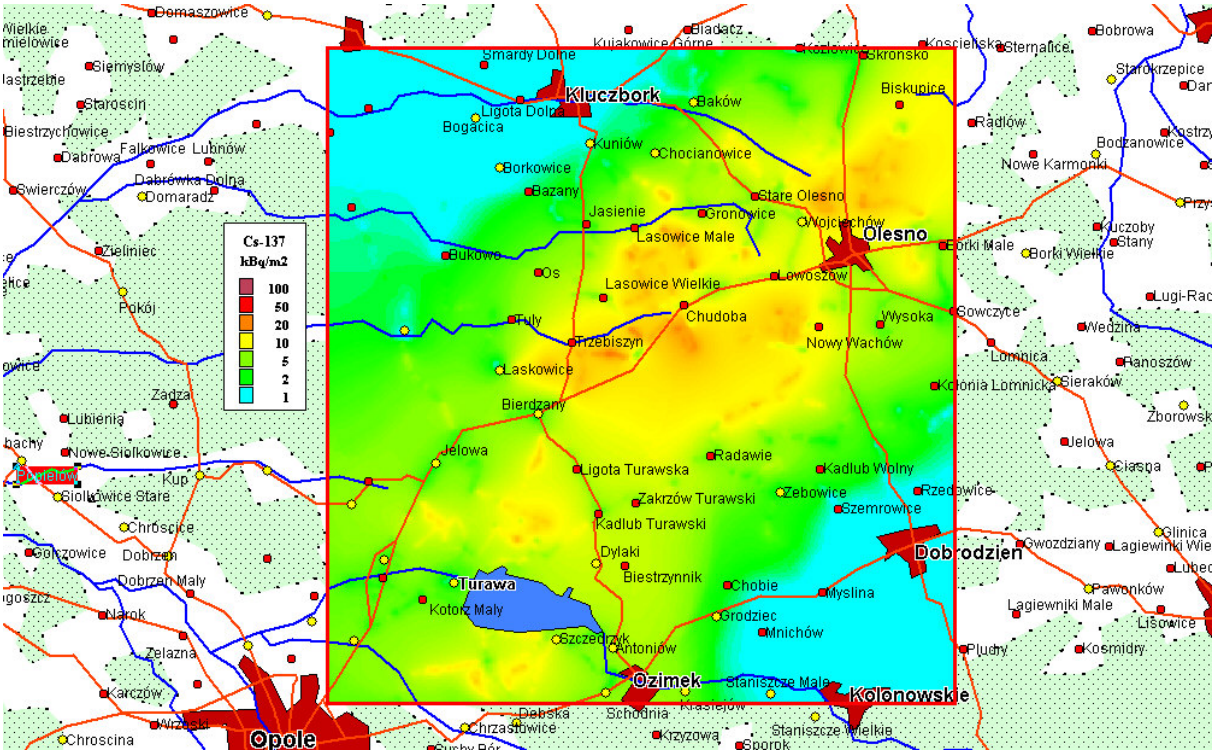
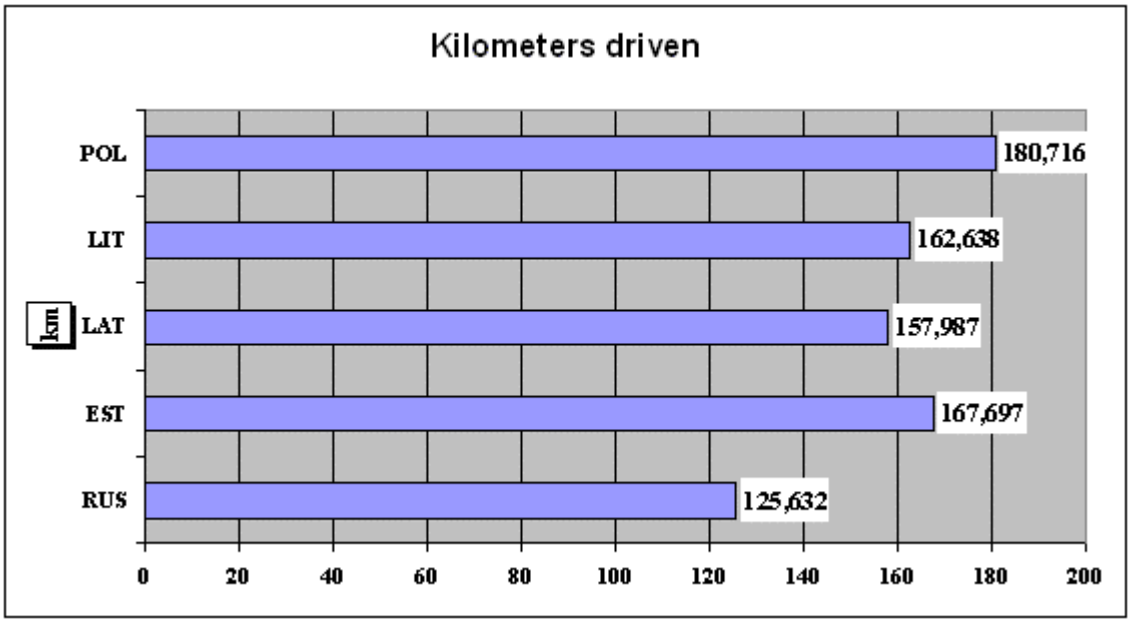


Fig.11. Concentration of ^{137}Cs measured by all teams – map raster.

Fig.12. Comparison of kilometers driving by all teams during the mapping day



(two methods of presentations).

The figure 12 shows the comparison of kilometers driven during the mapping day. Polish team drove the longest distance (180.7 km – 22.7 % of the total distance driven by all teams), and Russian team the shortest (125.6 km- 15.8%).

4.3.5 Sampling and high-resolution gamma spectrometry

Fig.13. Equipment for soil sampling

Before the exercises Polish team performed soil sampling. The samples were taken in March 2003.

The soil samples are collected using a knife-edge pipe of 2 inch diameter from the 10 cm thick surface layer at six places at the circumference of the circle of 2 m radius and in the center of the circle. The samples were collected in undisturbed areas without sheltering, vegetation or structures. In the laboratory the soil samples are dried at temperature not exceeding 105^{o}C. The dried material is crushed to obtain a homogeneous sample and put in a standard container of 0.5l Marinelli beaker.

The measurements of natural radionuclides and caesium isotopes concentrations in soil samples were made using gamma spectrometric GENIE 2000 system with HPGe detectors. The detectors were placed in low-background lead shielding chambers reducing the external gamma radiation background by two orders of magnitude. The walls of the shielding chamber consisted of three layers, consecutively: external layer of 100 mm of lead, central layer of 1 mm of cadmium and internal layer of 2 mm of copper. Time of each measurement was 80 000 s. Activity in soil samples is reported on a dry weight basis in Bq·kg^{-1} for natural radionuclides and on an area basis in kBq·m^{-2} for caesium isotopes.

The results of measurements are shown in tables 4-8.

Table.4. Results of measurements of soil sample nr. 1

	Point P1 N 50° 46’ 53.10”	E 18° 14’ 20.75”
Cs-137	184.7 ± 3.2 Bq/kg	24.96 ± 0.43 kBq/m^2
Cs-134	0.51 ± 0.03 Bq/kg	0.07 ± 0.01 kBq/m^2
K-40	372 ± 8 Bq/kg	1.23 ± 0.03 %
Ra-226	18.5 ± 0.8 Bq/kg	1.49 ± 0.06 ppm
Ac-228	18.0 ± 0.3 Bq/kg	4.38 ± 0.07 ppm

Table.5. Results of measurements of soil sample nr. 2

	Point P2 N 50° 50’ 22.50”	E 18° 16’ 58.20”
Cs-137	162.7 ± 2.8 Bq/kg	21.99 ± 0.39 kBq/m^2
Cs-134	0.37 ± 0.03 Bq/kg	0.05 ± 0.01 kBq/m^2
K-40	144 ± 4 Bq/kg	0.47 ± 0.01 %
Ra-226	8.2 ± 0.6 Bq/kg	0.66 ± 0.05 ppm
Ac-228	5.6 ± 0.2 Bq/kg	1.36 ± 0.05 ppm

Table.6. Results of measurements of soil sample nr. 3

	Point P3 N 50° 41’ 49.14”	E 18° 06’ 47.18”
Cs-137	99.7 ± 1.8 Bq/kg	13.47 ± 0.24 kBq/m^2
Cs-134	0.27 ± 0.02 Bq/kg	0.04 ± 0.01 kBq/m^2
K-40	247 ± 6 Bq/kg	0.81 ± 0.02 %
Ra-226	12.7 ± 0.6 Bq/kg	0.66 ± 0.05 ppm
Ac-228	12.4 ± 0.2 Bq/kg	1.36 ± 0.05 ppm

Table.7. Results of measurements of soil sample nr. 4

	Point P4 N 50° 45’ 39.95”	E 18° 15’ 54.73”
Cs-137	112.1 ± 2.0 Bq/kg	15.15 ± 0.27 kBq/m^2
Cs-134	0.28 ± 0.03 Bq/kg	0.04 ± 0.01 kBq/m^2
K-40	184 ± 4 Bq/kg	0.81 ± 0.02 %
Ra-226	10.0 ± 0.6 Bq/kg	1.02 ± 0.05 ppm
Ac-228	7.4 ± 0.2 Bq/kg	3.02 ± 0.05 ppm

Table.8. Results of measurements of soil sample nr. 5

	Point P5 N 50° 48’ 19.72”	E 18° 19’ 56.06”
Cs-137	440.0 ± 7.6 Bq/kg	59.46 ± 1.03 kBq/m^2
Cs-134	1.10 ± 0.04 Bq/kg	0.15 ± 0.01 kBq/m^2
K-40	213 ± 5 Bq/kg	0.70 ± 0.02 %
Ra-226	9.7 ± 0.8 Bq/kg	0.78 ± 0.06 ppm
Ac-228	10.2 ± 0.2 Bq/kg	2.48 ± 0.05 ppm

4.3.6 Summary

The exercise was the continuation of the intarcalibration exercises started in 1999. The Danish government ordered and equipped the mobile spectrometric laboratories based on the terrain cars, and passed them to the Baltic States. Such annual exercises serve as the test for the equipment and measuring skills of the crews.

Some of the elements of TURAWA 2003 exercise were already present during former intercalibrations (measurement along the predefined route and mapping). The novelty was the calculation of the distance to the hidden source and comparison of such results. Such skills could be of use during the search for lost or orphan radioactive sources.

The carborne systems delivered by the Danish government and used during this exercise proved to have quite similar response to the radioactivity.

All teams experienced some problems with the new on-board software. The problems were probably caused by the malfunctioning GPS dialog and resulted in temporal acquisition of several noised spectra.

Continuation of the exercises in the years to come would enhance the technical skills of the teams, test in the field the functioning of the equipment, and develop the spirit of cooperation between team members that might play a crucial role in the case of large-scale radiation emergencies.

ACKNOWLEDGEMENTS

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4.4 METHOD OF ^{228}Ra DETERMINATION IN ENVIRONMENTAL SAMPLES BY THE MEASUREMENT OF ^{228}Ac BETA ACTIVITY

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4.4.1 Introduction

The aim of this work was to implement a method of ^{228}Ra determination in environmental samples by measuring beta activity of ^{228}Ac which is a short-lived progeny of ^{228}Ra. The method was developed at the Risø National Laboratory.

^{228}Ra is a member of the thorium series, with half life $T_{1/2}$=5.75 years. The energy from beta decay of ^{228}Ra is very low (0.055 MeV), therefore it is convenient to determine this radionuclide via measurement of γ or β activity of ^{228}Ac. If the activity concentration of ^{228}Ra is high, this radionuclide is determined usually by measurement of ^{228}Ac, using gamma spectrometry. In case of low concentrations ^{228}Ra can be determined by separation of radium, and then after a ^{228}Ac ingrowth , by electrodeposition and measurement of ^{228}Ac β activity. This method can be applied for determination of ^{228}Ra in environmental samples, e.g. water, soil and bottom sediments.

4.4.2 Analytical procedure

The preliminary preparation depends on the type of sample. Water samples are acidified with HNO_3, evaporated to dryness and the residue is dissolved in distilled water. Samples of soil and bottom sediments are dried, homogenized and heated in a muffle furnace at 450˚C to remove organic matter. Afterwards the samples are digested with HNO_3 and HCl, filtered, evaporated to dryness and the residue is dissolved in distilled water. To the mineralized samples, Ba carrier is added for determination of chemical recovery of ^{228}Ra.

The next step is the removal from the sample actinides, lanthanides and iron by precipitation with ammonium hydroxide which should be carbonate free to avoid a co-precipitation of $Ba(Ra)CO_3$. After centrifugation, the supernatant solution is heated to boiling for removal of ammonia. Subsequently, by adding Na_2CO_3 in excess, radium is separated from the sample by co-precipitation with barium carbonate. The precipitate is centrifuged and dissolved in 8M HNO_3.

The start of $Ba(Ra)CO_3$ precipitation is the beginning of actinium ingrowth. The radioactive equilibrium between ^{228}Ra and ^{228}Ac is attained after 2 days; then actinium can be separated from radium by the ion exchange chromatography. To determine the yield of actinium separation, ^{225}Ac

tracer is added. The sample is passed through the column containing anion exchange resin Dowex 1×8 in nitrate form (Fig.1). The column is eluated with 8M HNO_3 to remove radium and actinium. Thorium is adsorbed on the resin. The eluate containing Ra and Ac is evaporated and the residue is dissolved in 0.3 M HNO_3. Sample is passed through the second column containing cation exchange resin Dowex 50W×8 in hydrogen form (Fig.2). The column is eluated successively with 2M HCl to remove bismuth, lead and francium, with 3M HNO_3 to remove radium and with 8M HNO_3 to remove actinium. The start of Ac fraction stripping is the beginning of actinium decay. The eluate with Ra is saved for determination of barium yield.

The eluate containing Ac is evaporated to near dryness and the residue is dissolved in sulphuric acid. Finally actinium is electrodeposited from the $(NH_4)_2SO_4$ solution on a stainless steel disc at a current of 1 A for 1.5 hours.

The ^{228}Ac activity is determined by beta counting using Low Level Beta Multicounter System GM-25-5 (Risø GM-25-5) connected with GM-25-5 software for Windows. Beta counting is repeated three times to ensure sample purity (the decay must be consistent with ^{228}Ac decay, $T_{1/2}$=6.13 hours).

The average barium yield is about 80%. The recovery of ^{225}Ac is determined immediately after β-counting of ^{228}Ac with alfa spectrometry system. PIPS detector for alfa spectrometry is placed in vacuum chamber and connected with multichanel analyzer Multiport II MCA (Canberra MP2-GE) with GENIE 2000 spectroscopy software. The average actinium yield is approximately 75%.

Lower limit of detection (LLD) with the counting time of 180 min is equal to 0.005 Bq/ sample.

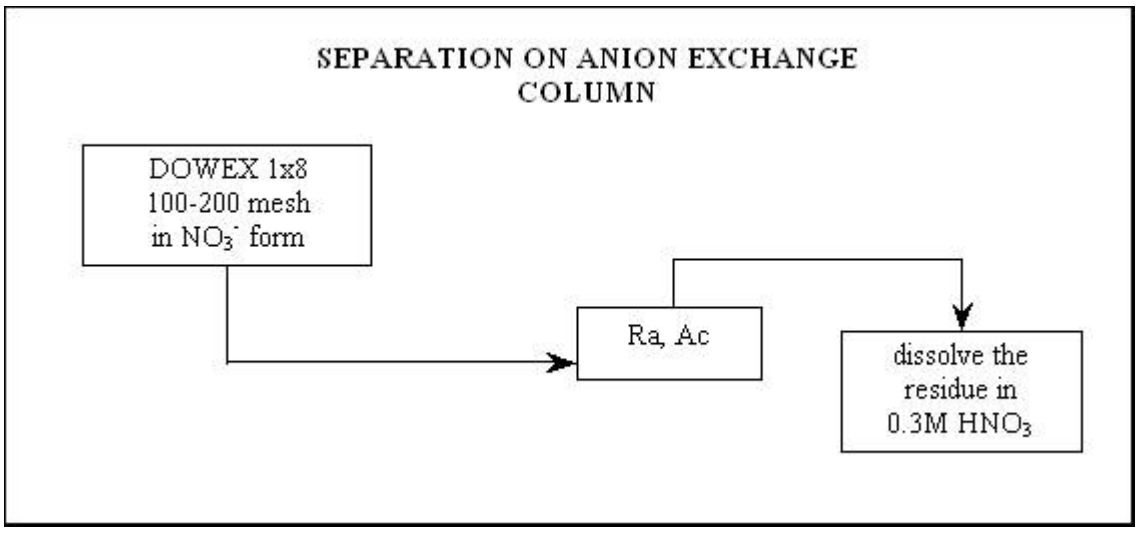

Fig.1. Actinium separation by anion exchange chromatography.

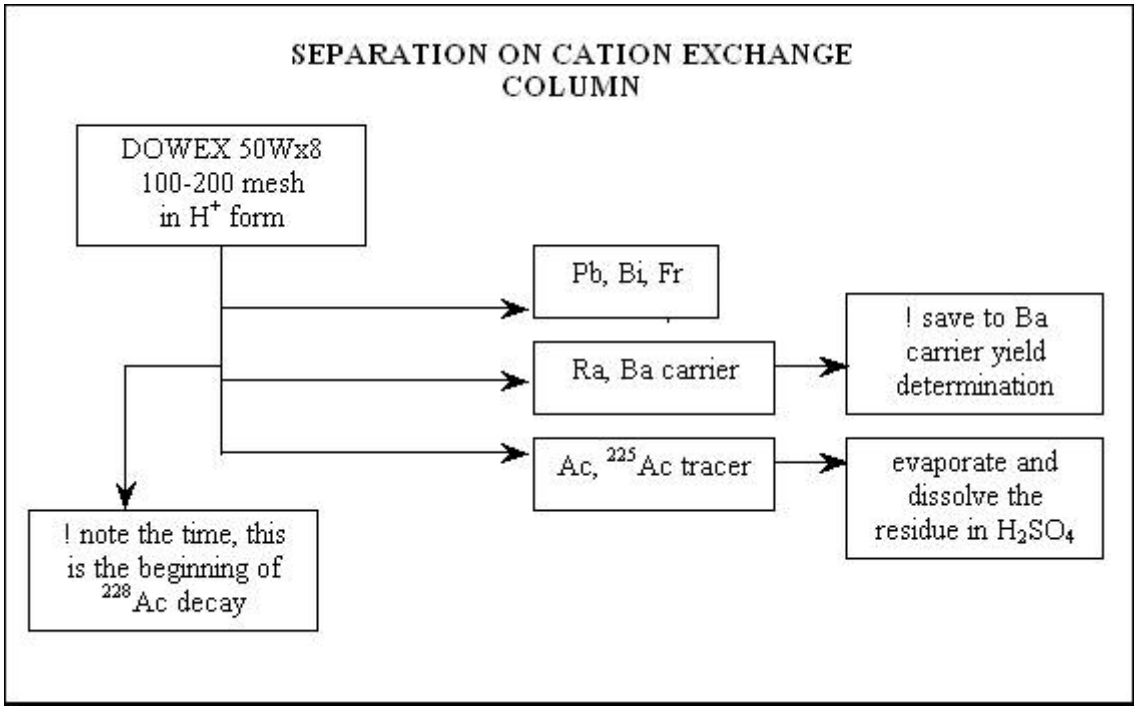

Fig.2. Separation by cation exchange chromatography.

4.4.3 Calculations

Activity concentrations of ^{228}Ra in sample is calculated according to formula:

$$A = \frac{C}{ER_1R_2} \times \frac{\lambda t_2}{\left(1-e^{-\lambda t_2}\right)} \times \frac{1}{\left(1-e^{-t_3}\right)} \times \frac{1}{e^{-t_1}}$$

in this formula $\frac{\lambda t_2}{\left(1-e^{-\lambda t_2}\right)}$ is a factor to correct the average count rate to the count rate at the beginning of counting

The symbols denote:

C-average net count rate, cps

E-counter efficiency, mBq/cps

R_1-chemical yield of ^{228}Ac tracer

R_2-chemical yield of Ba carrier

λ-the decay constant for ^{228}Ac, s^{-1}

t_1-the decay time of ^{228}Ac, s

t_2-the time of β-counting, s

t_3-the ingrowth time of ^{228}Ac, s

The beta counter is calibrated using thorium salt e.g. $Th(NO_3)_4$. Activity of ^{228}Ac in a known amount of $Th(NO_3)_4$ solution is determined by gamma spectrometry. Afterwards beta counting is performed. The counting efficiency is calculated according to the formula:

K=C/A [cps/Bq], where:
A is ^{228}Ac activity in Th $(NO_3)_4$ solution, [Bq/ml],
C is average net count rate of ^{228}Ac corrected for radioactive decay and chemical yield, [cps/ml].

4.4.4 Results

The reliability of the described above method of ^{228}Ra determination was checked by the participation in an intercomparison run for water samples, organized by International Atomic Energy Agency. The results of ^{228}Ra determination obtained at our Laboratory and values given by IAEA are presented in Table 1.

Table 1. Comparison of ^{228}Ra determination in IAEA reference samples of water with values obtained at CLOR.

Sample Code	^{228}Ra activity concentration [Bq kg^{-1}]	
	CLOR	IAEA
	Group 1 (synthetic samples)	
Standard solution	53850±2690*	55000±960
IAEA-430	8.37±0.43	8.20±0.15
IAEA-431	3.99±0.20	4.14±0.07
	Group 2 (natural samples)	
IAEA-425	0.57±0.04	0.50±0.18**
IAEA-426	8.17±0.41	8.20±3.0**

* combined standard uncertainty

** standard deviation

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5 TRAINING, INFORMATION AND STANDARDIZATION

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Training and Information Department

5.1 RADIATION PROTECTION TRAINING

Central Laboratory for Radiological Protection serves as a center for training in radiation protection, Scientific and Technical Information Center and as the Secretariat of the Committee for the Radiological Protection Standardization.

CLOR organizes systematic training of persons who intend to gain qualifications needed for work with ionizing radiation. For this aim in 2002 were organized courses for radiation protection inspectors (qualifications type B and C), for operators of accelerators (qualifications type C1), for heads of plants equipped with accelerators and for heads of laboratories of the I class (qualifications type E). The numbers of qualifications given in 2002 are shown in Table 1.

Table 1. Number of qualifications given in 2002

Type	B	C	E	C1	together
Number of qualification	214	97	2	65	378

According to the new national regulation „Atomic Low" in 2003 CLOR organized courses for radiation protection inspectors (qualifications type IOR-1 and IOR-3) and for operators of accelerators (qualification type S-A). The numbers of qualifications given in 2003 are shown in Table 2.

Table 2. Number of qualifications given in 2003

Type	IOR-1 and IOR-3	S-A	together
Number of qualification	152	40	192

5.2 SCIENTIFIC AND TECHNICAL INFORMATION CENTER

The Center of Information is involved in publication of scientific reports, guides, training materials, popular papers on radiation protection, and in exchange of materials between information centers in Poland and abroad.

The Center library contains 5633 volumes. The library is a subscriber of 25 Polish and 4 foreign journals.

In 2002-2003 the Scientific and Technical Information Center of CLOR provided about 3000 consultations and information for mass media, governmental, municipal, scientific and private institutions, and for members of public.

5.3 THE SECRETARIAT OF THE COMMITTEE FOR RADIOLOGICAL PROTECTION STANDARDIZATION

In 2002 - 2003 the Secretariat of the Committee for Radiological Protection Standardization prepared for publication the following standards:

- PN-ISO 4037-3 „ X and gamma reference radiation for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy - Part 3: Calibration of area and the measurement of their response as a function of energy and angle of incidence",
- PN-ISO 10703 „Water quality – Determination of the activity concentration of radionuclides by high resolution gamma - ray spectrometry",
- PN-ISO 6980 „Reference beta radiations for calibrating dosimeters and doserate meters and for determining their response as a function of beta-radiation energy",
- PN-ISO 7503-1 „Evaluation of surface contamination – Part 1: Beta – emitters (maximum beta energy greater then 0.15 MeV) and alpha-emitters",
- PN-ISO 8690 „ Decontamination of radioactively contaminated surfaces - Method for testing and assessing the ease of decontamination",
- PN-ISO 8769 „ Reference sources for the calibration of surface contamination monitors - Beta-emitters (maximum beta energy greater than 0,15 MeV) and alpha-emitters",
- PN-ISO 8769-2 „ Reference sources for the calibration of surface contamination monitors - Part 2: Electrons of energy less than 0,15 MeV and photons of energy less than 1,5 MeV".

Official "National opinion" on the 24 drafts of ISO standards were prepared.

Four meetings of the Committee for the Radiological Protection Standardization were organized.

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7 PARTICIPATION IN CONFERENCES, SYMPOSIA AND SEMINARS

(ORAL AND POSTER PRESENTATIONS)

7.1 Seminar on Detection of Nuclear and Radioactive Materials at Borders, Brno, Czech Republic, 21-23 January 2002 .

G. Smagała & R. Tańczyk: paper on "Combating Illegal Nuclear Traffic - Share of the Central Laboratory for Radiological Protection (CLOR)"

7.2 Swedish – Baltic Seminar on Illicit Trafficking of Nuclear and Radioactive Materials, Vilnius, Lithuania, 16-17 April 2002.

G. Smagała: paper on "Poland's National System to Combat Illicit Trafficking in Nuclear and Radioactive Materials".

7.3 Conference of Institute of Nuclear Chemistry and Technology: Nuclear Techniques in Industry, Medicine, Agriculture and Environmental Protection, Warszawa, Poland, 17–19 April 2002.

1. Henschke, J., Biernacka, M., Florowska, K., Sosińska, A., Exposure to the Ionizing Radiation in Poland in 2001.
2. Isajenko, K., Lipiński, P., Bekiert, W., Mobile Spectrometric Laboratory.
3. Mamont-Cieśla, K., Kusyk, M., Measurement of Radon Progeny at the Radon Reference Chamber of CLOR.
4. Żak, A., Biernacka, M., Kusyk, M., Mamont-Cieśla, K., Florowska, K., Radiological Characteristic of an Area Reclaimed by means of an Ash – Gravel Power Plants Wastes.

7.4 Regional Conference on Illicit Trafficking and Trade of Nuclear and Radioactive Materials National and Regional Responses, Almaty, Kazakhstan, 12-14 March 2002.

G. Smagała: paper on "Poland's National System to Combat Illicit Trafficking"

7.5 XXI th All-Polish Meeting: Present problems of radiological protection and protection against HF electromagnetic fields, Myczkowce, Poland, 20–24 May 2002.

1. Biernacka, M., Bekiert, W., Koczyński, A., Sosińska, A., Isajenko, K., Radiological Map of Poland.
2. Bysiek, M., Isajenko, K., Lipiński, P., ASS-500 stations network.
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4. Isajenko, K., Lipiński, P., Bekiert, W., Mobile spectrometric laboratory.
5. Isajenko, K., Lipiński, P., International exercise Barents – Rescue 2001.
6. Lipiński, P., Nuclear materials.
7. Żak, A., Lipiński, P., Building materials.

7.6 Swedish – Ukrainian Seminar on Nuclear and Radioactive Materials Illicit Trafficking Combating in Ukraine. Problems and Ways of Solving, Kiev, Ukraine, 22-23 May 2002.

G. Smagała :paper on Problem of the Nuclear and Radioactive Materials Illicit Trafficking Combating. Interaction of the Emergency Service with the Authorised Bodies. Poland's Experience.

7.7 Meeting of Project Group for Monitoring of Radioactive Substances in the Baltic Sea (HELCOM MORS-Pro 7/2002 4/9, Wilno 11-13 June 2002.

1. Krajewski, P., Suplińska, M. Doses to selected seawater organisms from ^{137}Cs, ^{226}Ra and $^{238,240}Pu$, a case study using a simple dose assessment method.
2. Suplinska, M., Adamczyk, A. Monitoring of radioactive Substances in the Baltic

7.8 Radiotoxicological Intercomparison Meeting- Dresden, Germany 17-19 June 2002

D.Grabowski, B.Rubel (discussion)

7.9 Nordic Society for Radiation Protection XIII Ordinary Meeting RADIOLOGICAL PROTECTION IN THE 2000′s- THEAORY AND PRACTICE, Turku, Finland, August 25-29, 2002

1. W. Muszyński, D. Grabowski, B.Rubel, W.Kurowski, J.Świętochowska, G.Smagała, „Radioactive Contamination of Agricultural Products in Poland" ,
2. B.Rubel, D.Grabowski, W.Kurowski, W.Muszyński, G.Smagała, J.Świętochowska, "Activity of Cs-137 in Forest Mushrooms in Poland in 2001"

7.10 Conference on detection of nuclear and radioactive substances taking into account quality of monitoring systems, Dychów, Poland, 9–11 September 2002.

1. Isajenko, K., Lipiński, P., "Mobile spectrometric laboratory-equipment and application",
2. Lipiński, P., Isajenko, K., Żak, A., "Investigation of samples measured by CLOR, Dosimetry Department for Border Guard and another aspects of cooperation between CLOR and Border Guard".

7.11 XXXII Annual ESNA Meeting, Warsaw, 10-14 September 2002.

1. Krajewski, P., L. Rosiak, L. "Transfer of radiocaesium to crops from different soil types in Poland as a function of radiocaesium interception potential and soil characteristics",
2. Rosiak, L., Pietrzak-Flis, Z. „Relationships between 226Ra, barium and calcium in soils and plants" ,
3. Pietrzak-Flis, Z., Krajewski, P., Radwan, I., Muramatsu, Y. „Retrospective evaluation of 131I deposition density and thyroid dose in Poland after the Chernobyl accident".

7.12 Seminar on Monitoring Strategies and Programmes – Baltic-Danish Co-operation on Radiation Protection", Riso National Laboratory, 30 September – 2 October 2002.

1. Kownacka, L., Radwan, I. "Radiological monitoring of the environment in the surrounding of nuclear and waste disposal facilities",
2. D. Grabowski, W.Kurowski, W. Muszyński, B. Rubel, G.Smagała, J.Świętochowska: "Radiation Monitoring Network in Poland",
3. Isajenko, K., Lipiński, P., "Permanent Monitoring System (PMS) and Aerosol Sampling Stations (ASS-500) Monitoring Networks in Poland".

7.13 Conference ECOpole'02, 16-19 October 2002, Jamrozowa Polana.

Pietrzak-Flis, Z. "Methods for retrospective evaluation of 131I deposition after the Chernobyl accident" plenary lecture.

7.14 37 "Berlin Kolloquium", Berlin, 23–26 October 2002.

1. Pietrzak-Flis, Z. "Emergency management in border crossing nuclear accident in Poland, 2. National Radiation Research Programme in Poland",
2. Krajewski, P., "Implementation of the Council Directive 97/43/EURATOM on Health Protection of Individuals against the Danger of Ionising Radiation in Relation to Medical Exposure",
3. Krajewski, P., "Prophylaxis of administration of small amounts of the iodine to avoid endemic disease of thyroid",
4. Krajewski, P., "Radon at workplaces".

7.15 Seminar on Sampling Techniques, Radiochemical Methods, Detectors and Measurements, Baltic-Danish Co-operation on Radiation Protection, Riso National Laboratory, 4-8 November 2002

1. Grabowski, D., Kurowski, W., Muszyński, W., Rubel, B., Świętochowska, J., Smagała, G., „Sampling techniques for Cs-137 and Sr-90 determination in food and environment in Poland"
2. Roos, P., Kamińska, I., Chrzanowski, E. „Procedure of ^{228}Ra determination in environmental samples by the measurement of ^{228}Ac beta activity" ,
3. Biernacka, M., Isajenko, K., Lipiński, P., „Aerosol Sampling and Measurements in Poland by means of ASS-500 Station",
4. Biernacka, M., Isajenko, K., Lipiński, P., "Systematic Measurements of Radioactive Contamination of the Earth Surface in Poland".

7.16 Seminar on Radioactive Waste, Modelling and Dose Assessment, Denmark, Risoe National Laboratory, Baltic- Danish Co-operation on Radiation Protection, 2 – 6 December 2002.

1. Lipiński, P., Bekiert, W., Isajenko, K., et al.: Radiological Monitoring of the Environment in the Surrounding of Radioactive Wastes Repository in Różan.
2. Krajewska, G., Krajewski, P. „Modelling approach in Central Laboratory for Radiological Protection".

7.17 PECO Project Review Meeting on „Combating Illicit Trafficking of Nuclear Materials in Poland", 1-2 April 2003, Warszawa.

G. Smagała : presentation on „Actual Status of the Project and its result: the Handbook for the response to illicit trafficking or inadvertent movement of nuclear and radioactive materials in Poland".

7.18 Lectures for SANEPID, Rzeszów, Poland, 28 – 30 May 2003.

Isajenko, K., Lipiński, P., Gamma spectrometry.

7.19 Meeting of Project Group for Monitoring of Radioactive Substances in the Baltic Sea (HELCOM MORS-Pro 8/2003 3/3, Risö 2-4 June 2003).

1. Suplinska, M., Adamczyk, A. "Monitoring of radioactive Substances in the Baltic Sea- ^{40}K, ^{137}Cs and ^{226}Ra in Southern Baltic Sea fish in 2002"
2. Suplinska, M., Pietrzak-Flis, Z. "^{129}I and ^{127}I in the bottom sediments of the Baltic Sea- Preliminary results".

7.20 Seminar during the national intercomparison of the instruments for measuring radon, thoron and radon progeny in air and methods of measurements of radon in water concentration in Polish radon laboratories, Warsaw, Poland, 9 – 13 June 2003.

Stawarz, O., "Investigation of response of AlphaGUARD radon monitors to thoron".

7.21 Radiotoxicological Intercomparison Meeting- Dijon Francja 17-19 June 2003

D. Grabowski, B. Rubel (discussion)

7.22 Meeting of Project Group for harmonization of techniques and methodologies for sampling and measurement of radioactivity in the environment, 10 July 2003, Karlsruhe.

Kamińska, I. "Organization and the main tasks of Central Laboratory for Radiological Protection"

7.23 International Conference on National Infrastructures for Radiation Safety: Towards Effective and Sustainable Systems, Rabat, Morocco, 1-5 September 2003.

Krajewski, P., Progress in implementation of national education and training framework for the groups professionally connected with the nuclear radiation, (poster, extended abstract),

7.24 **1st Plenary and Working Group Meetings of the IAEA Programme on Environmental Modelling for RAdiation Safety (EMRAS), IAEA, Vienna, 1-5 September 2003.**

Krajewski, P., EMRAS Iodine Working Group activities framework,

7.25 Mini-seminar on radioecology and measurement techniques, Risø National Laboratory, 8-9 September 2003.

Krajewski, P., Krajewska, G. "New Aspects of Models' Validation Approaches in a case of ^{131}I Releases

7.26 Seminar during international intercomparison exercise of mobile spectrometric laboratories TURAWA 2003, Turawa near Opole, Poland, 9 – 12 September 2003.

Lipiński, P., Isajenko, K., Turawa 2003 – organization, regulations, recommendations, social matters.

7.27 International Symposium „Off-site Nuclear Emergency Management – Capabilities and Challenges" - Salzburg, Austria 29 September – 3 October 2003 .

W. Muszyński (discussion)

7.28 International Conference on the Protection of the Environment from the Effects of Ionizing Radiation, 6–10 October 2003, Stockholm, Sweden.

Krajewski, P., Suplińska, M. "Doses to selected seawater organisms from ^{137}Cs, ^{226}Ra and $^{239,240}Pu$, A case study using a simple dose assessment method"

7.29 Workshop on Radioecological Modelling using ARGOS, Baltic- Danish Co-operation on Radiation Protection, Risø National Laboratory, Denmark, 10-11 October 2003.

Krajewski, P., Krajewska, G. ECOSYS for EXCEL (v.1.4e) test exercise on I-131 Chernobyl data in Poland,

7.30 Conference ECOpole'03, 16-18 October 2003, Jamrozowa Polana.

Kamińska, I., Pietrzak-Flis, Z., Chrzanowski, E. Uranium isotopes in waters and bottom sediments of rivers and lakes in Poland,

7.31 Scientific Conference „Safety of Food and Feeding as a problem of the public health in Poland a day before the integration with the EU, Warszawa 29 – 31 October 2003

1. D. Grabowski :„Action of the Central Laboratory for Radiological Protection for the control of the radioactive substances in food" ,
2. B.Rubel (discussion)

7.32 Seminar organized in frame of bilateral cooperation with V.G Khlopin Radium Institute, St Petersburg and CLRP, Warsaw. St Petersburg, 15-19 November 2003

1. Suplinska, M., Adamczyk, A. Monitoring of radioactive Substances in the Baltic Sea 2000-2002 1. K-40, Cs-137, Pu-238, Pu-239,240 and Ra-226 in bottom sediments, 2. K-40, Cs-137 and Ra-226 in fish",
2. Pietrzak-Flis, Z., Suplińska, M. „I-129 i I-127 in bottom sediments of the Baltic Sea and in the Polish soils".

7.33 Risø Baltic Training 2003, 6-12 December 2003, Risø National Laboratory.

1. Kamińska, I. 228Ra determination in environmental samples by the measurement of 228Ac beta activity, Kamińska, I., " ^{241}Am determination in environmental samples",
2. Rosiak, L., "Determination of 90Sr in organic and inorganic samples".

8 INTERNATIONAL AND NATIONAL COOPERATION

8.1 European Commission

- **International Programe FP-6 UE „ERICA, Environmental Risks from Ionising Contaminants: Assessment and Management „ Contract FI6R-CT-2003-508847**

- **Providing PMS measurements data on external dose rate for**:

  EURDEP (European Union Radiological Data Exchange Platform),

  CBSS (Council of Baltic Sea State),

  IMIS (Integrated Measurement and Information System), Germany.

  In a frame of this program co-operation with:

  Institute for Environment and Sustainability, JRC Ispra

  Radiation and Nuclear Safety Authority, STUK, Finland

  Norwegian Radiation Protection Authority, NRPA, Norway

  Swedish Radiation Protection Authority, SSI, Sweden

  Bundesamt für Strahlenschutz, BfS, Germany

- **Institute for Transuranium Elements ITU, JRC, European Union**

  „Project Group for Harmonization of Techniques and Methodologies for Sampling and Measurement off Radioactivity in the Environment" (12 institutions from 8 countries) - activities on verification of methodology used in normal and emergency operations,

  ITU and CLOR contract, 20791, 2 June 2003, - continuation of PECO, preparatory work to join International Laboratory Network on Nuclear Judicial Analysis of unknown materials.

8.2 International Atomic Energy Agency, IAEA, Vienna

- **intercalibration program**: determination of ^{238}U, ^{234}U, ^{226}Ra i ^{228}Ra in water samples,
- **EMRAS (Environmental Modelling for Radiation Safety), Iodine Working Group leadership**

  Validation of environmental models, identification the most important sources of bias and uncertainty in the model predictions, improvement of the accuracy of model predictions, improvement of modelling procedures.

- Training visits of IAEA fellowships in Secondary Standard Dosimetry Laboratory (3 persons)

8.3 United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR)

Participation in the annual sessions of the Committee and in preparing the scientific assessments and reports to the General Assembly.

8.4 National Council on Radiation Protection and Measurements (NCRP) (USA)

Peer-reviewing of the NCRP documents and reports.

8.5 Risø National Laboratory, Dania

Bilateral agreement (2001-2003):

- intercalibration on determination of Cs-137, Sr-90 and isotopes of Uranium and Thorium in bottom sediments and lakes water samples, 2003.
- training on determination of ^{241}Am in environmental samples, 6-12 December 2003.
- training on determination of ^{90}Sr in environmental samples, 6-12 December 2003.
- radiochemical methods and spectrometry training
- seminar on radioecological modelling RODOS I ARGOS, 10-11 October, 2003,
- NKS-B seminar on radioecology and measurement methods, 10-11 October, 2003.

8.6 Helsinki Commission, Baltic Marine Environmental Protection Commission, Helcom Mors

Monitoring of radioactive contamination in Baltic Sea (co-operation of Baltic Countries)

8.7 V.G Khlopin Radium Institute, St Petersburg

Bilateral cooperation on Baltic Sea radioactive contaminations researches

8.8 Bundesamt für Strahlenschutz, Berlin, Germany

International exercise on determination of ^{232}Th, ^{230}Th, ^{228}Th, ^{238}U, ^{235}U i ^{234}U in urine samples

Providing PMS measurements data on external dose rate for IMIS (Integrated Measurement and Information System)

8.9 Physik-Technik-Innovation, Elagen, Germany

Testing and modernisation of ultra-sensitive ASS-500 stations for air contaminations monitoring constructed and patented by CLOR .

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8.10 National co-operation in a framework of the Integrated Early Warning Network for Radioactive Contaminations

Technical University of Szczecin, Maria Curie-Skłodowska University in Lublin, Woivodship Sanitary-Epidemiological Station in Rzeszów, Niewodniczański Institute of Nuclear Physics (Polish Academy of Science) in Krakow, Institute of Meteorology and Water Management-Maritime Branch, Technical University of Wrocław, University of Zielona Góra, Technical University of Koszalin, University of Warmia and Mazury in Olsztyn, Technical University of Łódź, Nicolaus Kopernicus University in Toruń, Medical University of Białystok, Andrzej Sołtan Institute of Nuclear Studies, Central Mining Institute in Katowice, POLON JZOT Ltd in Milanówek

8.11 International project "Investigation of Pu isotopes contained in ground – level air in Central Europe"

Project began in 2001 and end in 2004

Polish Institutions:

Niewodniczański Institute of Nuclear Physics (Polish Academy of Science) in Krakow,
Medical University of Białystok

Foreign Institutions

Physikalish – Technische Bundesanstalt, PTB, Brunszwik, Germany,
Deutscher Wetterdienst, DWD, Germany,
Johannnes Gutenberg Universitat , JGU/IKC, Germany
National Radiation Protection Institute , NRPI, Czech Republic.

8.12 Exchange monitoring data on airborne radioactivity in a ground level air.

Belarus State Department for Hydrometeorology, Centre of Radiation and Environment Monitoring, Belarus,
Physikalisch – Technische Bundesanstalt, German,
Finnish Centre for Radiation and Nuclear Safety, Finland,
"Frederic Joliot-Curie" National Research Institute for Radiobiology and Radiohygiene, Hungary,
State Nuclear Regulatory Administration, Ukraine,
Federal Office of Public Health, Division of Radiation Protection, Switzerland.

8.13 EXERCISE „TURAWA 2003" (8-12 September 2003): INTERNATIONAL INTERCOMPARISON OF MOBILE SPECTROMETRIC LABORATORIES

The following teams participated in the exercise:

Denmark (2 persons), Estonia (3 persons), Latvia (3 persons), Lithuania (2 persons), Poland (3 persons), Russia (3 persons).

8.14 CO-OPERATION ON MEASURING METODOLOGY OF RADON AND RADON PROGENY

Czech Technical University in Prague, Faculty of Dosimetry, Czech Republic ,
National Radiation Protection Institute, Development & Rn Standardization, Czech Republic,
State Metrological Center for Radon, National Authority for NBC Protection, Czech Republic,
Institute of Chemical Process Fundamentals, Aerosol Laboratory, Czech Republic.

8.15 COUNTRY WIDE EXPERIMENTS ON INTERCOMPARISON OF INSTRUMENTS FOR MEASURING RADON AND RADON PROGENY CARRIED-OUT IN THE CLOR CALIBRATION CHAMBER

AGH University of Science and Technology, Medical University in Bałystok, Central Mining Institute in Katowice, Institute of Nuclear Chemistry and Technology, Niewodniczański Institute of Nuclear Physics (Polish Academy of Science) in Krakow, Nofer Institute Occupational Medicine, National Atomic Energy Agency, Technical University of Wrocław.

8.16 NATIONAL CO-OPERATION ON INVESTIGATION OF RADIOACTIVITY OF RAW AND BUILDING MATERIALS

Building Research Institute (TB) in Warsaw, Central Mining Institute in Katowice, Medical University in Bałystok, AGH University of Science and Technology, Technical University of Gdańsk, Technical University of Wrocław, Institute of Building Materials of Natural Origin in Opole, Research and Development Centre for Concrete Industry CEBET in Warsaw, Institute of Organization and Management in Industry in Toruń, Institute Research and Development Laboratory of Building Ceramics CERPROJEKT in Toruń.

8.17 POLISH RESEARCH LABORATORIES CLUB (POLLAB)

SECONDARY STANDARD DOSIMETRY LABORATORY FOR RADIATION PROTECTION acts as an actual member of POLLAB (N# 507) –Polish Research Laboratories Club.